The Future of National Infrastructure:
Outcomes from the UK Infrastructure Transitions Research Consortium

Institution of Civil Engineers

15th October 2015

ITRC

EPSRC
Engineering and Physical Sciences Research Council

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 national infrastructure 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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Consortium

Lead Universities

- University of Oxford
- University of Cambridge
- University of Southampton
- Newcastle University
- Cardiff University
- University of Leeds
- University of Sussex

Support

- Engineering and Physical Science Research Council Programme Grant £4.7 million (5 years)
- University contributions £1 million
- Industry contributions £1.6 million

Partnership

Over 40 partners in industry and government:

- Contractors
- Engineering & multi-disciplinary consultants
- Engineering institutions
- Government departments, agencies & local authorities
- Insurers
- NGOs
- Utility companies

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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The ITRC story

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

2012 Development of the NISMOD models and database

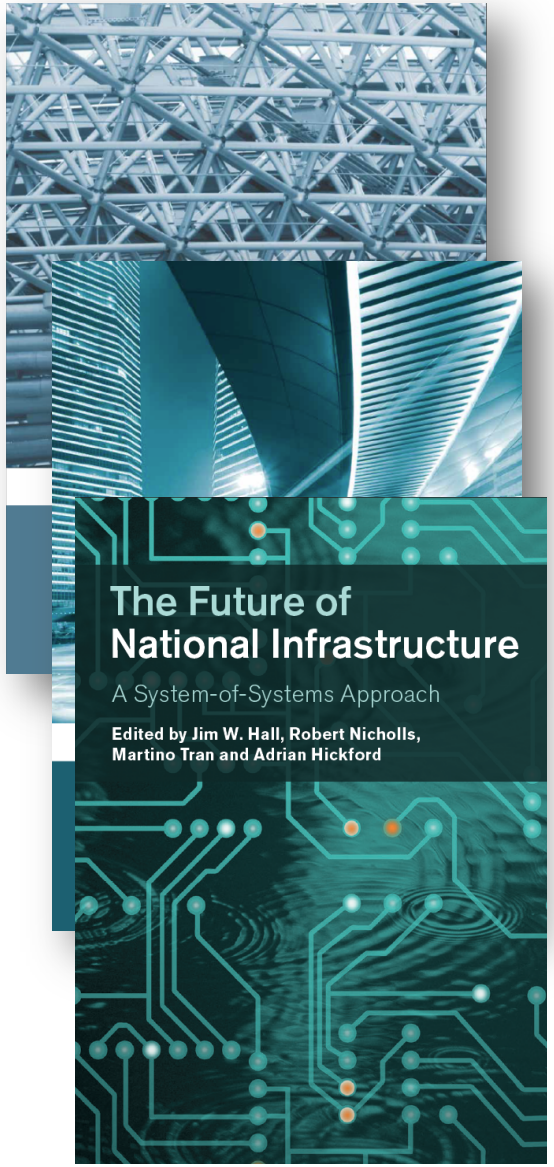
2013 Quantified assessment of the performance of national infrastructure strategies

Programme mid-term review

2014 ITRC first National Infrastructure Assessment

Integration of the NISMOD system

2015 NIP assessment and collaborations



Stakeholder interactions

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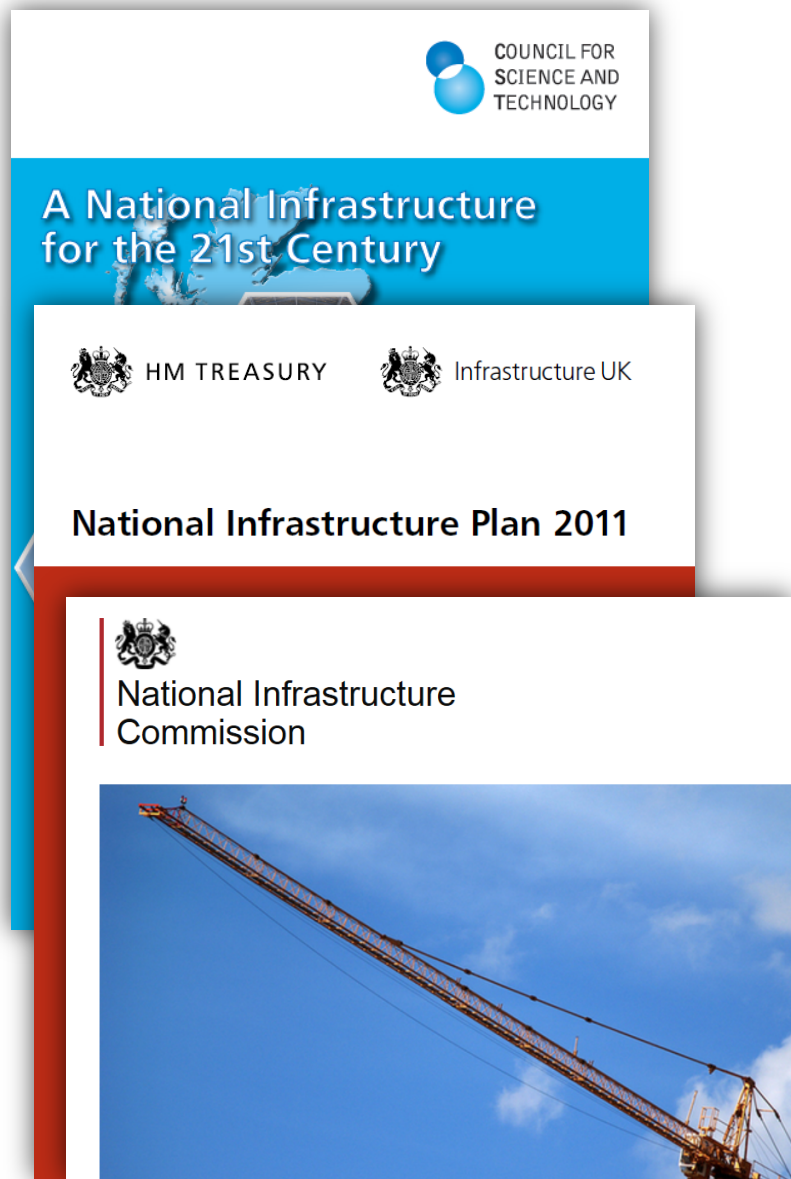
The changing policy landscape

"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 National Infrastructure Commission is an independent body that enables long term strategic decision making to build effective and efficient infrastructure for the UK."



International advisors and collaborators

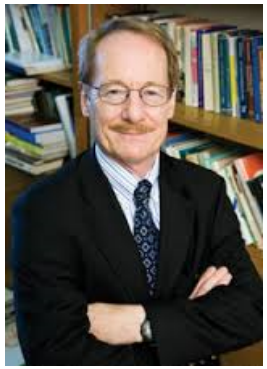
Garry Bowditch
University of Sydney

Margot Weijnen
Delft University of Technology

Stephanne Hallegatte
World Bank

Yakov Haimes
University of Virginia

Theresa Brown
Sandia National Laboratory



Geoffrey Hewings
University Illinois

ITRC

The Future of National Infrastructure

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Institution of Civil Engineers *Hashtag #INFRASYSTEMS* *15/10/2015*

13:30 – 14:00 **Arrival at the Institution of Civil Engineers** – refreshments, Rennie Room

14:00 – 14:20 **Overview of the ITRC's research achievements** - Jim Hall, *Godfrey Mitchell Theatre/Stephenson Room*

14:20 – 15:00 **Research highlights**

- **Future energy demand in Britain** - Nick Eyre
- **The future of Britain's energy supply and transmission infrastructure**- Modassar Chaudry
- **Vulnerability and resilience of energy networks** - Scott Thacker
- **A new strategic transport model for Britain** – Simon Blainey
- **A national water resources model and infrastructure assessment** – Mike Simpson
- **Optimising solid waste and resource recovery** - William Powrie
- **The future of digital connectivity** – Ed Oughton
- **Decision pathways for infrastructure investment** – Katherine Young
- **Governance of interdependent infrastructures** – Jim Watson

15:00 – 16:00 **Introduction to the Interactive session**

- **The National Infrastructure Model (NISMOD)** – Matt Ives
- **A national infrastructure database and visualisation toolkit** – Stuart Barr

NISMOD interactive demonstration - Meet the experts
Rennie Room – NIP Assessment; Sectoral modelling & Governance experts
Bazalgette Room –National Infrastructure Database & Visualisation; Interdependent Risk & Vulnerability experts

16:00 – 17:35 **Impact highlights**, *Godfrey Mitchell Theatre/Stephenson Room*

- **Strategic analysis of the National Infrastructure Plan** - Adrian Hickford (ITRC) and Geoff Baldwin (Infrastructure UK)
- **Risk analysis of Britain's infrastructure network** – Raghav Pant (ITRC)
- **Spatial modelling for future energy scenarios** - Raghav Pant (ITRC) and Russel Fowler (National Grid)
- **The risk of railway bridge scour**- Rob Lamb (JBA Consulting)
- **Geohazards to infrastructure** - Oliver Pritchard (ITRC) and Mark Heaton (Lincolnshire County Council)

Panel discussion - Colin Harris, ITRC External Advisory Board, Chair

Terry Hill, ARUP
Geoff Darch, ATKINS
Andrew Crudgington, ICE
Richard Ploszek, Infrastructure UK
Theresa Brown, SANDIA
Nick O'Reagan, UNOPS

17:35 – 17:45 **Next steps for the ITRC research and closing remarks – Jim Hall**

`17:45 – 19:00 **Reception - wine & canapés**

NISMOD interactive demonstration - Meet the experts

Research Highlights

- ***Future energy demand in Britain*** - *Nick Eyre*
- ***The future of Britain's energy supply and transmission infrastructure-*** *Modassar Chaudry*
- ***Vulnerability and resilience of energy networks*** - *Scott Thacker*
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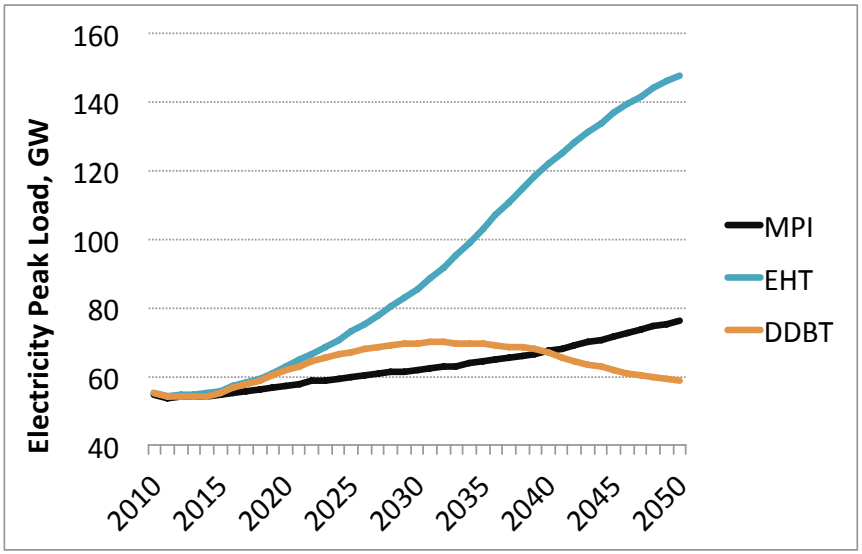
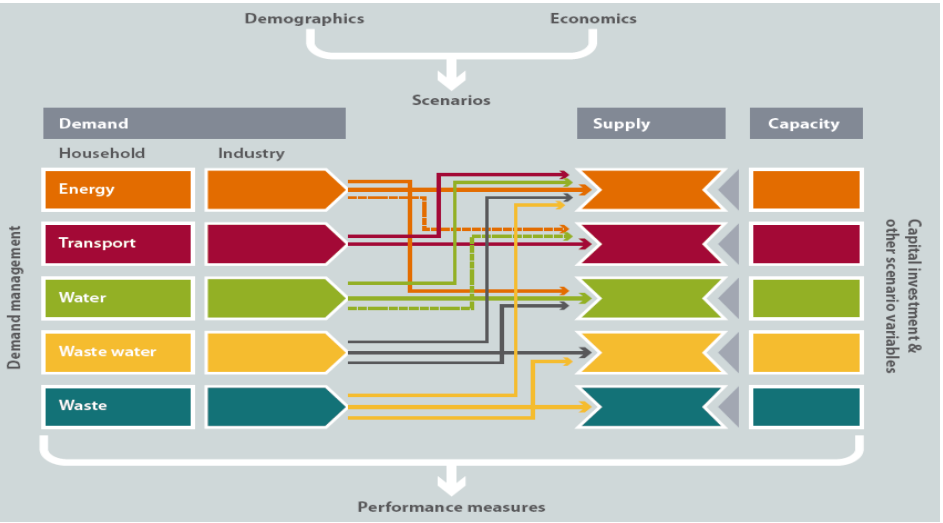
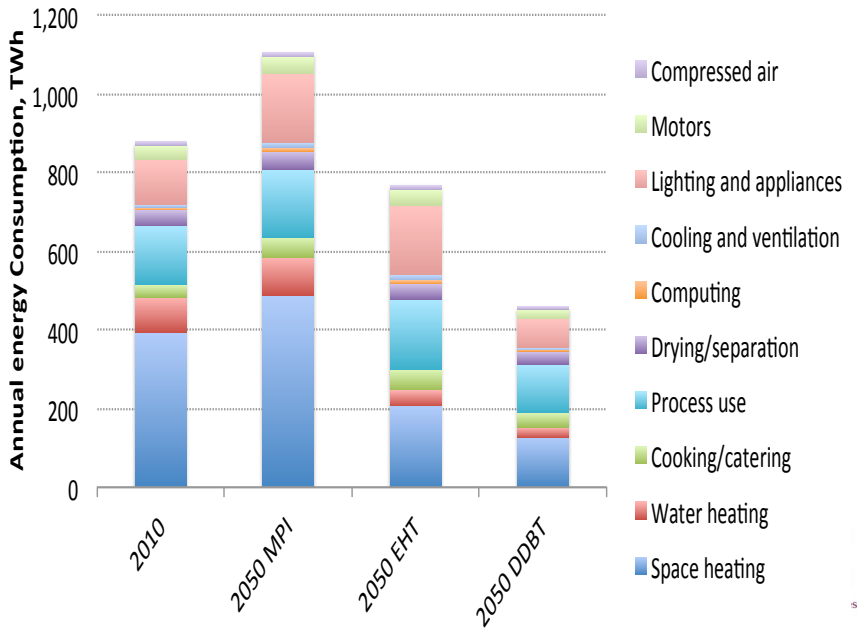
- ***Governance of interdependent infrastructures*** – *Jim Watson*

Future Energy Demand - Overview

A new model of energy demand in Britain to inform cross-sectoral infrastructure analysis

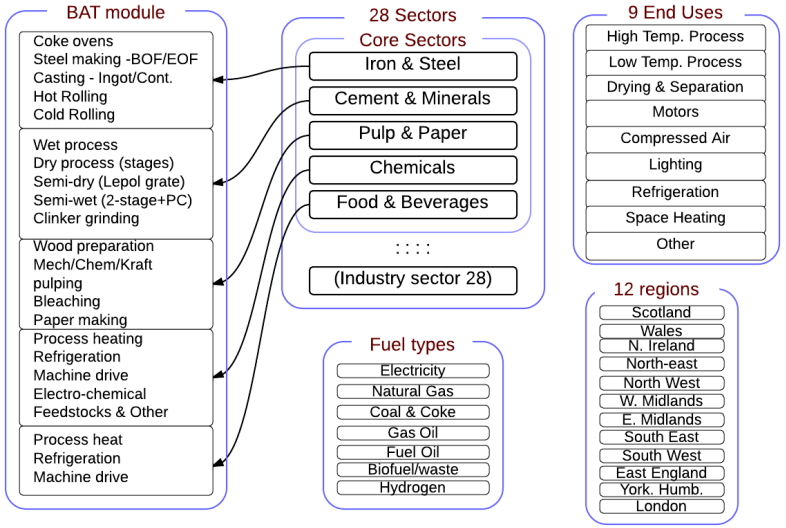


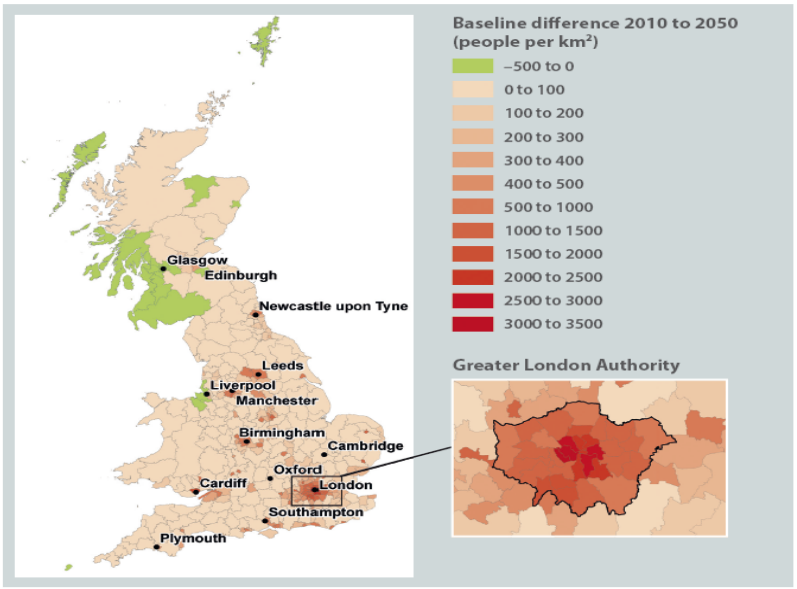




Future Energy Demand - Capabilities

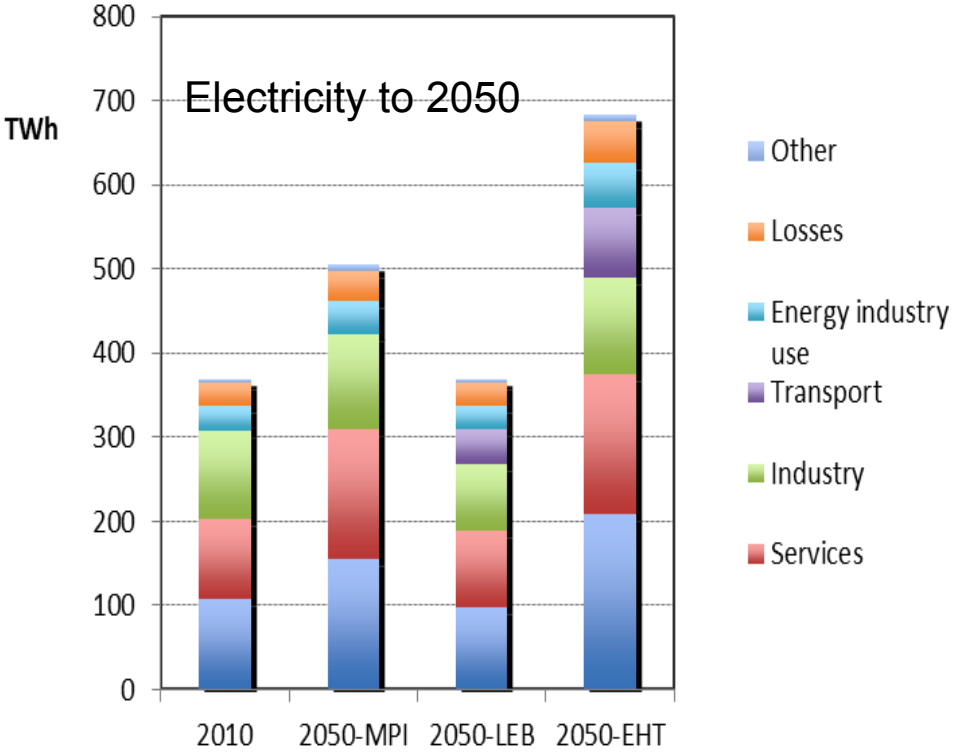
- Disaggregation by end use, region and year
- Demographic and economic uncertainties
- Strategies of diverse alternative energy futures
- Outputs provide model inputs to energy supply model

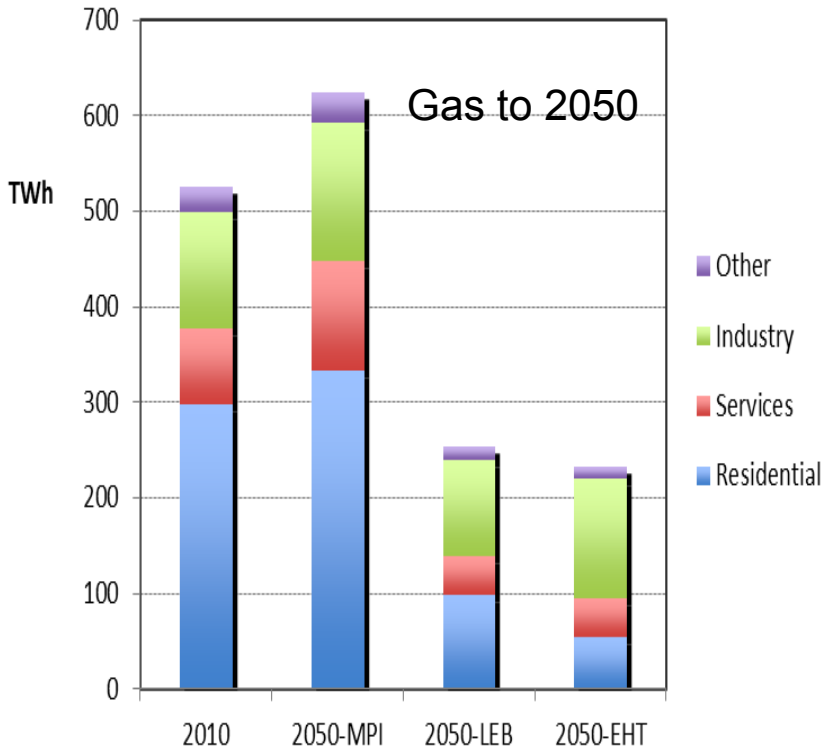




Future Energy Demand - Insights

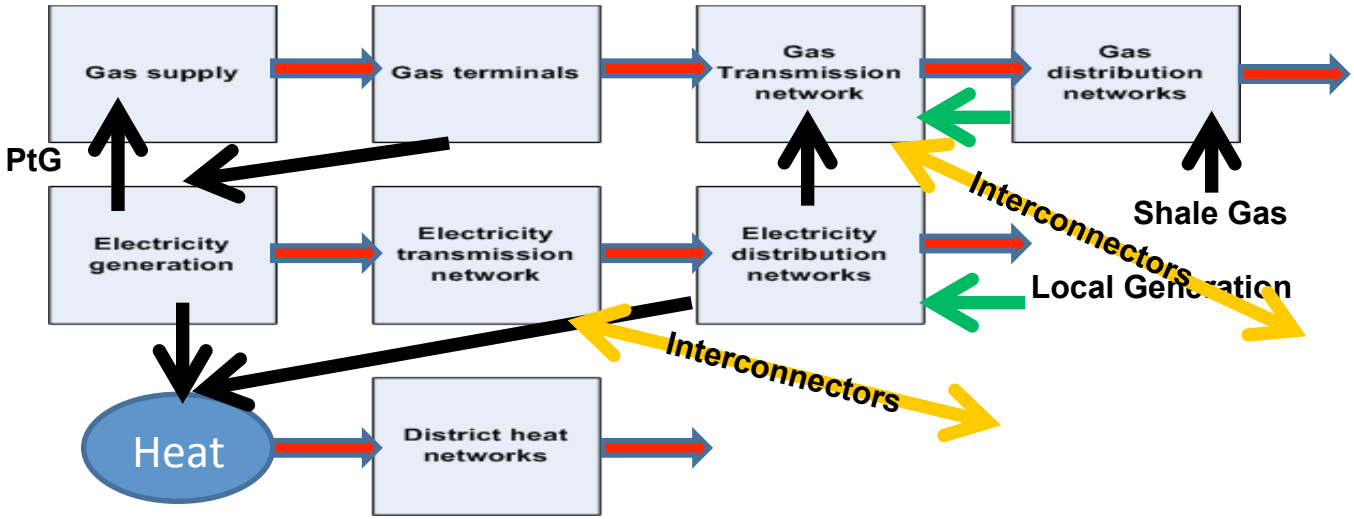
- Highly divergent outcomes of different strategies.
- Climate mitigation is a key driver of uncertainty.





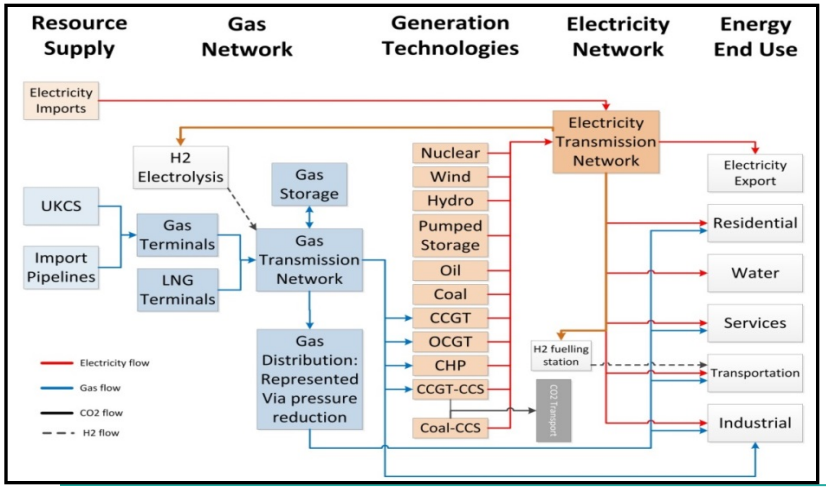
The future of Britain's energy supply and transmission infrastructure

Overview



- Increasing interactions (and complexity) between energy vectors
- There is a need for models to 'unpack' and make sense of this complexity
- Massive investment challenge facing energy networks (security; climate change; costs)

Energy Supply model developed to analyse gas and electricity networks:

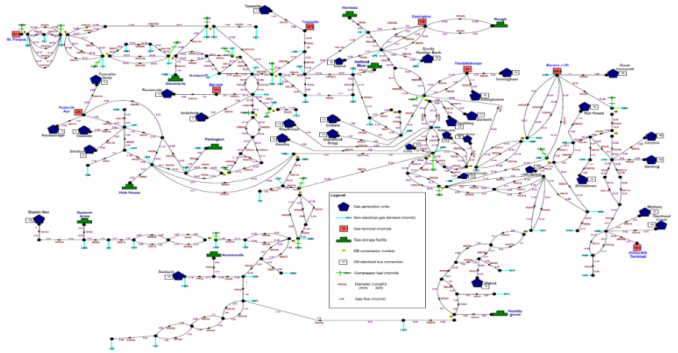


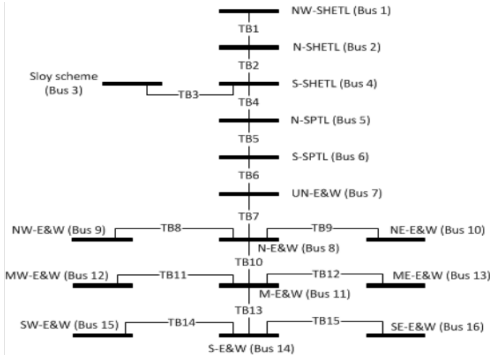
- Minimises operational/investment costs of gas and electricity networks
- Establishes optimal power generation dispatch, optimal gas and electrical power flows
- Determines where, when, what and how much capacity needs to be built to meet future energy demand

The future of Britain's energy supply and transmission infrastructure

Capabilities

Geographic scale





GB Gas network

GB Electricity network

Inputs

Regional and temporal (peak) demand data

Capacity/location/ type of the existing infrastructure

Capital and operating costs of infrastructure

Fuel and carbon prices; discount rates

Characteristics of infrastructure: efficiency, lifetime, emissions,…

Energy Supply model

(Non Linear Mixed Integer Programming)

- Objective function:

$$\min Z = \sum_t \frac{1}{(1+r)^t} \left(\underbrace{\text{capital cost of new infrastructure}} + \underbrace{\text{operating cost of the systems}} + \underbrace{\text{cost of unserved energy}} + \underbrace{\text{cost of carbon emission}} \right)$$

- Constraints
  - Emission and renewable targets (if set)
  - Meet gas and electricity demand (otherwise high load shedding costs are incurred)
  - Operation within technical capacity of infrastructure
  - Maintain minimum level of capacity margins
  - Resources availability: indigenous gas reserve, gas and electricity imports, wind energy (spatial and seasonal capacity factors)

Outputs

Optimal capacity/ location/ type of the new infrastructure

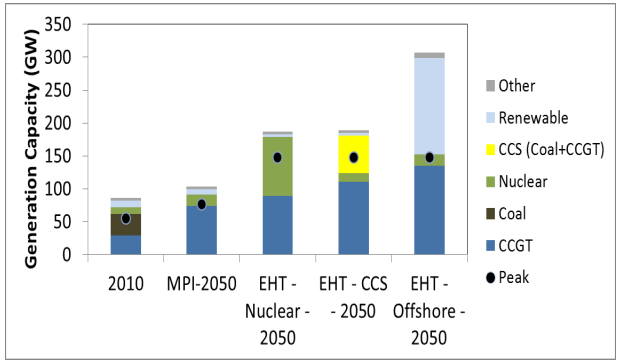
Optimal cost (investment and operation) of the system

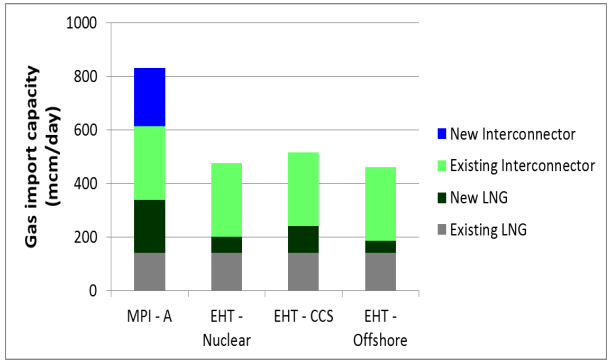
CO2 emission: total (tonne) and intensity (g/ kWh)

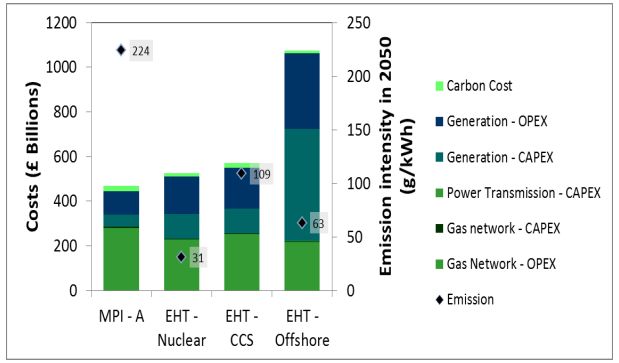
The future of Britain's energy supply and transmission infrastructure

Insights

The Energy Supply model was employed to evaluate the performance of a number energy strategies (Minimum Policy Intervention (MPI); Electrification of Heat and Transport (EHT)):







Import dependency

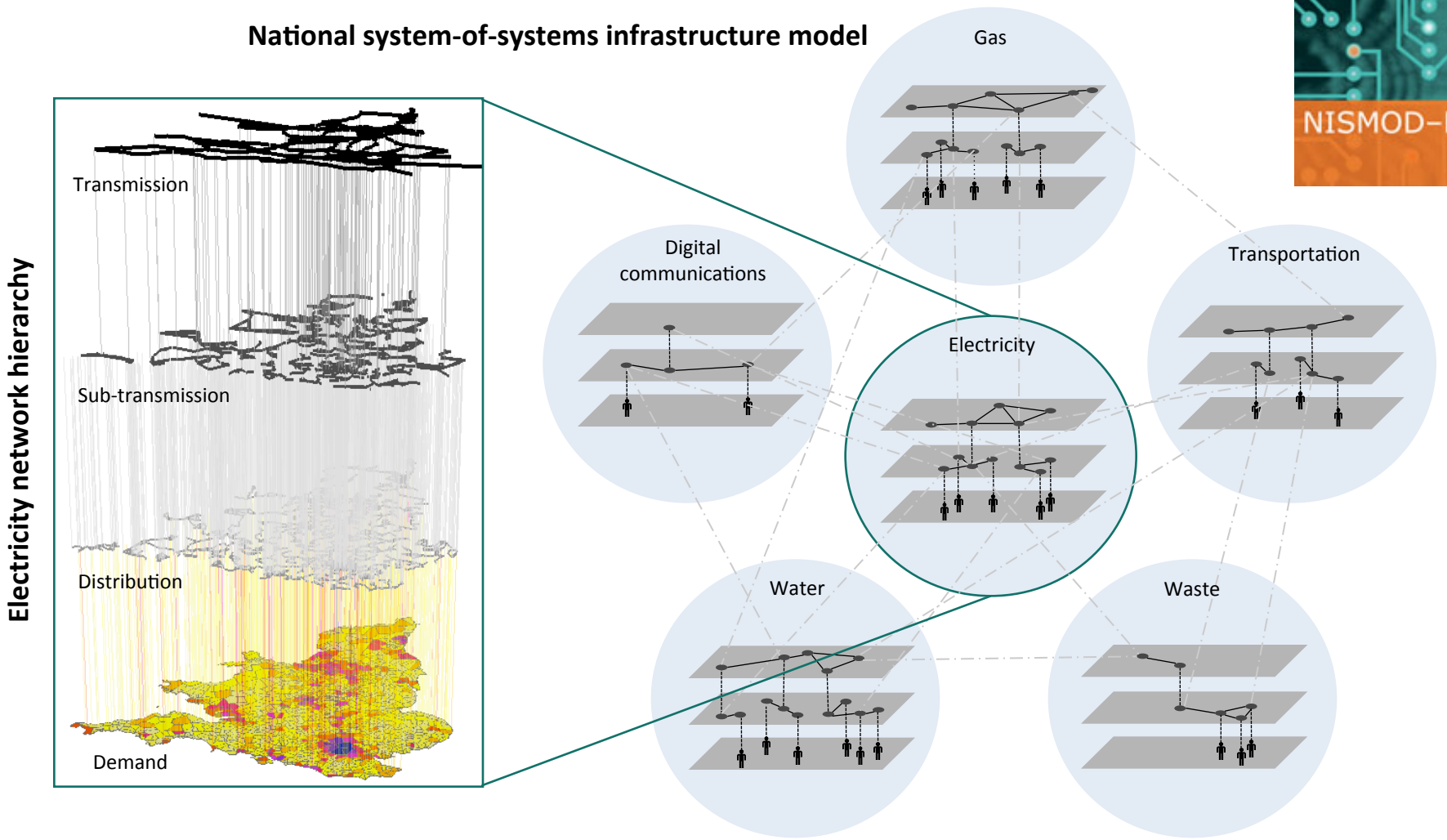
Strategy	2010	2050	
MPI	55%	94%	74%
EHT-Nuclear		84%	<56%
EHT-CCS		91%	
EHT-Offshore		85%	

How can shale gas help?

- Investment requirements in energy infrastructure are high in low carbon strategies (EHT– Offshore capacity **~2 x peak**).
- In low carbon strategies, total annual gas demand decreases, however import capacity will increase to meet the peak gas demand and to compensate for UKCS depletion.
- Gas-fired plants will play significant role in providing backup for variable and inflexible generation technologies .
- Capacity factor for CCGT plants drops to ~ 10% by 2050 in EHT strategies.
- Shale gas exploitation could help with security goals (reduced imports)

Vulnerability and resilience of energy networks

Overview

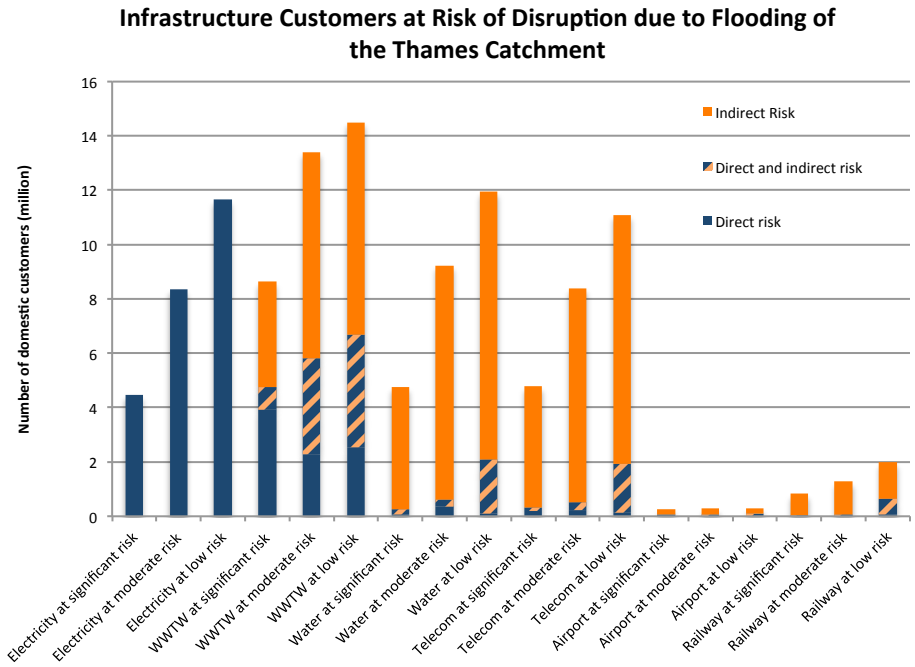


Vulnerability and resilience of energy networks
Capabilities

Real-time infrastructure risk assessment

NISMOD-RV

Flood hazards: Winter 2013-2014



Cyber security threats

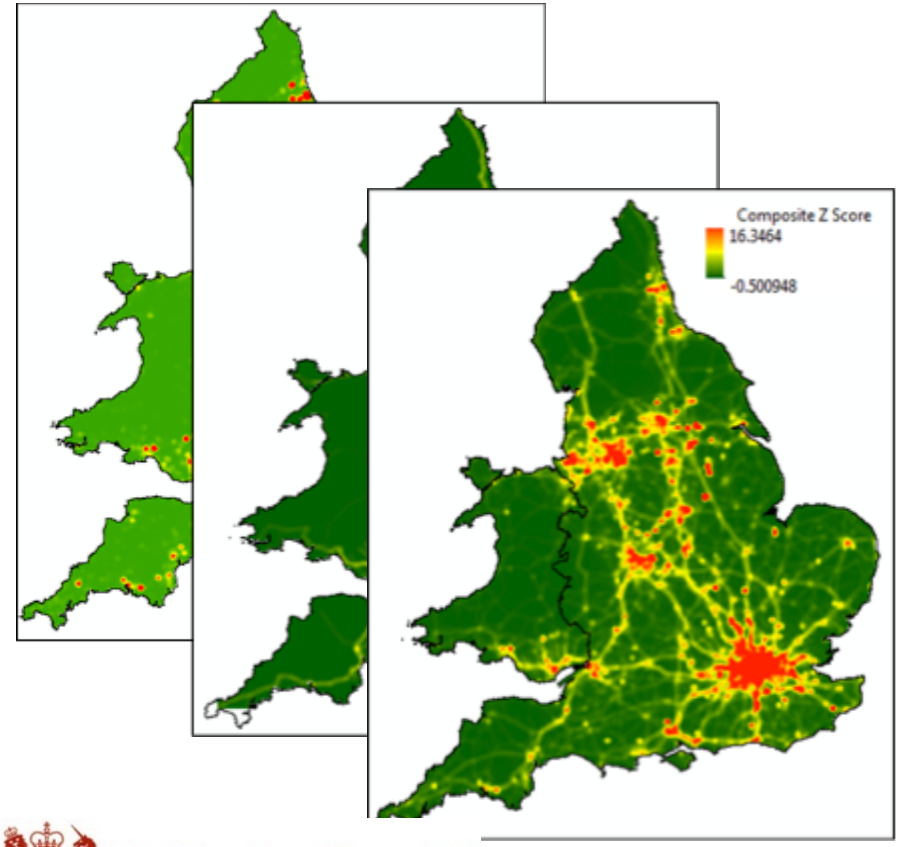
SAGE
Scientific Advisory Group for Emergencies

UNIVERSITY OF CAMBRIDGE Judge Business School | Centre for Risk Studies

Vulnerability and resilience of energy networks
Insights

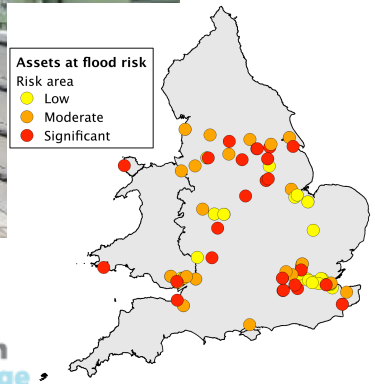
NISMOD-RV

Infrastructure criticality hotspot analysis



Infrastructure UK

Critical infrastructure adaptation

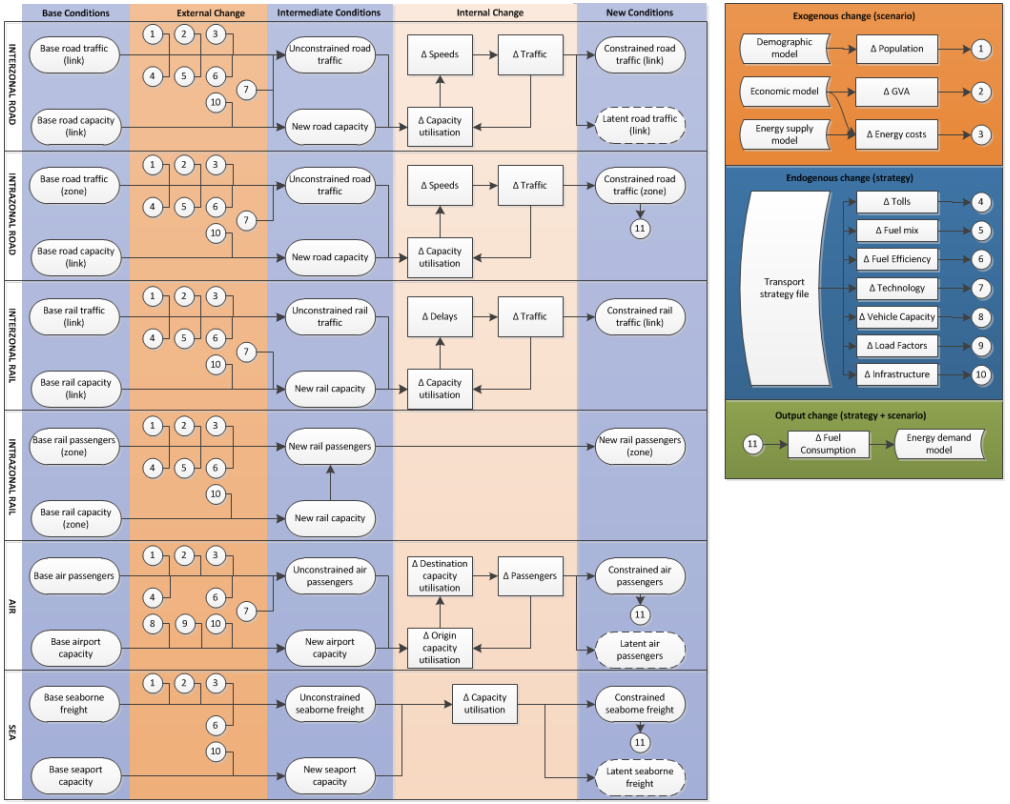


Committee on Climate Change Adaptation

A new strategic transport model for Britain

Overview

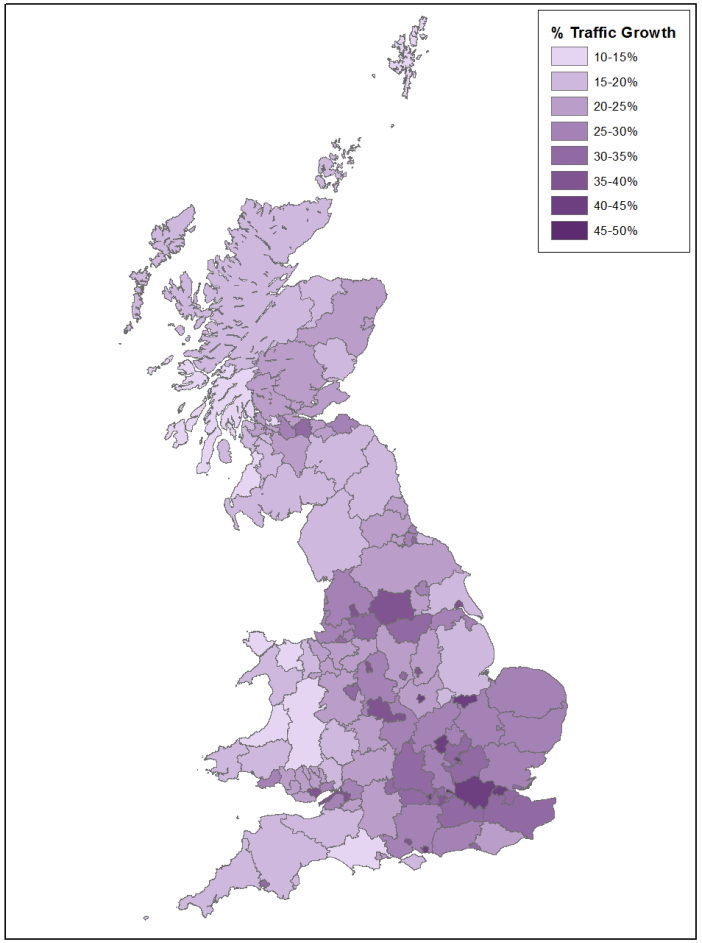
- Multimodal
- Spatially-disaggregated forecasts for 2011-2100
- Explicit interactions with energy sector
- Short run times
- Based on open source data



A new strategic transport model for Britain

Capabilities

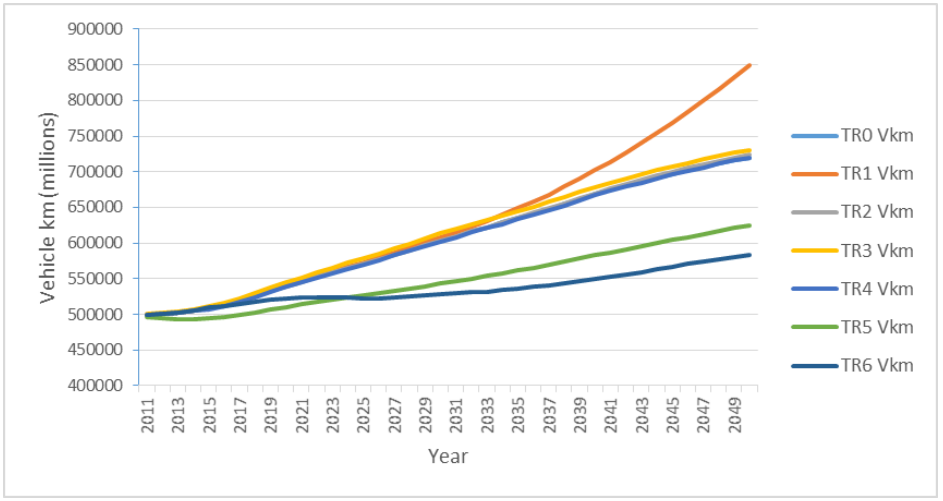
- Strategic assessment of infrastructure usage
- Analysis of impacts of exogenous change
- Comparison of policy and strategy options
- Quantification of transport impacts on energy sector

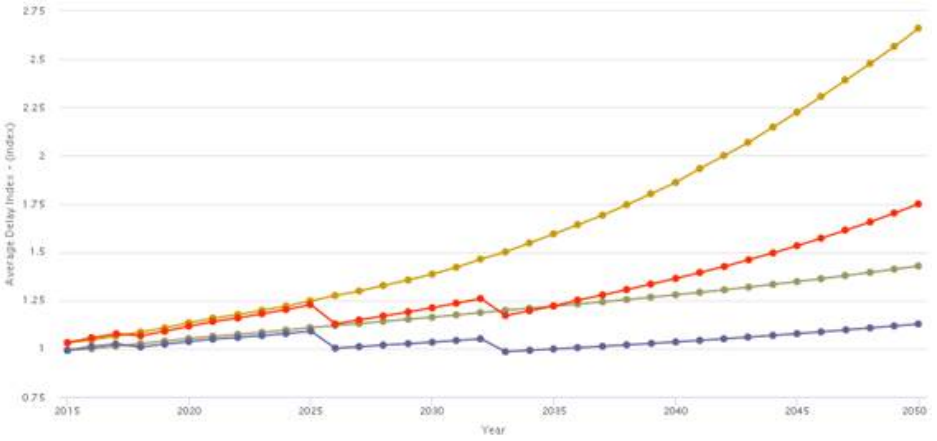


A new strategic transport model for Britain

Insights

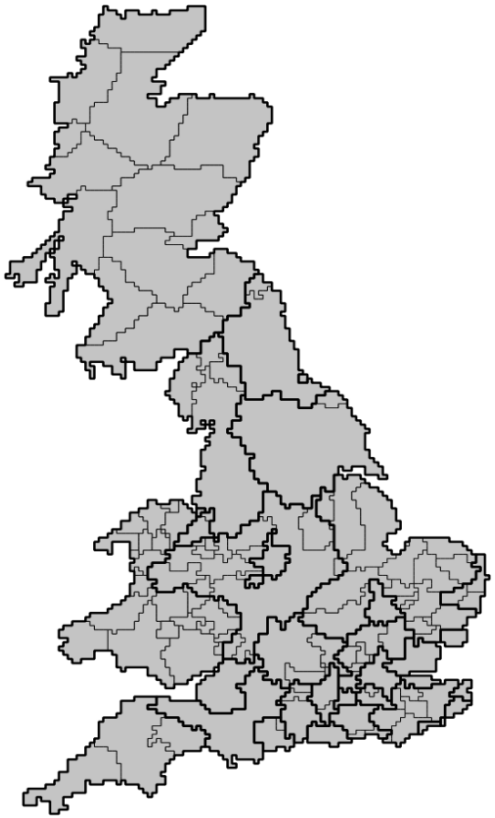
- Continued growth in travel inevitable?
- Targeted infrastructure construction can relieve congestion in short/medium term
- Infrastructure provision an important tool for demand management?



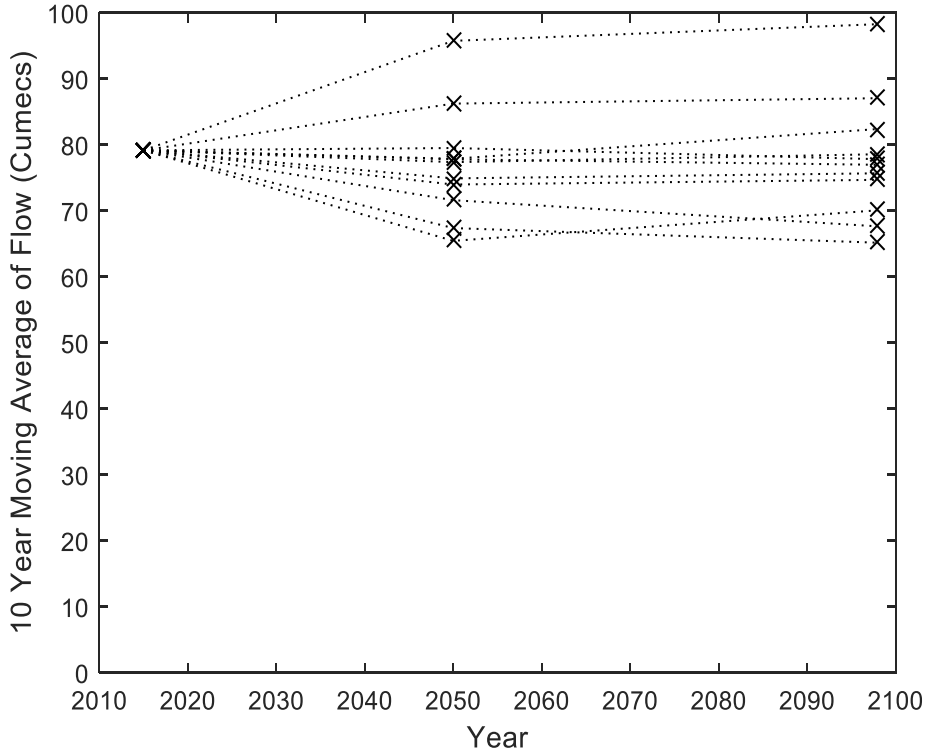


A National Water Resources Model and Infrastructure Assessment

Overview



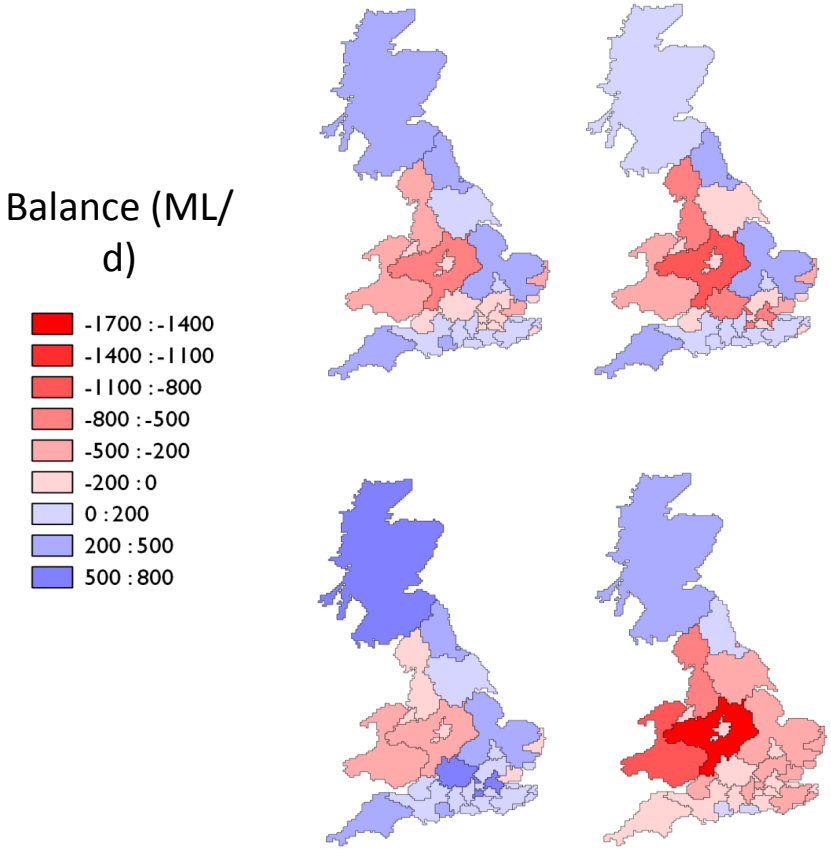
Water Resource Zones and Companies



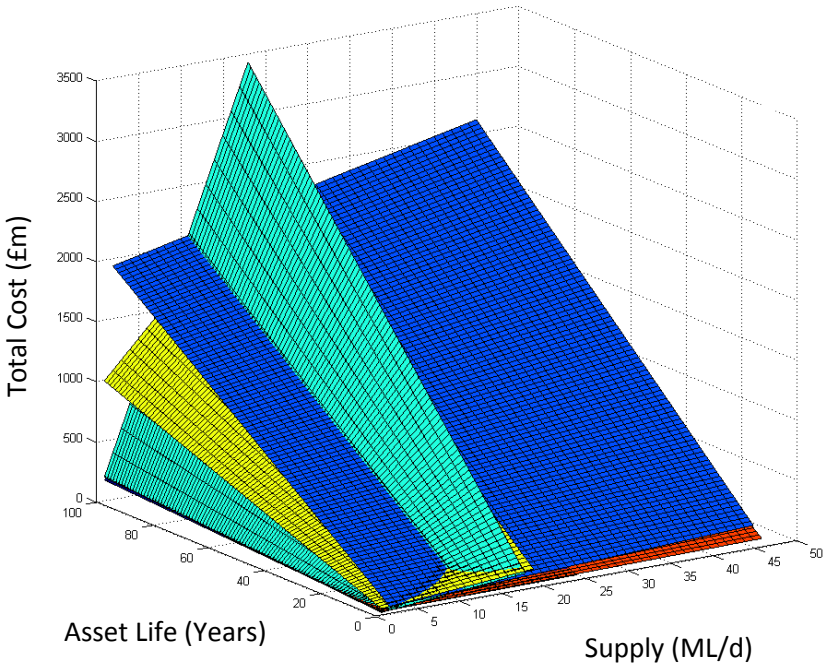
11 Projections of River Flow at Kingston (Thames)

A National Water Resources Model and Infrastructure Assessment

Capabilities



Impact of Climate Change and Population Scenarios on Future Water Supply-Demand Balance

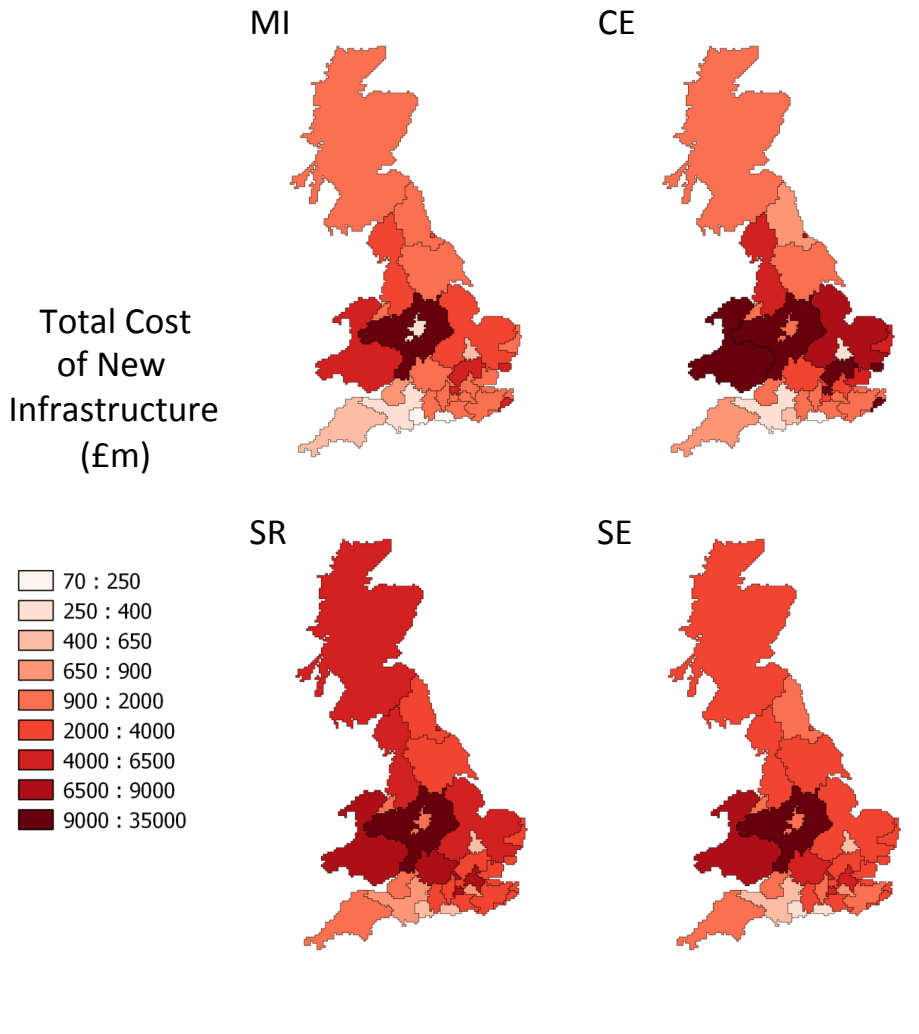


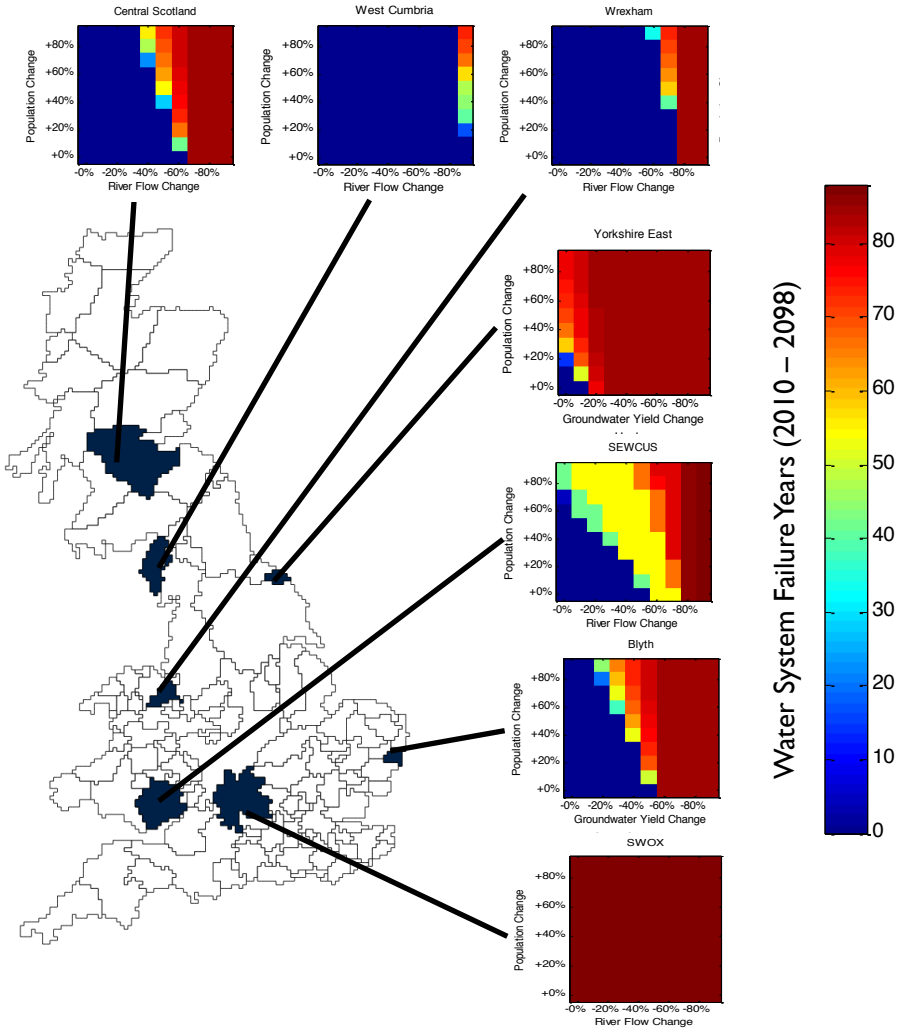
Blue – Desalination, Cyan – Demand Reduction,
Yellow - Effluent Reuse, Red – Leakage Reduction

Regressions of Cost against Asset Life and Supply

A National Water Resources Model and Infrastructure Assessment

Insights





Optimising solid waste and resource recovery

Overview

Simulate waste generation (demand for waste management services)

Calculate demand for additional waste treatment capacity in the future

Waste treatment processes (LCA models)

Collection	Transfer	Transport	Reprocessing	Reuse	
MRF	MHT	MBT	AD	Composting	Incineration
Gasification	CHP	Pyrolysis	UoL	Landfill	Dismantling

Capacity requirement analysis

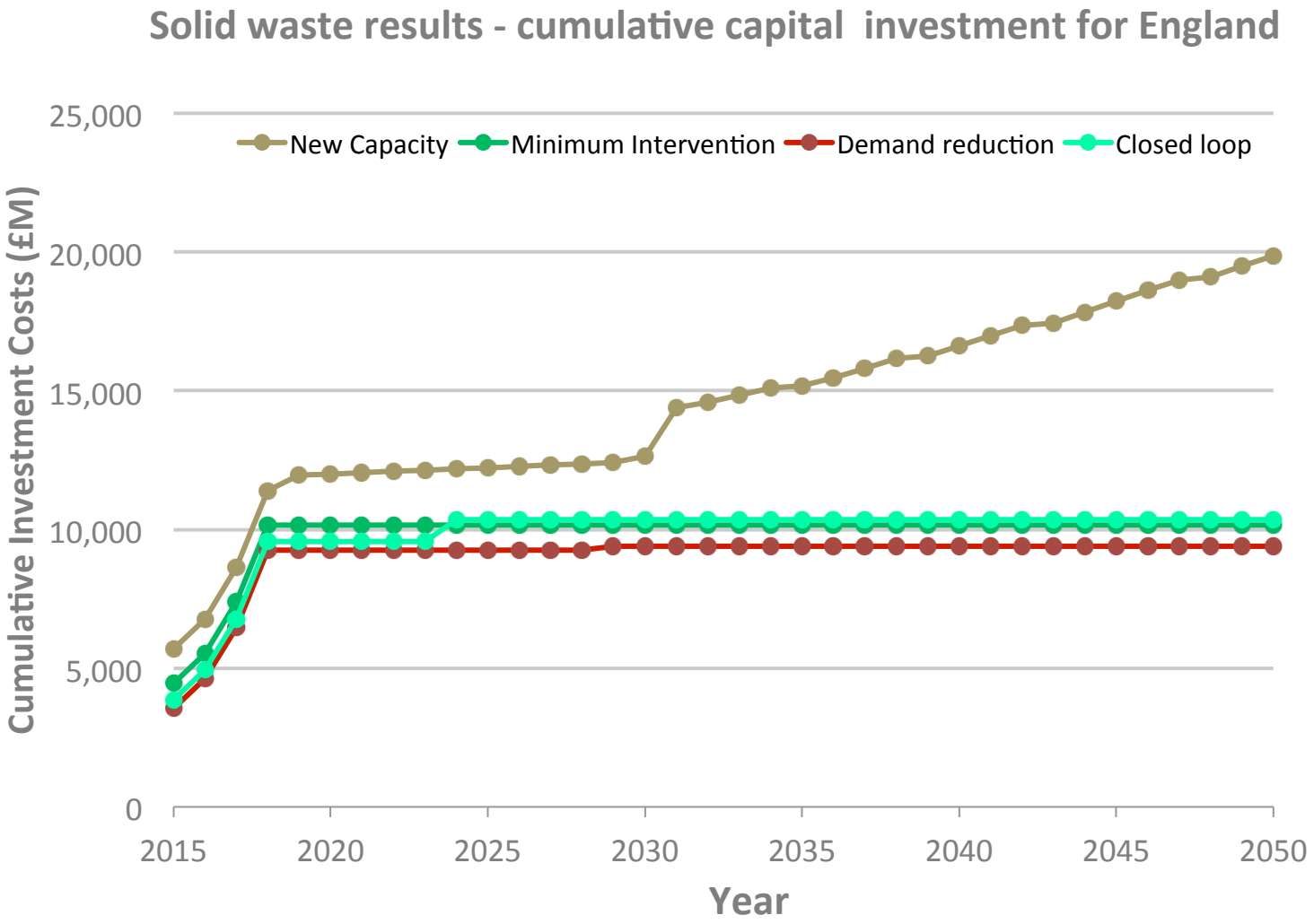
Capacity utilisation optimisation (treatment path order)

Calculate cost, emissions, etc

Optimise new build capacity

Optimising solid waste and resource recovery

Results – capital investment



After 2018, little further investment in Min. Intervention, Closed Loop and Demand Reduction strategies, but significant investment needed in New Capacity strategy

To 2018, model assumes investment in each case is nearly identical and infrastructure built is under construction or consented

Optimising solid waste and resource recovery

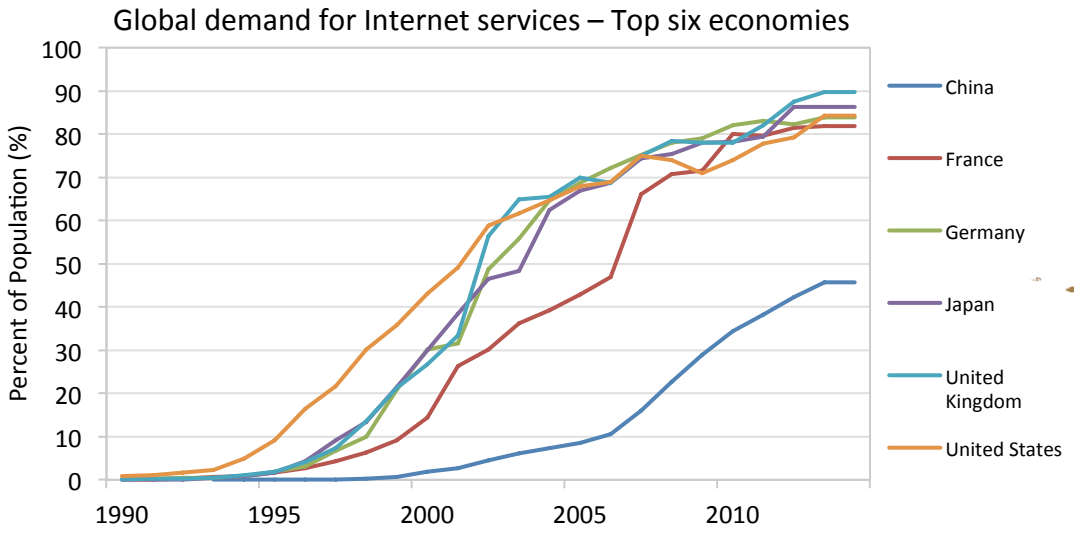
Insights

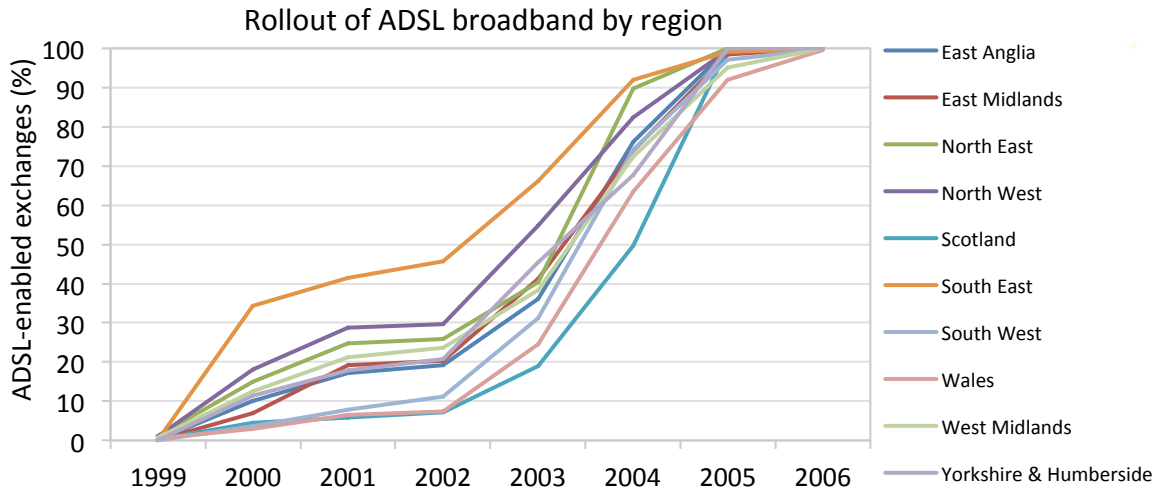
- Recent trends in reduction of waste arisings will be swamped by population growth and economic recovery unless we can further reduce waste production and significantly increase recycling and reuse

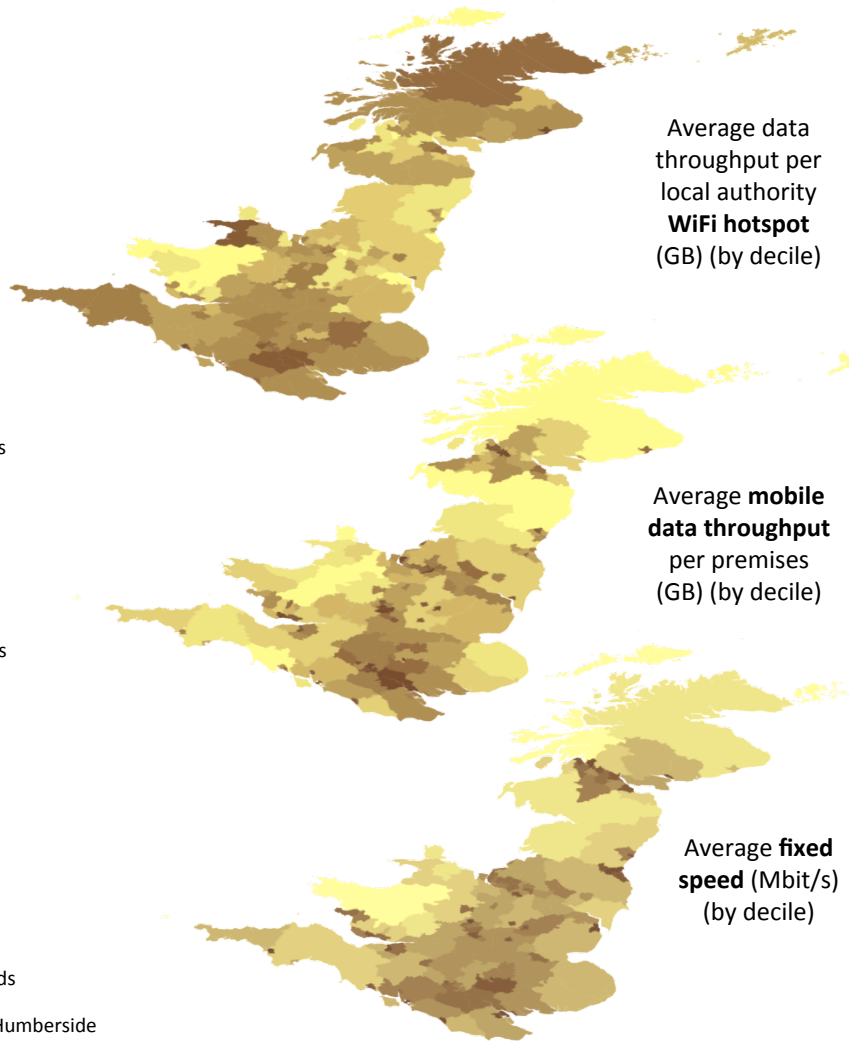
- Demand Reduction and Closed Loop strategies:
    - reduce the need to build additional infrastructure
    - have the highest capacity margins
    - result in the greatest CO2e savings

The future of digital connectivity

Overview







The future of digital connectivity

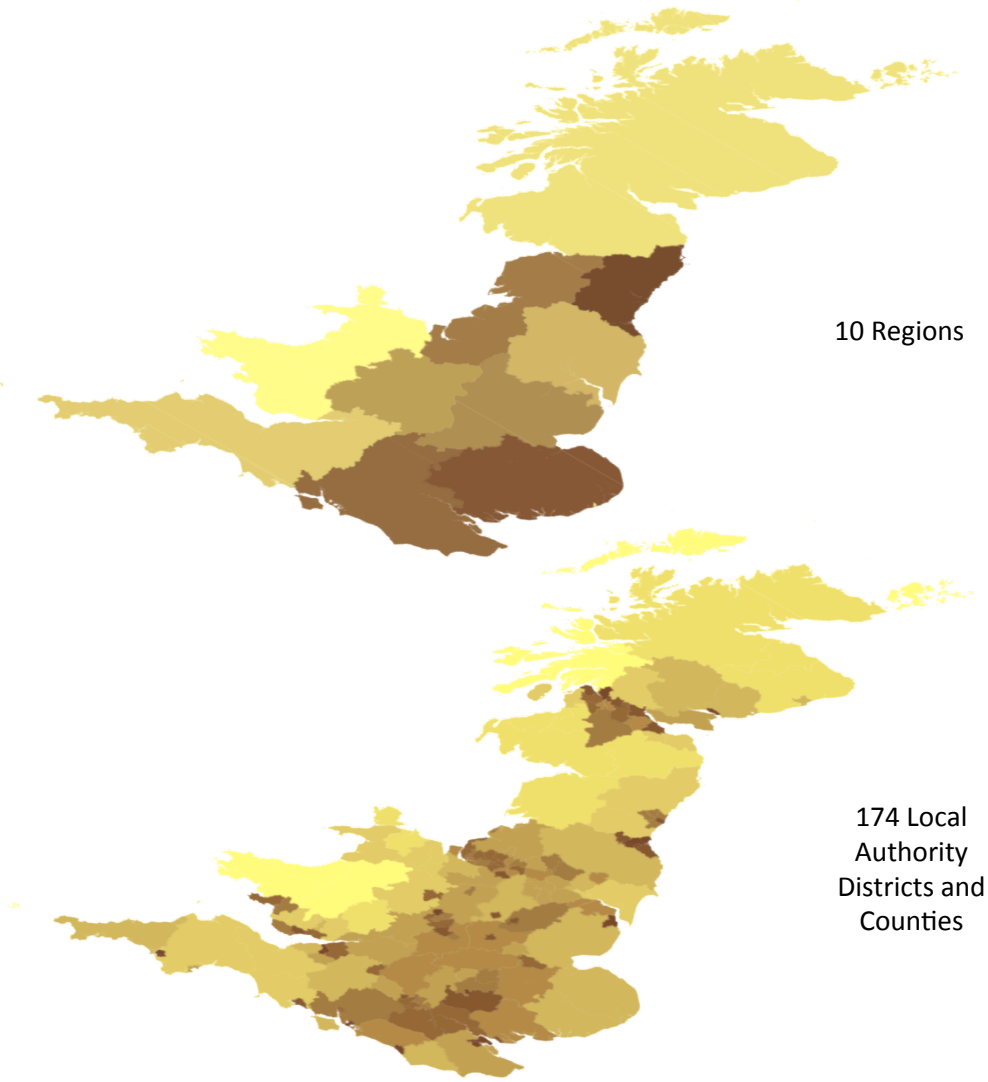
Capabilities

1. Forecasting the supply rollout of fixed and mobile broadband

2. Quantifying the key economic, demographic and geographic factors driving investment in fixed and mobile broadband infrastructure

3. Evaluating National Infrastructure Plan targets

4. Testing hypotheses about the supply and demand of digital communications infrastructure



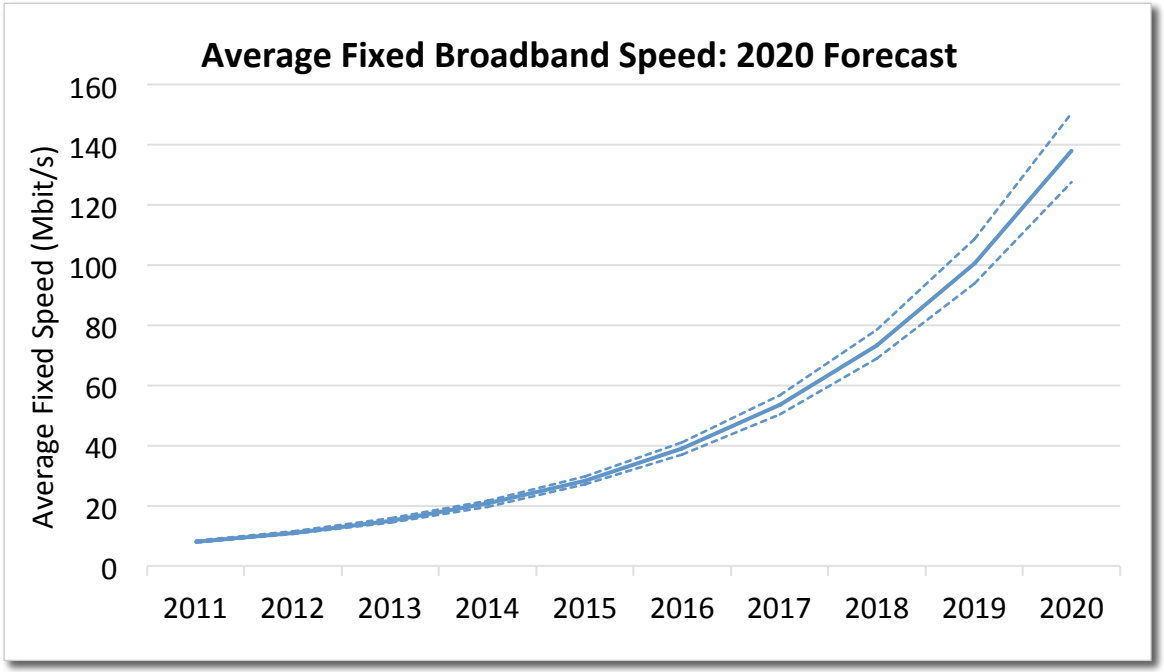
10 Regions

174 Local Authority Districts and Counties

The future of digital connectivity

Insights

- **Fixed broadband** driven by:
  - High population density
  - High median income
  - Low median age
- **Mobile broadband** driven by:
  - Population density
  - Number of firms
  - Low median age
- **Regional insights** :
  - England and Scotland are similar
  - Wales has poorer connectivity

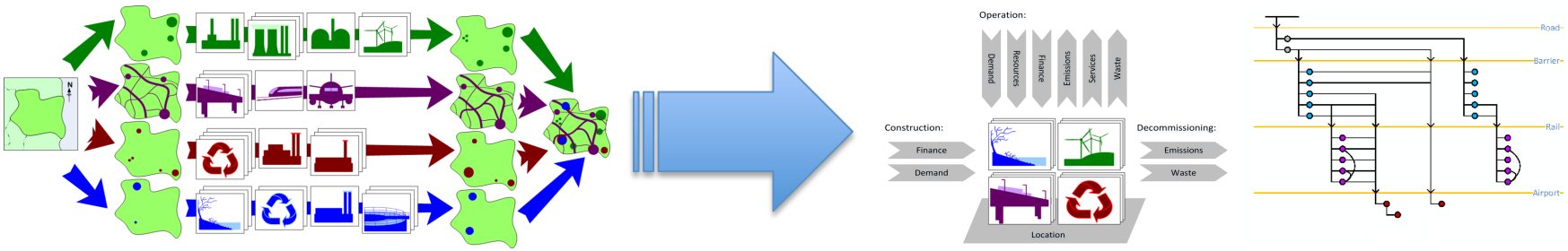


2020 estimate: Average Fixed Broadband Speed 138Mbit/s

2020 estimate: Average Mobile Data Throughput Per Premises 18GB

Decision pathways for infrastructure investment
Overview

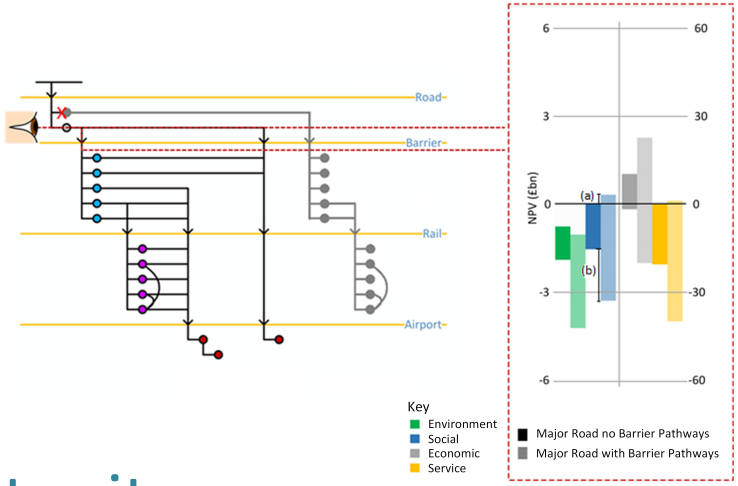
- A strategic appraisal of infrastructure as a system of systems, including:
  - A long-term regional assessment of multiple sector infrastructure investments and their interdependencies;
  - A common, cross-sector multi-attribute CBA; and
  - An active, pathways approach to decision support to prioritise robustness



Decision pathways for infrastructure investment

Capabilities

- A more complete evaluation of the system as a whole including:
  - System resource constraints
  - Cross-sector demands
  - System effects and
  - Visualization of trade-offs
- An understanding of the opportunity value and flexibility of assets
- A level playing field for cross-sector prioritisation

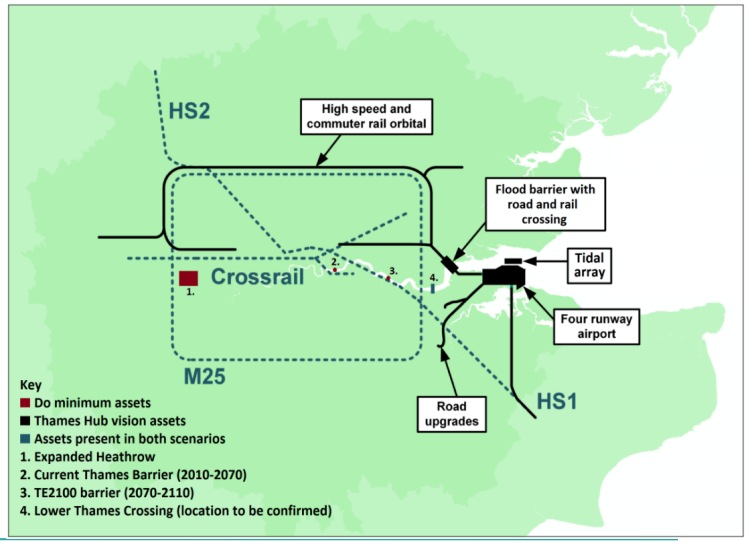


Decision pathways for infrastructure investment

Insights

Case Study: Thames Hub Vision

- Importance of a multi-attribute perspective
- System effects reverse the portfolio appraisal result
- Enablement effects can be an order of magnitude larger than direct impacts
- System can be used to offset costs and reduce the effects of long term uncertainties



Governance of interdependent infrastructures

Why governance?

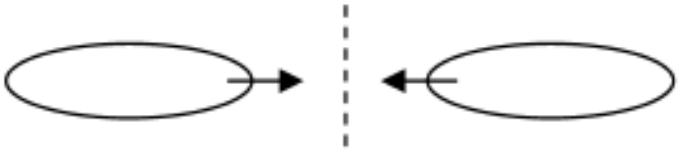
'Hollowing out' of the State: liberalisation and globalisation of many infrastructure sectors

- Power has transferred 'upwards' (e.g. to the EU; multilateral agreements)
- It has also transferred 'outwards' (e.g. to regulatory agencies; public-private partnerships)
- Some decentralisation and devolution (e.g. to Scottish government; 'Northern powerhouse')

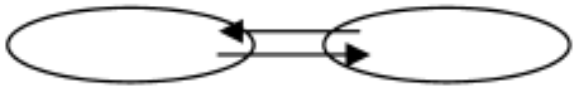
Decision-making by multiple actors, including government(s), private sector and civil society

Governance of interdependent infrastructures

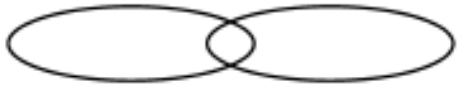
ITRC analysis



Competition



Symbiosis



Integration

Spill-over

Renewable energy in the water sector

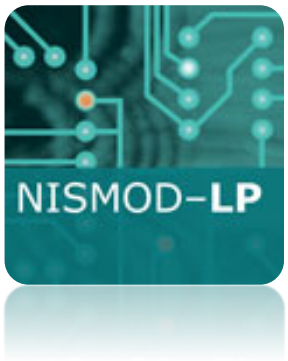
Smart grid demonstrations

Governance of interdependent infrastructures

Insights

- Increasing interdependencies over time: from symbiosis to deeper interactions
- Similarities (e.g. economic regulation of networks); and differences (e.g. competition and innovation).
- Electricity-water case illustrates opportunities and pitfalls of integrated approach to sustainability
- Electricity-ICT case highlights challenges of innovation across very different sectors
- Radical changes of approach will require similarly fundamental changes to policy and regulation

UK Infrastructure Transitions Research Consortium



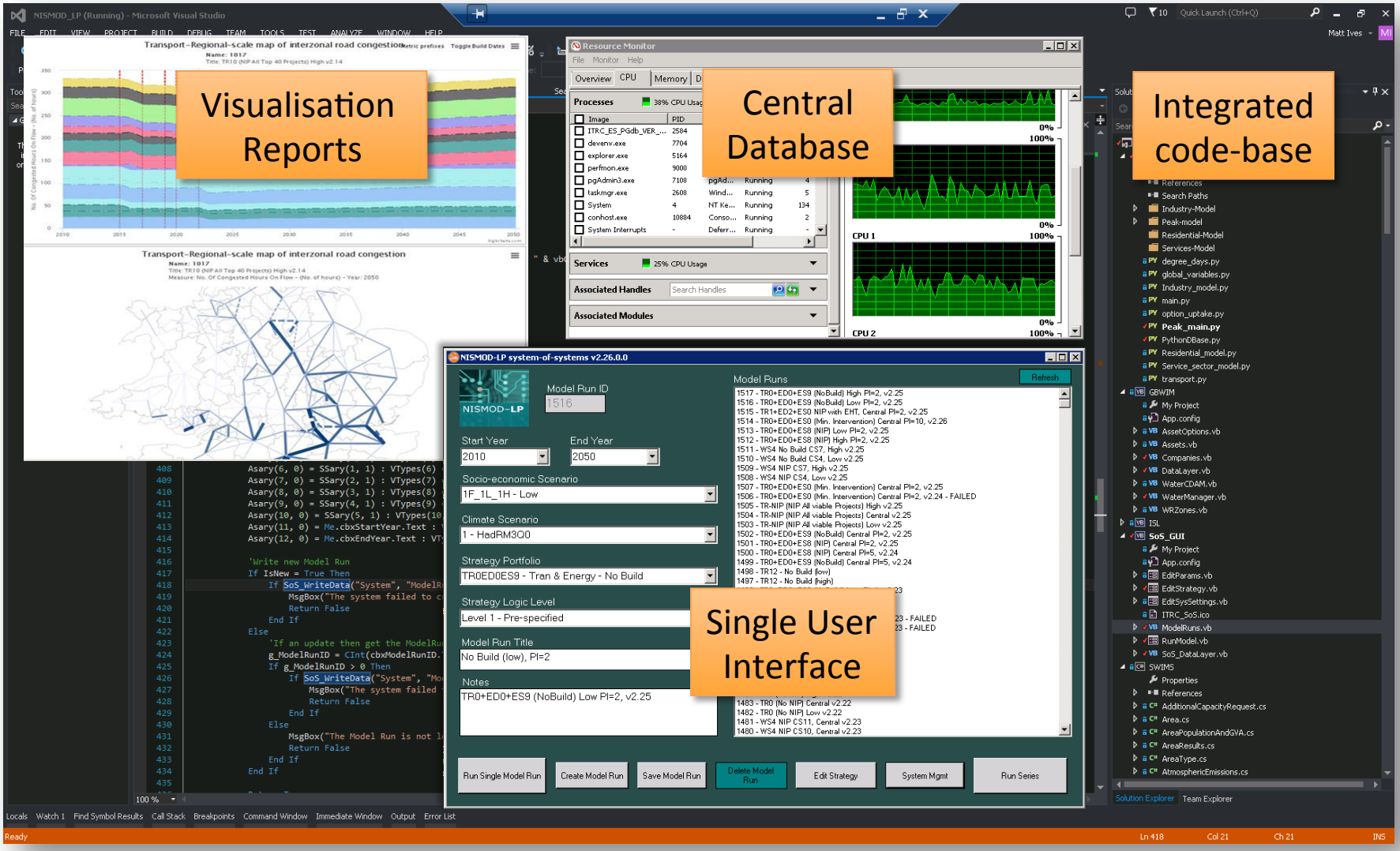
The National Infrastructure Systems Model for long-term performance (NISMOD-LP)

Dr Matt Ives

15th October 2015

NISMOD-LP

What is NISMOD-LP?



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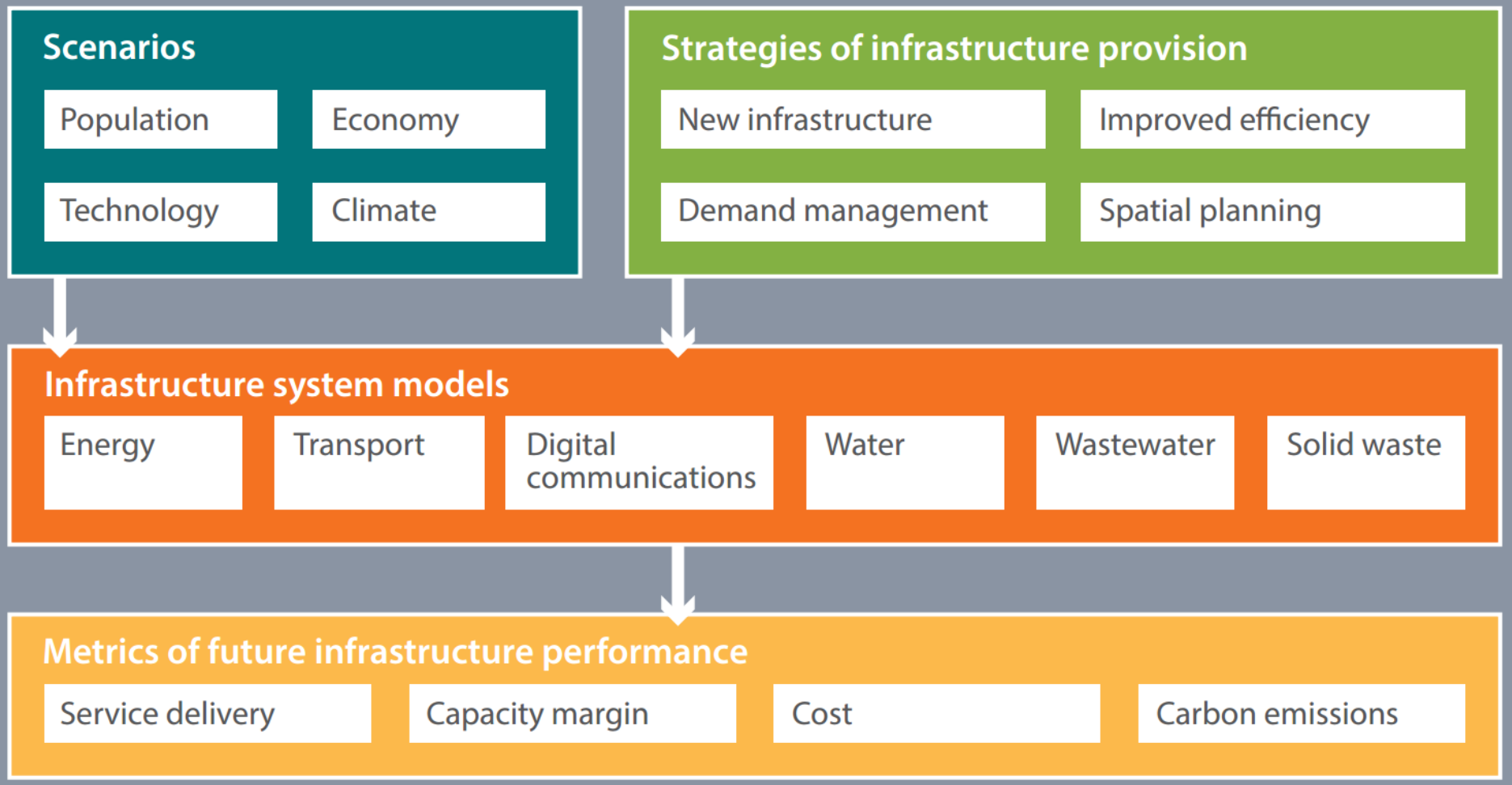
NISMOD-LP

How NISMOD-LP works



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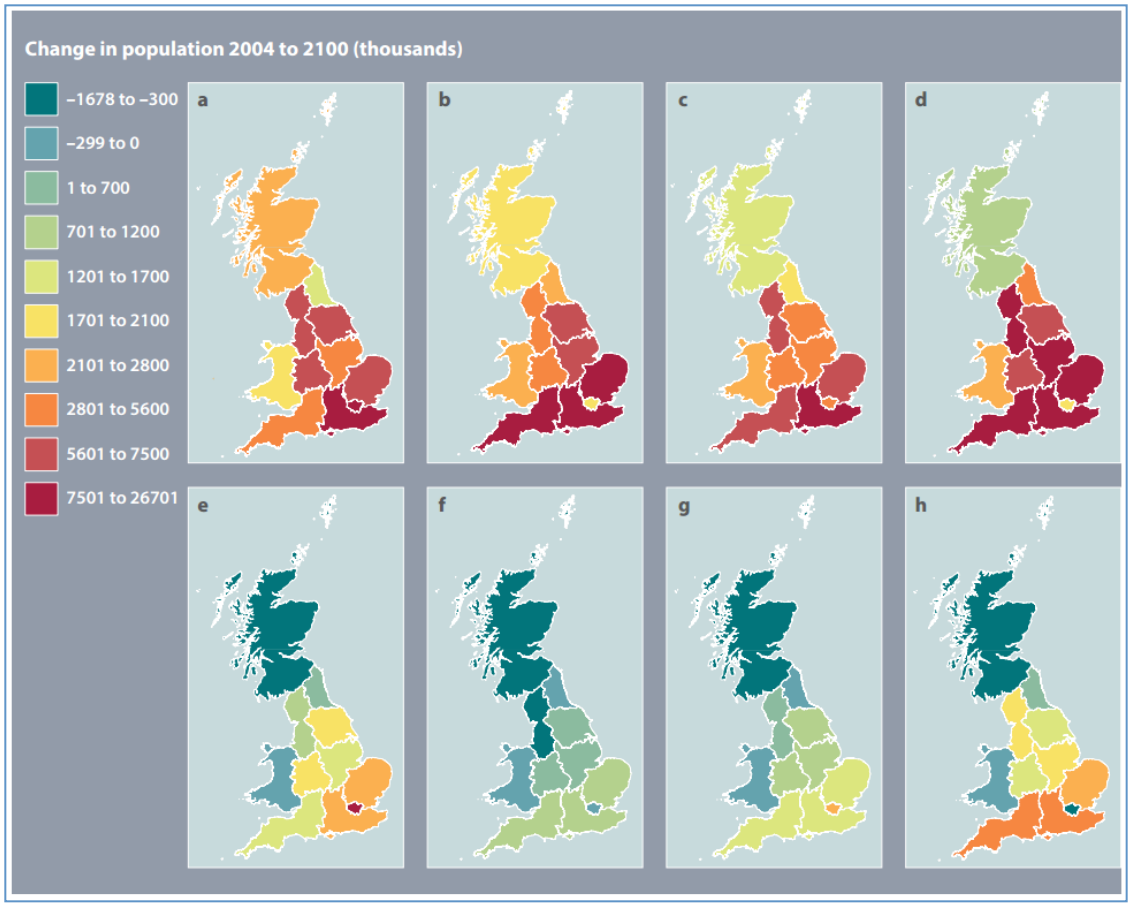
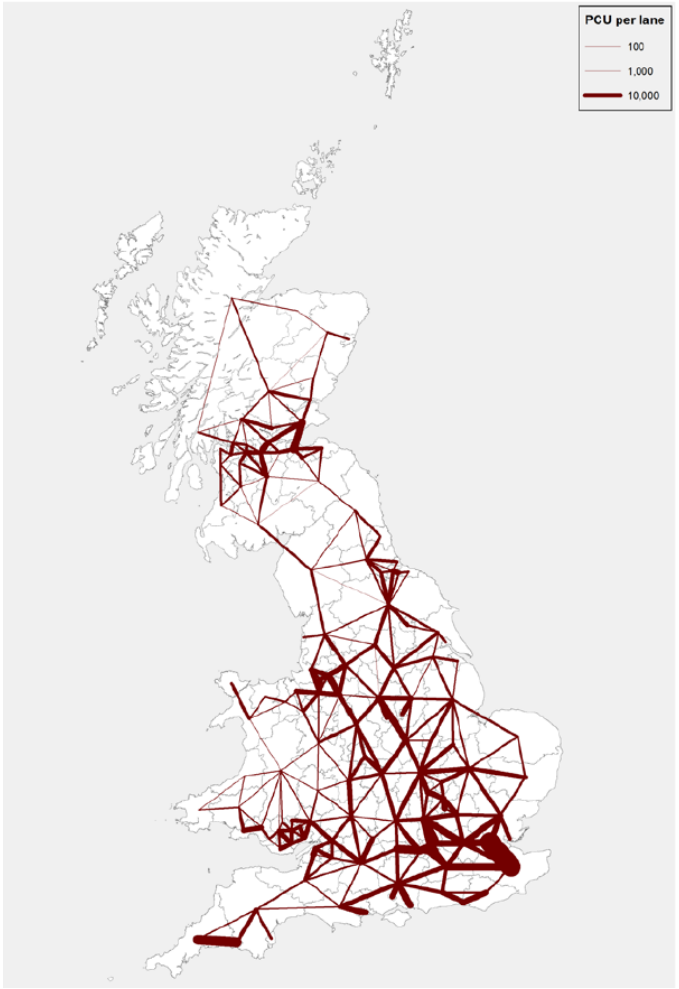
NISMOD-LP

National and regional applications



Alternate population scenarios at a regional scale



Estimated passenger car units for the inter-zonal transport corridors

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NISMOD-LP

Long-term interdependencies

Onshore and Offshore wind farms
http://www.offshorewind.biz/2013/09/04

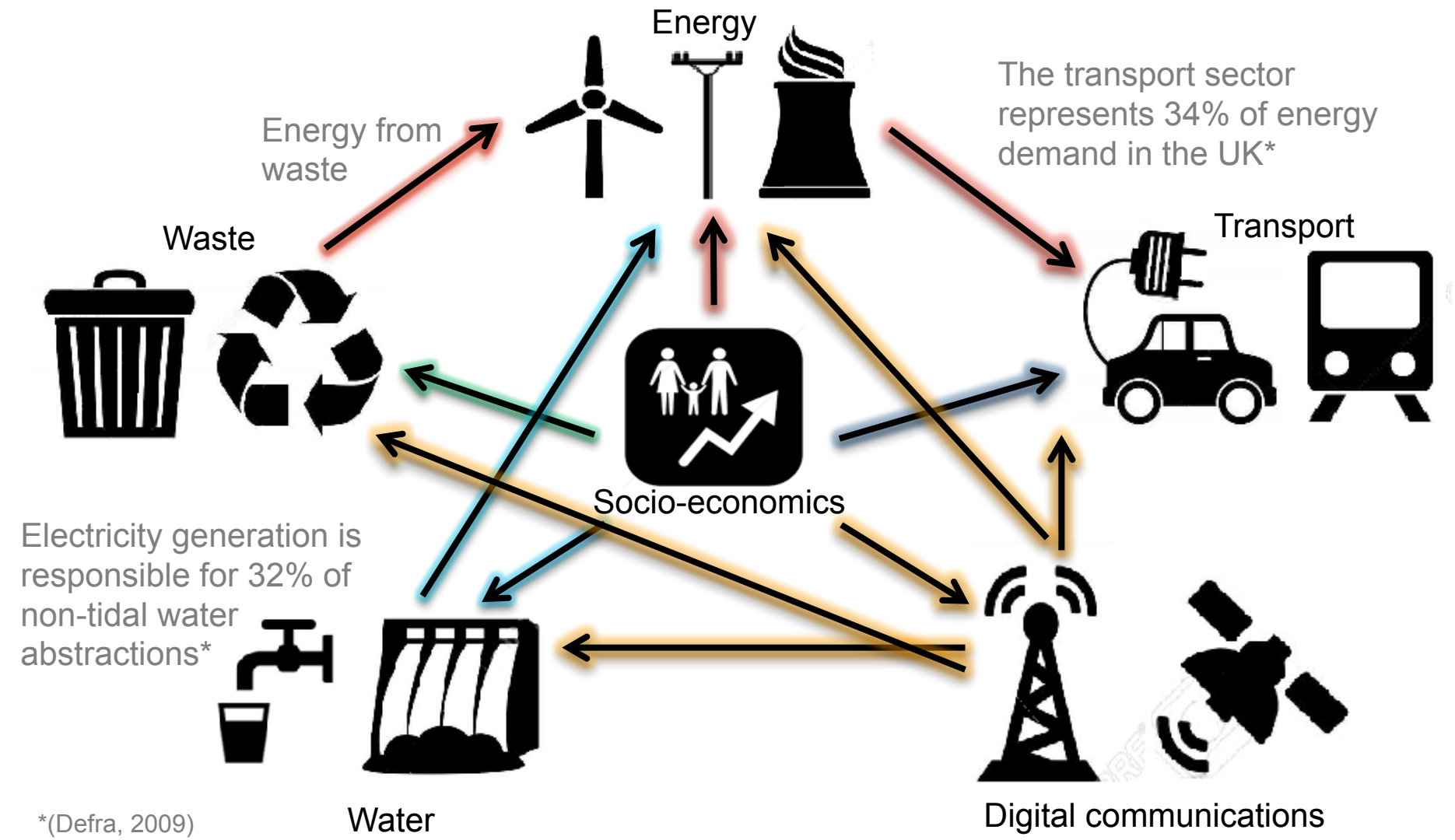
The Tesla Model S Electric Vehicle
(http://www.shifting-gears.com/2014/11/20/tesla-electric-cars-coming-to-india/)

2011 water levels in reservoirs near Manchester
http://www.dailymail.co.uk/news/article-1387801

Socio-economic change
http://www.dailymail.co.uk/femail/article-2205669

NISMOD-LP

A system-of-systems approach



*(Defra, 2009)

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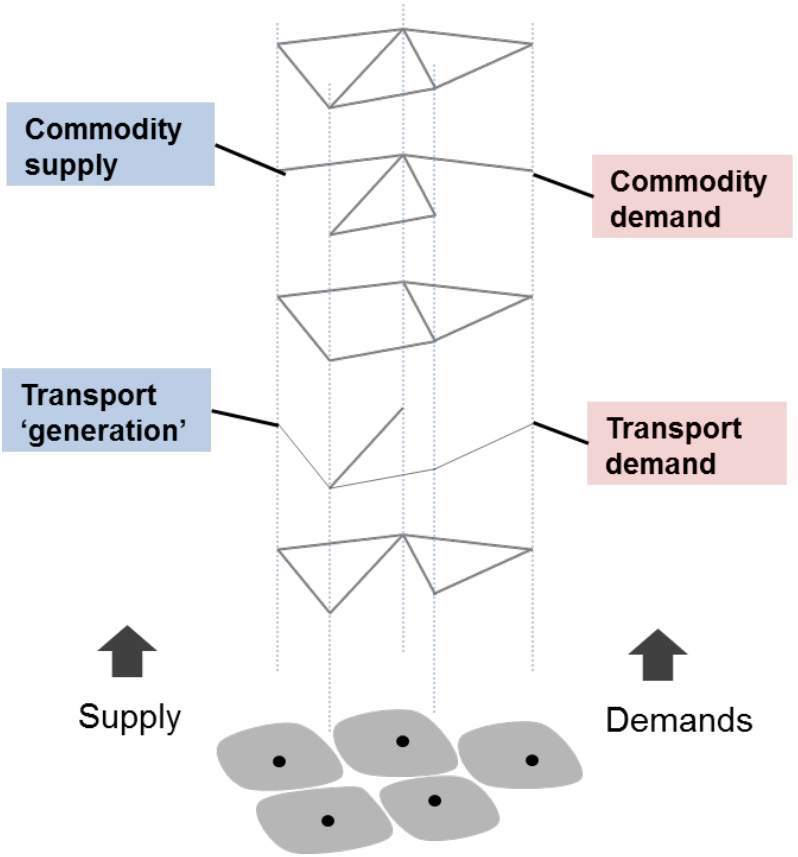
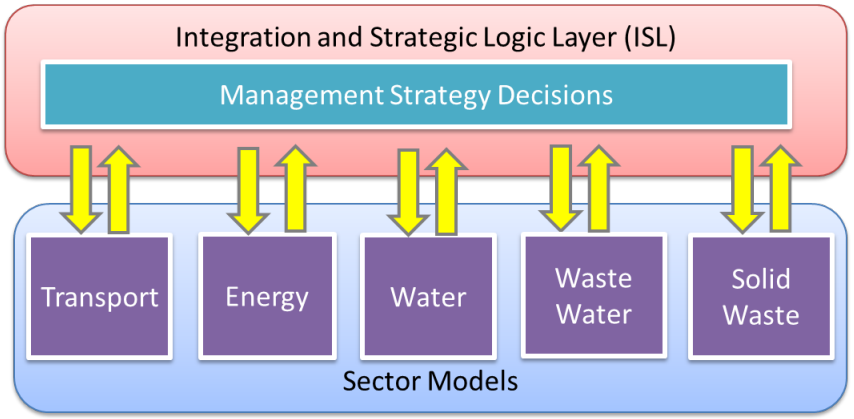
NISMOD-LP

Making decisions about infrastructure provision



Dirks, B. et al., (2015), Integrated Infrastructure Modelling - A Generic Approach to Managing Interdependencies



Level 1: Pre-specified

System is run using a predetermined set of investments e.g. the National Infrastructure Pipeline

Level 2: Rule-based

System performance indicators trigger infrastructure investment e.g. congestion triggers motorway widening

Level 3: Optimisation

System performance is optimised with respect to an objective function e.g. least cost to achieve a CO2 emissions target

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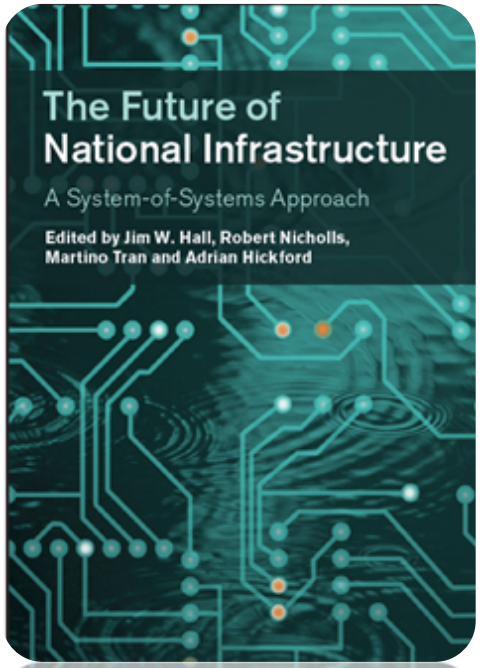
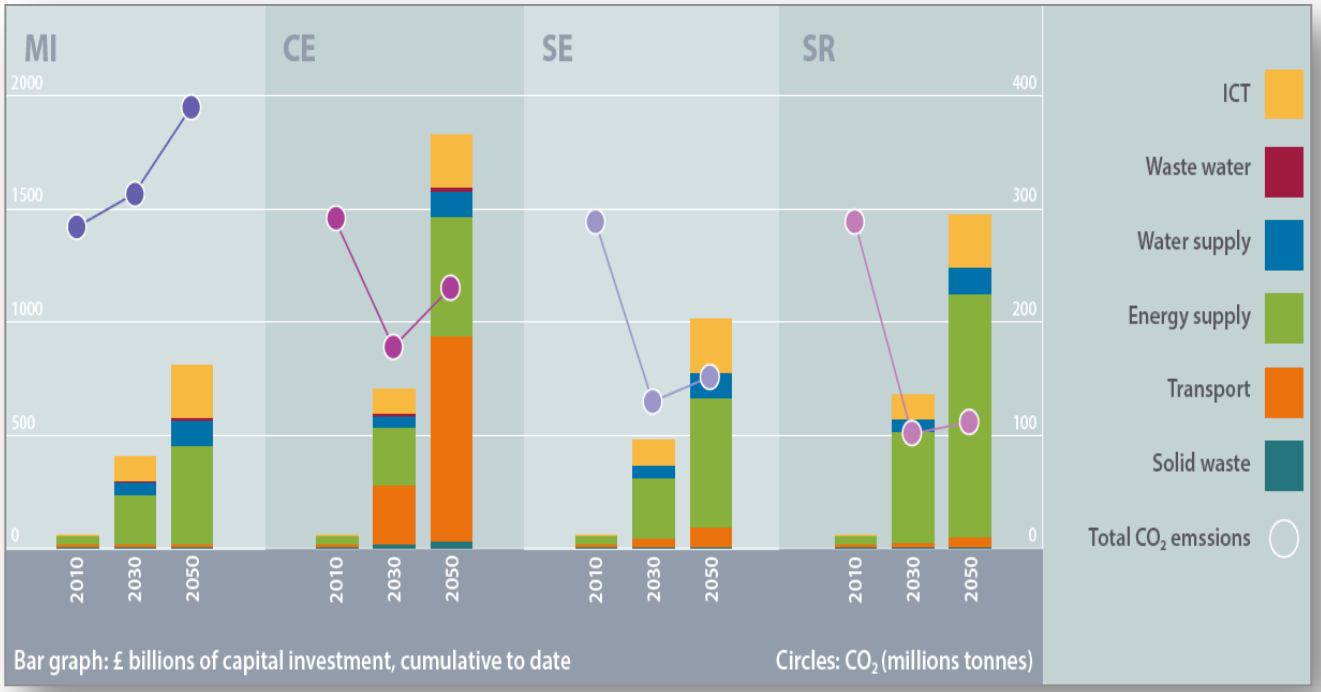
NISMOD-LP

Applications of NISMOD-LP





Minimum Intervention (MI) – historical levels of investment, continued maintenance and incremental system change.

Capacity Expansion (CE) – large scale, long-term investment into physical capacity expansion.

System Efficiency (SE) – technological and policy interventions to increase system throughput targeting supply and demand.

System Restructuring (SR) – rethinking the system through innovation, design, new service delivery models, demand reduction.

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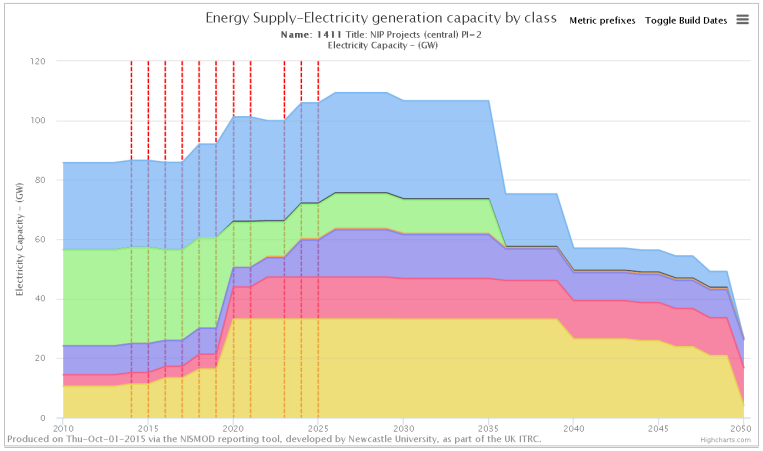
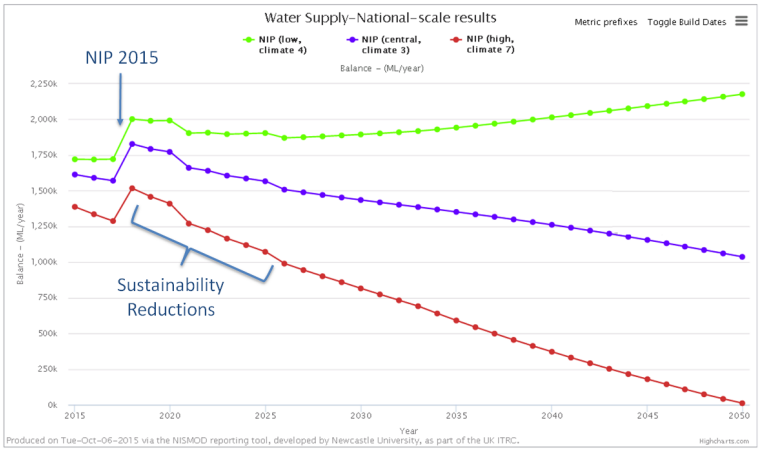
Applications of NISMOD-LP

National Infrastructure Plan 2015

- Overall infrastructure pipeline

  £411bn



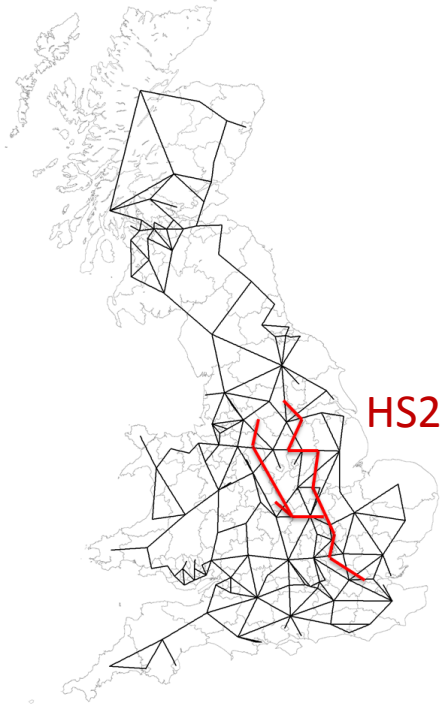


Top 40 Priority List

- 40 themes/major projects

(219 total projects/programmes)

• Transport	22
• Strategic roads	7
• Rail	8
• Local transport	4
• Aviation / Ports	3
• Energy	9
• Floods	1
• Communications	4
• Water	2
• Waste	0
• Science and Research	2



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Infrastructure UK

NISMOD-LP: In summary

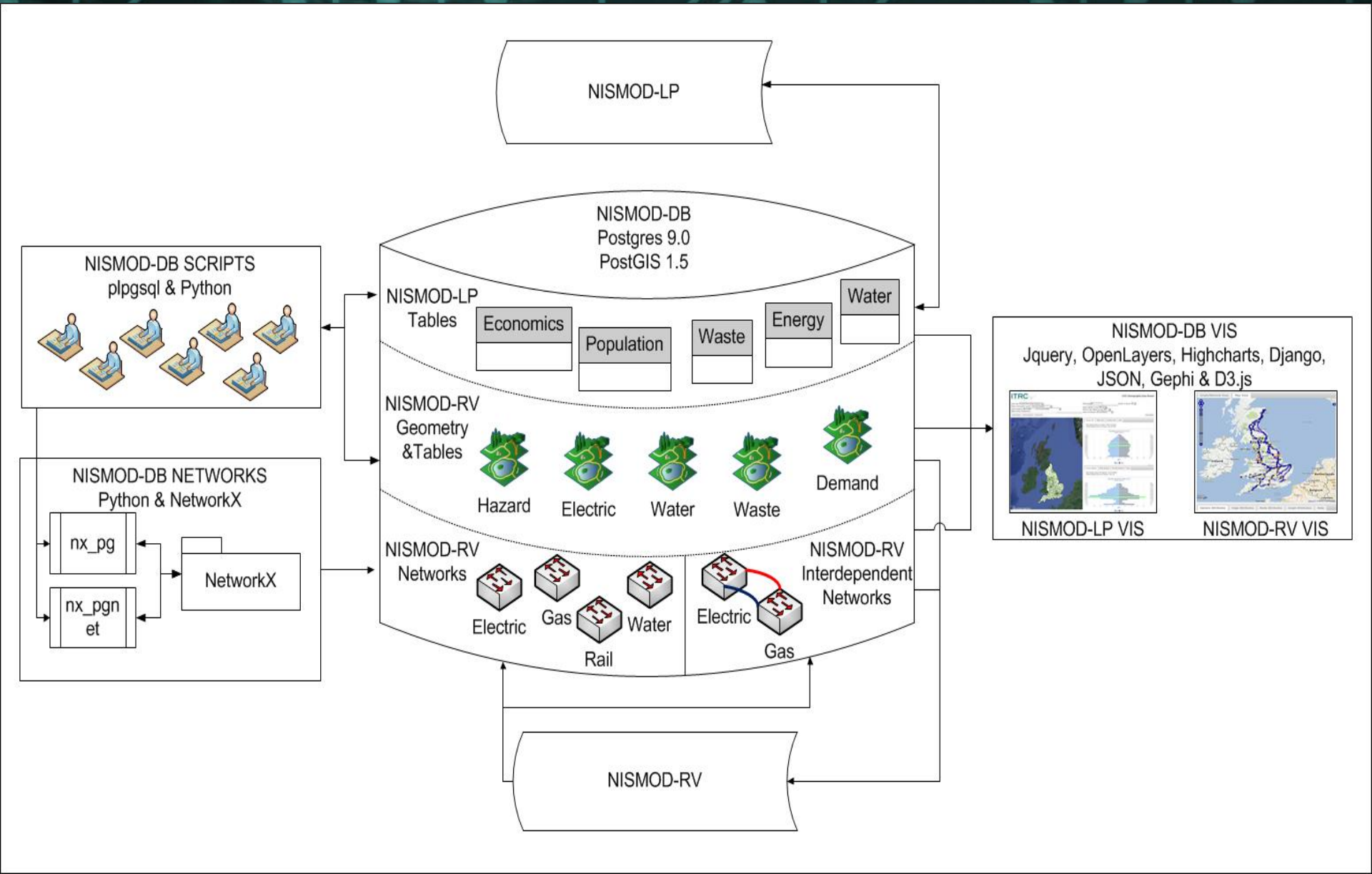
- NISMOD-LP is a long-term infrastructure analysis tool
- Applies a consistent set of socio-economic and climate scenarios to all sector models
- Incorporates major interdependencies between infrastructure sectors
- Allows the exploration of alternative investment strategies and their robustness to long-term uncertainty

UK Infrastructure Transitions Research Consortium

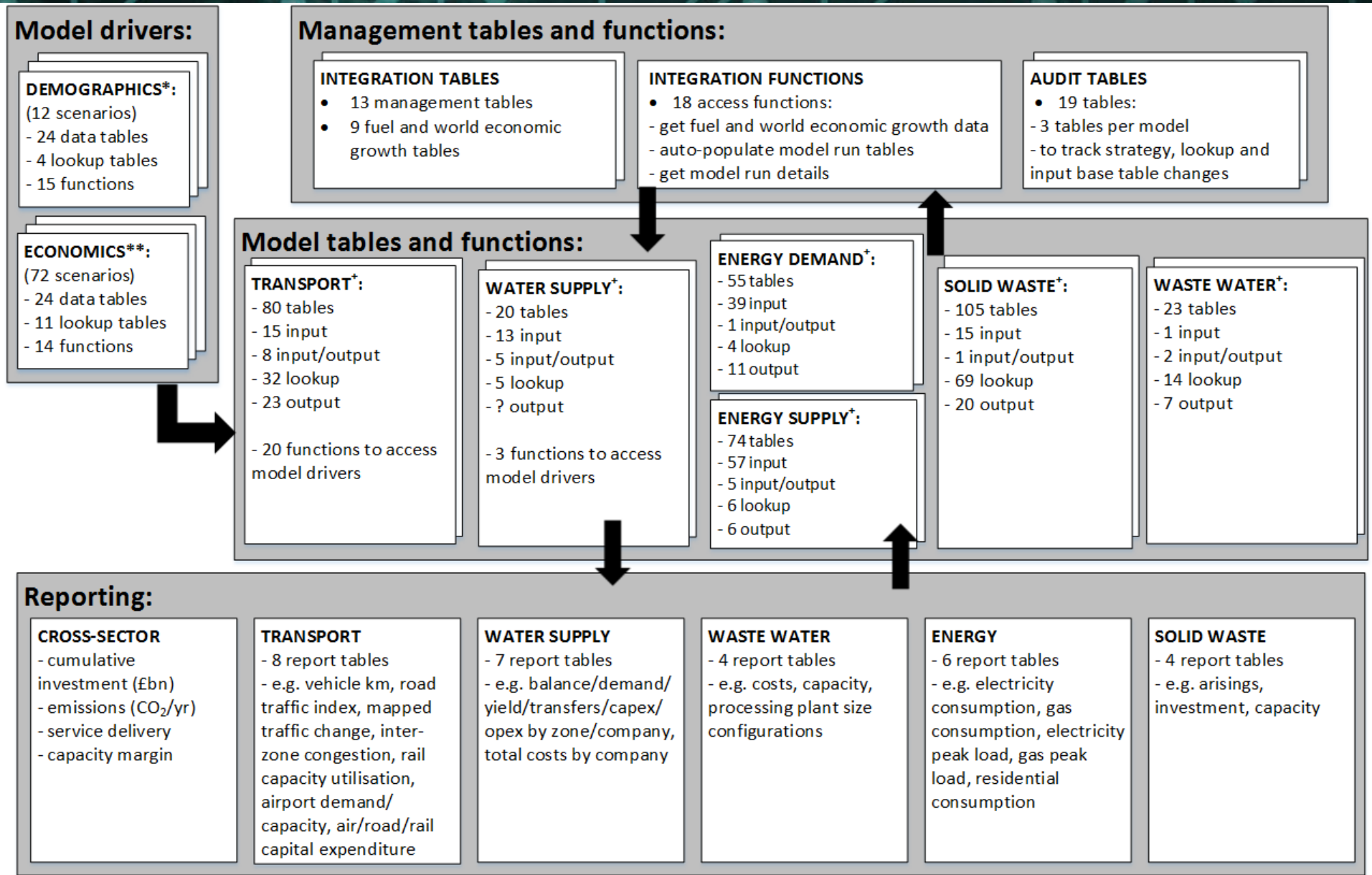
A national infrastructure database and visualisation toolkit

Stuart Barr

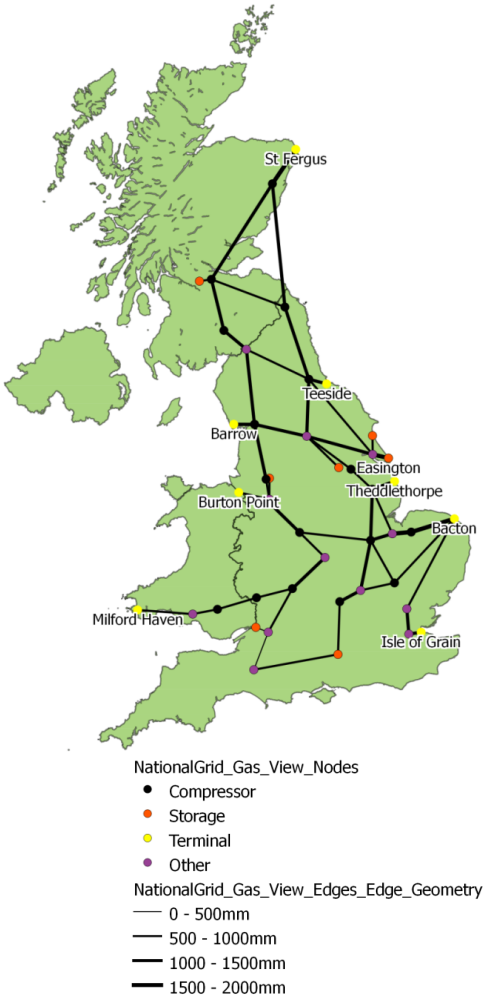
NISMOD-DB Overview

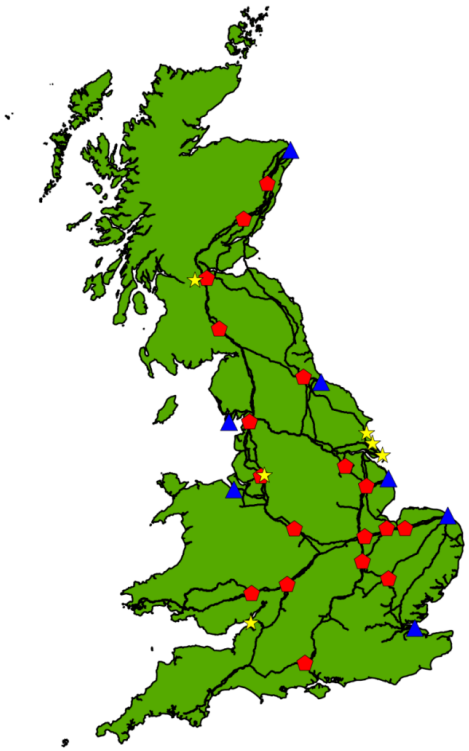


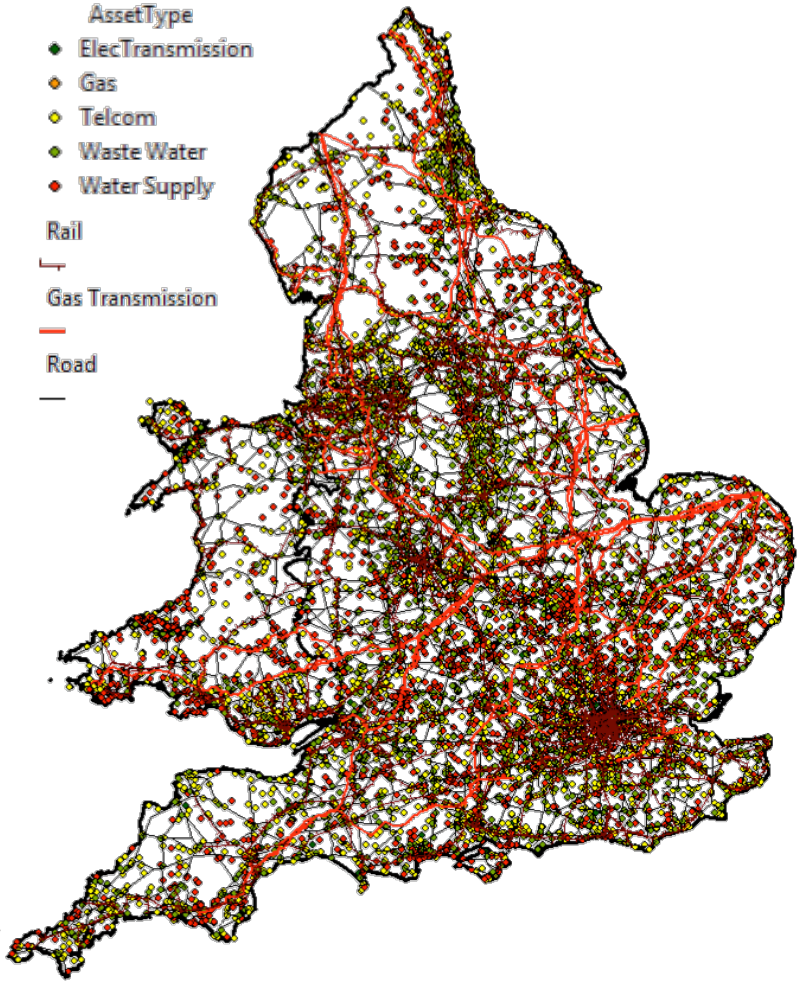
NISMOD-DB & NISMOD-LP



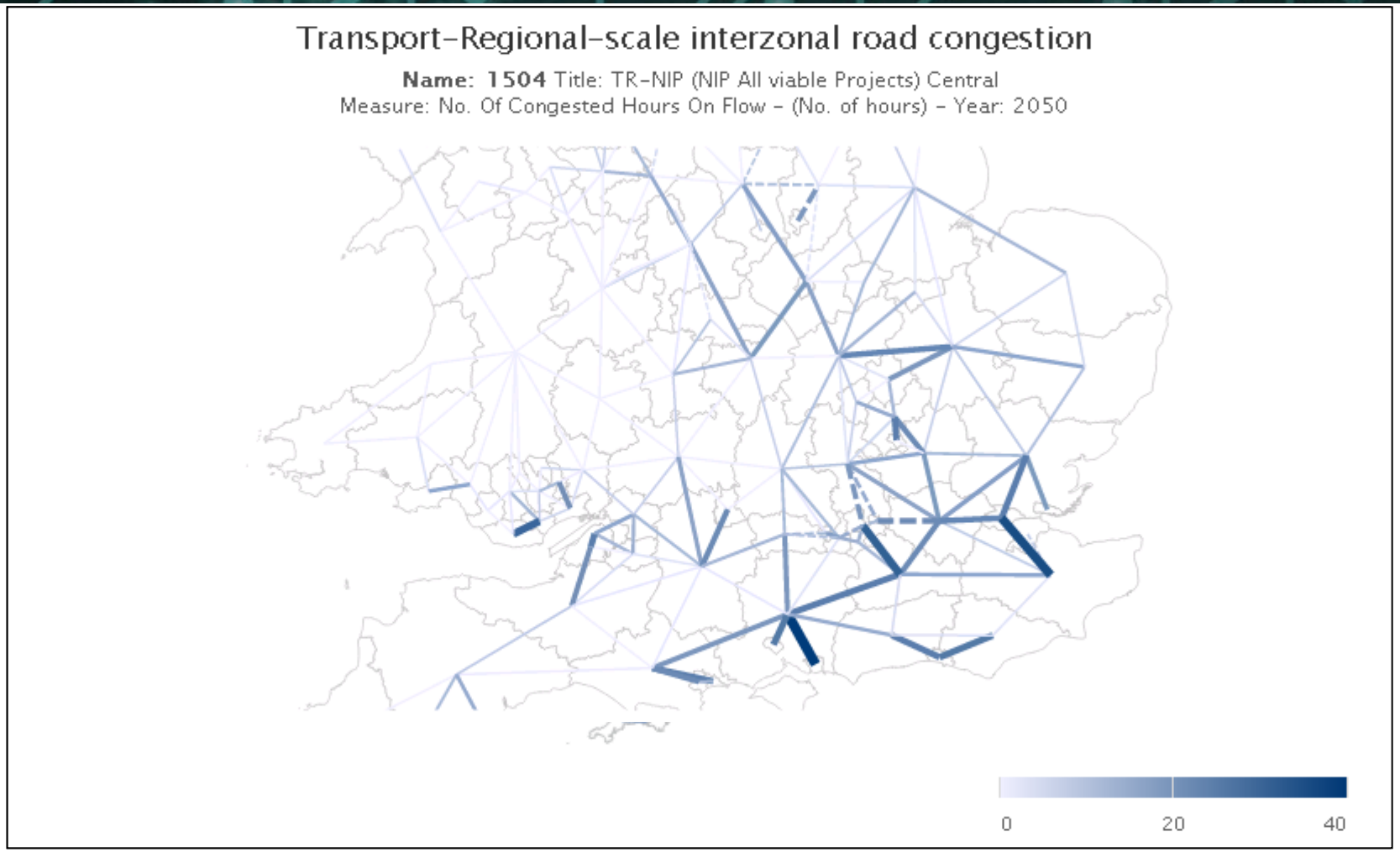
NISMOD-DB & NISMOD-RV







NISMOD-DB Visualisation Toolkit



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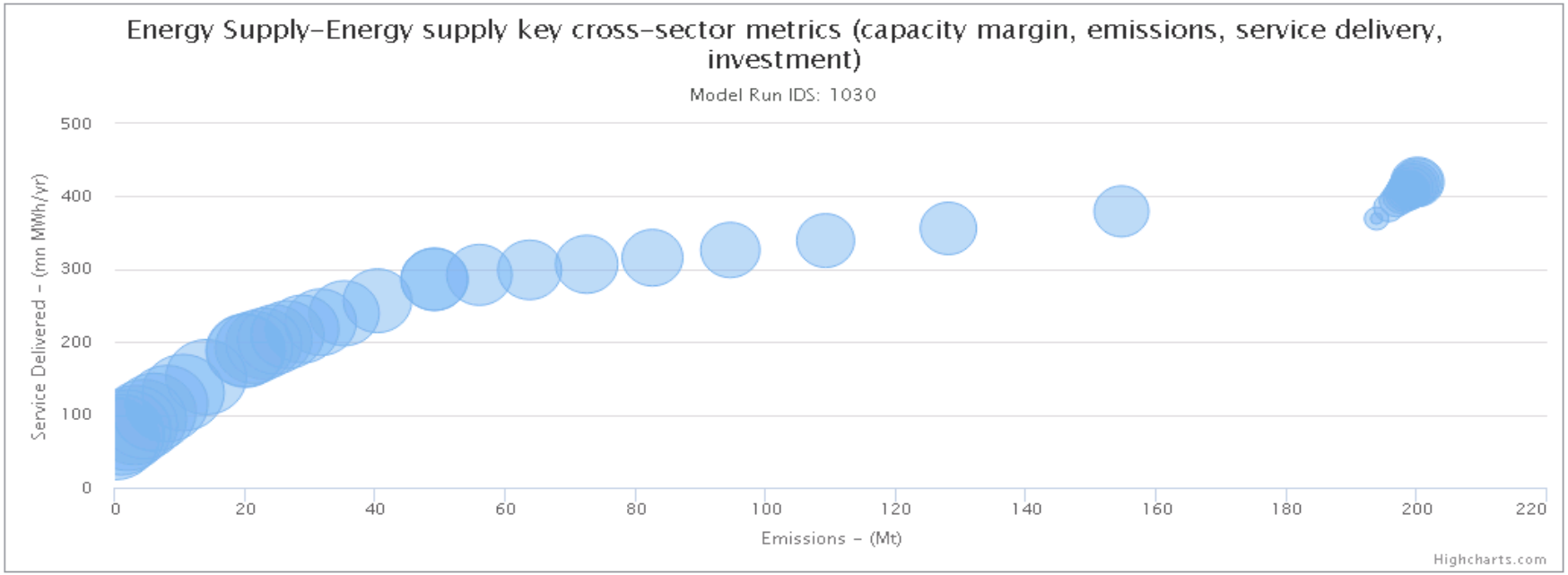

Show: 10 ▾ Search:

Showing 1 to 10 of 41 records

Pages: Previous 1 2 3 ... 5 Next

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1030	2014	1030	197.562194109383	399.777020695099
1030	2015	1030	198.170358743655	404.647615431849
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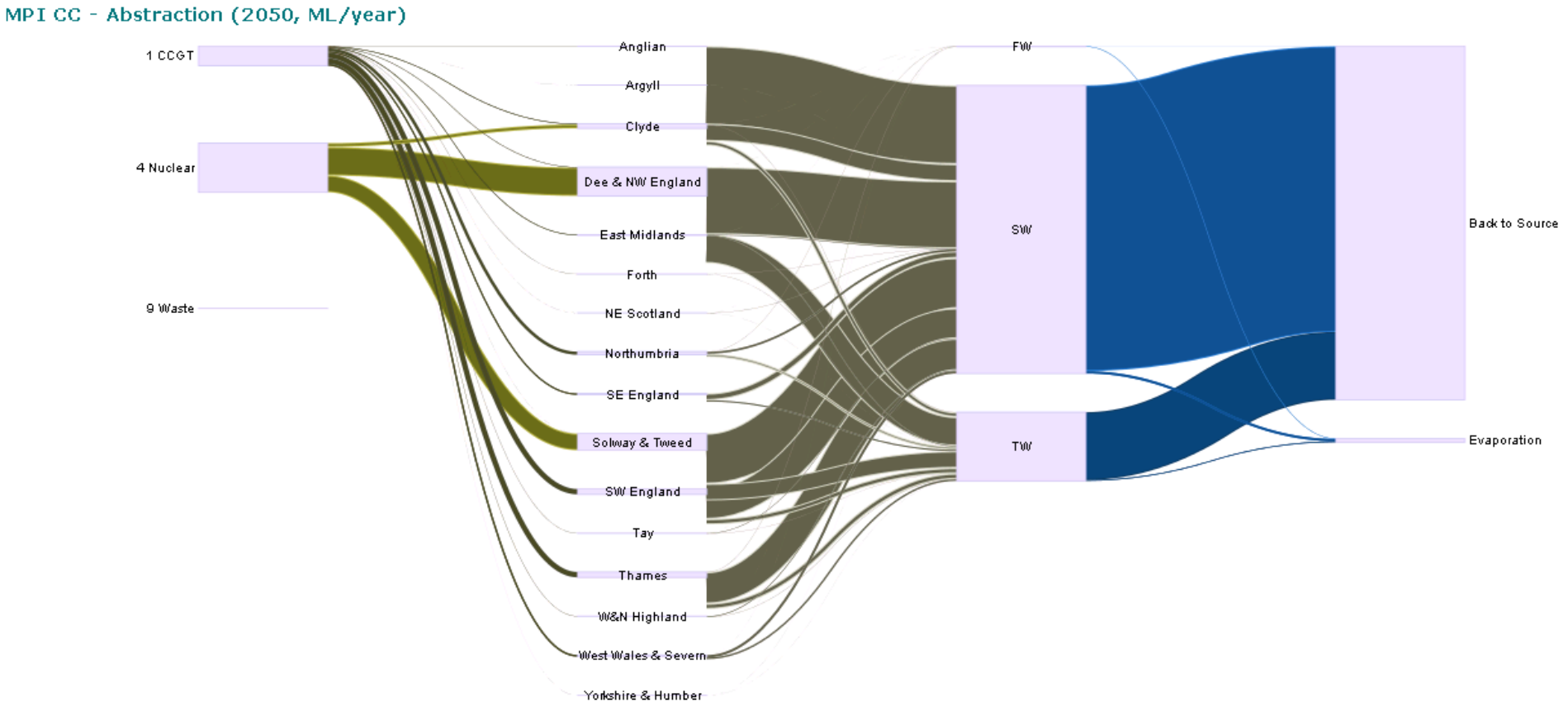
NISMOD-DB Visualisation Toolkit



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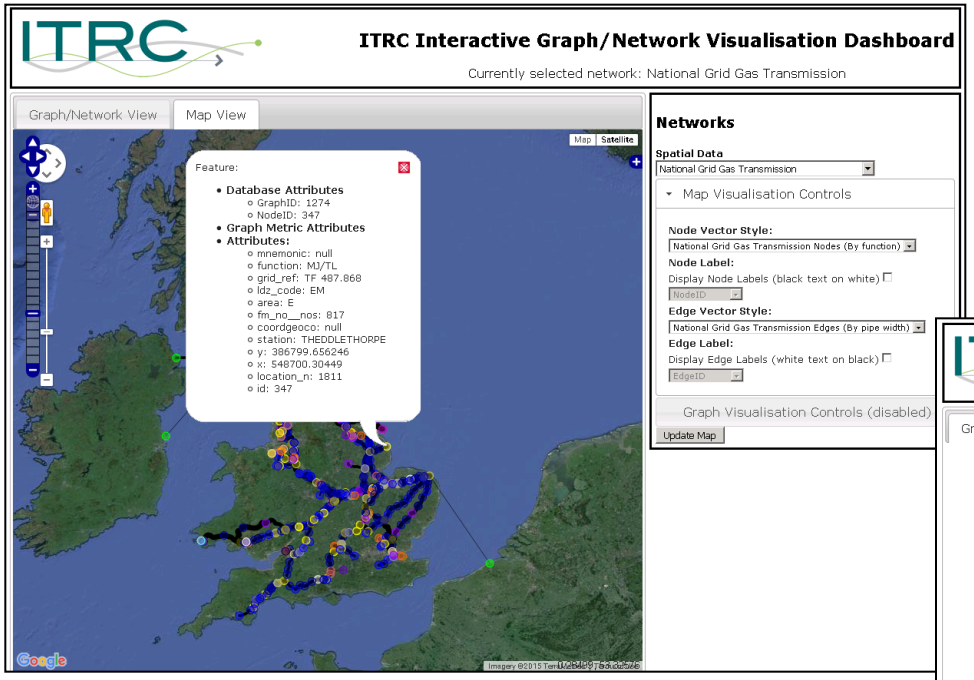
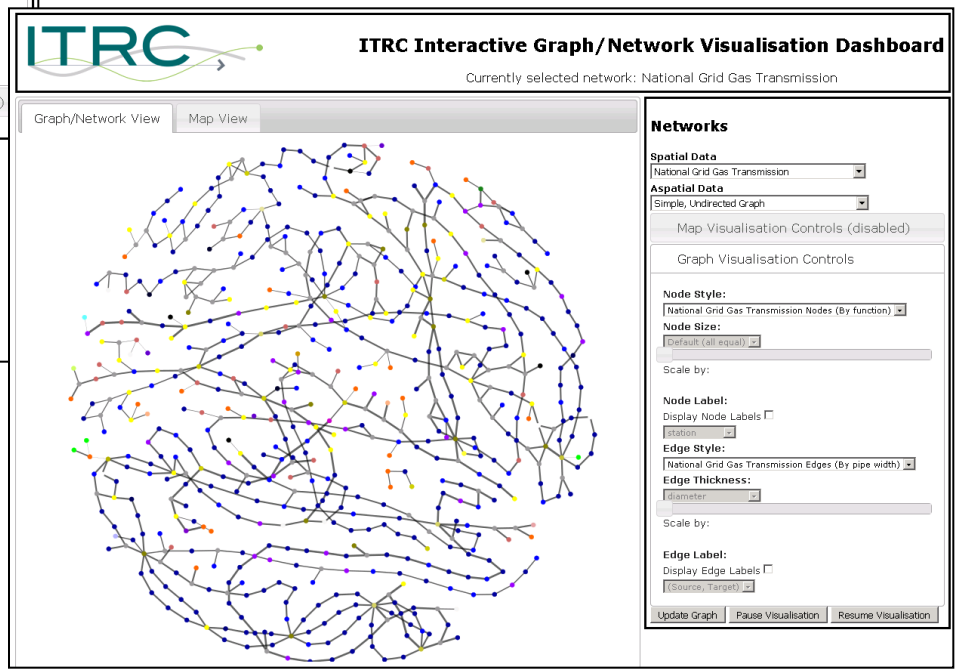




The Future of National Infrastructure:
Outcomes from the UK Infrastructure Transitions Research Consortium

Institution of Civil Engineers

15th October 2015

Impacts Highlights

- ***Strategic analysis of the National Infrastructure Plan*** - *Adrian Hickford (ITRC) and Geoff Baldwin (Infrastructure UK)*
- ***Risk analysis of Britain's infrastructure network*** – *Raghav Pant (ITRC)*
- ***Spatial modelling for future energy scenarios*** - *Raghav Pant (ITRC) and Russell Fowler (National Grid)*
- ***The risk of railway bridge scour -*** *Rob Lamb (JBA Consulting)*
- ***Geohazards to infrastructure*** - *Oliver Pritchard (ITRC) and Mark Heaton (Lincolnshire County Council)*

UK Infrastructure Transitions Research Consortium

Strategic analysis of the National Infrastructure Plan

Adrian Hickford (University of Southampton)
Geoff Baldwin (Infrastructure UK)

15 October 2015

Infrastructure UK

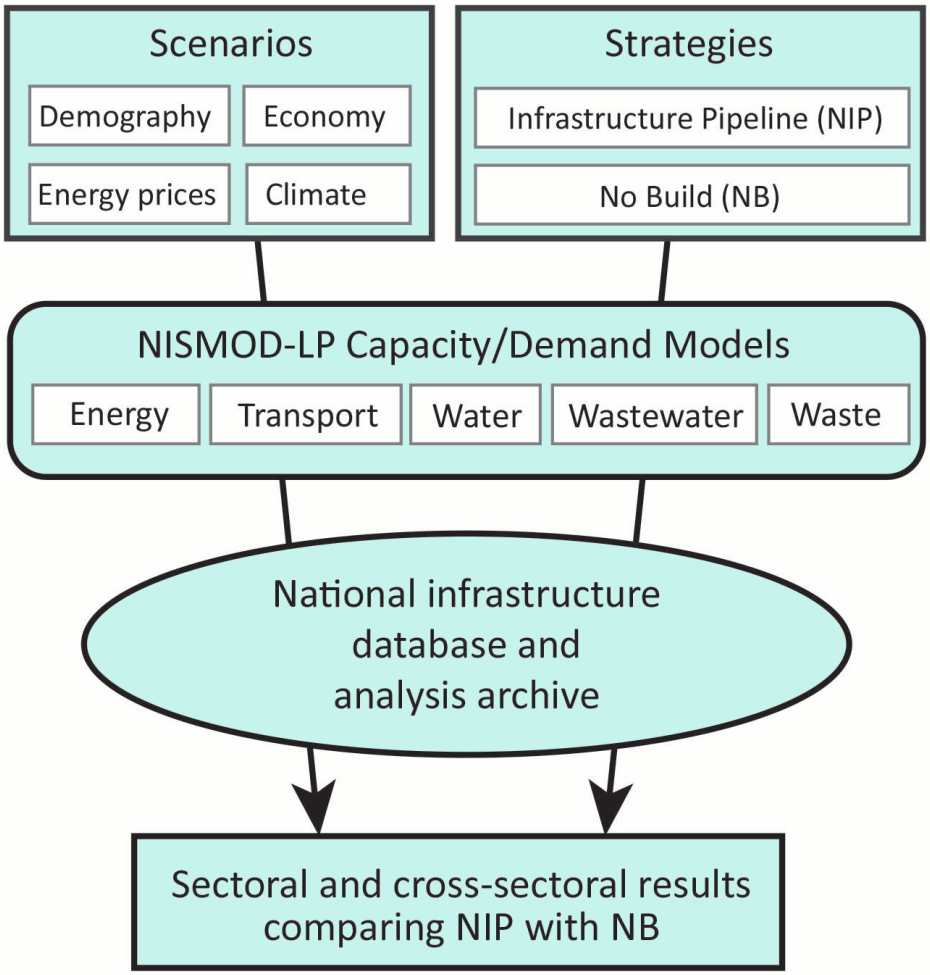
ITRC

EPSRC
Engineering and Physical Sciences Research Council

ITRC/IUK collaboration Background

- EPSRC-funded Impact Acceleration Account (IAA) collaboration
- 3 universities: Oxford (Matt Ives), Newcastle (David Alderson), Southampton (Adrian Hickford)
- Unique opportunity to assess the impact of IUK's National Infrastructure Pipeline (NIP) project investments – particularly for Energy, Transport and Water
- Use the NISMOD-LP model to analyse the sensitivity of the proposed pipeline to various future socio-economic scenarios
- Enable a comparison of NIP investments with a 'No Build' (NB) future
- Test-case of ITRC visualisation tools for reporting results

ITRC/IUK collaboration
Modelling process



ITRC/IUK collaboration
Socio-economic scenarios

72 possible Scenarios

3 key Scenarios

High	HIGH Economic Growth HIGH Population Growth LOW Energy Costs
Central	CENTRAL Economic Growth CENTRAL Population Growth CENTRAL energy costs
Low	LOW Economic Growth LOW population Growth HIGH energy costs

National Infrastructure Pipeline

National Infrastructure Plan 2015

- Overall infrastructure pipeline £411bn

Top 40 Priority List

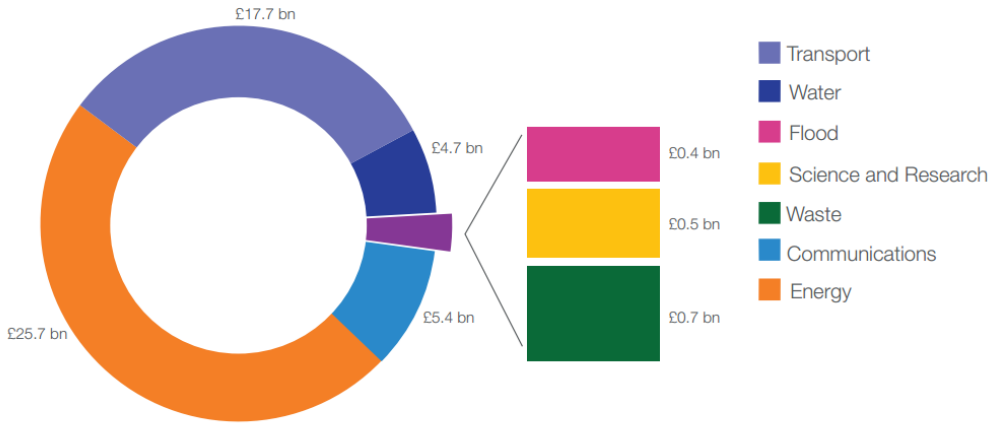
- 40 themes/major projects

(219 total projects/programmes)

- Transport 22
  - Strategic roads 7
  - Rail 8
  - Local transport 4
  - Aviation / Ports 3
- Energy 9
- Floods 1
- Communications 4
- Water 2
- Waste 0
- Science and Research 2

Sector	Pipeline value (£bn)	Number of projects/ programmes	Number in priority list
Communications	7.0	6	4
Energy	244.9	158	65
Flood	3.5	27	27
Science and Research	1.4	26	6
Transport	127.4	302	88
Waste	1.0	16	0
Water	25.7	29	29
Total	411.0	564	219

Chart ES.1: 2014 infrastructure pipeline, by sector, spend in 2015-16



Source: HM Treasury, Major Infrastructure Tracking Unit

Note: Spend on energy in 2015-16 includes oil and gas of £12 billion

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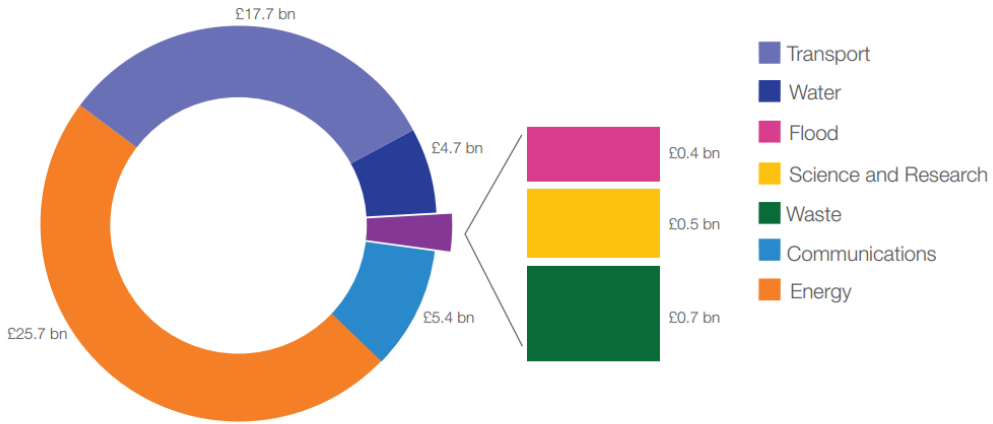

Source: HM Treasury, Major Infrastructure Tracking Unit

Note: Spend on energy in 2015-16 includes oil and gas of £12 billion

NIP:NISMOD assessment
Overview of parameterisation

Stage 1
Identification of project types which can be parameterised within NISMOD

Not all projects can be parameterised within NISMOD – generally those that add capacity/generation can be included; research/maintenance are excluded

Stage 2
Prioritisation of acceptable projects

Tier 1: 'Top 40' Priority investments (translatable into NISMOD inputs)
Tier 2: Higher investment (e.g. >£50m for Transport), but not within 'Top 40'
Tier 3: Lower investment (e.g. <£50m for Transport), and not within 'Top 40'

Stage 3
Translation of project details to NISMOD inputs

The modelling teams have provided details of the variables which will need to be included to enable the assessment of the NIP14 projects

Tier 1 projects should all be included in the assessment, together with as many Tier 2 projects as feasible within the timeframe (especially since extracting the detailed information can be time consuming)

NIP:NISMOD assessment – Energy Overview

- The Energy Demand model calculates demand for residential, services and industrial sectors from socio-economic scenarios and uses outputs from the transport model.
- The Energy Supply model attempts to meet demand using existing or new capacity, optimising on indicators such as costs.

Model can assess 53 of the 65 'Top 40' NIP15 energy projects:

Tier 1 – Electricity generation:

•Nuclear	(3 of 3 projects)
•Wind (On and Offshore)	(27 of 27 projects)
•Biomass	(5 of 5 projects)
•Gas (CCGT)	(2 of 3 projects)
•CCS	(2 of 3 projects)
•Advanced Conversion Tech	(2 of 3 projects)
•Energy from Waste	(2 of 2 projects)
•Photovoltaics	(3 of 3 projects)

Tier 1 – Electricity transmission:

•Interconnectors	(7 of 8 projects)

Tier 1 – Not assessed:

- •Smart meters
- •Decommissioning
- •Other transmission/distribution
- •Research programmes

Electricity transmission network with large power stations (Source: National Electricity Transmission System Seven-year statement, 2011)

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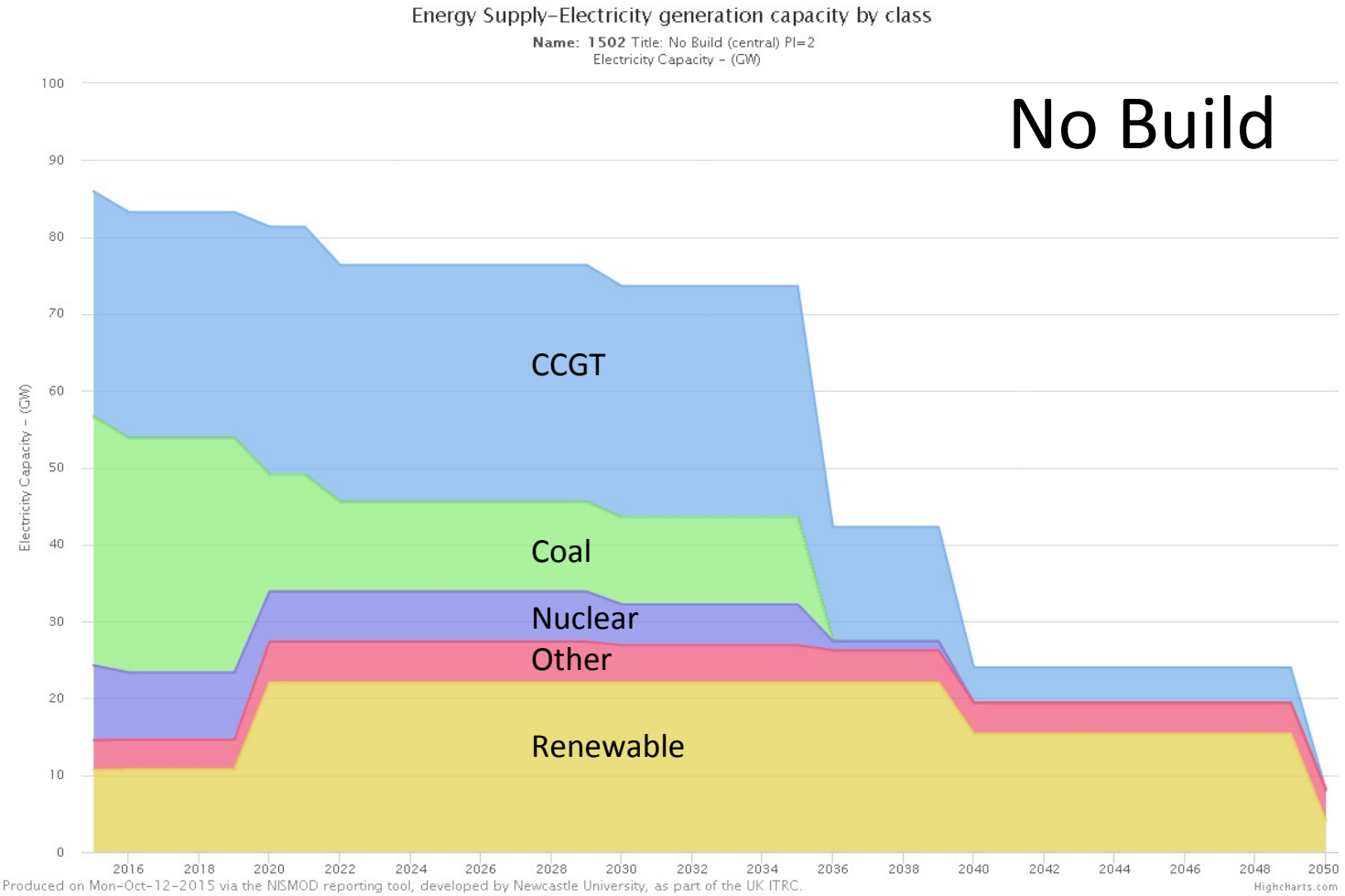
NIP:NISMOD assessment – Energy Electricity generation investments

Generation type	Total cost	Capacity	Lifespan
Wind	£13.2bn	9.5 GW	30 years
Nuclear	£45bn	9.4 GW	60 years
Interconnectors	Not given	8.7 GW	40 years
CCGT	£1.3bn	2.8 GW	30 years
Biomass	£2.3bn	1.5 GW	30 years
CCS	Not given	784 MW	30 years
Energy from Waste	£946m	157 MW	30 years
Solar	£39m	39 MW	30 years

Data source: National Infrastructure Plan 2015/DECC

NIP:NISMOD assessment – Energy Projections of electricity generation



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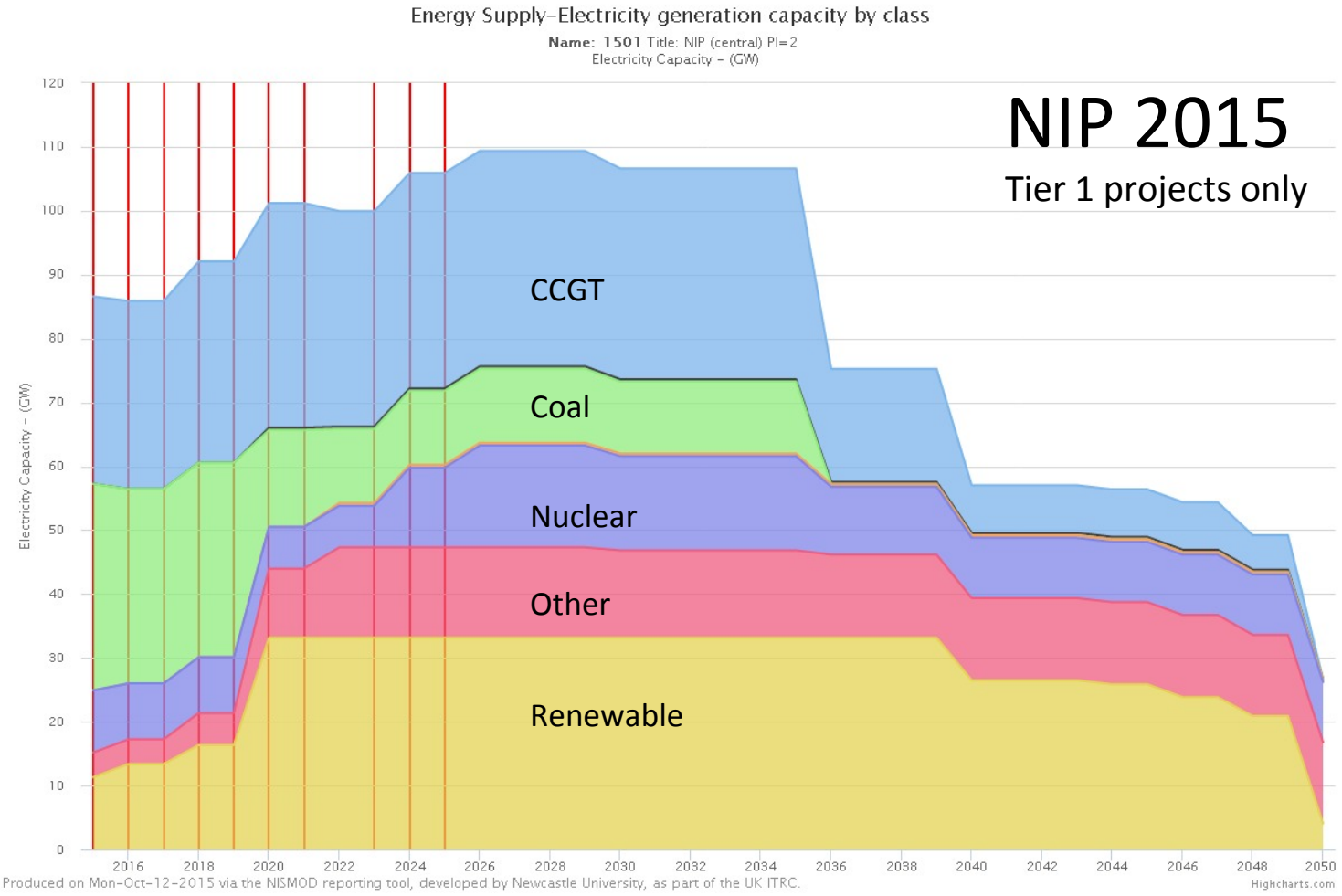
NIP:NISMOD assessment – Energy Projections of electricity generation



CCGT | CCGT CCS | COAL | Coal CCS | NUCLEAR | Other | Renewable

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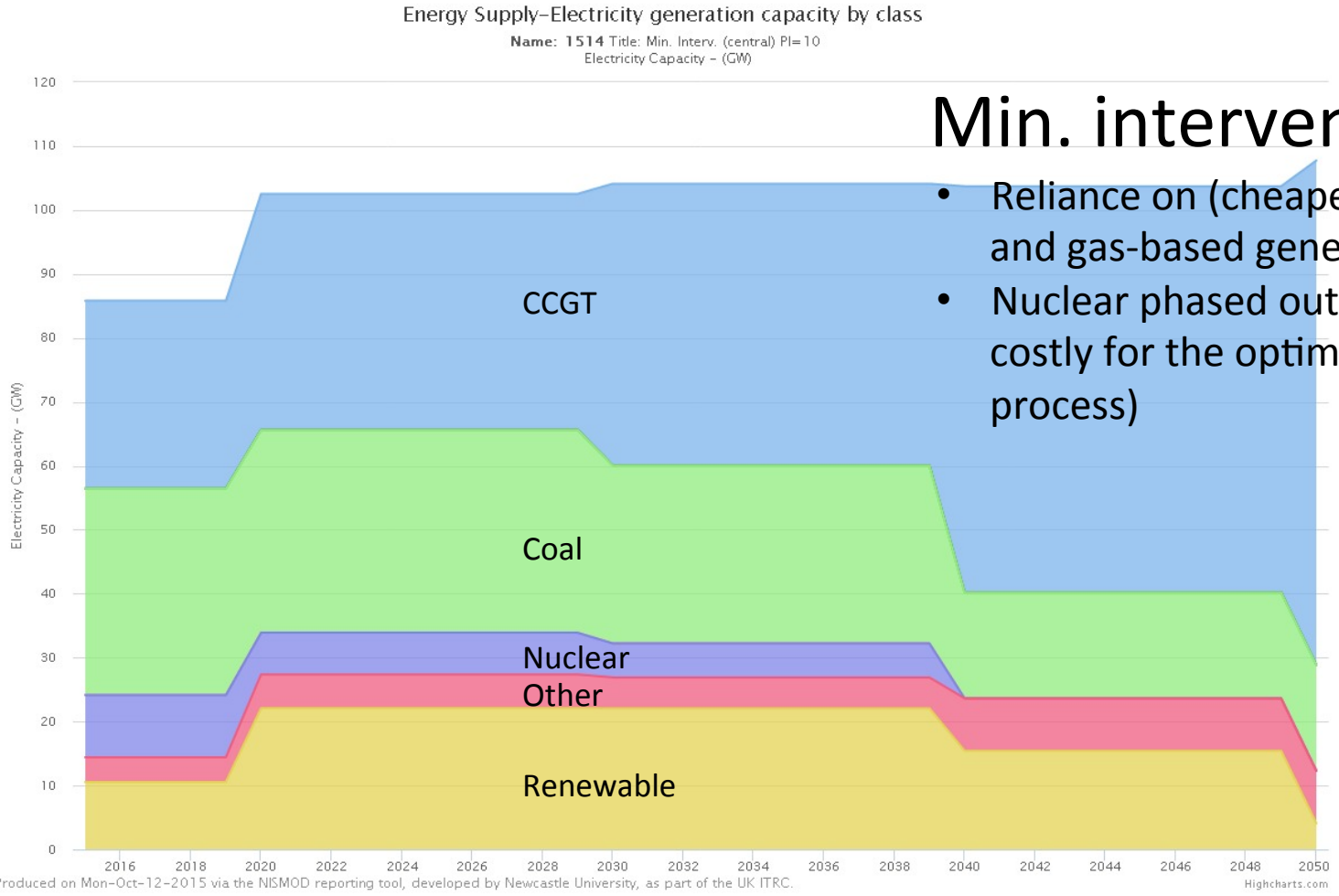
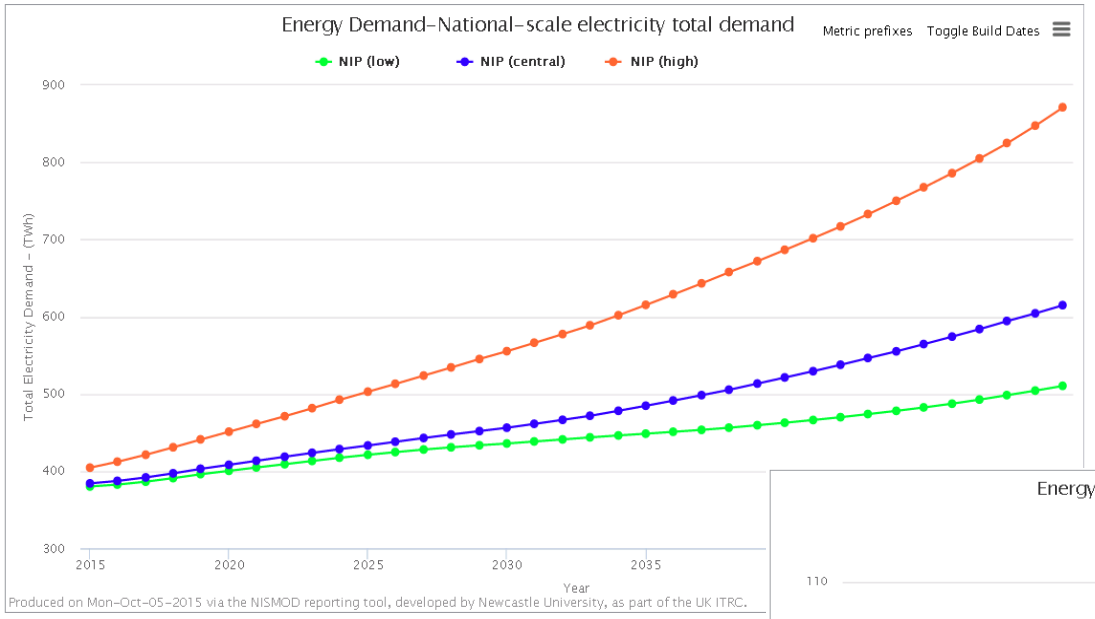
NIP:NISMOD assessment – Energy Projections of electricity generation



Min. intervention

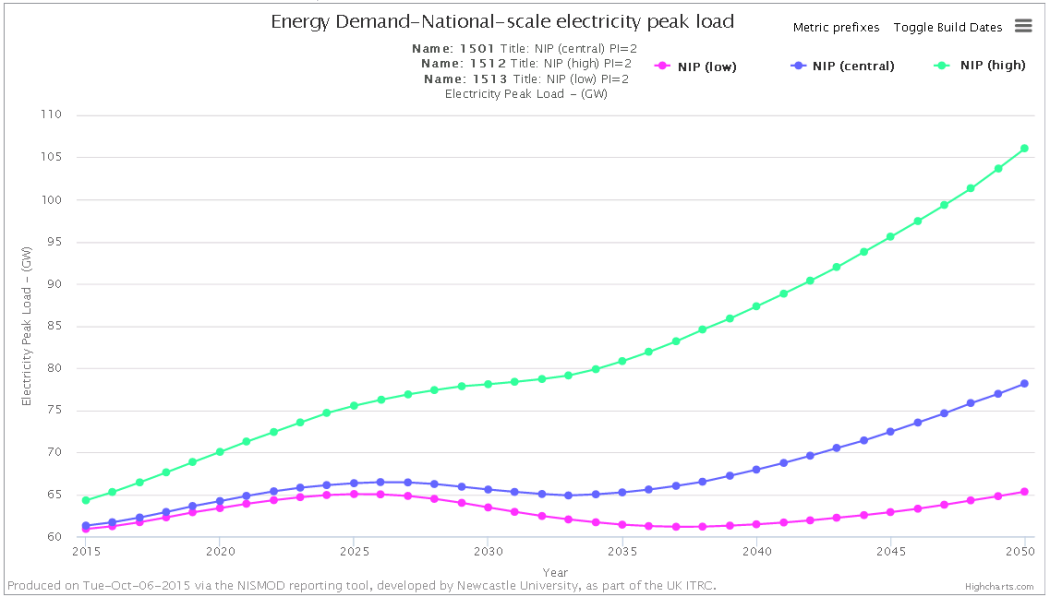
- Reliance on (cheaper) coal- and gas-based generation
- Nuclear phased out (as too costly for the optimisation process)

NIP:NISMOD assessment – Energy Projections of electricity demand



Demand profile correlated with population change

Peak demand shown to be affected by technological improvements (e.g. improved energy storage)



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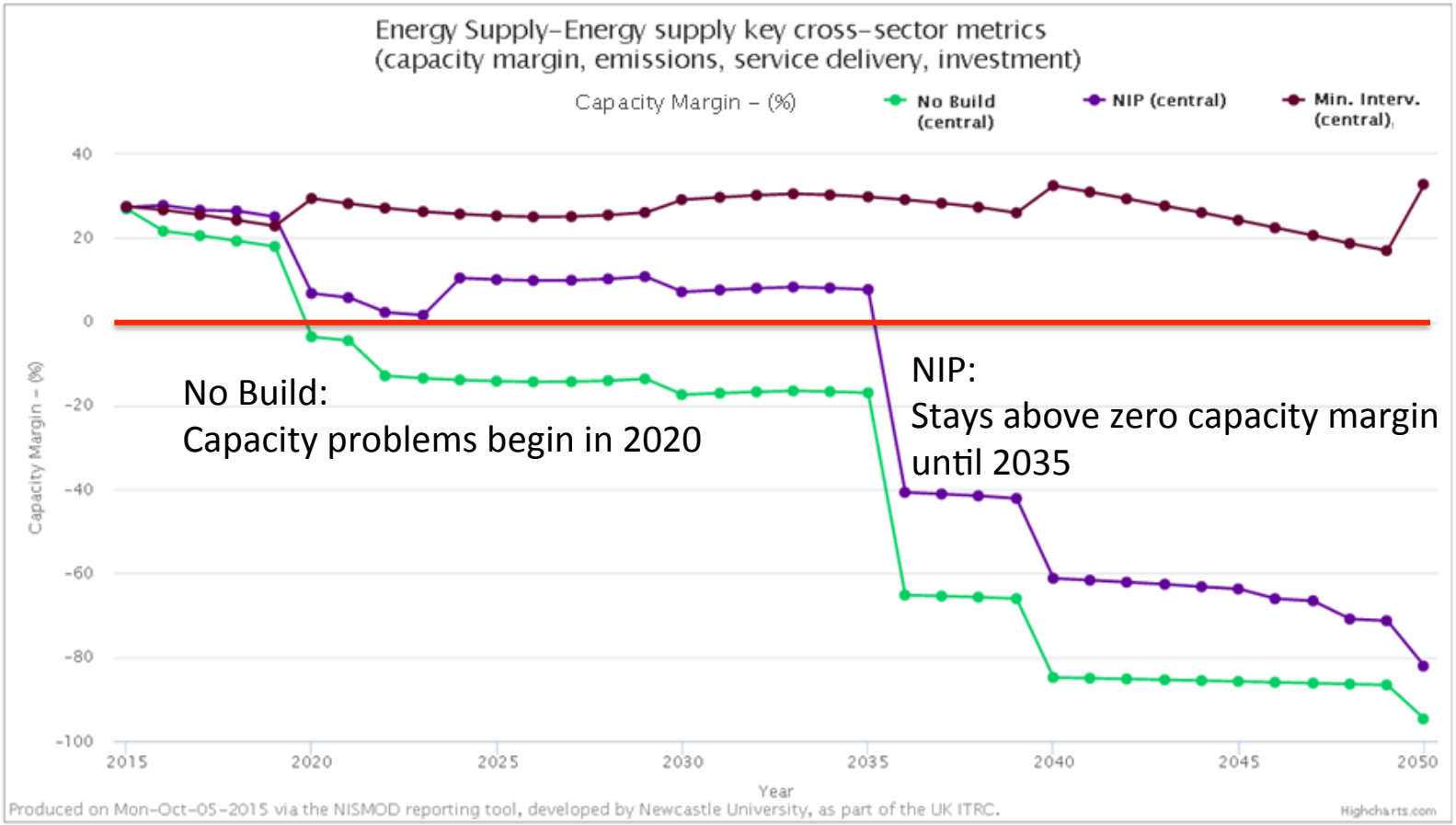
NIP:NISMOD assessment – Energy Electricity capacity margin

$$capacity\ margin\ (\%) = \frac{total\ available\ electricity\ capacity - peak\ demand}{peak\ demand} \times 100$$



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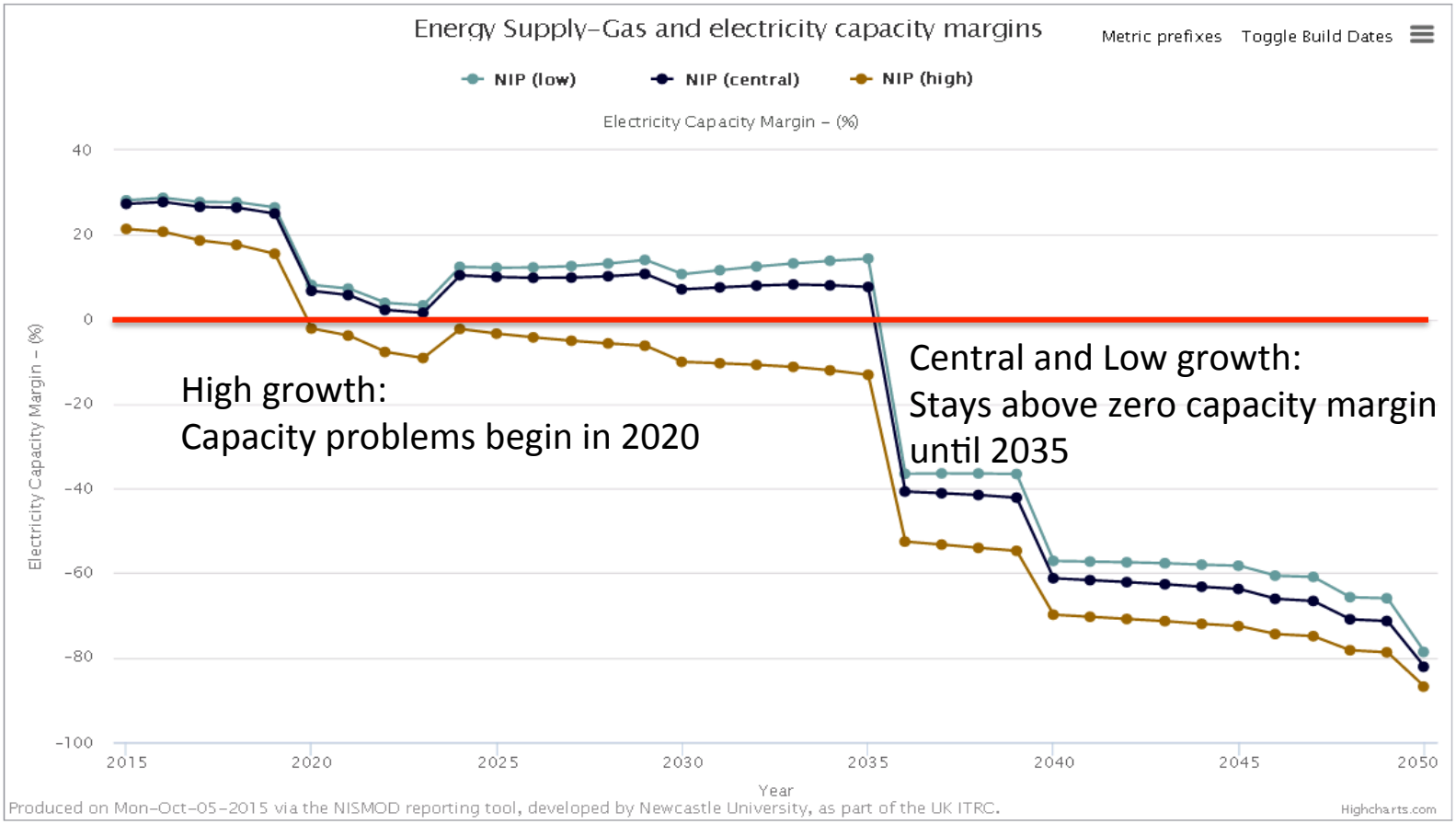


NIP:NISMOD assessment – Energy Electricity capacity and demand

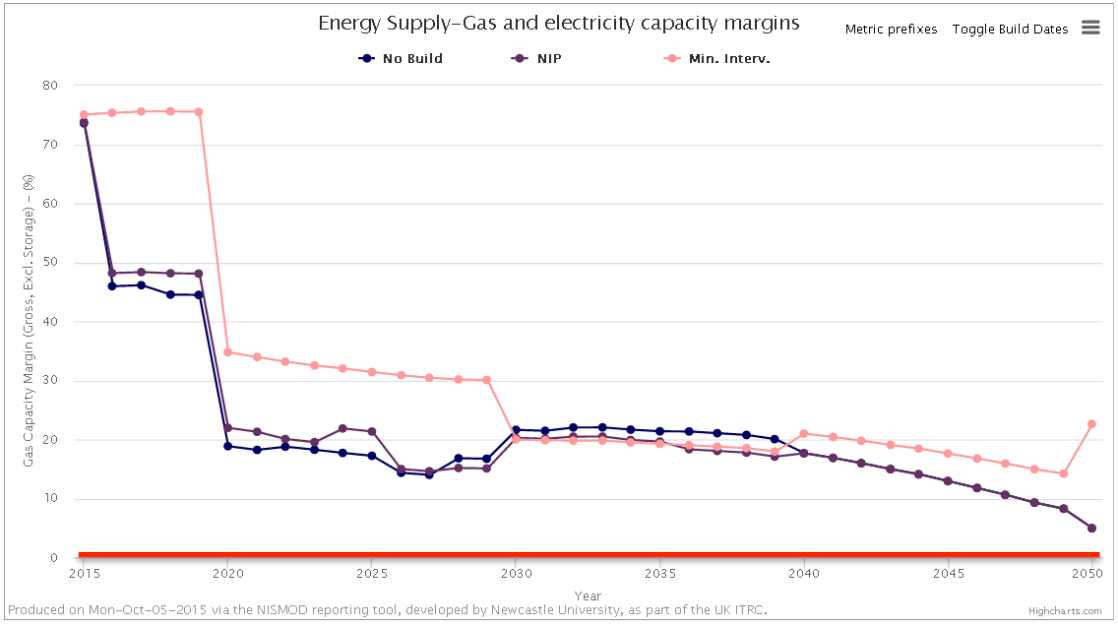
Key Points:

- NIP projects deliver ~33 GW of new capacity
- This pushes the point when the capacity margin goes below zero from 2020 to 2035 in a central population/ economic scenario
- High growth could push this date forwards to 2020
- The Minimum Intervention strategy would yield additional capacity, but with increased gas dependence and locking in CO_2 emissions

NIP:NISMOD assessment – Energy
Gas capacity and demand

Key Points:

- The projected shortfall in gas is less than in electricity New investments in LNG are required to compensate for reducing domestic supplies



NIP:NISMOD assessment – Transport Overview

Transport road model uses 144 Zones (and 296 links between neighbouring zone centroids) based on LAD and aggregated London boroughs

For NIP15, model can assess 24 of the 32 'Top 40' road-based projects:

Tier 1 – Road:

- Local Authority Majors (6 of 10 projects)
- Highways England Majors (18 of 22 projects)

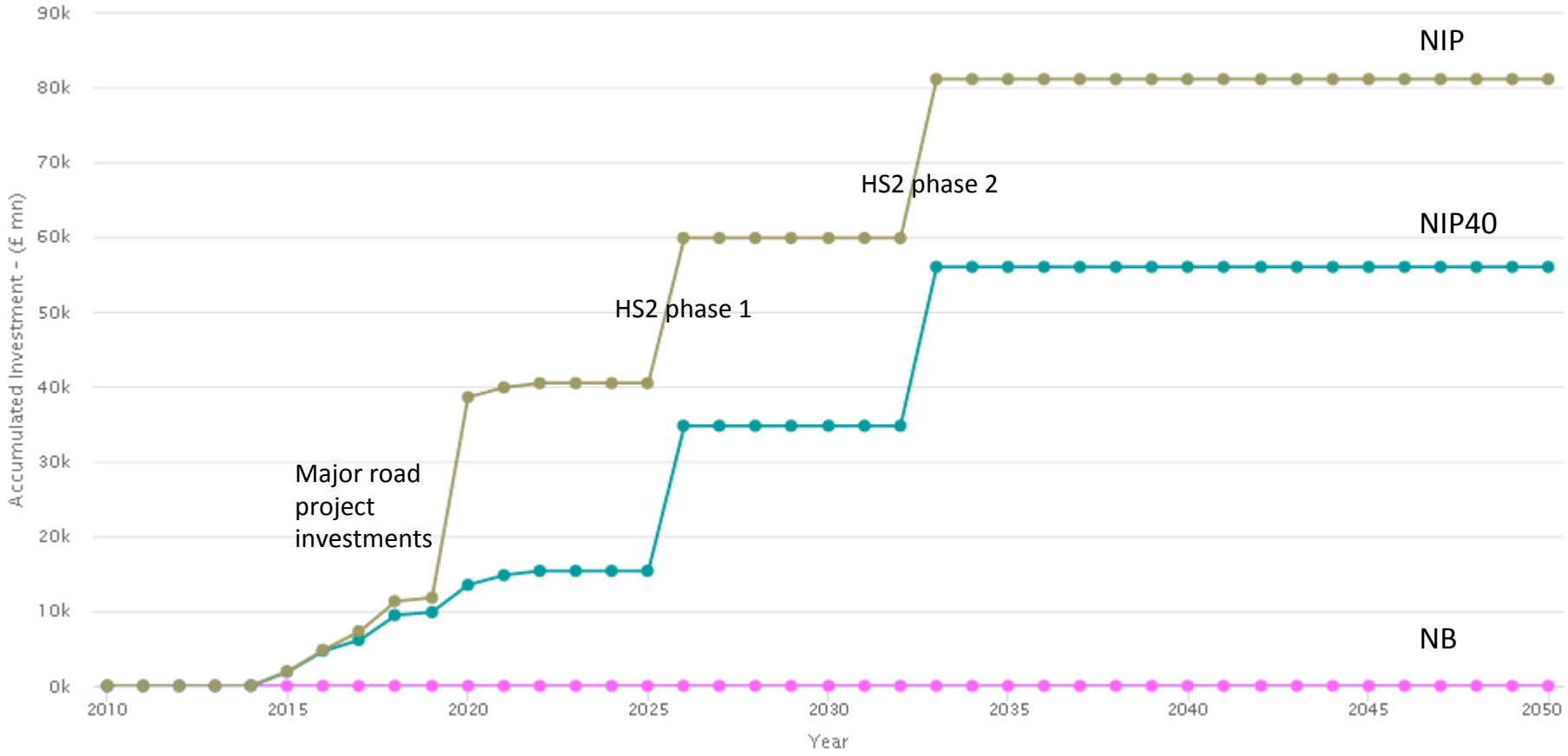
The model also assesses a further 29 road-based projects outside the 'Top 40', including 12 Smart Motorway projects

Not assessed:

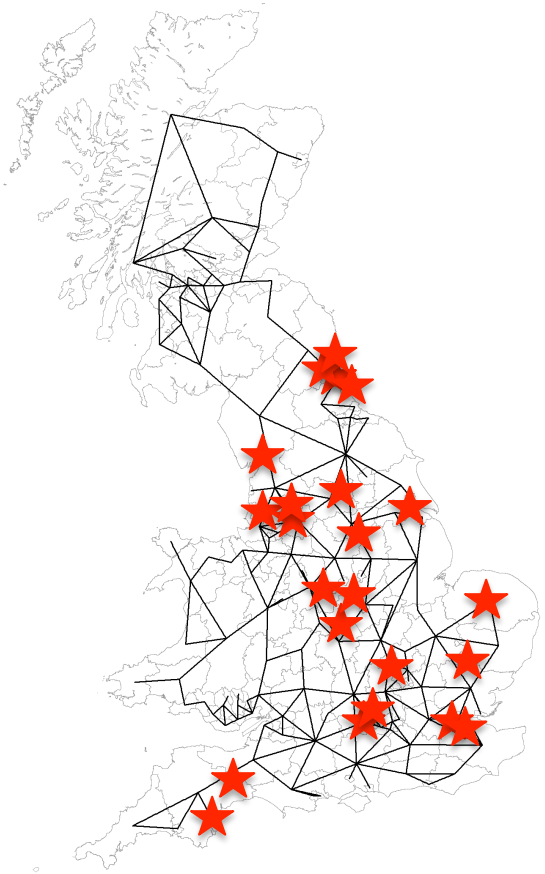
- Metro/Tram systems
- Junction improvements
- Pinchpoints
- Feasibility studies
- Local Growth Funding (including LEP allocations)
- Integrated Transport Block Funding
- Maintenance Block Funding
- Challenge Fund

NIP:NISMOD assessment – Transport
Investment profiles of assessed projects

Cumulative investment



NIP:NISMOD assessment – Transport
Roads: location and scale of assessed projects



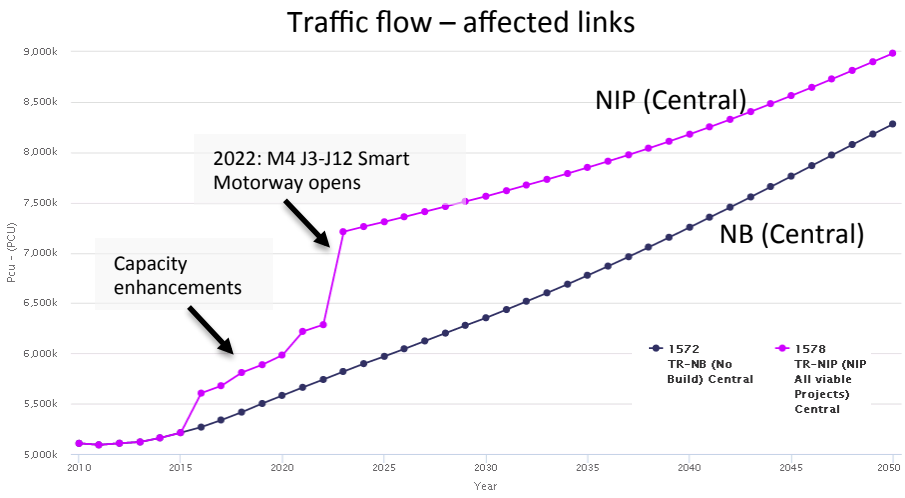
Interzonal flow lanes (links)			
	Base model	NIP additions	Change
Motorway	869	38	4.37%
Dual carriageway	1,431	16	1.12%
Single carriageway	1,713	-2	-0.12%
Total	4,013	52	1.30%

Intrazonal lane km (zones)			
	Base model	NIP additions	Change
Motorway	21,219	996	4.69%
Rural A dual	20,082	742	3.69%
Rural A single	61,224	-73	-0.12%
Rural minor	425,362	30	0.01%
Urban dual	11,635	51	0.44%
Urban single	266,391	0	0.00%
Total	805,913	1746	0.22%

NISMOD assessment aims to quantify the effect of adding:

- 52 new interzonal flow lanes, an additional 1.30%
- 1746 intrazonal lane km (including 861km of managed motorway/all lane running), an additional 0.22%

NIP:NISMOD assessment – Transport Roads: impact of NIP on traffic and speed

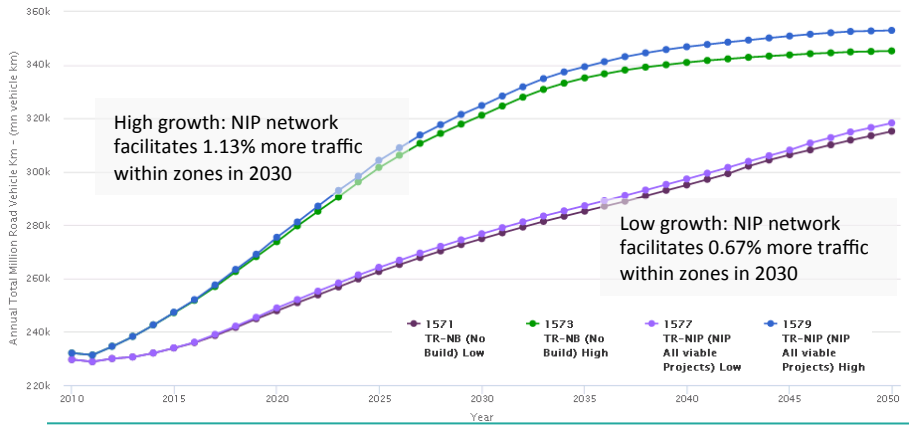


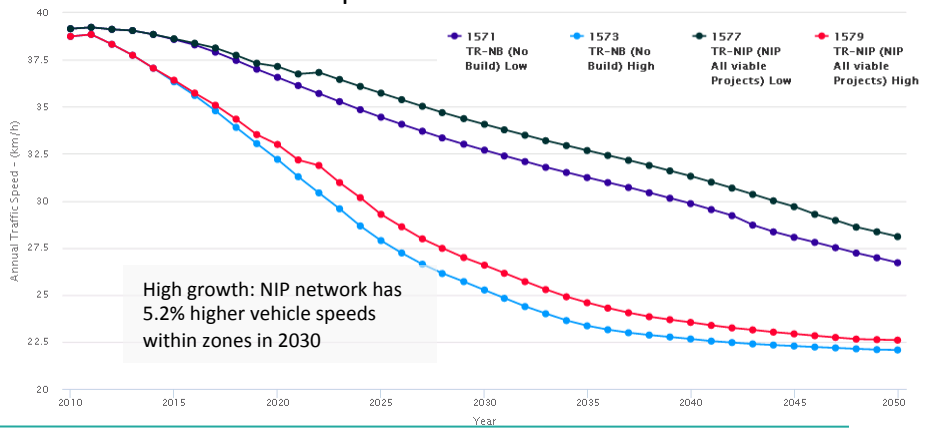
Impact of increasing capacity across links

- Road projects add capacity to the network. Latent demand at these locations fills available road space, and flows increase. 2022: M4 J3-J12 opens – releasing 2 extra lanes on a long stretch of busy motorway (crossing 8 interzonal links).

Impact of increasing lane km within zones

- Slight growth in NIP traffic flows (1.13% in High growth in 2030)
- Increased capacity enables traffic speeds to remain high compared with No Build





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NIP:NISMOD assessment – Transport Roads: main messages

Key Points:

- NIP investments (included in this assessment) are a very small proportion of the overall asset base
- The effects of this investment are localised
- If demand growth continues to be strong, more aggressive policy responses (in terms of investment and demand management) will be required

NIP:NISMOD assessment – Transport
Rail: electrification

Project name	Project description
Great Western Programme	Great Western Electrification
East-West Rail and Electric Spine	Electric spine
Midland Main Line Programme	Midland Mainline Electrification
East-West Rail and Electric Spine	East West Rail
Great Western Programme	Welsh Valleys electrification
North of England Programme	North Trans Pennine Electrification
North of England Programme	North West Electrification
Network Rail - Other	Edinburgh Glasgow Improvement Programme
Network Rail - electrification	Scotland - Rolling Programme of Electrification
Network Rail	West Coast and Midlands CP5 scheme
Surface Transport: Other capital	Gospel Oak to Barking - electrification

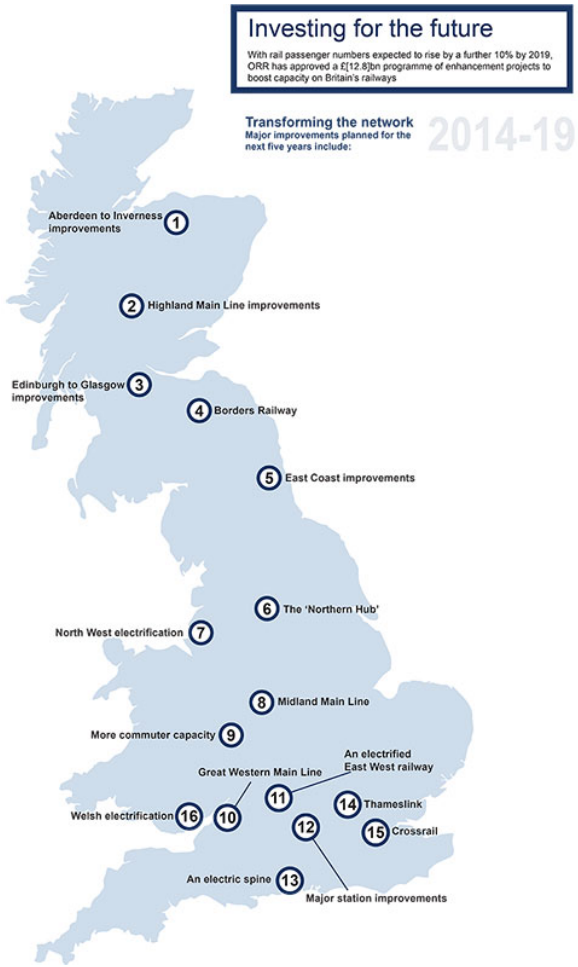
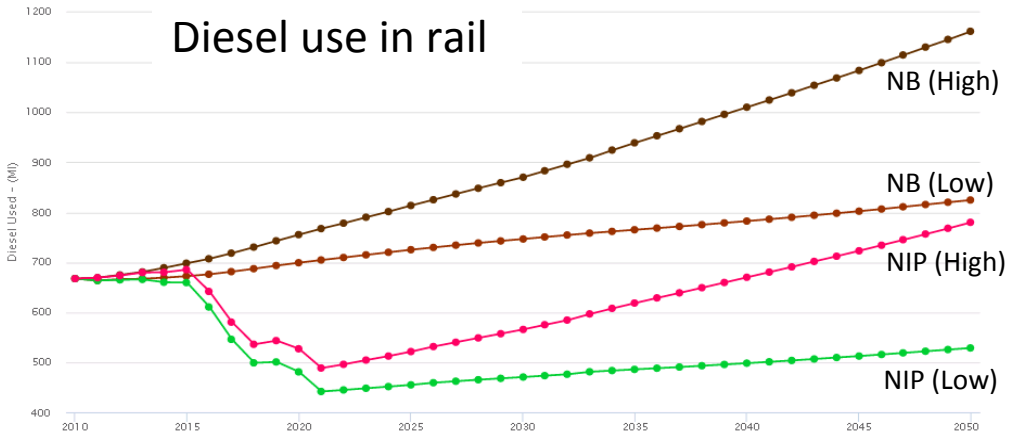
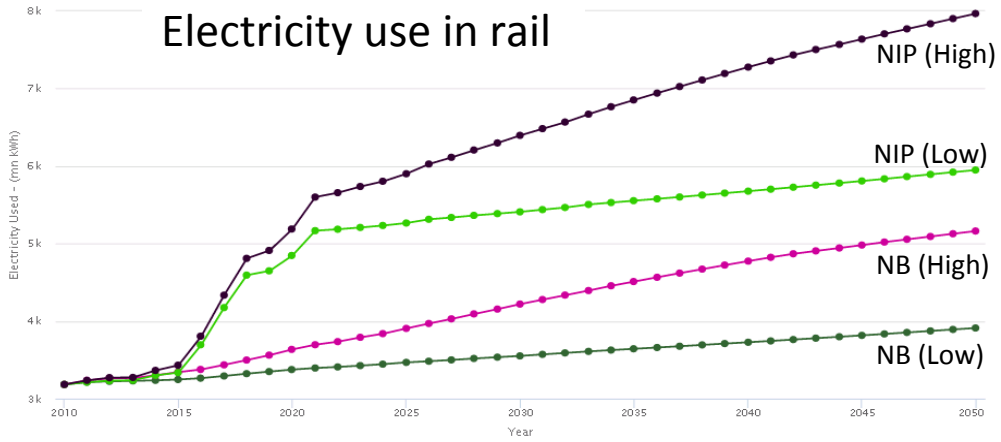


Image source: Office of Rail and Road (orr.gov.uk)

NIP:NISMOD assessment – Transport
Rail: electrification

- Diesel use reduced by 35% by 2022
- Electricity use increased by 39% in same period
- Future electrification will continue this trend
- Total number of trains will increase, which may also result in more delays on congested tracks

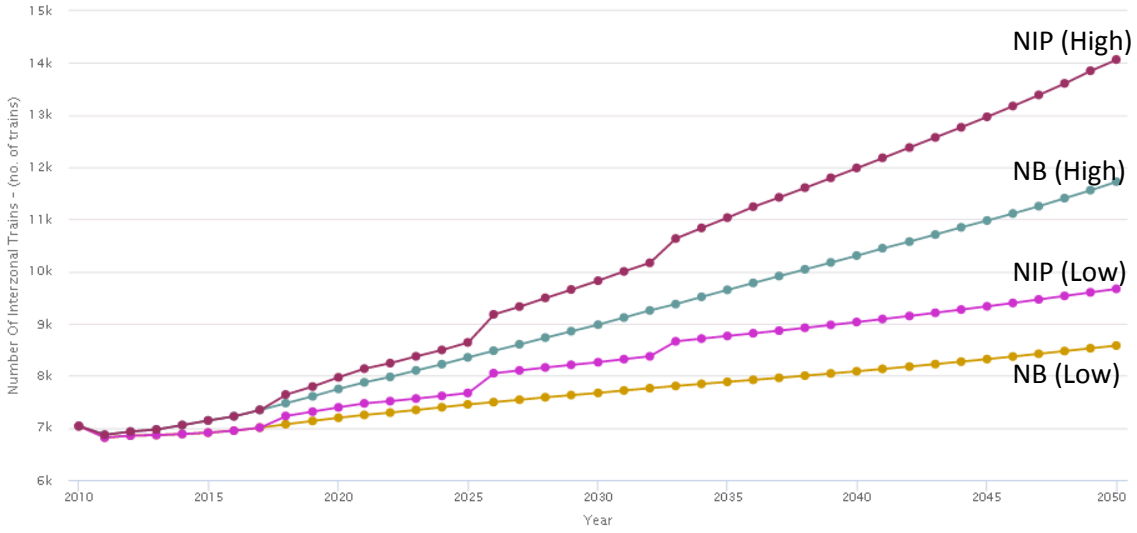


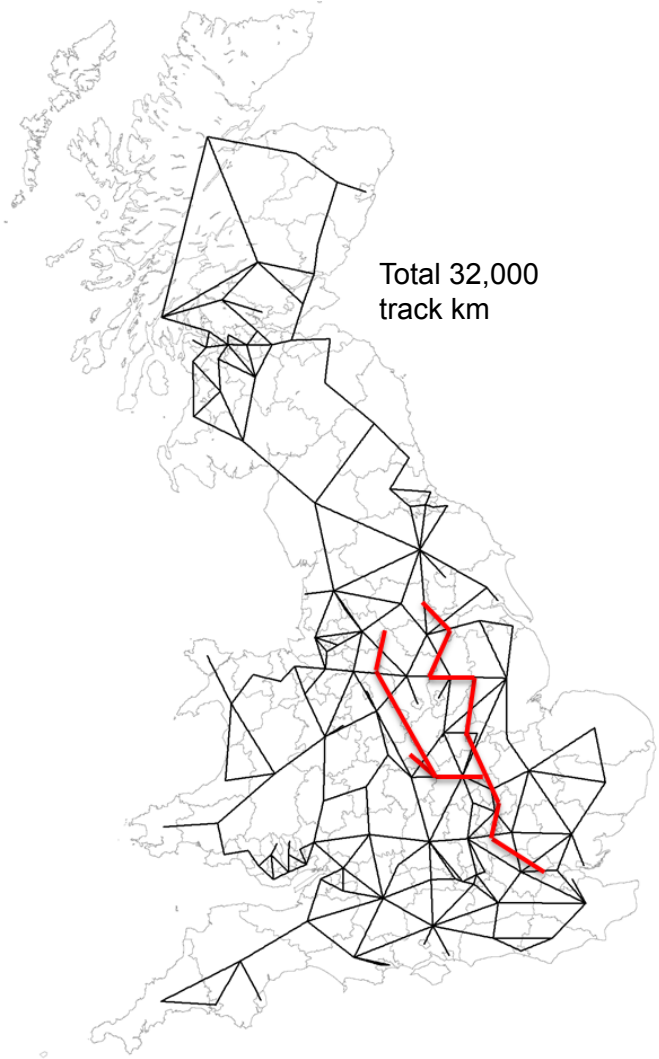


NIP:NISMOD assessment – Transport
Rail: HS2

Phase 1 adds 384 km of new high-speed track (192 km length, double track), linking busiest urban hubs, so much larger impact than simply adding 1.2% track to the network .
Phase 2 adds a further 700km (a further 2.2%)

Number of trains on NIP affected links





NIP:NISMOD assessment – Transport
Rail: HS2

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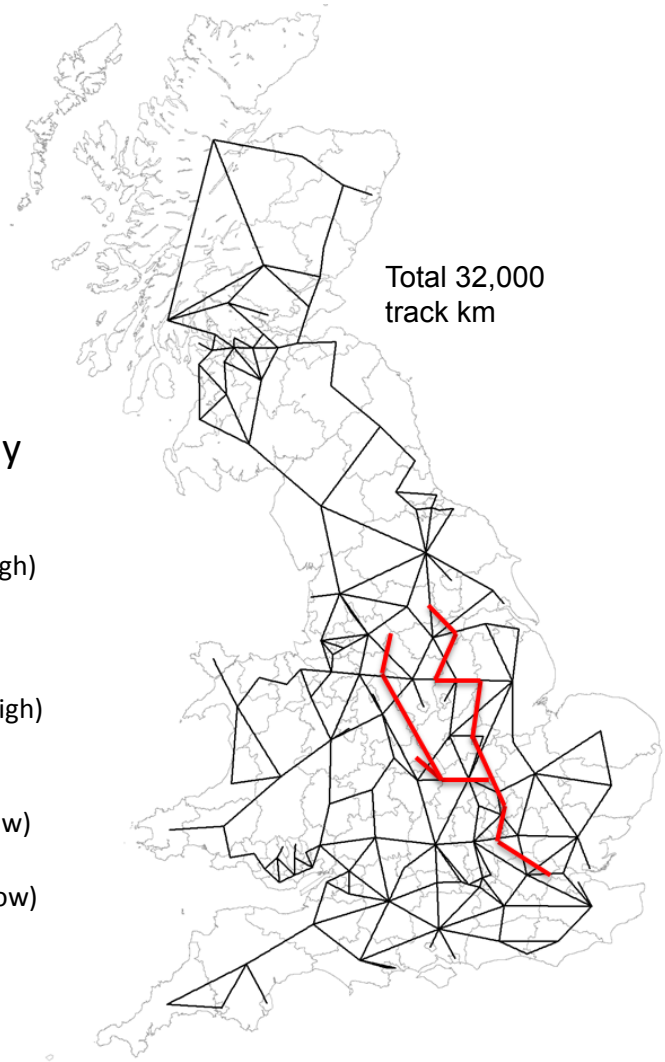
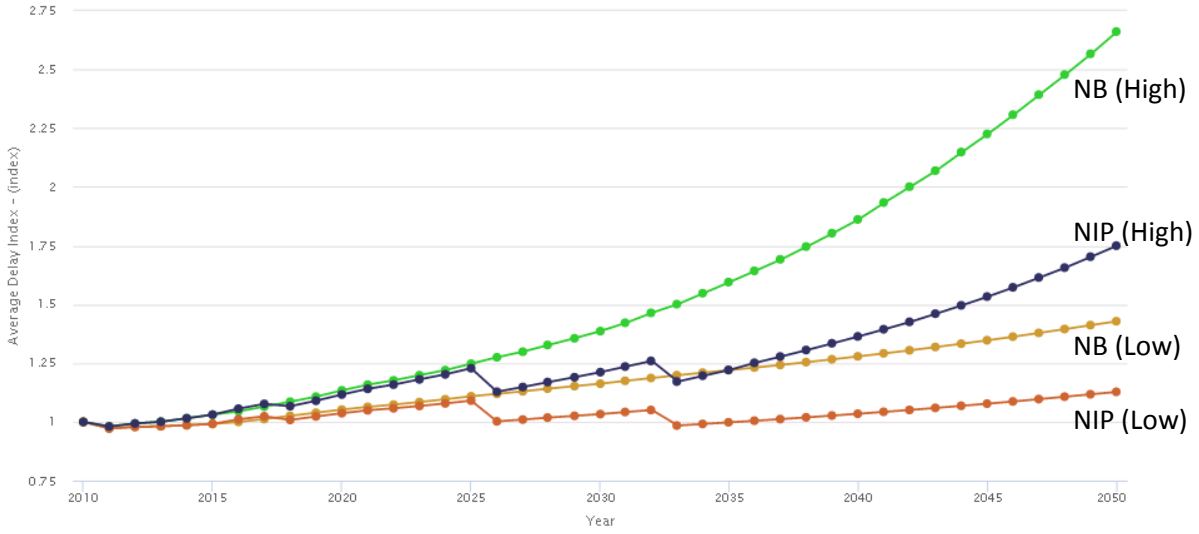


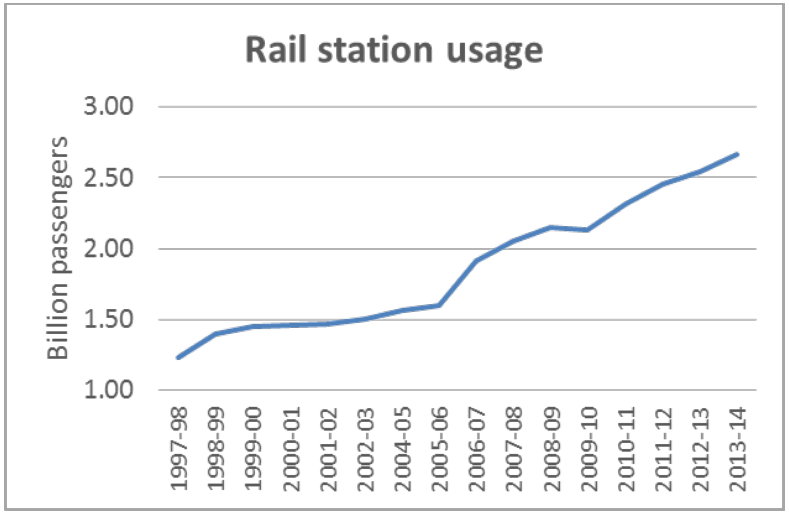
Index of average rail delay (2010 = 1) – NIP affected links only



NIP:NISMOD assessment – Transport
Rail: main messages

Key Points:

- Electrification is assumed to increased rail use
- NIP electrification schemes exchange ~20% of diesel for electric by 2030
- HS2 adds 3.4% track (Phase 1&2), to significant routes – increasing train numbers, but with reduced level of delays
- Continued growth in rail use



NIP:NISMOD assessment Outcomes

This collaboration has demonstrated:

- Long term evaluation of the performance of national infrastructure plans…
- against a range of (consistent) population, economic and demand scenarios
- What infrastructure plans can (and can't) deliver on a range of timescales

We have developed visualisation tools to enable scrutiny of the results geographically and through time

UK Infrastructure Transitions Research Consortium

Strategic analysis of the National Infrastructure Plan

Adrian Hickford (University of Southampton)
Geoff Baldwin (Infrastructure UK)

15 October 2015

Infrastructure UK

ITRC

EPSRC
Engineering and Physical Sciences Research Council

UK Infrastructure Transitions Research Consortium

Critical infrastructure hotspot analysis

Prof. Jim Hall, Dr. Stuart Barr, Scott Thacker, David Alderson, Dr. Raghav Pant

October 15, 2015

ITRC

Infrastructure UK

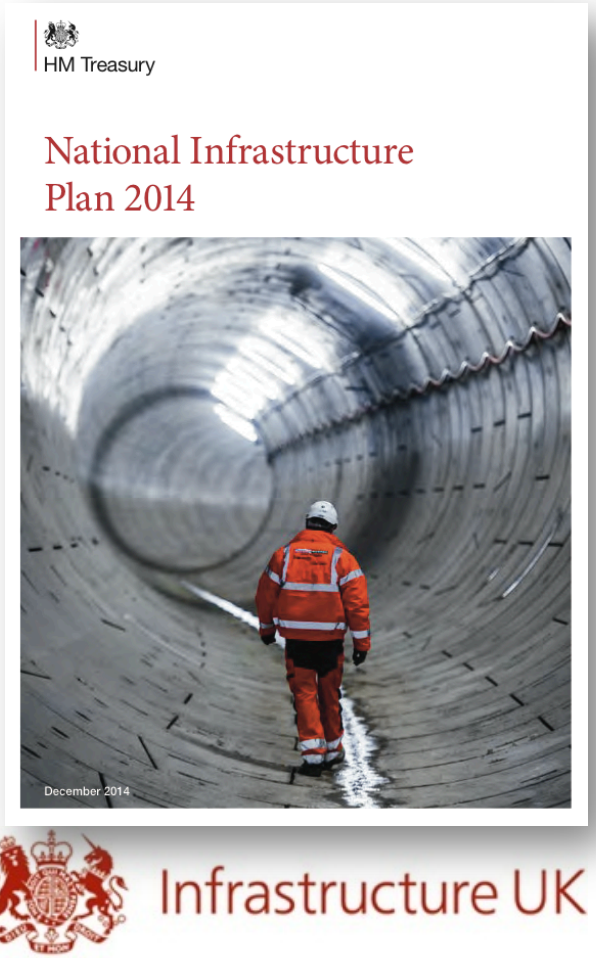
EPSRC
Engineering and Physical Sciences Research Council

Project objective

- The UK infrastructure system is a highly complex, interdependent set of networks and assets that rely on each other to work effectively.

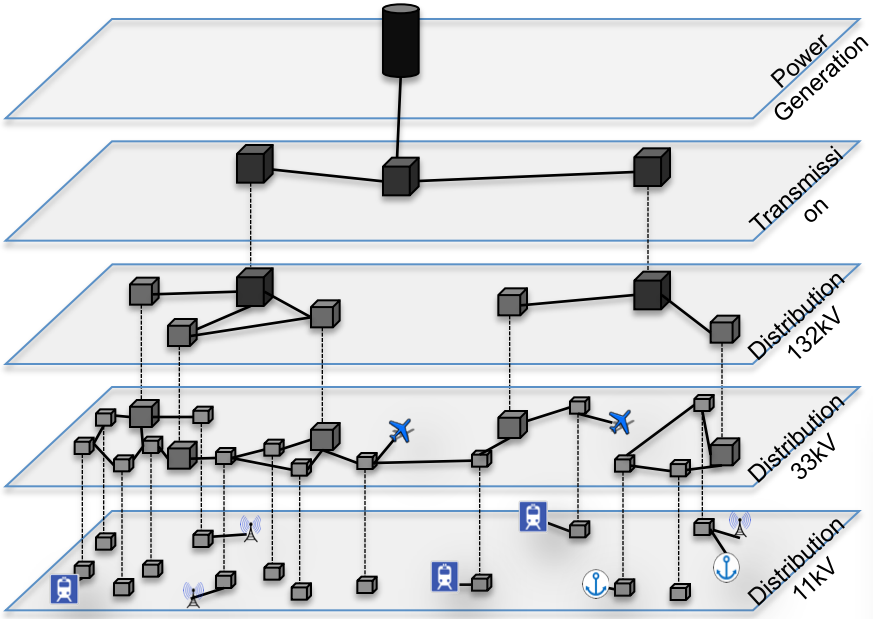
- The government is working with academia, regulators and industry to develop a more strategic, coordinated and efficient approach to future infrastructure development.

Chapter 15, pp 127

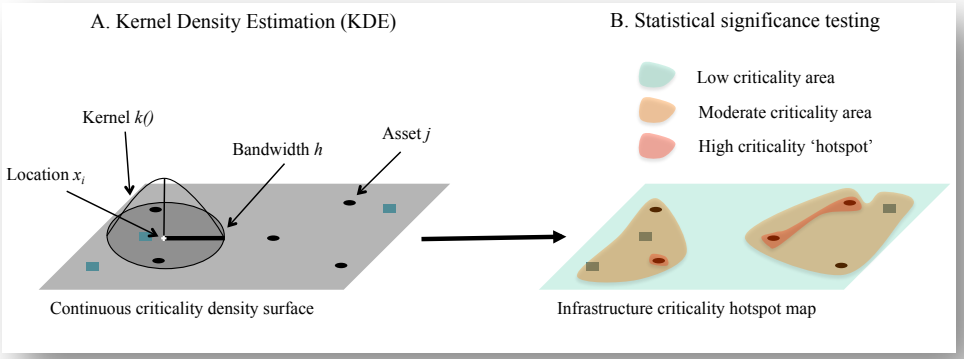


Hotspot analysis overview

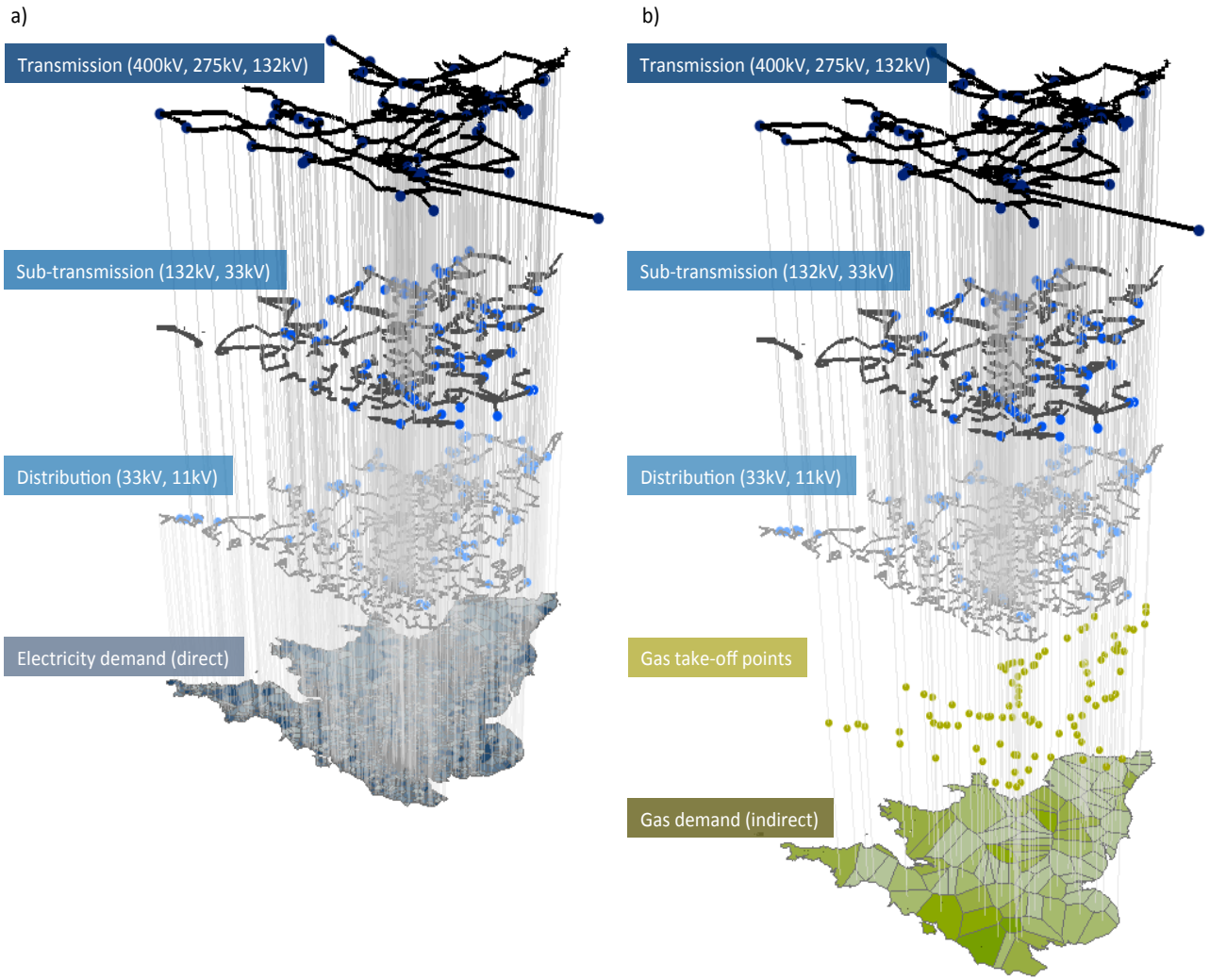
An infrastructure criticality hotspot is ***a geographical location where there is a concentration of critical infrastructure****, measured according to number of* ***customers directly or indirectly dependent on the infrastructures in that location***



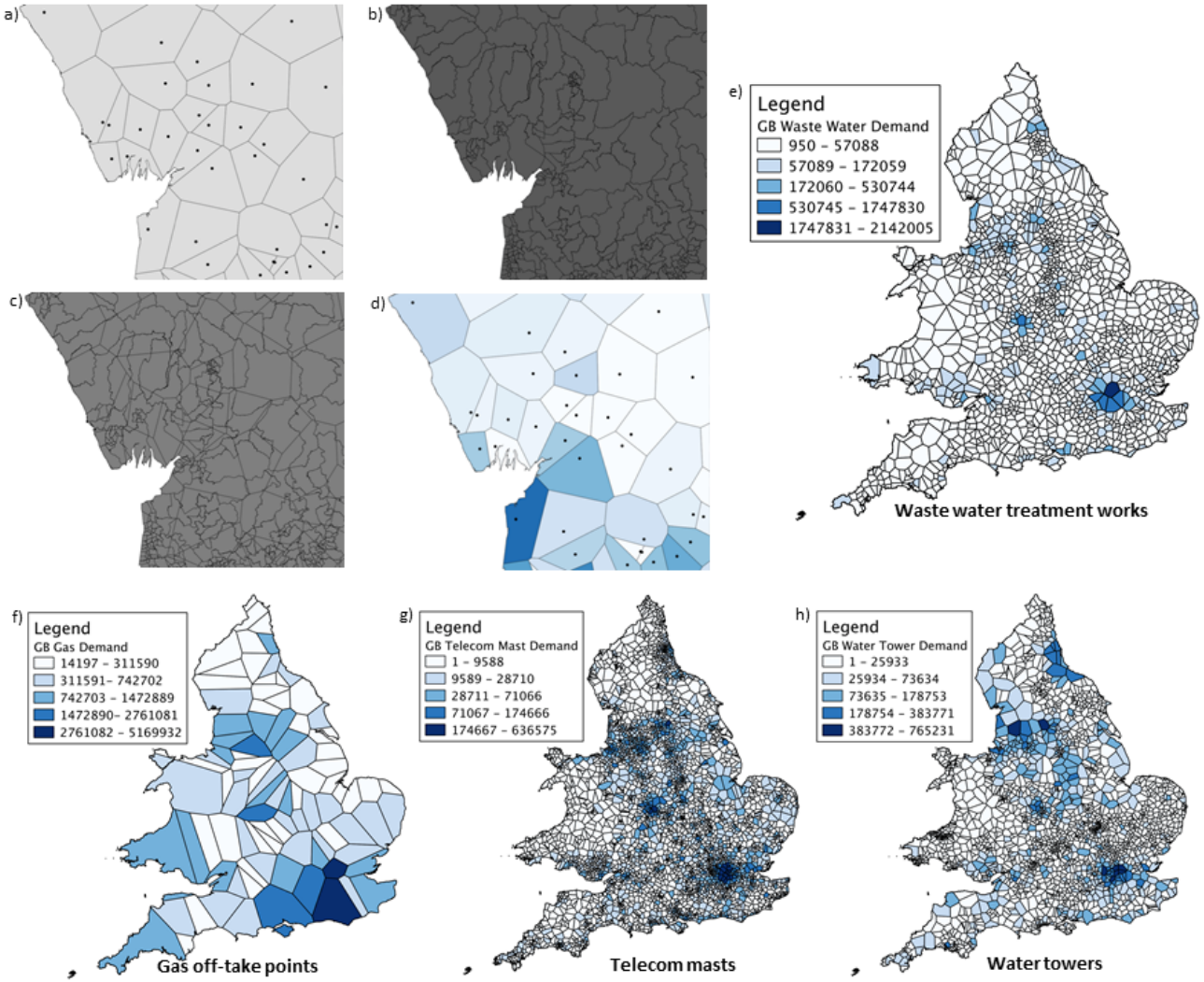
Unique national infrastructure network models and database ~ 200,000 assets



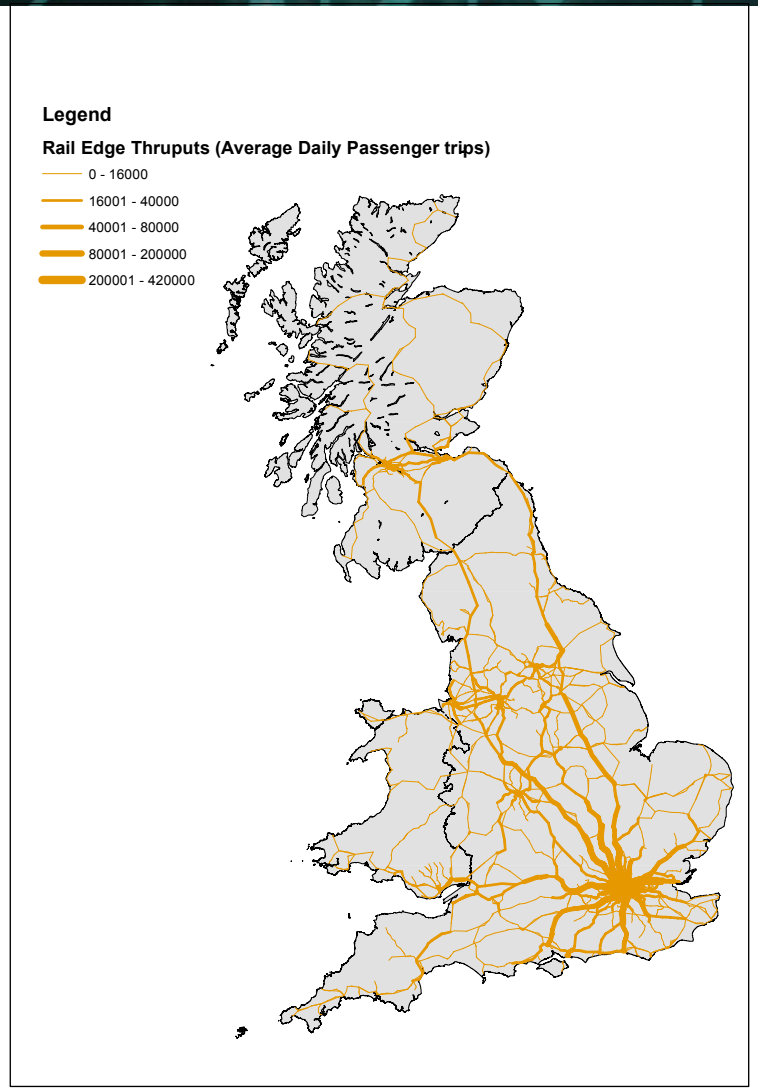
Interdependent network assembly

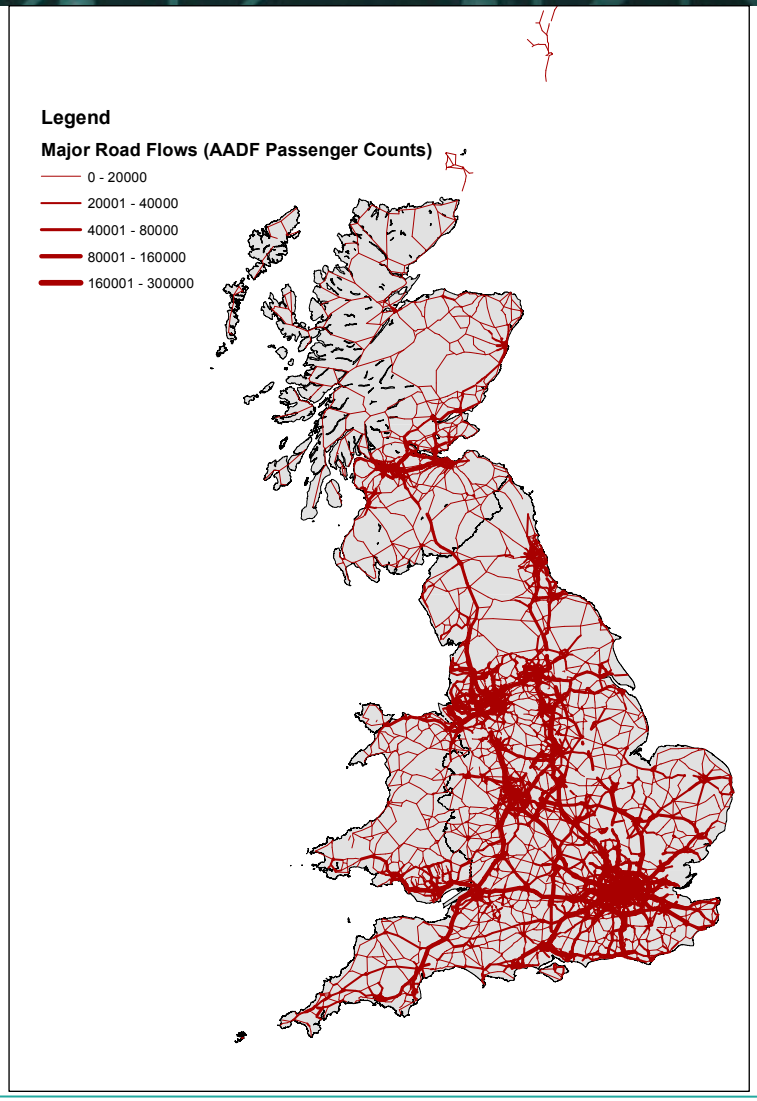


Mapping customer demands

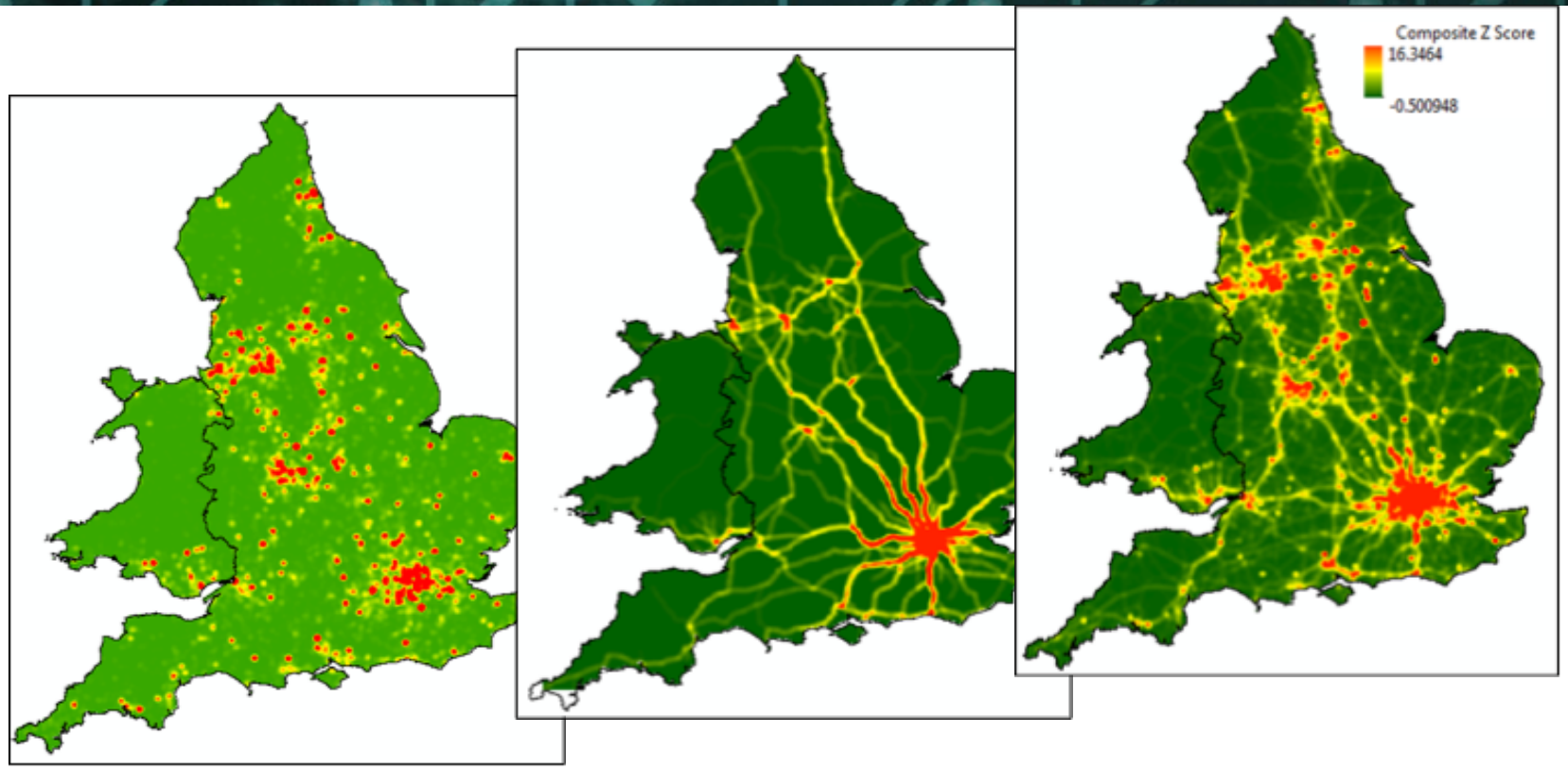


Building transport flows





Integrated critical assessment - hotspot analysis



"Useful in explaining to others why we have to adjust our thinking from silo-sectored to a multi-sector and cross-sector one."

David Penhallurick , Strategic Lead, Cross-Sector Delivery, Infrastructure UK

UK Infrastructure Transitions Research Consortium

Single point of failure analysis Transport

Dr. Raghav Pant, Prof. Jim Hall

October 15, 2015

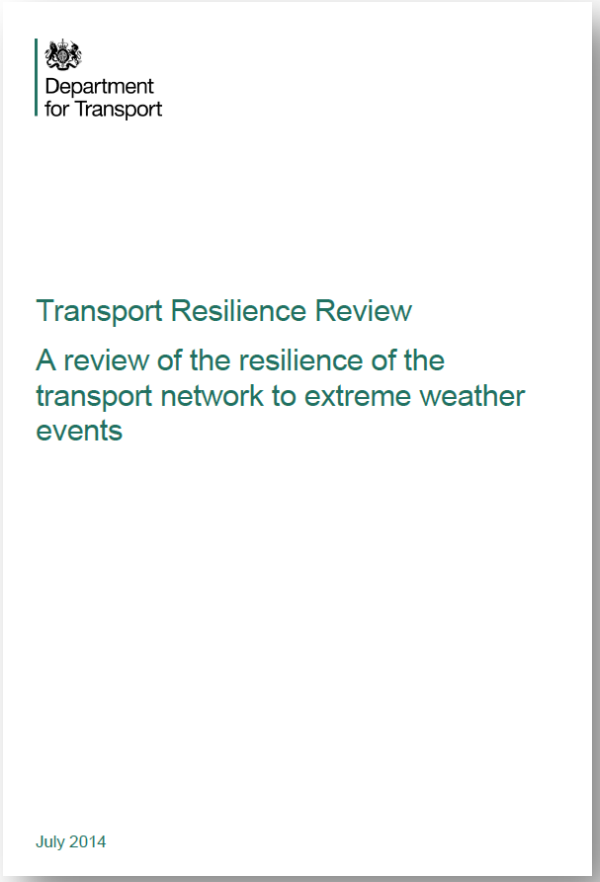
Department for Transport

Project objective

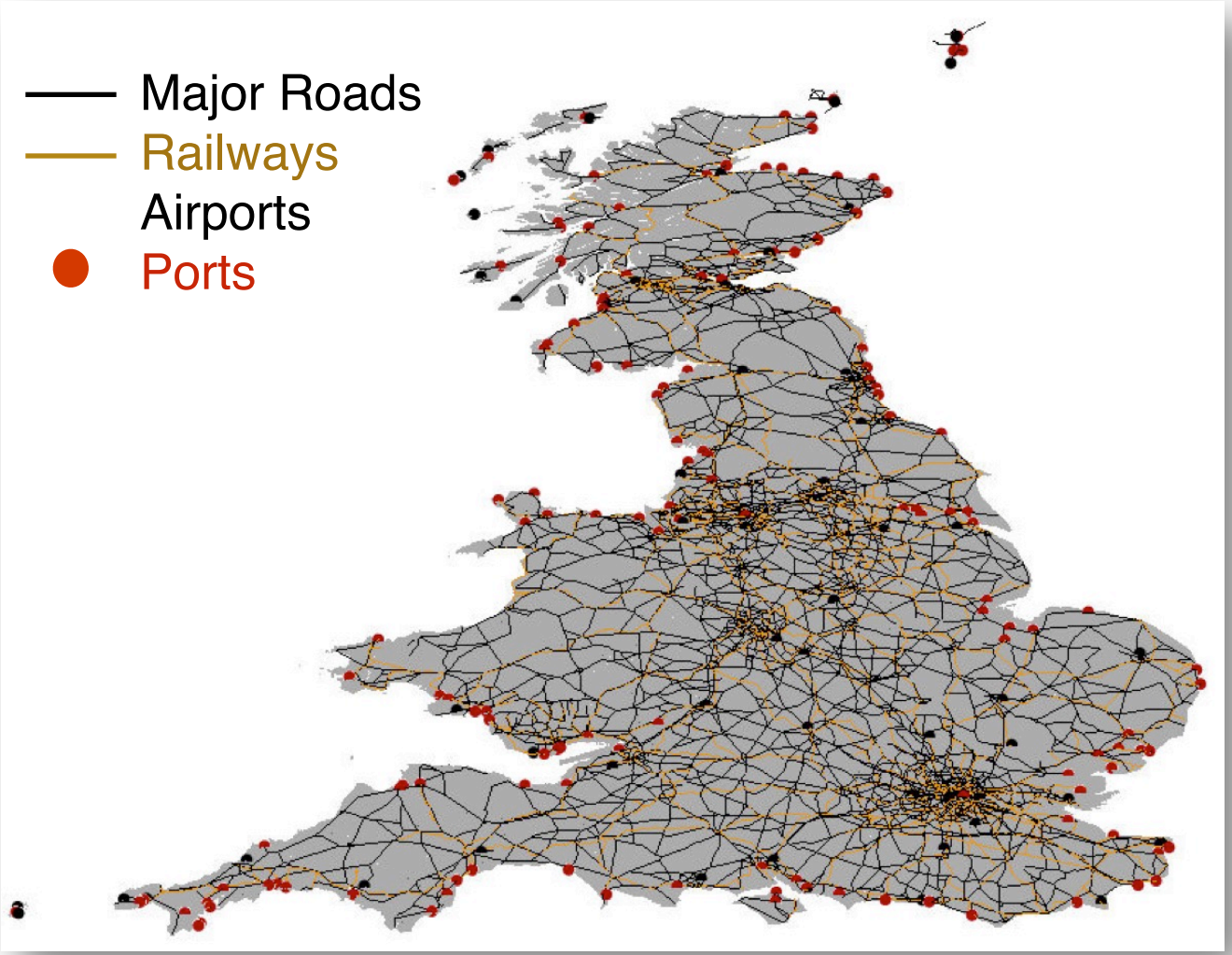
***Key question*: *Whether there are potential 'single points of failure' in the strategic transport networks, which leave parts of the country at risk of having vital economic and social links severed*?**

The Department wishes to procure a piece of analysis to better understand the 'single-points' question. The project should seek to:

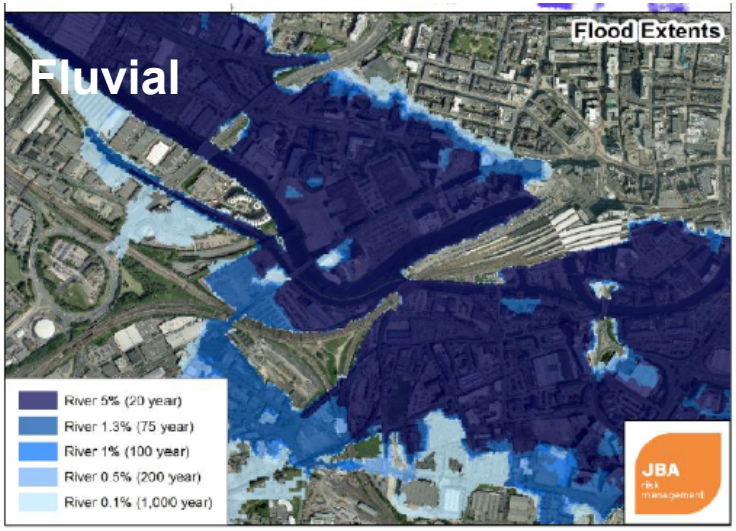
- Identify the key locations of risk from single and multiple weather/climate threats.
- Assess the availability and/or suitability of alternative transport routes.

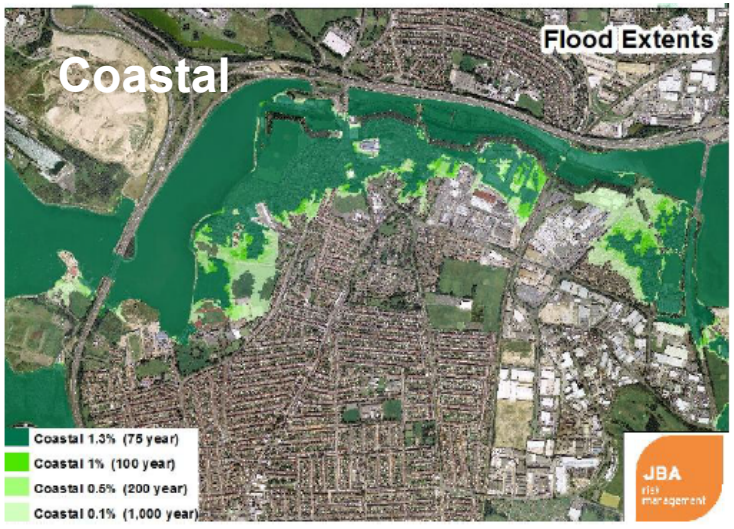


Multi-modal transport analysis



Hazard assessment - Flooding





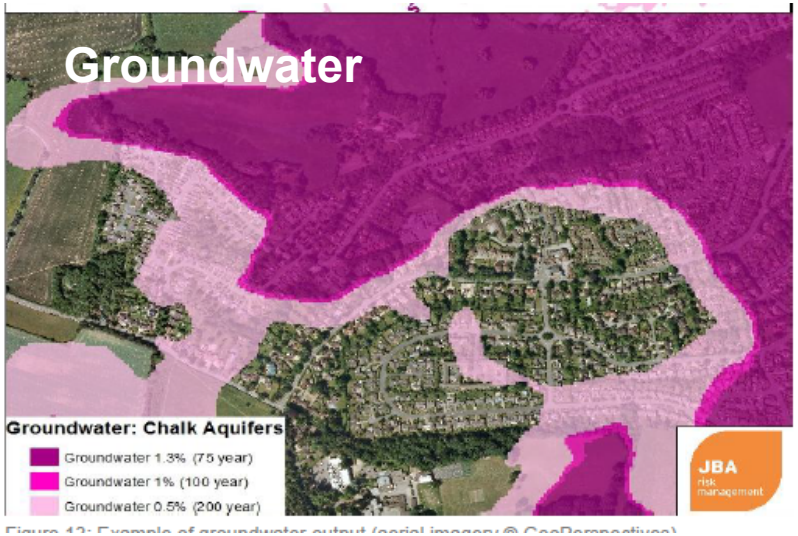
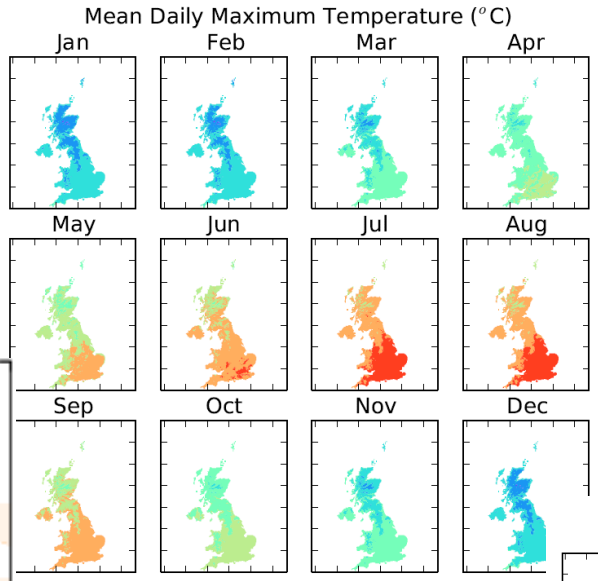


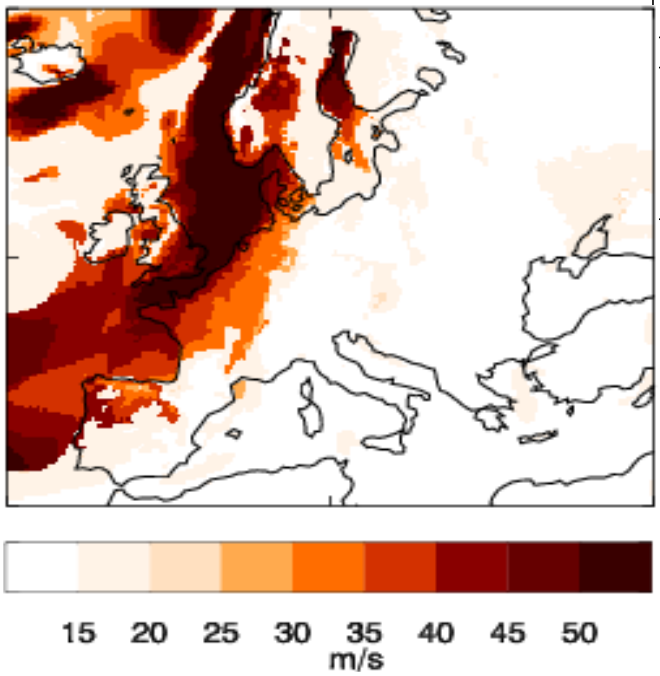
Figure 12: Example of groundwater output (aerial imagery © GeoPerspectives)

Wind, Heat, Cold hazards

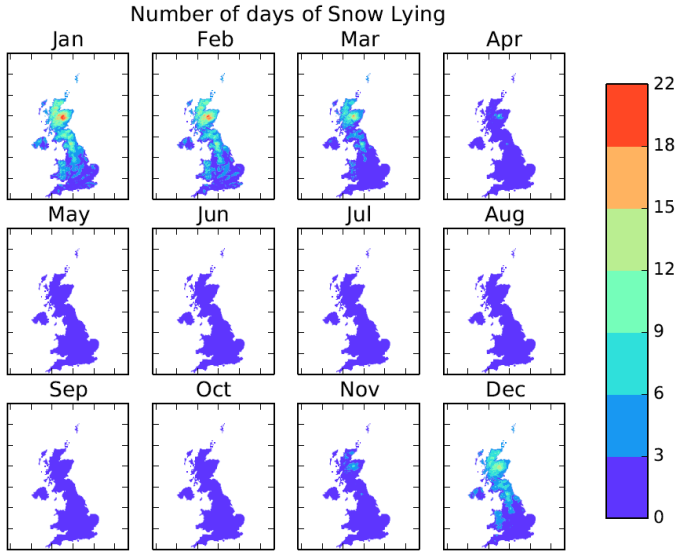
Heat (Met Office)



Wind (XWS Catalogue)



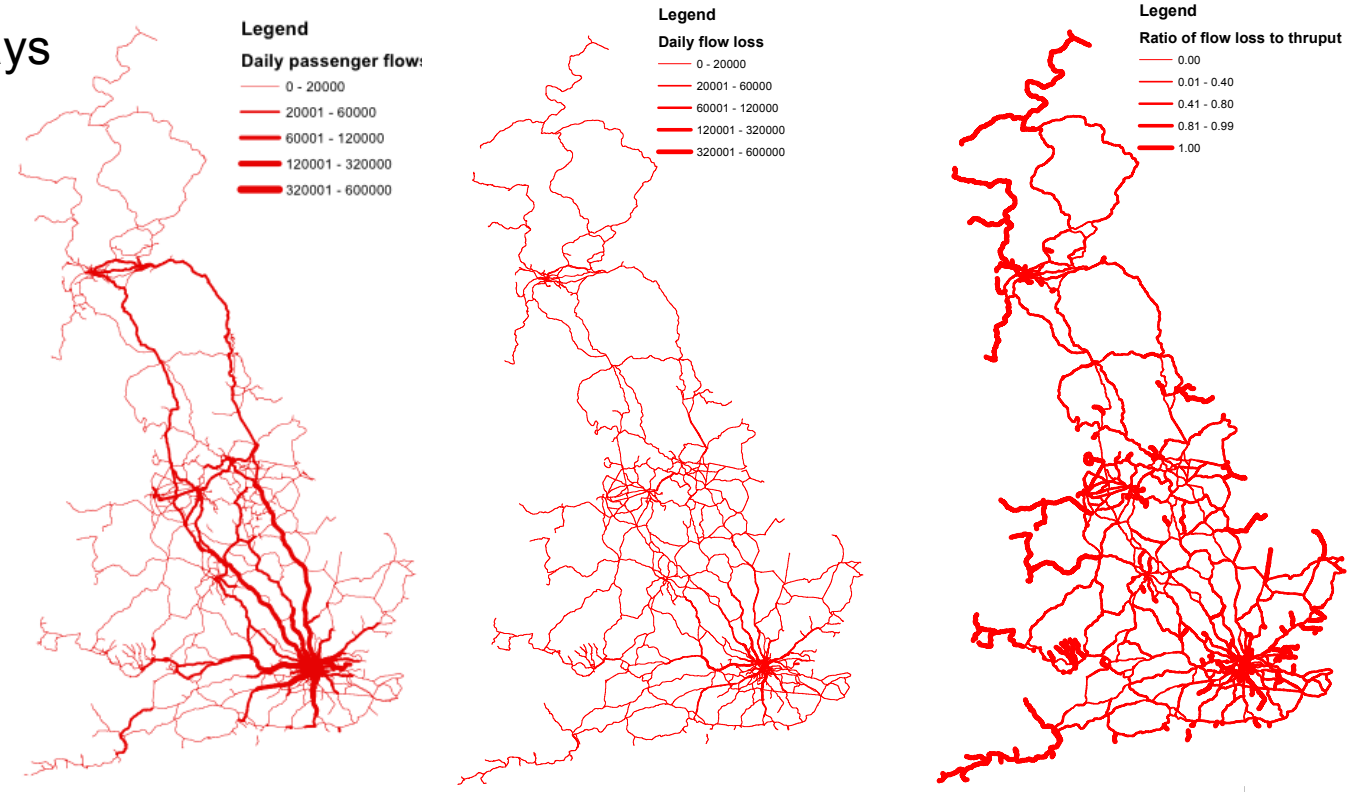
Ice (Met Office)



Multi-dimensional criticality

Criticality is measured in terms of the **volume of flows** along routes, the **losses of flows** when routes are disrupted and the **ratio of post-disruption losses to pre-disruption flows**

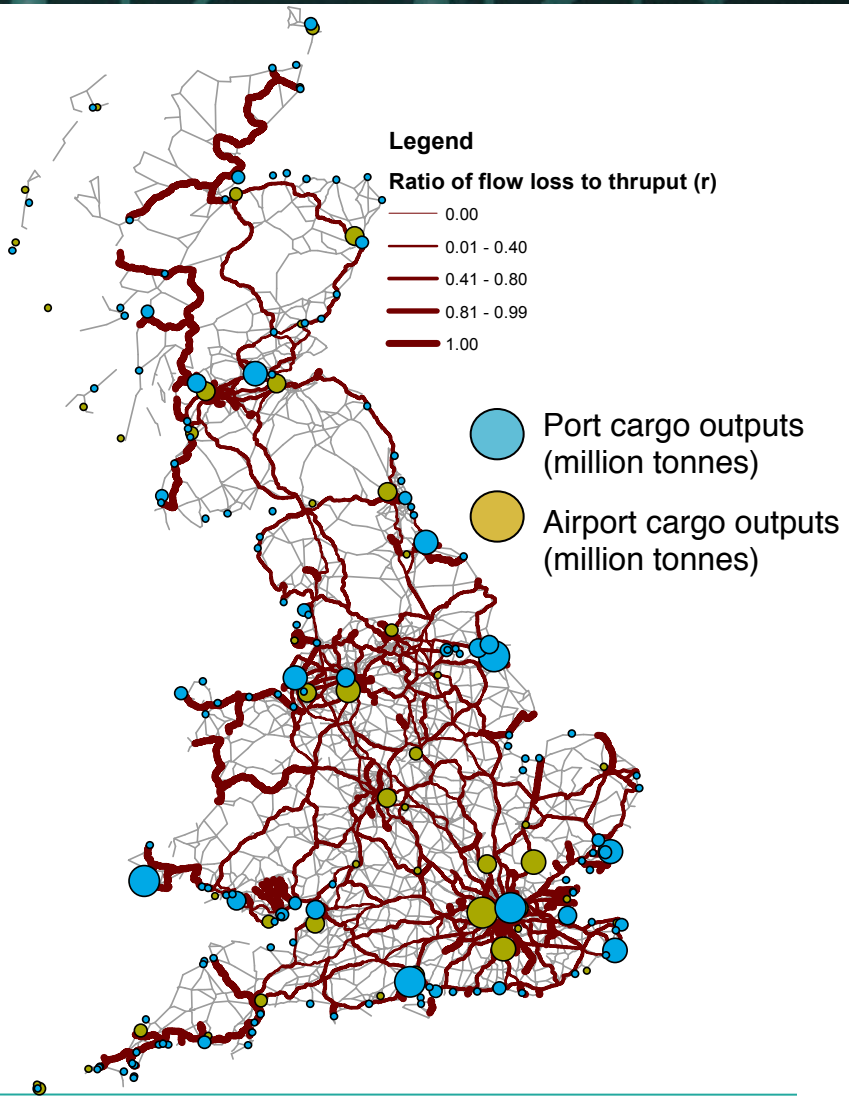
Example: Railways



Multi-modal criticality

Understanding and informing:

- Key locations of systemic criticalities
- Identifying priority locations for strengthening assets and resilience planning



Department for Transport

nationalgrid

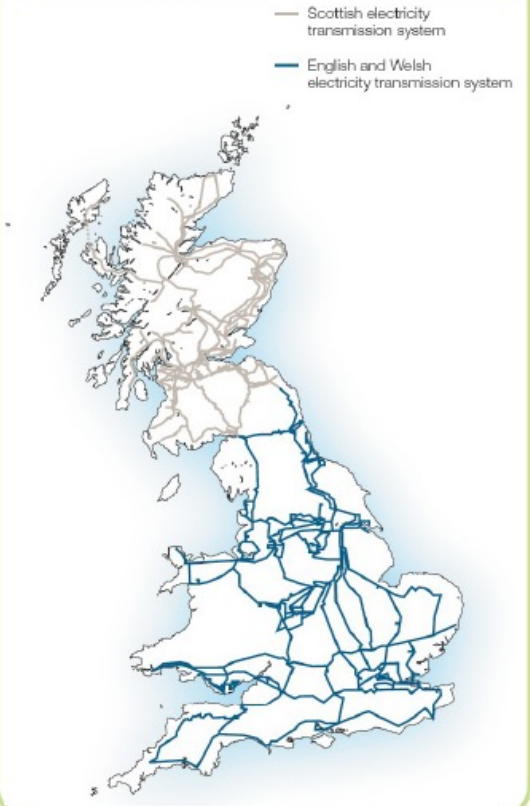
Future Energy Scenarios 2015

National Grid and ITRC

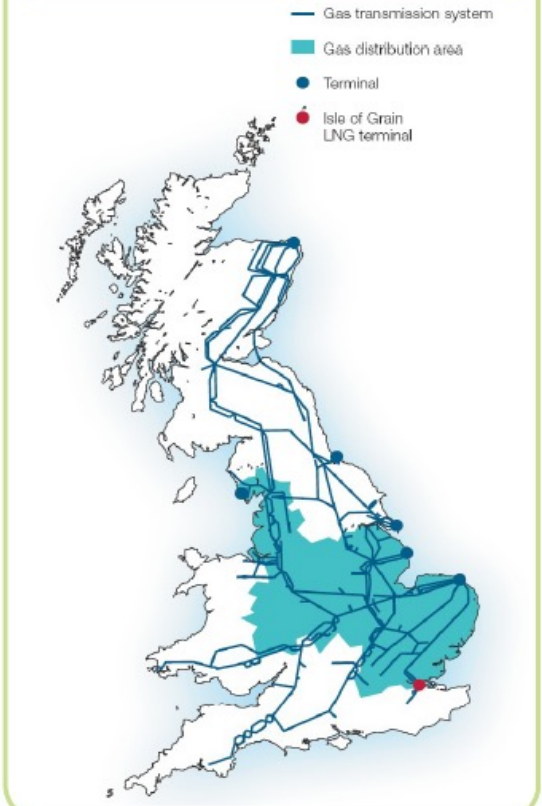
National Grid: Who are we?

nationalgrid

Electricity – UK

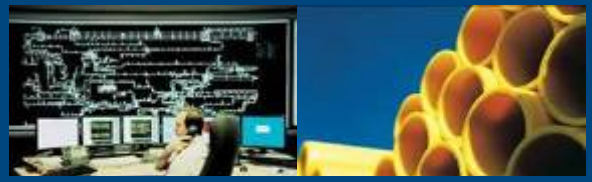


Gas – UK



Electricity – US

Gas – US

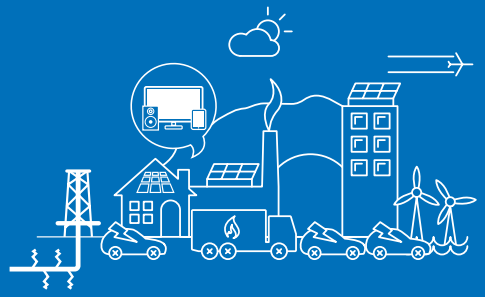


The 2015 scenarios
Evolution not revolution

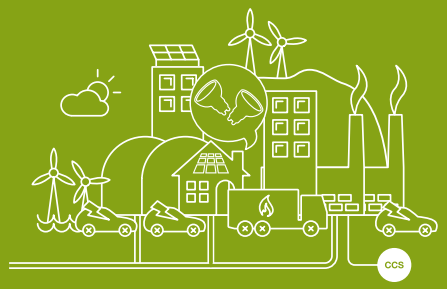
nationalgrid

+ Prosperity −

Consumer Power

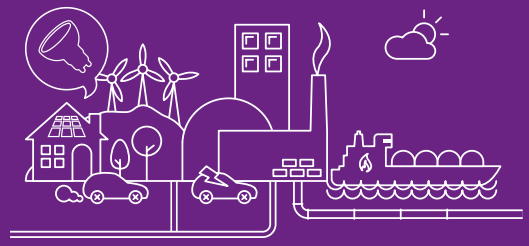


Gone Green



No Progression

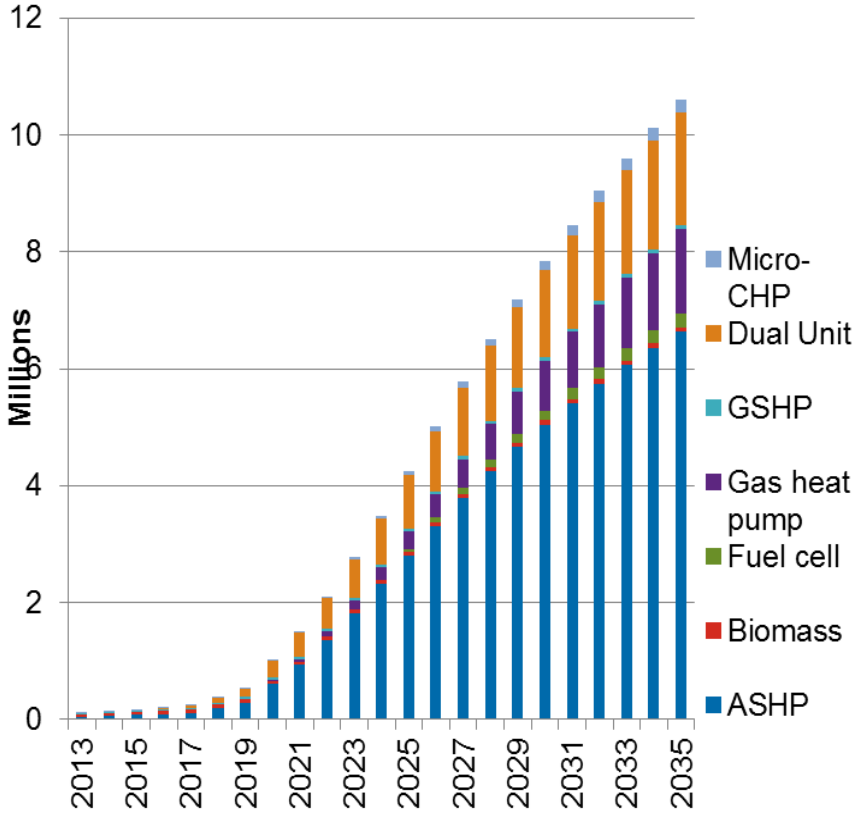
Slow Progression

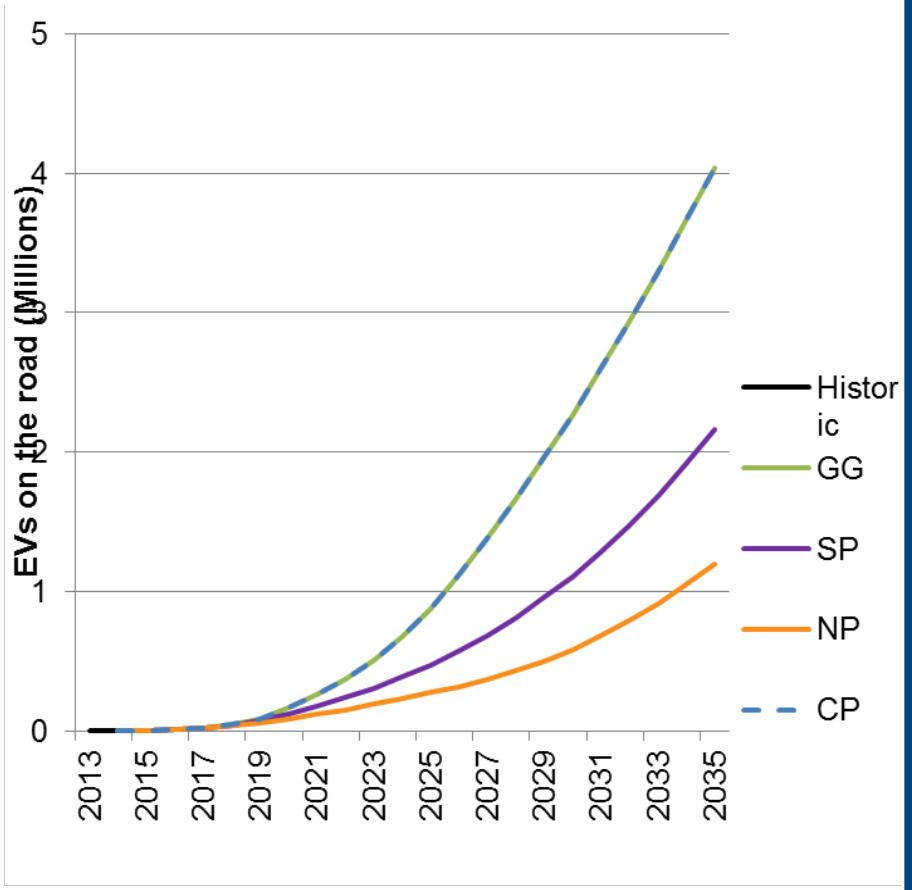


− Green ambition +

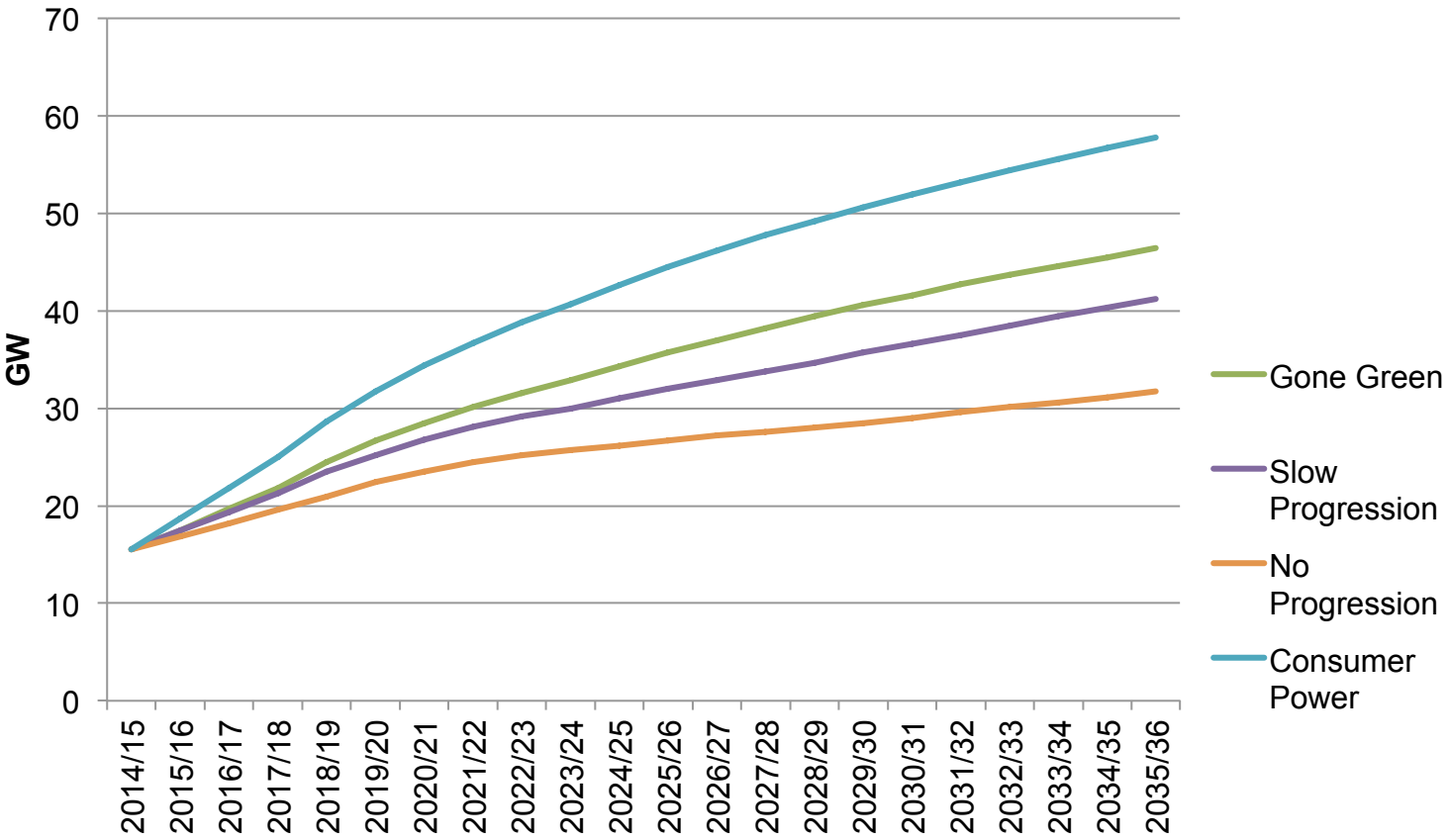
Low Carbon Heating and Electric Vehicles

nationalgrid





Distributed & Microgeneration



nationalgrid

- Helping us to answer the following:
- Where is all of this new technology?
- Where will it be in future?
- What sort of networks should be built?

Finally:

nationalgrid

Microsite: fes.nationalgrid.com

Email: Transmission.ukfes@nationalgrid

UK Infrastructure Transitions Research Consortium

Spatial demand modelling for future energy scenarios

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EPSRC Impact Acceleration Award - Secondment

nationalgrid

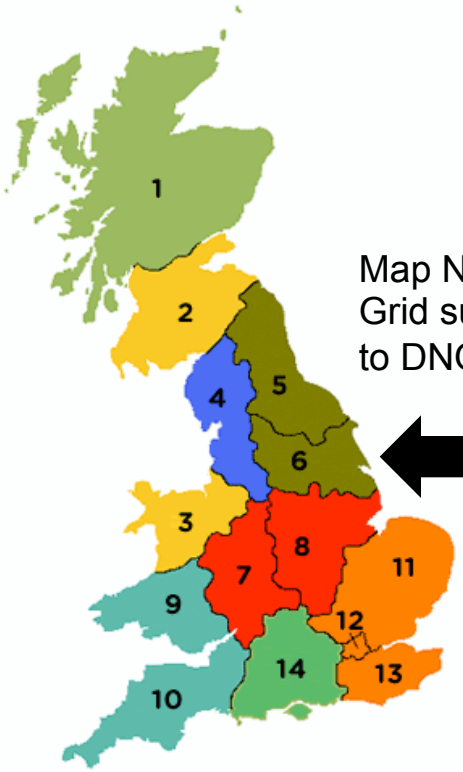
Project objective

- To develop a spatial analysis tool for National Grid
- Properties of the tool
  - Synchronizing different data types
  - Finding numbers, capacities and generation data for different types of installations
- Usefulness of the tool
  - Better demand modeling than current practice
  - Outputs feed into future energy scenarios

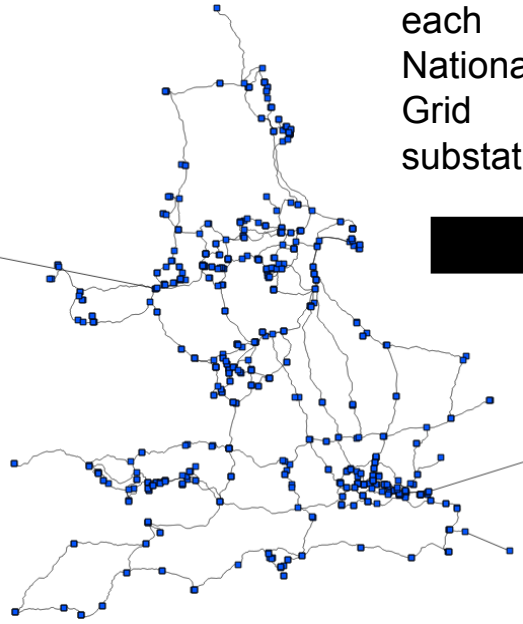
Project objective

- To develop a spatial analysis tool for National Grid
  - Synchronising different datasets from National Grid and ITRC to provide new insights
  - Mapping electricity capacity and demand at a high spatial resolution
  - Exploring the potential effects on demand of distributed generation types (PV, wind)
  - Projecting changes in demand into the future
- Usefulness to National Grid
  - Better demand modeling than current practice
  - Outputs feed into future energy scenarios

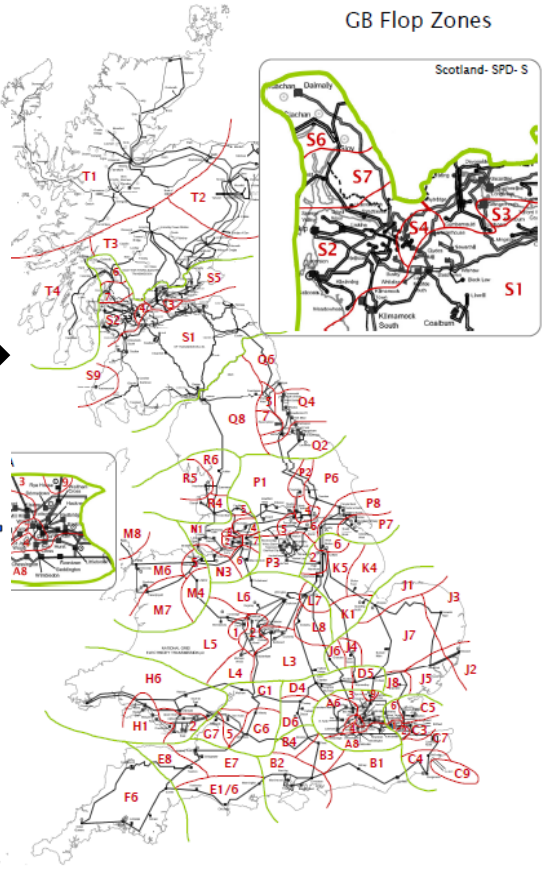
Spatial tool overview



Map National Grid substation to DNO regions

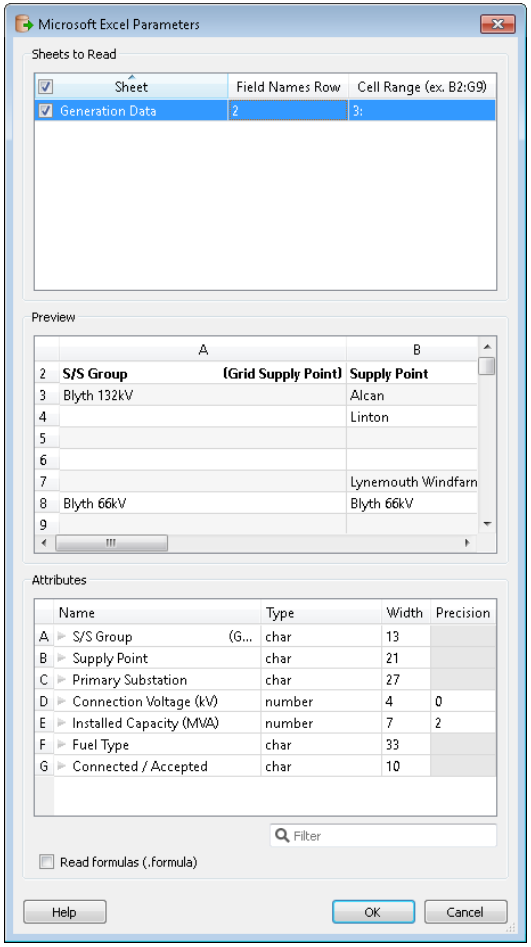


Map output areas of each National Grid substation



- Map installed capacity for each Grid Supply Point
- Find embedded generation types (solar, wind, CHP) linked to Grid Supply Point

Outcomes



Spatial tool outputs:

- Details of the National Grid substation (Name, Location, Voltage)
- Connection to DNO
- Installed capacity from all distributed generation types
- Fuel types (PV, wind, etc.)
- Spatial output area

Bridge scour: fragility and risk analysis

Rob Lamb, JBA Trust & Lancaster University

Paige Garside, JBA Trust

Raghav Pant and Jim Hall, Oxford University (ITRC)

Bridge scour

"The most common cause of bridge failure is due to scour during floods"

Kirby et al., CIRIA 'Scour Manual'

"Scour… is the most common cause of highway bridge failures in the United States"

Kattell & Eriksson, USDA

JBA input to railway bridge scour management

- Over 7,000 bridge assessments since 1995
- Development of scour assessment standards
- Scour assessment, modelling and design at over 120 bridges
  - Including £24m HMT enhanced spend programme 2012-14
  - Reduced the number of structures requiring flood event response by 20%

But scour assessment is subject to uncertainty

- Occurrence and magnitude of flood events
- Debris, blockage, changes in river/catchment
- Information and measurement uncertainties

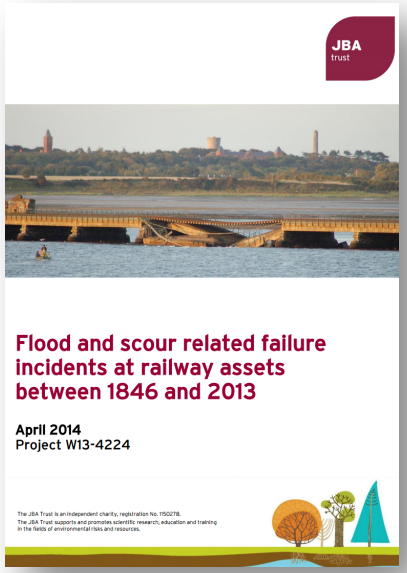
→ **How to quantify uncertainty for a network-scale risk analysis?**

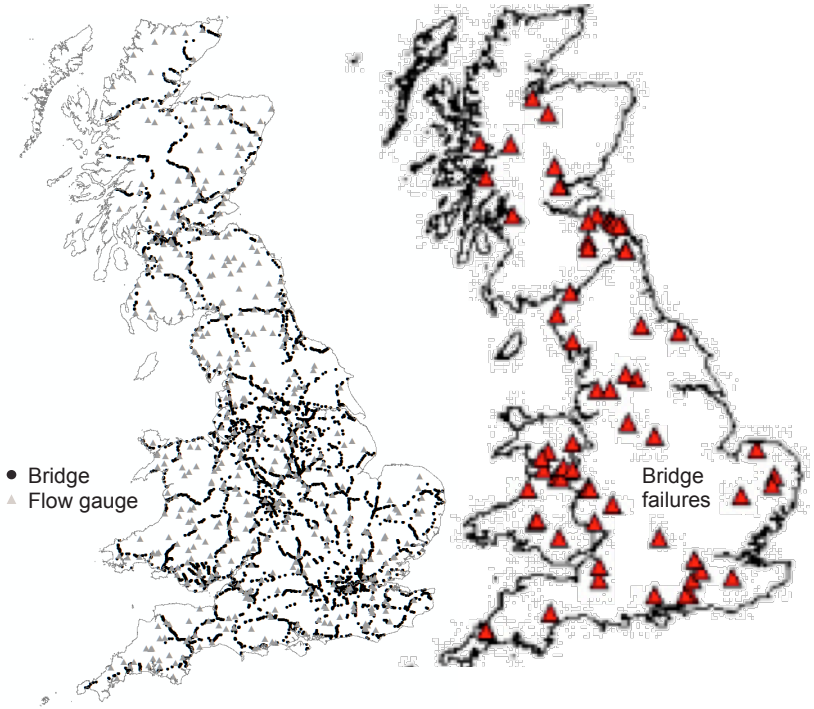
Debris and blockage

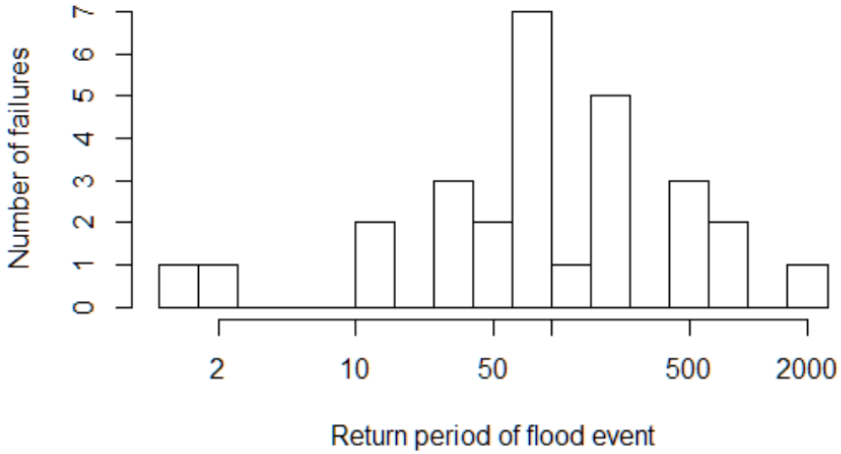
Information uncertainties

Historical scour-related bridge failures

- Unique data: 100 rail bridge failures since 1846
- Flood events reconstructed from observations



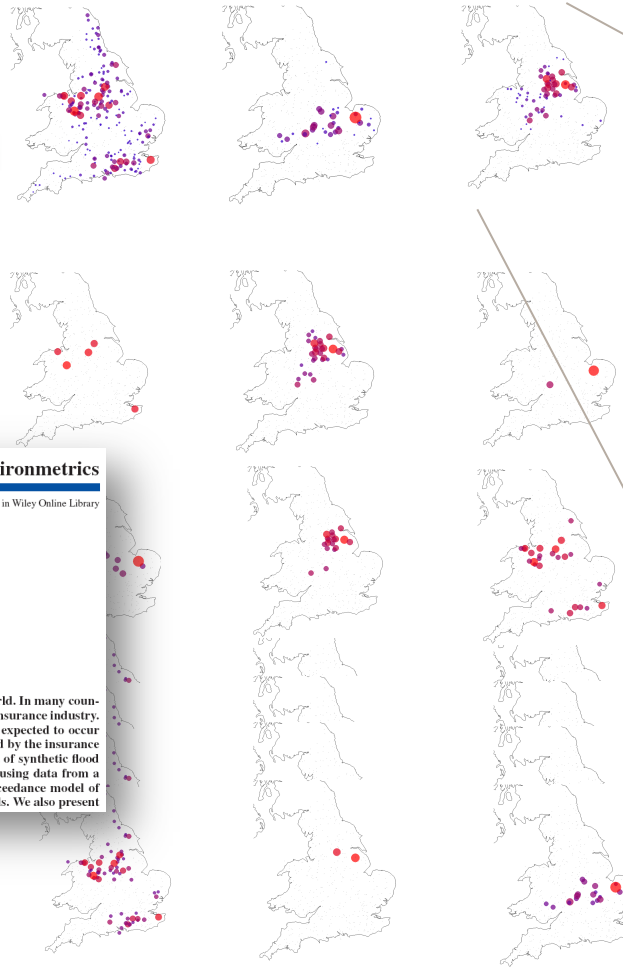


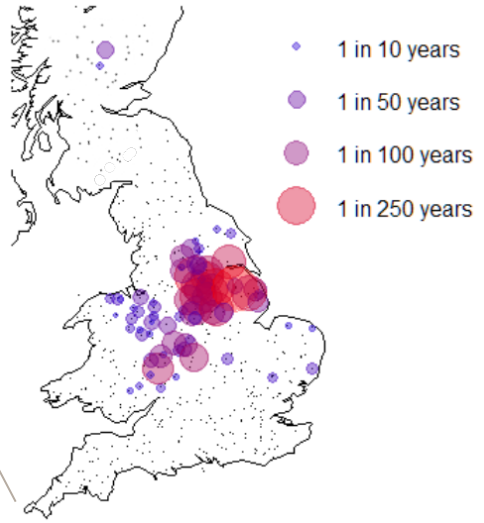


On average 1.9 structures failed per flood

JBA model for national flood event scenarios

10,000 years of simulated flood events





Journal of Flood Risk Management

A new method to assess the risk of local and widespread flooding on rivers and coasts

R. Lamb[1], C. Keef[1], J. Tawn[2], S. Laeger[3], I. Meadowcroft[3], S. Surendran[3], P. Dunning[1] and C. Batstone[1]

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Abstract

To date, national- and regional-scale flood risk assessments have provided valuable

Research Article **Environmetrics**

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Estimating the probability of widespread flood events

Caroline Keef[a]*, Jonathan A. Tawn[b] and Rob Lamb[c]

Flooding is a natural phenomenon that regularly causes financial and human devastation around the world. In many countries the risk of flooding is managed by society through a combination of governmental agencies and the insurance industry. For both these types of organisation an estimate of the largest, or most widespread, events that can be expected to occur is useful. Such estimates can be used to help in preparing or co-ordinating flood mitigation activities and by the insurance and re-insurance industries to assess financial risk. In this paper we develop a method to simulate a set of synthetic flood events that can be used to estimate the probability of widespread floods. We demonstrate this method using data from a set of UK river flow gauges. The model used in this simulation process is based on the conditional exceedance model of Heffernan and Tawn, extended to incorporate features typically found in the data for extreme river floods. We also present

Collaboration between JBA Trust and ITRC

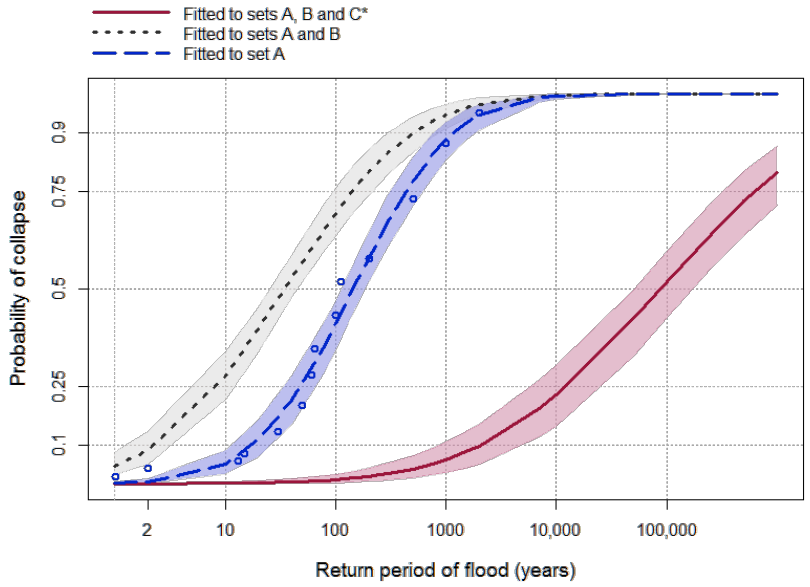
- How can we link the historical bridge failure data and flood event model to inform a network-scale risk analysis?

- ITRC research provides a theoretical framework for broad scale infrastructure network risk assessment

- Focus initially on fragility analysis to model the performance of bridges in response to flood events

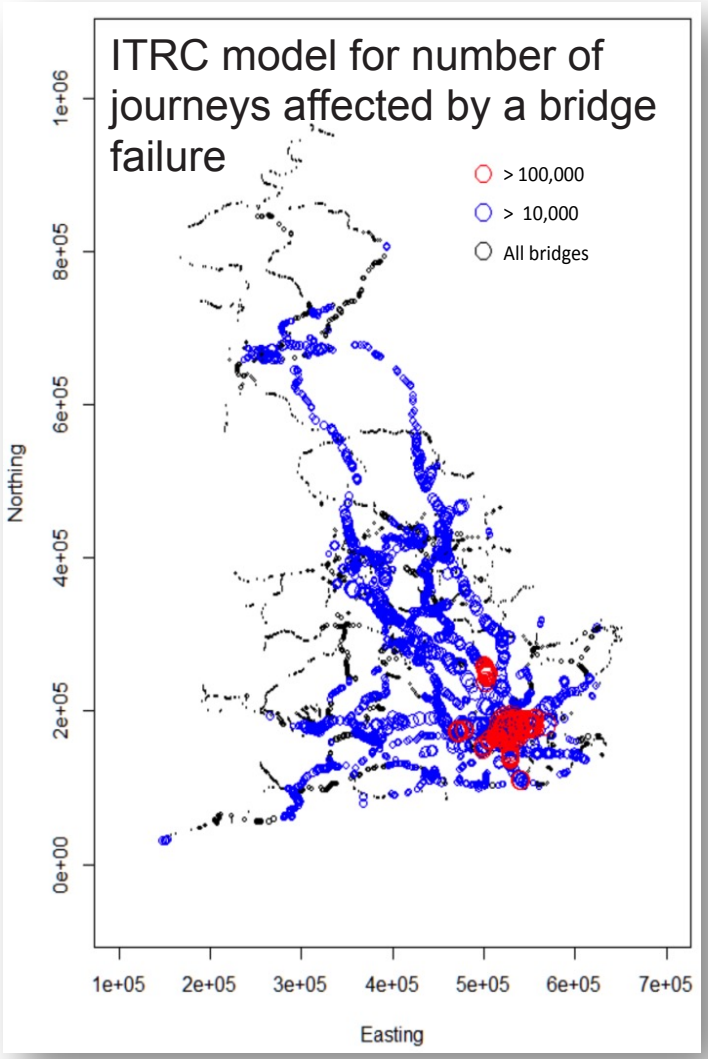
Collaboration between JBA Trust and ITRC

- JBA Trust
  - Collated historical observations and Network Rail's asset data
  - Implemented fragility curve analysis
  - Developed spatial model for extreme flows at rail bridges



- ITRC
  - Suggested fragility analysis theory
  - Developed a framework for broad scale risk analysis
  - Modelled disruption to passenger journeys

Next steps: network risk analysis



Flood event model ✓

↓

Fragility model ✓

↓

Disruption model ✓

↓

Network-wide assessment including risk of extreme events causing multiple bridge failures ☐

Achievements and opportunities

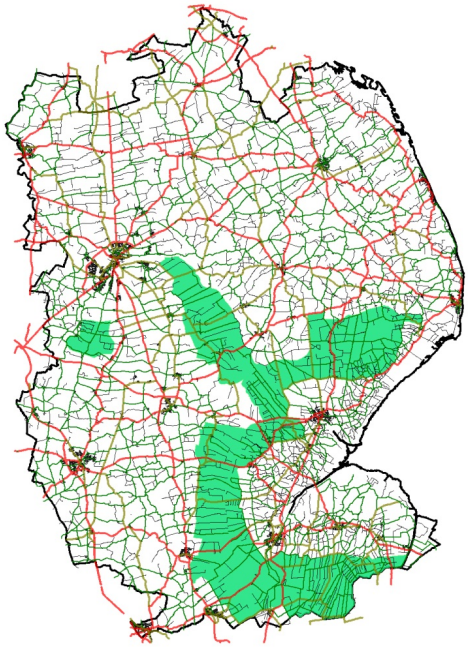
- Collaboration with ITRC unlocked the potential of existing data sets
- New broad scale analysis of scour at bridges, a significant risk to national transport infrastructure
- Provides a historical “baseline” analysis
- Generic theoretical approach – could be applied to other risks
- Made possible by ITRC’s programme, allowing sustained collaboration with JBA Trust

The problem….

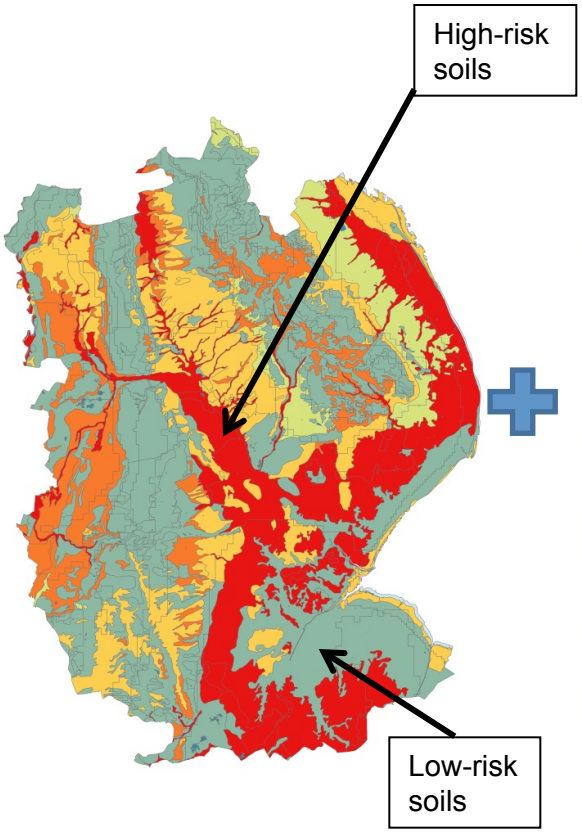
- Lincolnshire County Council (LCC) approached Cranfield University for soils expertise
- LCC reported extensive damage to roads during drought periods
- Need to understand relationship between spatial distribution of potentially hazardous soil types and road condition
- Lincolnshire soils are diverse
- ITRC project provided mechanism in bringing infrastructure and soils research together

Authority	Reported drought damage (£ 000)
Lincolnshire	7397
Essex	5614
East Sussex	5568
Kent	4167
Cambridgeshire	3522
Hampshire	3030
Peterborough	2400
West Sussex	2221
Isle of Wight	1500
Wiltshire	1302
Buckinghamshire	1200
Surrey	1000
Suffolk	750
Norfolk	650
Bedfordshire	300
Total	40 621

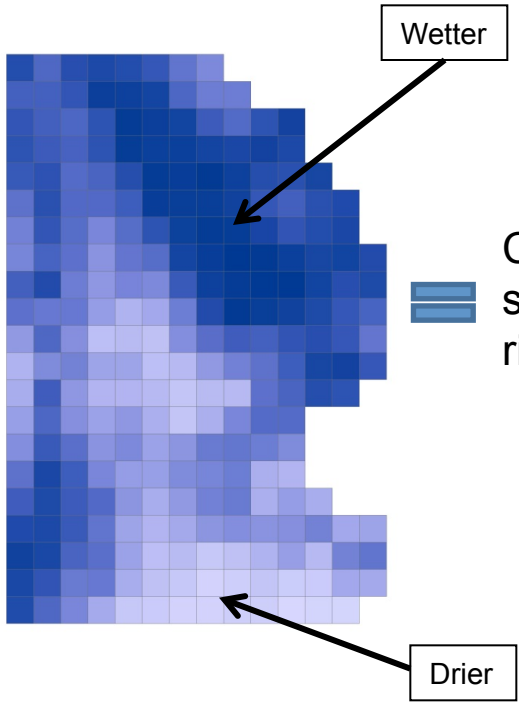
Road damage, clay subsidence and climate



Drought damaged roads identified by LCC



Soil shrinkage potential



Accumulated Potential Soil Moisture Deficit

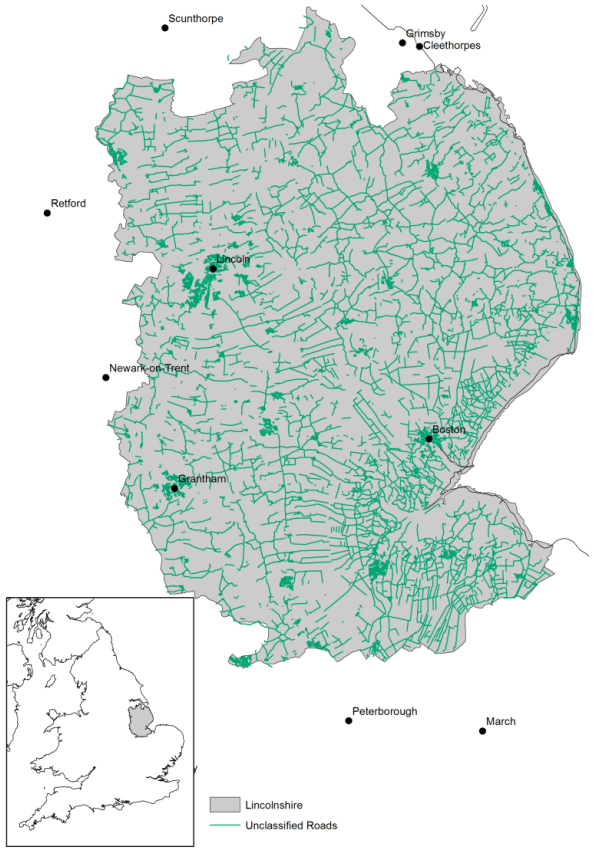
Met Office

UK CLIMATE PROJECTIONS

Lincolnshire network and subsidence risk

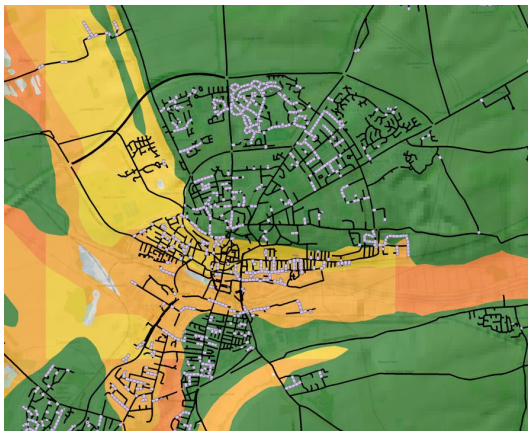
- 5,800km (66%) unclassified (U) roads
- Road condition data from LCC
- Spatially intersected with geohazard data

Unclassified road distribution

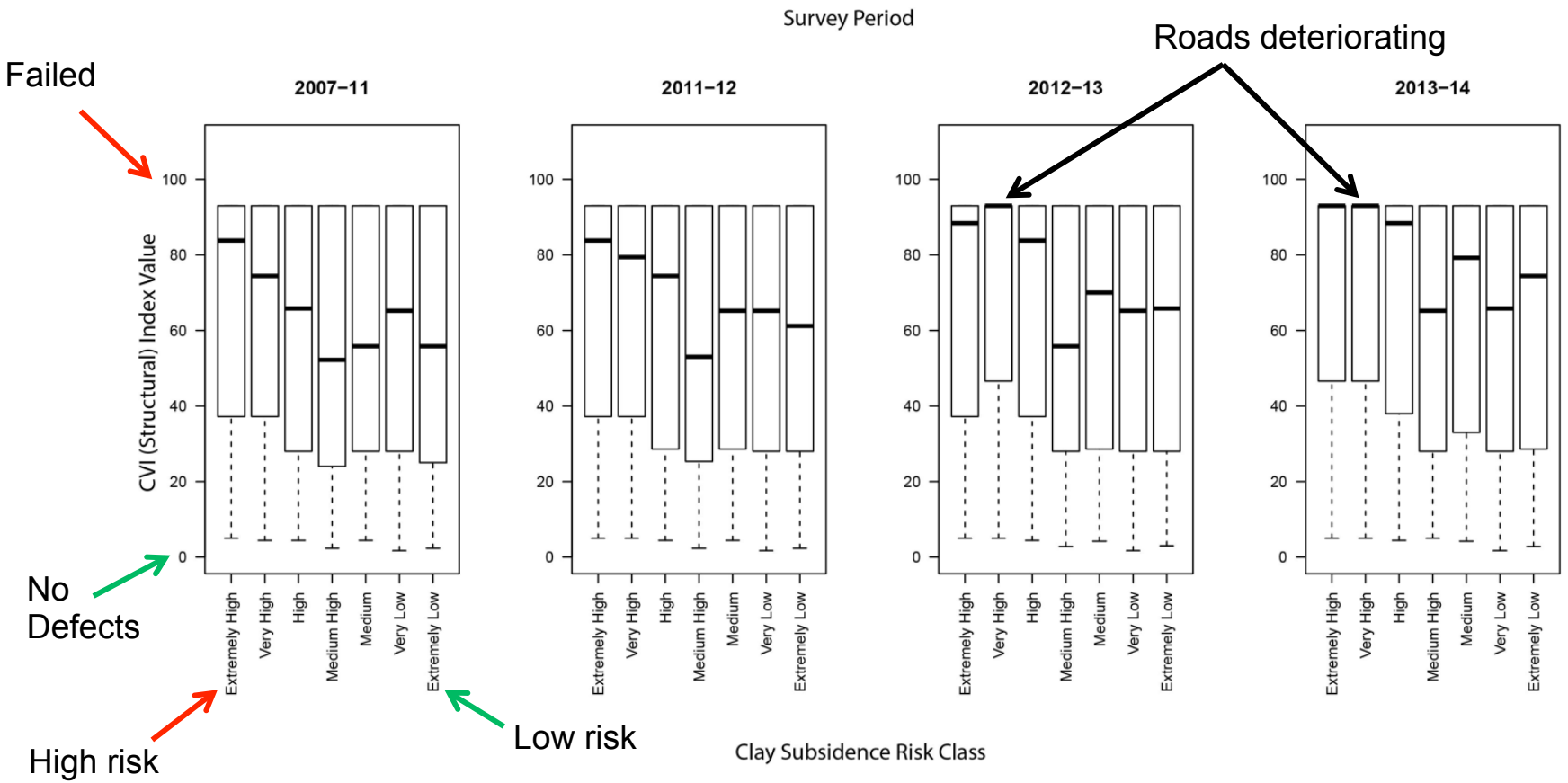


Road condition data

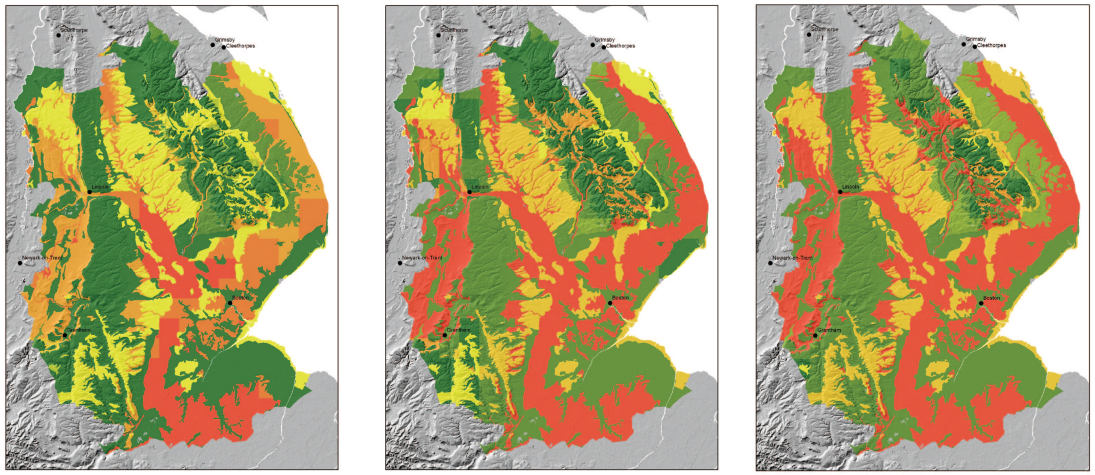
Geohazard mapping



Impact of soils on road condition



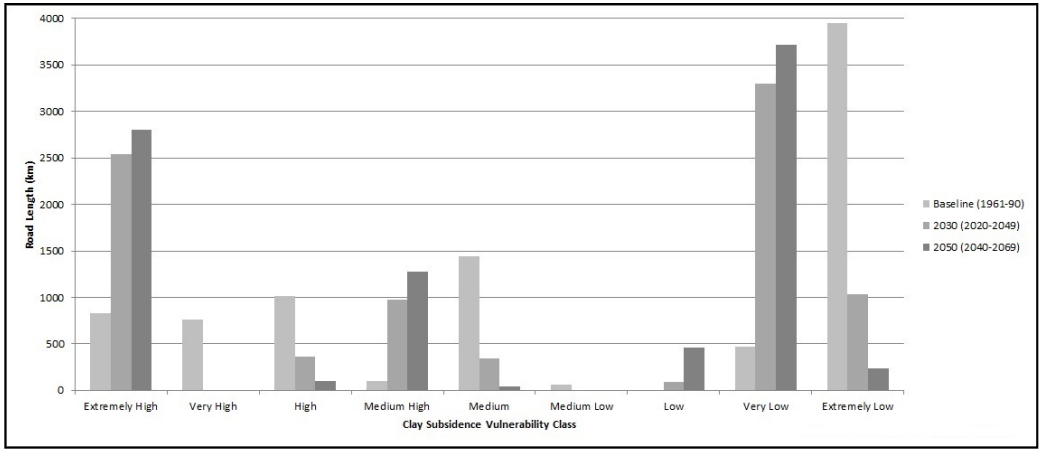
A future outlook for road damage…



Baseline (1961-1990) 2030 (2020-2049) 2050 (2040-2069)

- Projections of Potential Soil Moisture Deficit calculated from UKCP09 scenarios and incorporated into geohazard models (Pritchard et al. 2015)

- Subsidence hazard intersected with LCC network to understand future risk

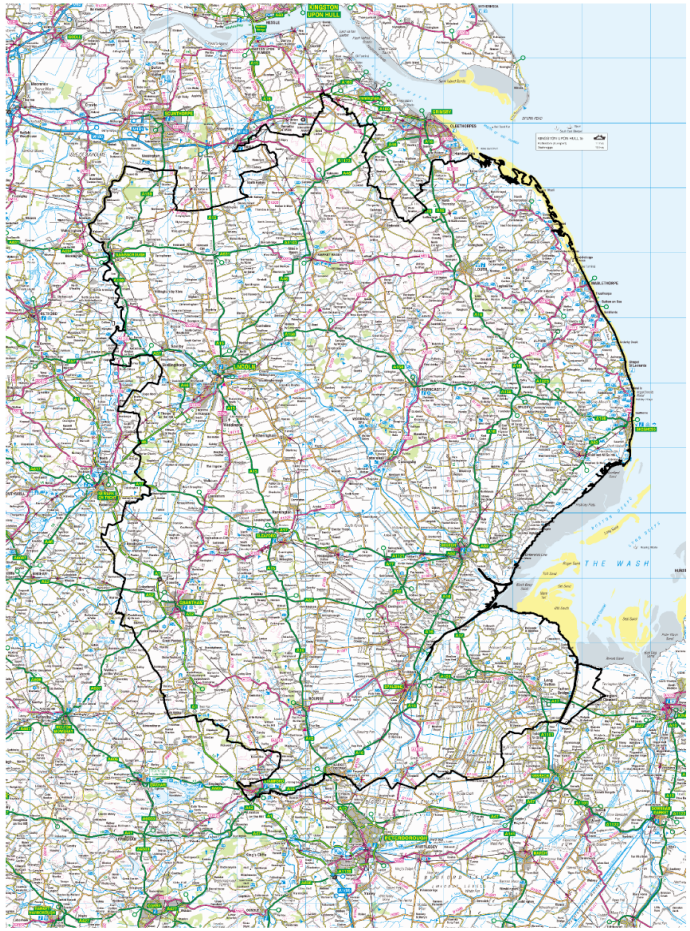


Outcomes and impacts

- Identified areas, current and future, at particular risk of clay-related subsidence
- Provided a soil-informed maintenance strategy for asset management of Lincolnshire roads – from 2014 £0.5-1 million per annum in maintenance
- Can easily be extrapolated to other local authorities
- Results formed peer-reviewed publication and EPSRC case-study
- Has changed strategy of Lincolnshire County Council Highways resurfacing for these areas…..

Pritchard, OG., Hallett, SH., Farewell, TS. 2015. Soil geohazard mapping for improved asset management of UK local roads. Natural Hazards and Earth System Sciences. 15(9): 2079-2090.

Lincolnshire Highway Network



Carriageway Lengths

A roads = 1,074km (12%)
B roads = 787km (9%)
C roads = 2,919km (34%)
U/C roads = 3,961km (45%)

Total = 8,741km

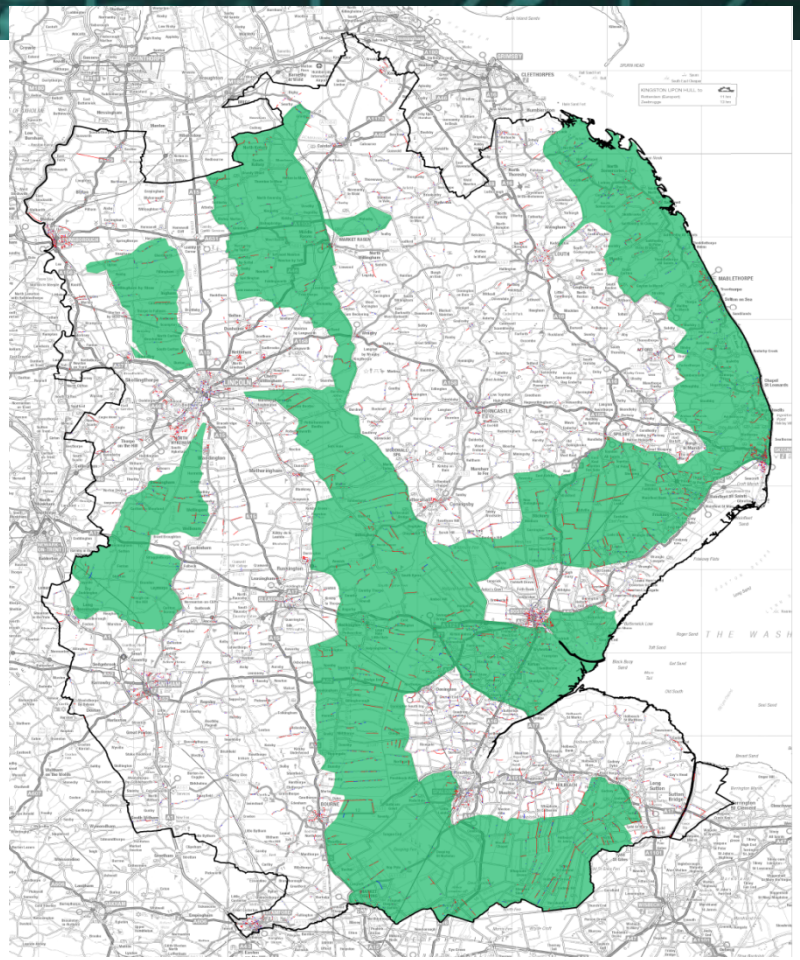
Gross Replacement Cost = £9.74bn

Drought Network approx. 1,500km

Maintenance Budget = £31m

Lincolnshire COUNTY COUNCIL

Drought Susceptible Network



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Lincolnshire Highway Network

- "Evolved" Largely Rural Network – Few Designed Roads
- Drought Network critical to the Agri Food Sector and the Lincolnshire/UK Economy
- Major Drought Damage events 2003/4 and 2011/12
- 2011/12 damage estimated at >£7.4m
- Accidents and claims
- Highways Asset Management Strategy

Lincolnshire COUNTY COUNCIL

Lincolnshire
COUNTY COUNCIL

Benefits of Research

- Greater awareness and understanding of drought network
- Highlighted increased risk of re-occurring drought events associated with climate change
- Changed spending priorities and works programmes
- Revised maintenance techniques on drought affected network
- Sharing Research and Practice with other Authorities

Lincolnshire COUNTY COUNCIL

Managing the Problem

- Central co-ordination and programming of works
- Specific funding allocated to Unclassified Roads affected by drought
- Prioritisation based on scoring matrix
- Standard Treatments include
  - "Retread" process for U/C Roads
  - In-situ recycling
  - Steel Mesh reinforcement

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