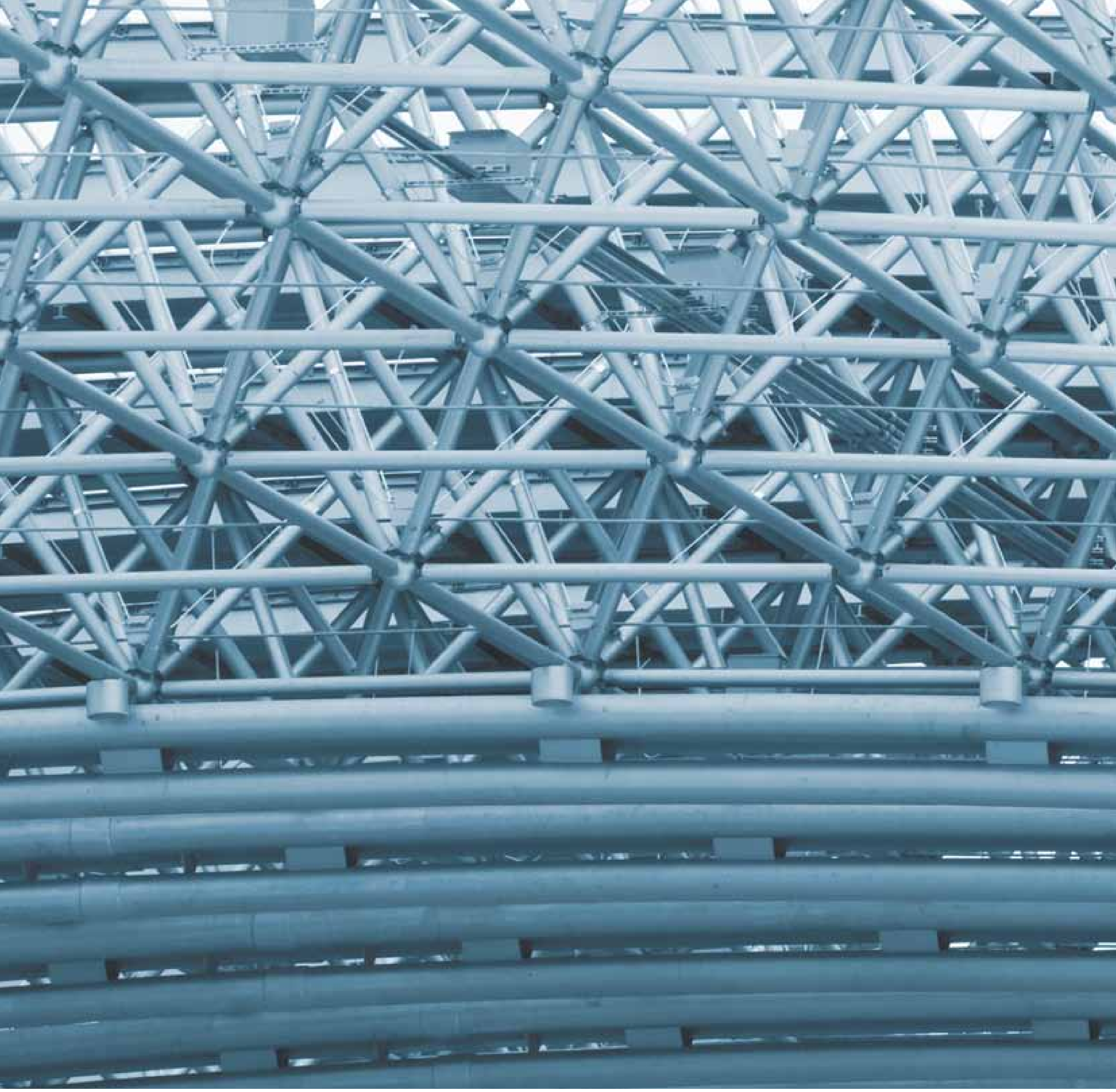

ITRC

A Fast Track Analysis of strategies for infrastructure provision in Great Britain

Executive Summary

A FAST TRACK ANALYSIS OF STRATEGIES FOR INFRASTRUCTURE PROVISION IN GREAT BRITAIN: EXECUTIVE SUMMARY

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ACKNOWLEDGEMENTS

The UK Infrastructure Transitions Research Consortium (ITRC) is supported by the Engineering and Physical Science Research Council under grant EP/I01344X/1. The support and advice of the ITRC's partners in industry and government is also gratefully acknowledged. The names of these organisations are listed at: www.itrc.org.uk/about-itrc/partners/

ISBN 978 1 874370 50 5

This report should be referenced as:

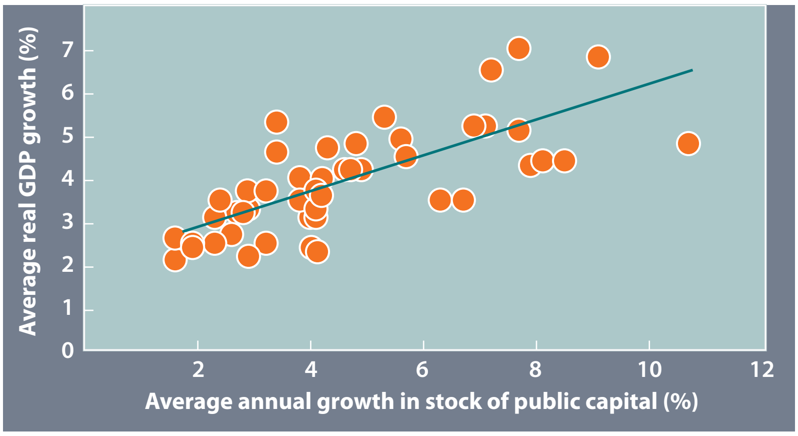
Hall, J.W., Henriques, J.J., Hickford, A.J. & Nicholls, R.J. (eds) 2012. A Fast Track Analysis of strategies for infrastructure provision in Great Britain: Executive Summary. Environmental Change Institute, University of Oxford.

A GLOBAL PRIORITY

National Infrastructure (NI) provides the foundation for economic productivity and human wellbeing, and is the cornerstone of modern industrialised society. It shapes many of the interactions between human civilisation and the natural environment. However, in the UK and other advanced economies, NI faces serious challenges of:

- Growing demand for infrastructure services from a modern economy and growing and ageing population;
- Significant investment requirements so that an ageing infrastructure system can meet this demand and provide reliable, cost-effective and high quality services;
- Increasing complexity and interdependence of infrastructure networks.

Figure 1: Relationship between growth in infrastructure capital stock and GDP growth. Modified with permission from Arslanalp, S. *et al*. (2011).[2] The data are for 48 advanced and developing countries between 1960 and 2001.



A growing stock of infrastructure helps to promote economic growth (see Figure 1) by increasing productivity, participation in the economy and aggregate demand. Infrastructure investment is also necessary to reduce the likelihood and consequences of system failure and to ensure a healthy environment and a stable climate.

The lead-time and long lifetime of major infrastructure means that a long term view is essential. Yet a long term strategic approach is challenged by the associated uncertainties, be they technical, environmental, political or financial. Interdependence between infrastructure sectors add to the complexity and uncertainty in the strategic planning of NI.

In the 2011 National Infrastructure Plan (NIP),[1] the UK government has identified a strategy for meeting infrastructure needs. Metrics for monitoring UK infrastructure performance and strategic priorities for the future are set out in the NIP. The NIP underlines the importance of taking a long term and cross-sectoral view of infrastructure provision.

1 HM Treasury and Infrastructure UK (2011). National Infrastructure Plan 2011. London, UK: HM Treasury.

2 Arslanalp, S., Bornhorst, F. and Gupta, S. Investing in growth. Finance & Development (March 2011), International Monetary Fund.

THE UK INFRASTRUCTURE TRANSITIONS RESEARCH CONSORTIUM

The UK Infrastructure Transitions Research Consortium (ITRC) has been funded by the Engineering and Physical Sciences Research Council (EPSRC) to develop and demonstrate a new generation of system simulation models and tools to inform analysis, planning and design of NI. The research programme deals with energy, transport, water, waste and ICT systems at a national scale, developing new methods for analysing their performance, risks and interdependencies. ITRC will provide a virtual environment in which to test strategies for long term investment in NI and understand how alternative strategies perform with respect to policy constraints such as reliability and security of supply, cost, carbon emissions, and adaptability to demographic and climate change.

The 5 year ITRC research programme started in January 2011. In its first year, the ITRC has begun the development of a new generation of simulation models for national infrastructure assessment that will be ready for piloting in 2013. In parallel, the ITRC has undertaken a Fast Track Analysis (FTA) in order to:

1. Ensure that the ITRC research programme is building upon existing knowledge.

2. Review and refine the scope of the ITRC research.

3. Pilot and communicate new analysis concepts.

4. Strengthen the relationship between the research team and the consortium's partners in government and industry.

This report describes the method and results from the FTA. It includes:

1. A review of the energy, transport, water, waste and ICT sectors, including governance arrangements and future opportunities and threats.

2. Development of a scenario framework for long term analysis of NI, and associated uncertainties.

3. Development and analysis of alternative long term strategies for infrastructure provision.

4. Synthesis of insights that will be used to focus the remainder of the ITRC programme.

THE CURRENT STATE OF NATIONAL INFRASTRUCTURE AND FUTURE CHALLENGES

Review of literature and consultation with industry has identified current trends and issues in the NI sectors.

ENERGY SECTOR

Reliability of the energy sector is high. Major investments are anticipated in electricity generation and distribution in order to maintain and increase capacity, meet the UK's greenhouse gas (GHG) emissions reduction commitments and address EU directives. All other infrastructure sectors are dependent upon the energy sector, but of these only transport represents a significant proportion of energy demand (34%). Yet the energy sector is also dependent upon ICT and transport infrastructure and is responsible for 32% of fresh water abstraction, though the majority of that cooling water is eventually returned to rivers.

TRANSPORT SECTOR

Demand for transport infrastructure has grown steadily over the years for a variety of reasons, including population growth, economic growth combined with relatively low costs making travel affordable for most people, and societal changes such as increasing numbers of female drivers. Growth seems likely to continue, although demand for personal car transport may reach a saturation point. Continued growth in demand will result in increased congestion and delays, particularly on roads and rail, which will in turn tend to inhibit further growth. Building new transport infrastructure will alleviate congestion and delays in the short term but also induce further demand. Increasing transport costs will act to inhibit demand, which could have an adverse impact on the economy unless transport growth can be decoupled from economic development. Ambitious carbon reduction targets will drive development in vehicle and fuel technologies and result in increased use of electric vehicles on roads, increased rail electrification and lower use of carbon fuels. This will require substantial investment in energy infrastructure, particularly for electricity. Providing new energy infrastructure will impose further requirements on the transport system, for example, a change in the combination of imported fuels may have alternative shipping and storage requirements which will affect ports infrastructure.

WATER SUPPLY SECTOR

The water industry supports a diverse range of uses for water, all of which possess stringent levels of service with respect to both water quantity and water quality, dictated by a complex legislative and regulatory framework. As well as significant geographical and seasonal variability, pressures including increasing consumptive demand, an ageing and deteriorating infrastructure, affordability, and a potentially critical redistribution of resource under future climates, providing a potent set of challenges for the water supply sector in the 21st century. It is unlikely that even major change in the behaviour of consumers will be sufficient to alleviate such pressures without additional investment in infrastructure. Thus, a broad programme of measures combining management of consumptive demand across all users of the water environment alongside strategic provision of new supplies is necessary.

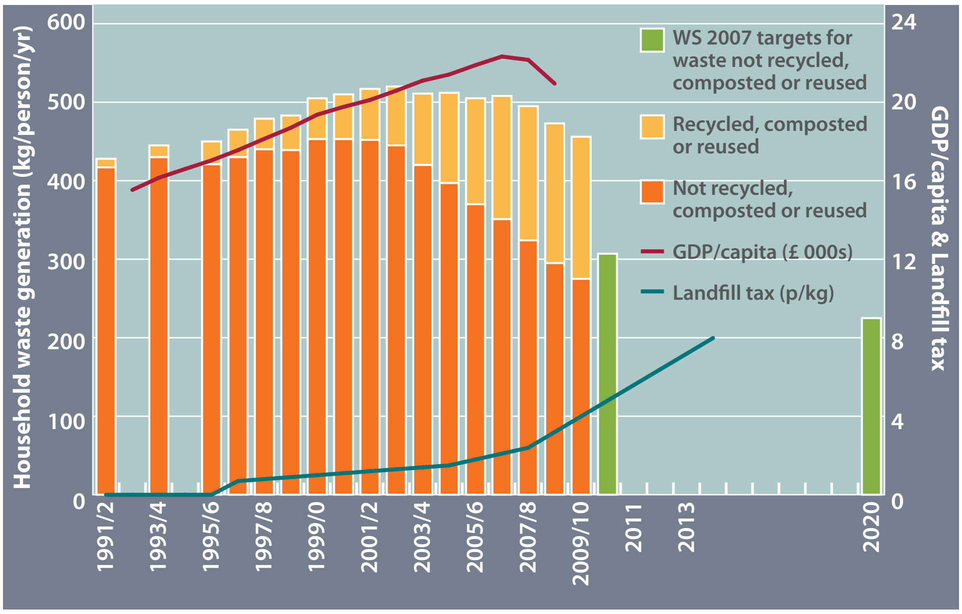
WASTEWATER SECTOR

Wastewater treatment accounts for the majority of the total asset value of the water industry, with capital expenditure on sewerage services programmed to exceed £12 billion between 2010 and 2015 in England and Wales alone. There has been extensive investment in wastewater treatment in order to improve water quality standards in rivers and coastal waters, though improved treatment standards imply escalating energy costs. Energy use in wastewater treatment now averages roughly 300 MW. Options that would reduce or eliminate energy use in wastewater treatment are needed to ensure the future affordability of service. Projected changes in rainfall patterns due to climate change and major and minor flooding pose a risk to the existing drainage infrastructure.

SOLID WASTE SECTOR

The solid waste sector deals with approximately 300 million tonnes of waste annually in the UK. In the last decade, the sector has transformed rapidly, responding to EU and national legislation. This has increased the amount of waste recycled, composted or reused and nearly halved waste going to landfill. Historically, economic growth and household waste generation were coupled, but there is some evidence that this may no longer be true (see Figure 2). National and EU directives (e.g. possible banning of all biodegradable municipal waste to landfill in the next decade) for reducing solid waste will affect the levels of investment needed in the near term. There is the possibility of a complete paradigm shift towards solid waste becoming a resource recovery industry.

Figure 2: Recent relationship between household waste generation and GDP: have they decoupled?



INFORMATION AND COMMUNICATIONS TECHNOLOGIES (ICT)

In comparison to the physical infrastructure sectors already discussed, ICT is a new and rapidly changing sector, but it is less clearly defined and understood. ICT infrastructure is considered to comprise of communication (including fixed and mobile telephony, broadband, television and navigation systems) and computation systems (including data and processing hubs). Significant increases in ICT capacity have been provided (Figure 3) via a competitive industry, which has innovated to provide new technologies and respond to consumer demand (which is itself largely driven by innovations in consumer and enterprise technologies). Further rapid increases in coverage, in particular in superfast broadband, are anticipated, though there are some locations where the market alone cannot deliver. The current way that the electro-magnetic spectrum is used may also become a constraint: solutions include reallocation of the spectrum use and technological innovation. ICT has a critical role in infrastructure interdependence and failure.

INFRASTRUCTURE GOVERNANCE

Alongside these sector-specific issues, the shift towards liberalisation, private provision and competition in infrastructure sectors has led to a more complex governance landscape in which utility providers must negotiate with a range of other actors to effect change. Additionally, current governance arrangements continue to operate in isolated sector-specific silos, paying limited attention to cross-sectoral synergies and interdependencies.

Figure 3: Communications infrastructure availability by percentage of population covered. Data from Ofcom 2011. *Note that Fibre optic broadband refers to Fibre-to-the-cabinet (FTTC).

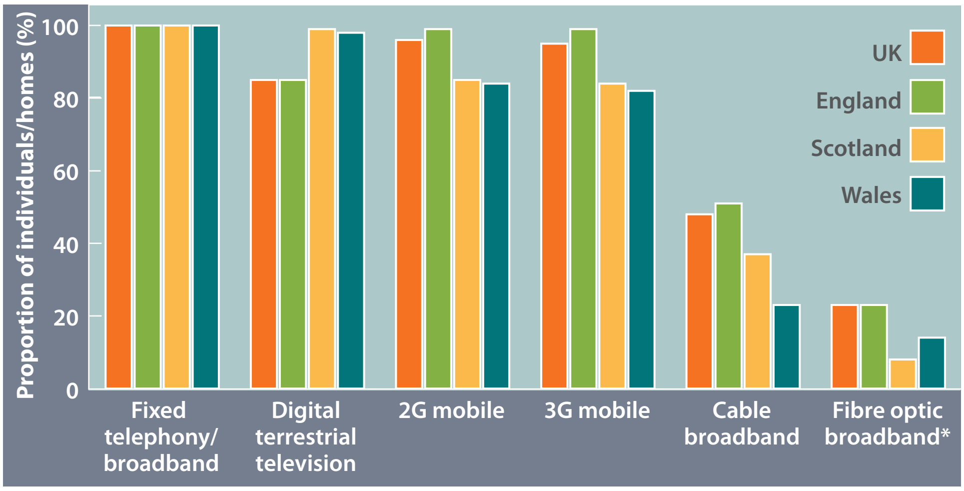


Table 1: Summary of NI systems and governance in Great Britain

	Energy	Transport	Water	Waste		ICT
				Wastewater	Solid waste	
Example component systems	Electricity Natural gas Liquid and solid fuels	Roads Rail Aviation Shipping	Water supply	Sewerage Wastewater treatment	Household Commercial and industrial Construction and demolition	Fixed (cable, wireless) and mobile (mast, satellite) communications Mass data and computation facilities.
Scale	National International	Regional National International	Regional	Regional	Regional	National International
Ownership	Private	Mixed (by mode)	Mixed (by region)	Mixed (by region)	Mixed (public responsibility with private operation)	Private
Governance & regulation	Varies, e.g. electricity has unregulated market prices but regulated network charges (Ofgem)	Varies, e.g. rail has regulated efficiency targets and prices; roads are government planned with some private provision	For England and Wales, price and investment regulated by Ofwat, drinking water quality regulation by DWI, Environmental regulation by EA. Similar structure in Scotland		Local Authority run. Environmental regulation by EA/ DEFRA in England and Wales, SEPA in Scotland	Competition regulation by Ofcom
Issues	Security of supply GHG emissions targets	Congestion High speed rail Airport capacity	Demand management Climate change Environmental regulation	Energy costs Environmental regulation	Waste minimisation and recycling targets Resource recovery	Technological innovation

THE ITRC FAST TRACK ANALYSIS METHODOLOGY

National Infrastructure systems have to cope with the implications of long term changes in population, the economy, society and the environment. The nature of these changes is hard to predict in the long term, so the ITRC is adopting an approach in which plausible ranges of these future changes are analysed. A simplified version of this methodology has been developed for the FTA, in which three primary scenario dimensions that are common to all infrastructure sectors have been analysed: demographic change, energy prices and economic growth (Figure 4).

Whilst the ITRC modelling tools that are now under development will enable the analysis of many combinations of these and other scenario dimensions, in the FTA the analysis has been restricted to only three combinations, representing low, medium, and high growth scenarios (Table 2, and Figure 5).

Figure 4: The dimensions of the FTA scenario space.

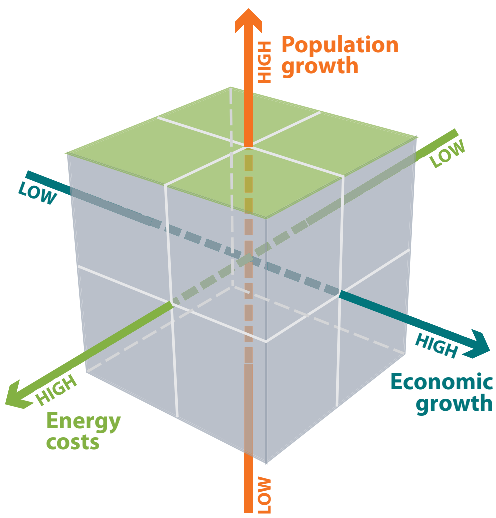
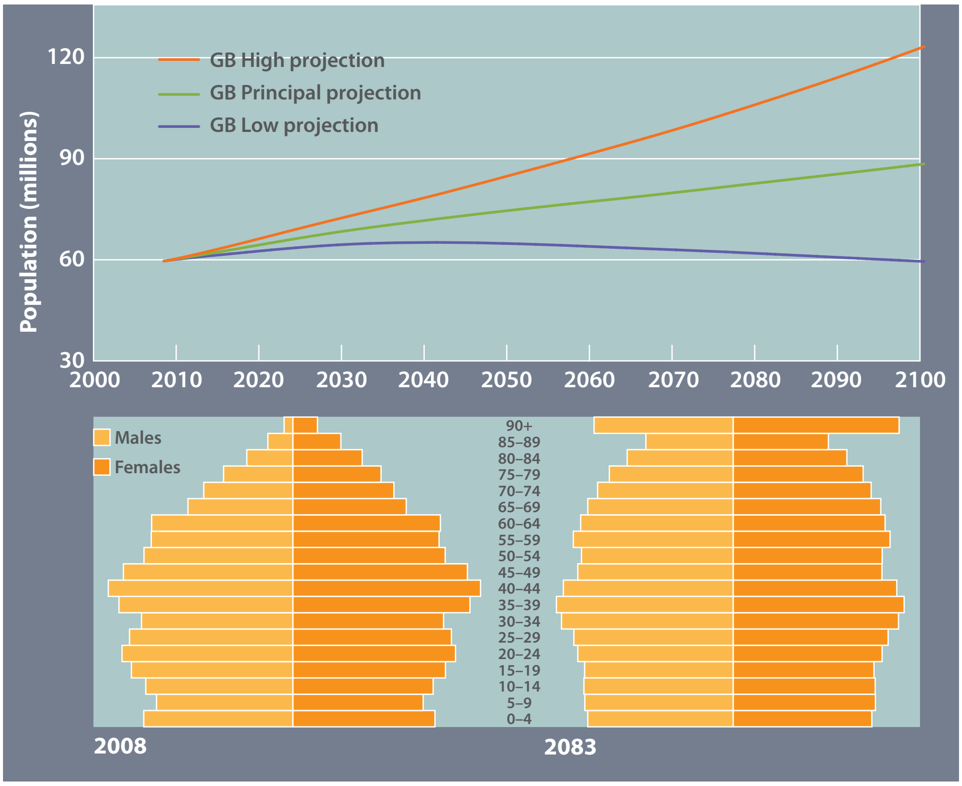


Table 2: Summary of the FTA scenarios	Low growth scenario	Medium growth scenario	High growth scenario
GB population (see Figure 5)	Low ONS projection	Principal ONS projection	High ONS projection
GDP growth per year	1.6%	2.3%	3.0%
Energy cost[1]	DECC High fossil fuel prices	DECC Central fossil fuel price	DECC Low fossil fuel price

1 DECC (2010). Updated energy and emissions projections. Department for Energy and Climate Change, London: TSO.

Figure 5: Great Britain population projections for the FTA scenarios. Data from the Office of National Statistics population projections (2008–2083), extended to 2100 by the authors. Population pyramids (for the principal projection) for 2008 and 2083. Data from the Office of National Statistics sub-national population projections (2008–2033), extended to 2083 by the authors.



Sector-specific issues can be as influential as these cross-cutting scenario dimensions, and include for:

- **Energy**: GHG emissions targets.
- **Water supply and wastewater**: the effects from climate change on water availability and quality; the requirements of the Water Framework Directive.
- **Solid waste**: EU directives and national standards.

A multitude of possible means of providing NI are conceivable in the context of these scenarios, including supply and demand-side measures. The ITRC is seeking to explore how integrated cross-sectoral approaches may yield new insights and benefits. As a first step, in the FTA three distinct and cross-sectoral transition strategies have been identified (Figure 6):

1. The **capacity-intensive** (CI) strategy represents high investment in new capacity to keep up with demand and maintain good security of supply in all sectors.

2. The **capacity-constrained** (CC) strategy represents low investment, in which there are no increases in the current level of infrastructure investment, but an emphasis is placed upon demand management measures.

3. The **decentralised** (DC) strategy represents a reorientation of infrastructure provision from centralised grid-based networks to more distributed systems. This will involve a combination of supply and demand-side measures.

The three transition strategies are analysed against the demand for infrastructure services associated with each of the three FTA scenarios in order to provide insights into future infrastructure performance in a range of possible conditions (Figure 7).

Figure 6: Relative location of the FTA infrastructure transition strategies in relation to investment requirements and centralisation/decentralisation.

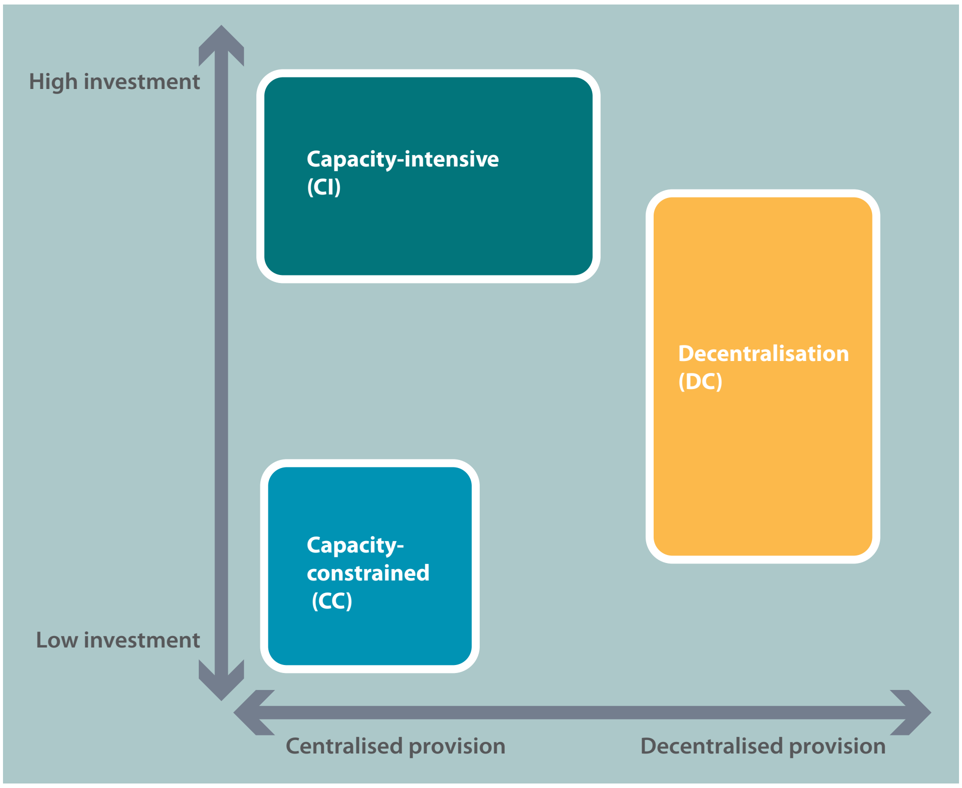
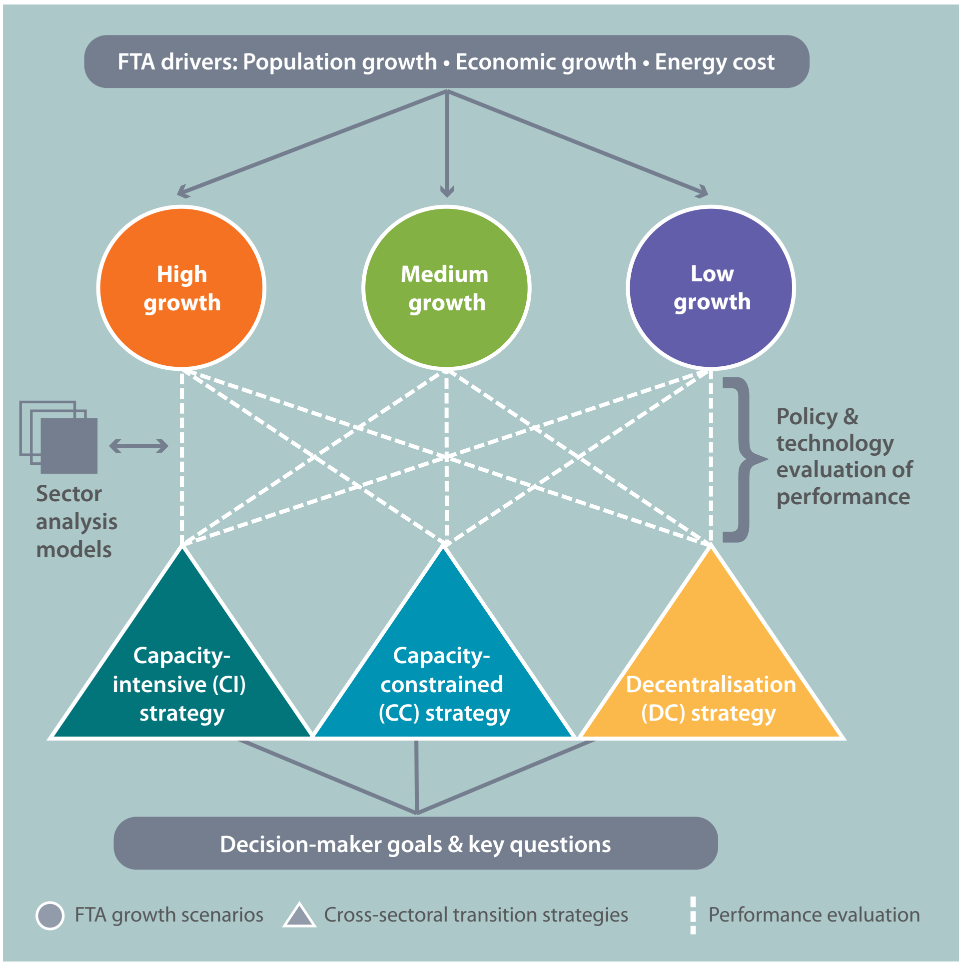


Figure 7: Summary of the Fast Track Analysis methodology.



RESULTS FROM THE FAST TRACK ANALYSIS

Results are reported by NI sector, followed by a cross-cutting synthesis.

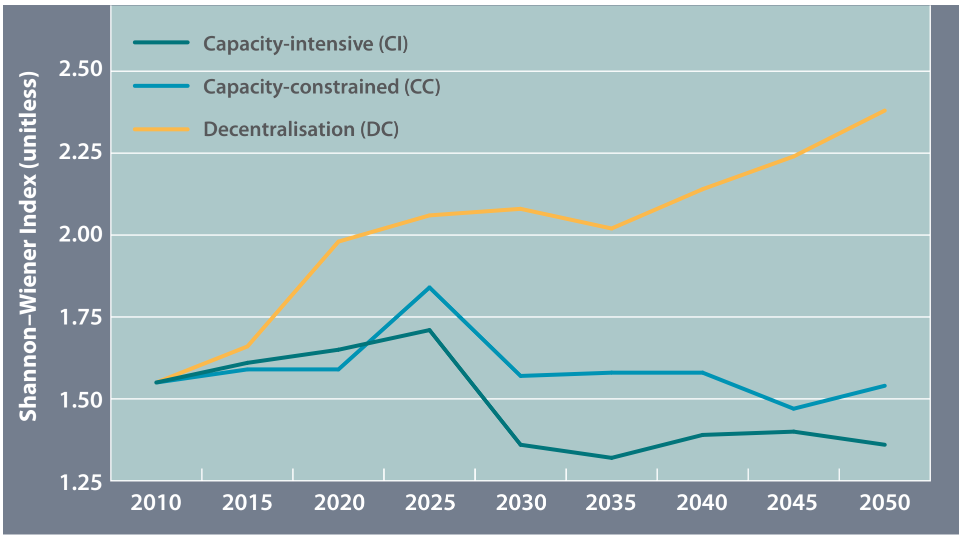
ENERGY SECTOR

The analysis of transition strategies for the energy sector using the MARKAL model demonstrates that, under the FTA medium growth scenario, carbon emissions reductions of 80% across the economy can be delivered by all of the infrastructure transition strategies. All strategies can deliver continued electricity supply security, provided the required investment levels can be met.

In all FTA scenarios, the CC strategy has the lowest cost due to an emphasis upon demand reduction. The DC strategy scenario has the highest cost due to use of less cost-effective technologies. The DC strategy offers benefits in terms of increased supply diversity (see Figure 8), although the Shannon–Wiener index does not account for the security benefit provided by over-capacity in the CI transition strategy.

Under the high growth scenario, carbon targets would inevitably be more challenging, and higher absolute levels of investment are required to ensure security, but this investment is a lower proportion of GDP. Conversely, under low growth carbon targets are less challenging but investment requirements form a higher proportion of GDP.

Figure 8: Diversity of supply options for the Energy sector high growth scenario across the three transition strategies using the Shannon–Wiener index. Higher index values denotes greater diversity of supply.



TRANSPORT SECTOR

Low, medium and high growth scenarios for transport demand have been developed, using an elasticity model to relate transport demand growth to growth in population, fuel prices and GDP, with any added taxes or charges also being considered (e.g. national congestion charge). Demand suppression due to congestion was modelled using feedback relationships between demand and resulting journey times. The low growth FTA scenario is more consistent with historical trends in transport demand (Figure 9). The transition strategies that were analysed in the FTA involve differing levels of capital investment in roads and rail, including investment in the HS2 high speed rail link (Figure 10). Transport infrastructure would be particularly stressed under the high growth scenario.

Vehicle emissions standards and differing rates of uptake of electric vehicles were also analysed. Future electrification of road transport sector would reduce emissions at the point of use, but could result in more congestion due to energy price effects (moving from highly taxed petrol to untaxed electricity).

The CI strategy (high investment and fast uptake of electric vehicles) would result in higher growth in demand (e.g. 23% more car/van km in 2050 compared to the reference case). Whilst contributing to congestion, this demand growth is compensated by improved fuel efficiency (approximately 70%), thus it results in the largest reduction in CO_2 emissions (19% fewer emissions from cars and vans, and 25% fewer emissions from HGVs in 2050 compared to reference case).

The CC strategy (low investment, low uptake of electric vehicle, introduction of a national congestion charging scheme) would result in the lowest growth of demand, with an estimated reduction of car/van km by 3%, and with reduced CO_2 emissions of 7.3% for car/vans and 2.4% for HGVs in 2050 compared with the reference case.

Figure 9: Past transport demand and the FTA growth scenarios.

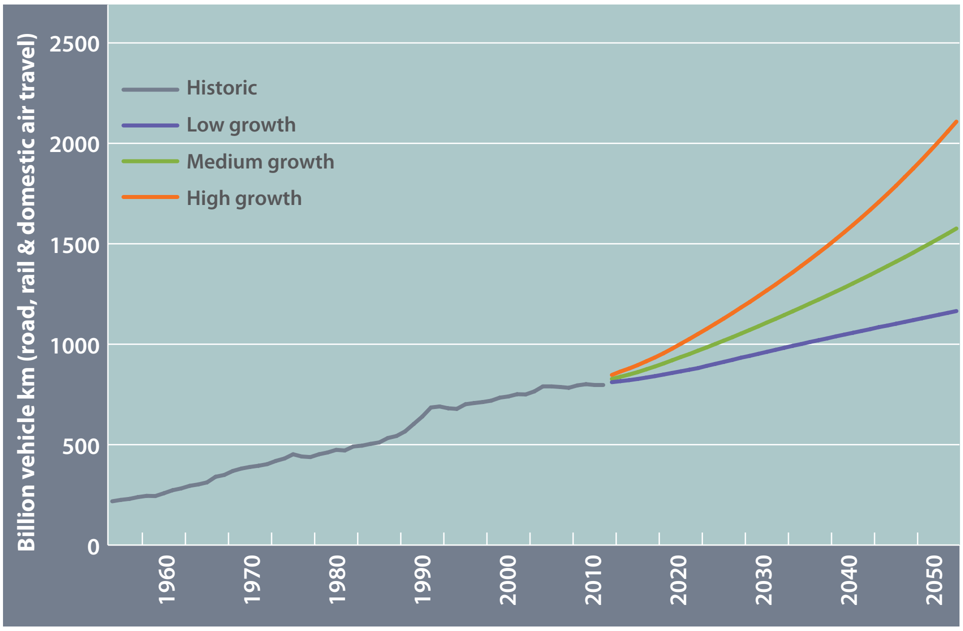
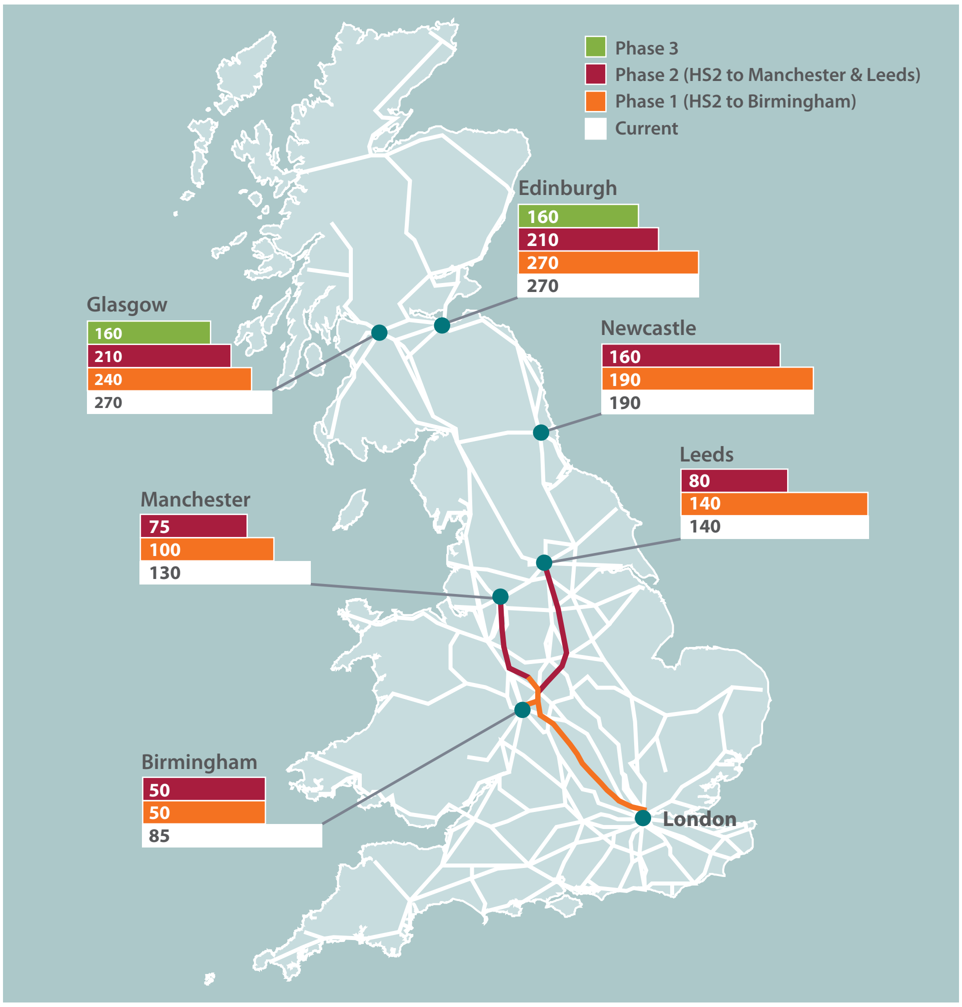


Figure 10: Train travel times[1] to London with and without HS2 phases 1 and 2. Phase 3 times[2] for Glasgow and Edinburgh are indicative, based on an England–Scotland extension. Figures rounded to 5 minutes.



WATER SUPPLY SECTOR

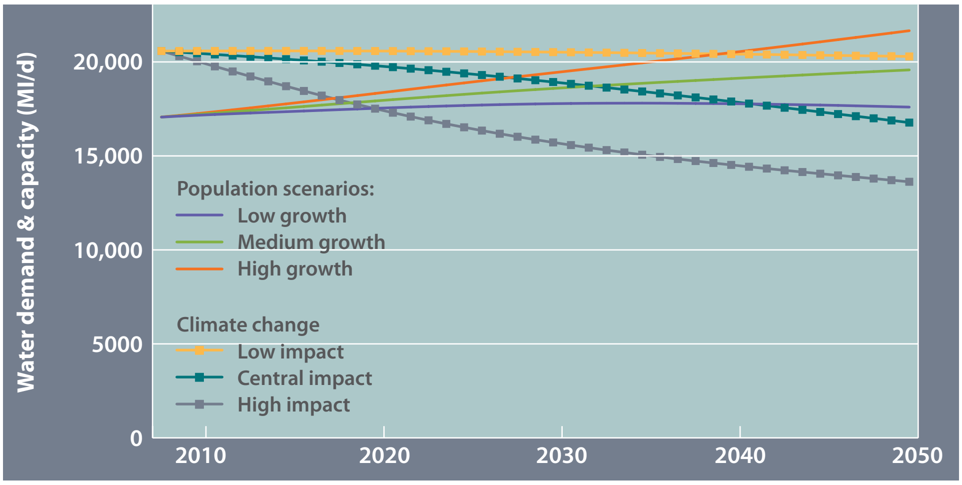
Contrasting levels of water demand and supply-side measures were tested in the CI and CC strategies using data on public water supply in England, Scotland and Wales. Whilst security of supply is currently good, population growth and climate change represent a threat to the industry over the coming decades, unless per capita demand is reduced and or capacity is increased (Figure 11). This needs to take into account the large regional variations across Great Britain. The CI transition strategy implies high investment in supply infrastructure (including reservoirs, transfers and desalination) as well as in capital programmes of leakage reduction. These measures contribute to security of supply in terms of both capacity and flexibility of use of resources. In high climate change and population growth scenarios, the strategy sees rapidly increasing capital and energy costs. The strategy is threatened by the possibility of climate change reducing water availability, the requirements for restoring aquatic environments and the energy implications of desalination and inter-basin transfers.

The DC strategy implies more local self-sufficiency, which is vulnerable to supply and demand side uncertainties. The CC strategy emphasises vigorous price and regulatory measures to reduce demand to an average of 110 litres/person/day by 2050, which have the added benefit of reducing energy use, in the water sector and by water consumers. At the same time margins between supply and demand are eroded, with implications for security of supply.

1 Department for Transport and HS2 Ltd, 2011. High Speed Rail: Investing in Britain's Future, Consultation.

2 GreenGauge21, 2009. Fast Forward: a High-speed Rail Strategy for Britain.

Figure 11: Demand for public water supplies in Great Britain for the three population scenarios (with constant per capita demand), and the effect of the low, central and high climate change on capacity (without the provision of additional water supplies).



WASTEWATER SECTOR

For wastewater treatment, demand is determined by population. However, population density and the treatment technologies implemented determine the unit cost of treatment. As with water supply, economies of scale favour centralised strategies and increasing population density further reduces costs. In the CC strategy, for which we assume incremental changes to current infrastructure, energy costs increase rapidly. The performance of the CI transition strategy is characterised by replacement of existing energy-intensive treatment capacity with new treatment capacity using new energy recovery technologies. These technologies allow wastewater treatment to become an energy-neutral or energy-generating process. However, these new treatment technologies still require research and development. The cost and long design life of the existing sewerage infrastructure means that radical transitions would be very costly. This will mean managing the existing assets actively and intelligently, perhaps accelerating the adoption of the active monitoring and control of sewerage systems and developing strategies to incrementally replace or renew the network.

SOLID WASTE SECTOR

For solid waste, in most scenarios, EU and local government imposed targets will require new capacity for some treatments (e.g. composting and recycling) but this could be achieved at the investment levels envisaged in any of the transition strategies. However, in high growth FTA scenario it will be challenging to meet recycling targets and the implied requirement for new treatment sites may also be problematic.

INFORMATION AND COMMUNICATIONS TECHNOLOGIES (ICT)

ICT capacity has continued to rapidly expand keeping well ahead of demand thanks to on-going innovation in a competitive market. It is anticipated that this arrangement will continue, so the sector has not been subject to the same quantified analysis as other sectors. In 2010, ICT consumed an estimated 13–16% of the total electricity in the UK. Projections indicate that global electricity usage in ICT will grow by approximately 9% per year, a trend that may continue up to 2020. However, since 2000 there has been a continuing decrease in growth for home computing and other electronic consumer goods in the UK, and new products have greater energy efficiencies, which may serve to depress future growth of energy use in ICT. Beyond 2020, technological changes make electricity demand from ICT very difficult to project.

Figure 12: Summary of transition strategy performance assessment using cross-sectoral metrics of cost, emissions and security of supply. In the transport sector, the 'security of supply' metric relates to congestion.

CROSS-SECTORAL SYNTHESIS

Each NI sector requires a somewhat different set of metrics to evaluate its performance, which are presented in the main text of the FTA report. In Figure 12, performance has been reported with respect to three metrics that apply across all sectors: (1) cost, (2) CO_2 emissions and (3) security of supply. This enables the cross-sectoral evaluation of the transition strategies and evaluation of key questions of interest to stakeholders.

What are the implications of growing demand for infrastructure services?

High growth in demand for infrastructure services is associated with increasing needs and costs for infrastructure provision, in particular given the CI and DC transition strategies, but high growth in demand is associated with scenarios in which more resources would be available for infrastructure investment. However, high growth in demand is also associated with higher GHG emissions, unless the CI transition strategy is adopted, in which case innovation and investment enables a successful transition to infrastructure systems that are all effectively decarbonised. Higher transport demand is associated with increased transport congestion even given a CI approach to transport infrastructure provision, as, without demand management measures, demand continues to expand to fill the available capacity.

What are the implications of constrained investment in UK infrastructure capacity?

Evaluating the performance of the CC strategy provides insight into the implications of constraints on investment levels for NI. For example, in the water sector the CC strategy requires vigorous price and regulatory measures over many years, in order to achieve the per capita water demand target of 110 litres per day. Security of supply is eroded, especially in high growth scenarios. The CC strategy is the least cost approach, as costly supply-side measures are avoided through demand management. However, whilst demand reduction can under some circumstances result in efficiency improvements without deterioration in the quality of the infrastructure service (for example, improved building insulation reduces energy requirements for space heating), in other sectors, notably transport, stringent demand reduction will have implications for the economy and society.

What are the implications of a carbon-constrained future?

As a consequence of the Climate Change Act (2008) the UK is committed to a reduction in GHG emissions of at least 80% (relative to 1990 levels) by 2050. Increasing global demand for fossil fuels at a time of reducing global oil reserves reinforces the case for reducing dependence upon fossil carbon. The UK's GHG mitigation commitments imply a major restructuring of the UK's energy supply infrastructure and ripple through other NI sectors, which are all dependent upon energy. Changes within these sectors in turn influence the energy sector, in particular in the case of a transition to electric vehicles. For both wastewater and solid waste, there is the potential for the energy demand from these sectors to be met through conversion of the waste streams to energy.

What are the implications of a decentralised National Infrastructure system?

The FTA revealed that reorientation towards a decentralised arrangement of infrastructure (both in terms of technology and governance) could result in NI performance increases. The energy sector analysis, for example, revealed that the decentralisation transition strategy resulted in the greatest diversification of energy supply options. Decentralisation also has the potential to capitalise upon interdependencies (e.g. via local waste to energy conversion or combined heat and power plants) and provide new supply options (e.g. rainwater harvesting in the built environment). However, the evaluation of the cross-sectoral performance of the DC transition strategy indicated that there are significant front-loaded capital investment requirements to transition towards a decentralised arrangement, particularly in the high and medium growth scenarios.

What are the implications of interdependence between infrastructure sectors?

Demand for different infrastructure sectors is highly correlated, both due to the final demand associated with population and economic growth and because of intermediated demands between infrastructure sectors. The FTA has revealed the importance of cross-sectoral interdependence, in particular via energy demand from all sectors. Potential changes in demand (e.g. from electric vehicles and as a consequence of ICT) need to be accommodated in the energy sector. Changes in other sectors, for example, in transport congestion or water availability will also have cross-sectoral impacts. The FTA has not revealed new opportunities that could be accessed by taking interdependence into account, though these may exist at the scale of individual facilities or infrastructure corridors. However, understanding interdependence is essential to recognise new cross-sectoral demands that otherwise might not be accommodated and to minimise the risks of infrastructure failure.

NEXT STEPS FOR THE ITRC

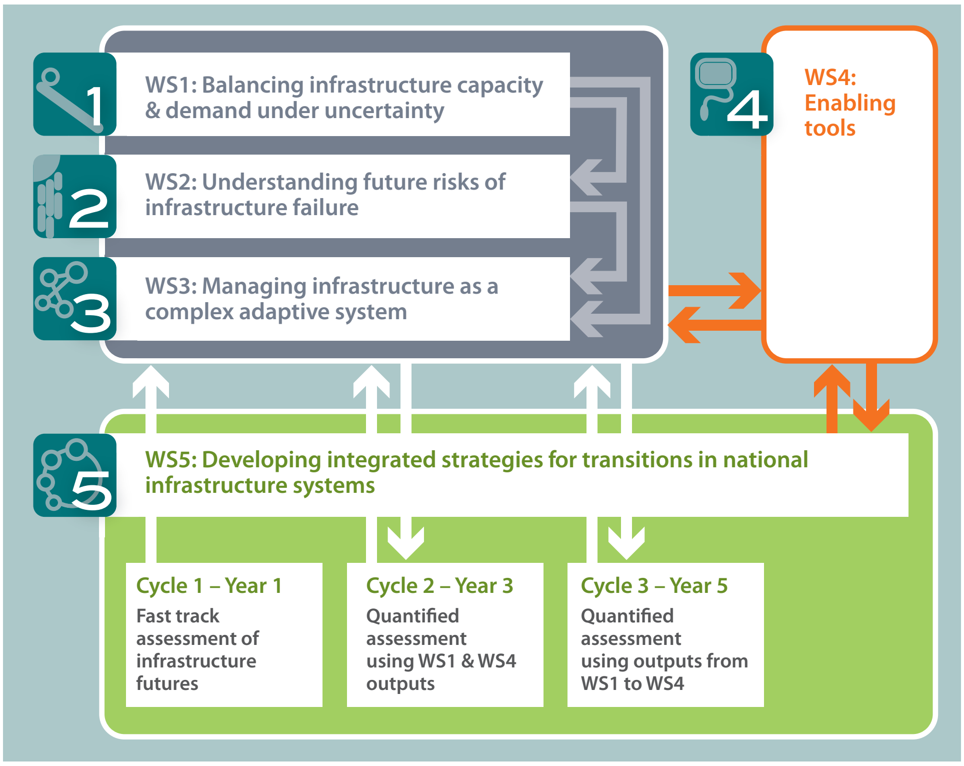
The Fast Track Analysis has demonstrated the feasibility and utility of long term cross-sectoral analysis of infrastructure demand and capacity. Cross-sectoral analysis has demonstrated how different sectors are shaped by many of the same drivers, especially those that influence demand (demography, economy) and energy prices. Where new investment is required, different sectors may be competing for the same pools of public and/or private finance.

A cross-sectoral approach provides the opportunity to define a common direction of travel and to understand the contribution that separate policies or plans make to overall performance. Yet analysis of governance arrangements has underlined how current regulatory frameworks are not well adapted to this 'system of systems' perspective.

Undertaking the FTA based on currently existing datasets and models has not been straightforward as there is no tradition in the UK or internationally of taking a 'system of systems' approach to analysis of NI. The FTA analysis of each sector is therefore to some extent shaped by the assumptions and constraints of existing approaches within that sector, as set out in the FTA report and annexes.

Going forward, the ITRC is adopting three methodological perspectives in its development of tools for analysis of NI provision. The development of models and tools is taking place in the first three ITRC Work Streams (Figure 13) and are explained below.

Figure 13: Overview of the ITRC Work Stream (WS) structure.



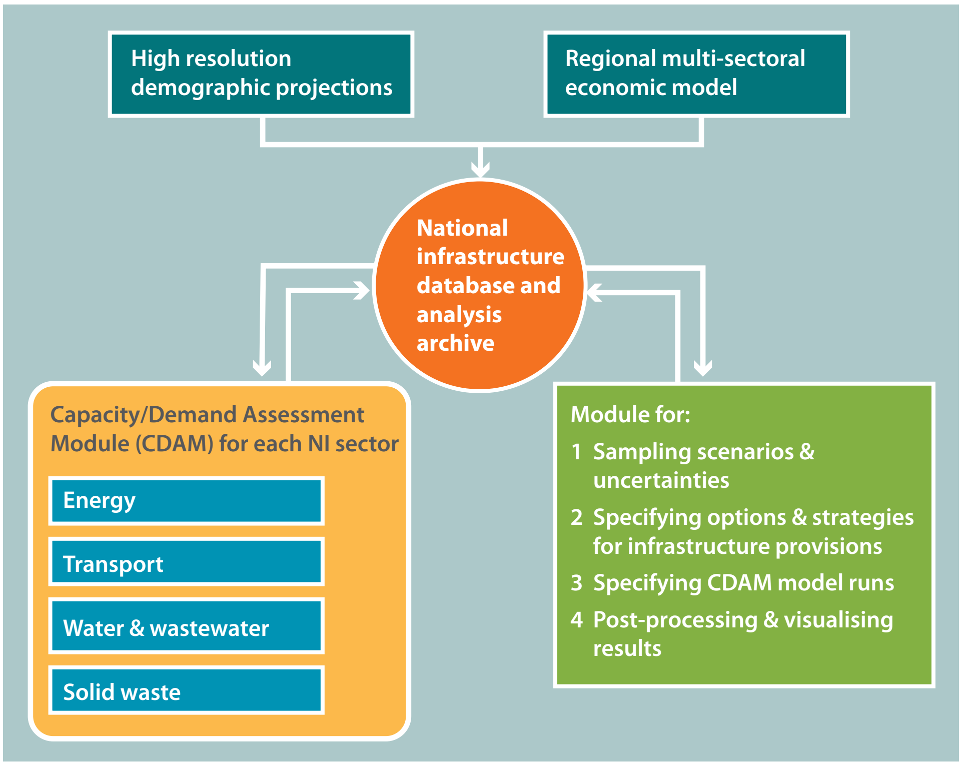
Work Stream 1 (WS1) is developing a system of quantified capacity/demand assessment modules (CDAM) for analysis of long term strategies for infrastructure provision. In that sense it will resemble the FTA but will be based upon more quantified and more fully integrated models including:

- A micro-simulation model for generation of high resolution demographic and demand scenarios.
- A regional economic model that will generate regional multi-sectoral projections of industrial demand for infrastructure services.
- A model of the UK electricity and gas networks and a new disaggregated energy demand module.
- A national strategic model of trunk road, rail, port and airport infrastructure.
- A national water resources system model, coupled with a model of wastewater treatment systems.
- A national solid waste assessment model.

ICT will be excluded from the WS1 analysis, as the FTA has illustrated that new capacity has being provided historically and this can be expected to continue for the foreseeable future. Further the demand is very sensitive to unforeseen technological developments which makes future analysis difficult.

These models will be coupled in an overall simulation framework in which the main scenario uncertainties are extensively sampled, expanding upon the small number of scenarios analysed in the FTA. A set of infrastructure investment options will be developed for each sector and assembled flexibly into cross-sectoral packages, representing a major extension of the three transition strategies analysed in the FTA. New tools will be developed to explore and visualise the results of the analysis.

Figure 14: Structure of the system of assessment models and databases now under development in Work Streams 1 and 4 of ITRC.



The interaction between this overall modelling system and the NI database being developed in Work Stream 4 (WS4) is illustrated in Figure 14. The WS4 database, which is built using an open source spatial database architecture, already contains more than 300 different layers of infrastructure and demand data and is rapidly expanding.

Development of this new generation of models is due to be completed in March 2013. They will be used to conduct a much more complete and quantified analysis of infrastructure transition strategies than has been feasible in the FTA. That second cycle of national infrastructure assessment is due to be delivered at the end of 2013.

The FTA has not examined in any depth the risks of infrastructure failure and the ways in which interdependence between infrastructures may exacerbate those risks. This topic is the focus of ITRC Work Stream 2 (WS2). Given the severe long term threats posed by climate change, WS2 has begun by focussing upon climate-related hazards, though scope to extend to other natural hazards and man-made hazards will be explored later in the research programme.

Spatially coherent probabilistic scenarios of extreme climate related hazards and their associated uncertainties are being developed. Working with our industrial partners and building upon previous studies, WS2 will characterise the vulnerability and interdependence of energy, transport, water, waste and ICT systems. Central to WS2 will be the development and testing of network models for analysis of interdependent NI failure and risk. Quantification of the direct consequences of infrastructure failure will use the economic and demographic scenarios developed in WS1. The indirect economic consequences of failure and recovery will be analysed at regional and national scales using an input–output modelling approach. Results will be presented as a range of metrics of vulnerability and risk.

Scoping of Work Stream 3 (WS3) is now under way, exploring a variety of complex systems approaches to simulate and interpret the long term interactions between infrastructure, society and the economy. The research in WS3 will start with exploratory simulations of synthetic examples and work up to more realistic models. Complex systems methodologies under examination include land use and transport spatial interaction models, dynamic network models and a variety of methods in evolutional economics. The most promising approaches will be tested in order to identify patterns of emergence and to understand how in the real world these new insights may be used to steer NI systems towards sustainable outcomes.

The Fast Track Analysis has helped the ITRC to frame its research programme for the coming 4 years. It has identified priorities for more detailed analysis and has helped to refine understanding of those factors that need to be incorporated in development of the new generation of NI models that is now under way within the ITRC.

CONTENTS OF THE FAST TRACK ANALYSIS REPORT

The Fast Track Analysis report and technical annexes are available on-line at www.itrc.org.uk/outputs/

UK INFRASTRUCTURE TRANSITIONS RESEARCH CONSORTIUM

The UK Infrastructure Transitions Research Consortium is informing the analysis, planning and design of national infrastructure, through the development and demonstration of new decision support tools, and working with partners in government and industry.

The research is taking a national-scale 'system of systems' approach which integrates energy, transport, water, waste and ICT (Information and Communications Technologies) infrastructure.

FAST TRACK ANALYSIS

In its first year, the ITRC has begun the development of a new generation of simulation models for national infrastructure assessment that will be ready for piloting in 2013. In parallel the ITRC has undertaken a Fast Track Analysis (FTA) in order to:

1. Ensure that the ITRC research programme is building upon existing knowledge.
2. Review and refine the scope of the ITRC research.
3. Pilot and communicate new analysis concepts.
4. Strengthen the relationship between the research team and the consortium's partners in government and industry.

ITRC

A Fast Track Analysis of strategies for infrastructure provision in Great Britain

Environmental Change Institute, University of Oxford. January 2012

ISBN 978 1 874370 50 5

www.itrc.org.uk