An assessment of the UK National Infrastructure Pipeline

Outcomes from the ITRC/IUK Collaboration

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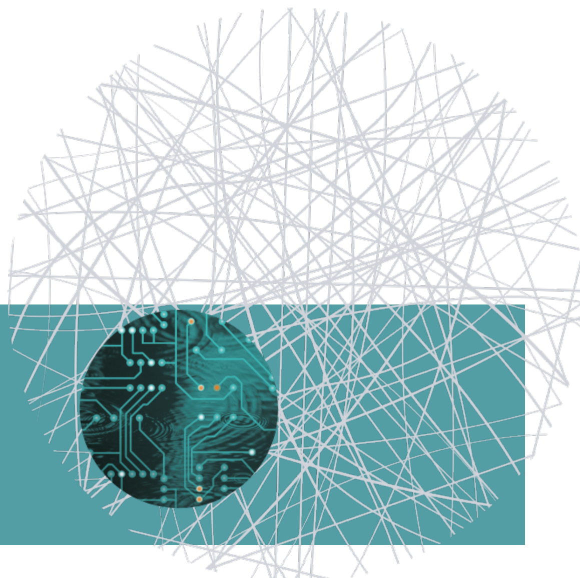

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Executive Summary

This report presents the results of collaboration between the EPSRC-funded Infrastructure Transitions Research Consortium (ITRC) and the Major Infrastructure Tracking (MIT) team of Infrastructure UK (IUK), using tools developed by ITRC to assess the benefits of investment in the National Infrastructure Plan (NIP).

The National Infrastructure Plan outlines the Government's vision and approach for the key economic infrastructure sectors of energy, transport, water, waste, communications, flood defences, and science. The NIP is supplemented by the infrastructure pipeline, which sets out details of major commitments for investment in important infrastructure projects to 2020 and beyond. In the NIP 2015 the pipeline consisted of 560 projects and programmes with a budget of £411 billion.

To support delivery of its objectives in each sector, the NIP also includes an indication of the 'Top 40 priority infrastructure investments' – large individual projects and broad themes containing a range of investments which either make the most significant contribution towards achieving a particular objective, or carry the most risk should they fail, both strategically and in value for money terms.

The MIT's work has focused upon the cost, finance, timing and implementation of the national infrastructure pipeline, with less explicit analysis of the system performance benefits that would be achieved by investing in these infrastructures. Assessment of benefits will have been carried out in individual project appraisals, but to date, the MIT has not had access to evidence about the future performance of infrastructure investments at a system scale. ITRC's modelling suite, NISMOD-LP (LP for Long-term Performance) provides that evidence, in terms of being based on a consistent set of assumptions for growth, tested across a consistent set of metrics.

The pipeline assessment includes results across the energy, transport and water sectors (which represents over 90% of the overall investment), testing and comparing the impact of the NIP pipeline projects with a 'No Build' future, in which the investments set out in the NIP pipeline are assumed not to have been undertaken (although projects under construction at the outset of the study were assumed to have been completed). The results are also compared across three contrasting socio-economic future pathways, each with different levels of growth in population and the economy. For water, the effect of climate change was also considered.

For energy, the assessment considers existing energy supply and transmission assets plus all projects in the 2014 and 2015 National Infrastructure pipeline listings. These projects amount to around 25GW of additional generation capacity at a cost of around £44bn with an additional 8.7GW of capacity being provided through new interconnectors with Europe. These investments provide capacity improvements up to the mid-2030s, but there is a steep decline in generation capacity in 2035, at which point capacity margins would drop significantly. In reality, such a sudden change would not occur; the NIP also contains a significant budget for additional generation projects beyond 2030 that have yet to be defined which would ameliorate this projected decline in capacity margins. The lack of certainty regarding such future investments means that they are not included in these analyses.

The future for gas seems more robust; despite the decline in domestic gas supplies (which may have implications for future new investments in LNG), the current gas infrastructure is able to ensure sufficient capacity in the gas network over the period from 2015 to 2040 without new capacity investment under all growth scenarios. Only in the high-growth scenario is there a danger of the gas capacity margin dropping below zero beyond 2040.

In the transport assessment, 24 of the 32 'Top 40' road-based projects in the NIP can be analysed using NISMOD-LP. These are comprised of 6 of the 10 Local Authority Major projects and 18 of the 22 Highways England Major projects. The analysis also assesses a further 29 road-based projects outside the 'Top 40', including 12 Smart Motorway projects. Project types not included in the assessment are those concerned with metro systems (which are currently not represented in NISMOD-LP), junction improvements and general maintenance programmes and smaller scale local projects outside the Top 40 priority list which would have little impact on a national scale. While these road investments are a very small proportion of the overall asset base (52 new inter-zonal flow lanes (an additional 1.30%), and 1,750 intra-zonal lane km (an additional 0.22%, including 861km of managed motorway/all lane running)), and are likely to have only a slight effect at an aggregate national scale; in terms of national road vehicle km, the extra road space added as part of the NIP allows an extra 0.4% traffic flow by 2030, rising to 0.8% by 2050. This reflects that fact that the UK highway network is already largely complete. The NIP investments can be seen to relieve local congestion hotspots; for those links affected by the NIP investment there will be 2% more traffic using the network by 2030 (compared to No Build), increasing to an additional 4.6% more traffic in 2050. Nevertheless, increasing road capacity may not be enough to manage continued growth in traffic, especially if the extra road space releases latent demand, as is assumed in the model and in Department for Transport (DfT) projections; more aggressive policy responses (in terms of infrastructure investment and demand management) will be required.

For rail, all seven electrification projects are included in the assessment, as well as an assessment of the impact of HS2. The rollout of electrification schemes across the country will obviously have substantial impacts on the fuel mix used throughout the network, with around 20% of current diesel use switching to electricity by 2030. The opening of Phase 1 of HS2 in 2026 will provide capacity for a large number of extra trains along those affected links, with a further increase as Phase 2 opens in 2034. There are obviously projected to be more trains using the network and NISMOD indicates that these investments will help to limit the growth in rail congestion, as the amount of delay on those rail links will drop to 2015 levels, compared with an estimated 14% rise in delays by 2026 without HS2, increasing to 30% more in 2034.

The NIP projects and programmes listed for the water sector consist primarily of the investments over the next five years (2015-2020) contained in each of the water companies' Water Resource Management Plans (WRMPs) for Asset Management Programme 6 (AMP6). Future projections of demand produce a wide range of possible outcomes for Great Britain as a whole, from a reduction in demand in the low population/per capita demand scenario to a 20% increase in total demand by 2050 in the high population/per capita demand scenario.

The NIP investments amount to an 18% increase in water supply capacity for Great Britain by 2018; however, this increase in supply is countered by a potentially larger decrease in yield from reductions in water abstractions that have been mandated to restore the aquatic environment, which amount to around a 22% decrease in supply levels by 2025. In the central growth scenario, there is then a steady decline in supply-demand balance due to population and climate change. While the NIP investment helps to alleviate potential problems in regional supply-demand balance when compared to a No Build future, there may still be shortages for specific regions.

The collaboration between ITRC and Infrastructure UK has demonstrated how the future performance of a complex portfolio of infrastructure investments can be analysed. It has demonstrated the extent to which the NIP projects will be able to cope with national infrastructure needs in the long term, under a range of possible future scenarios. Visualisation tools (which have been used to plot the results presented in this report) have been developed to explore and communicate the implications of different infrastructure investments. NISMOD-LP provides a virtual environment in which future infrastructure strategies can be developed and tested. Further research is now exploring a wider range of possible long-term strategies for infrastructure provision.

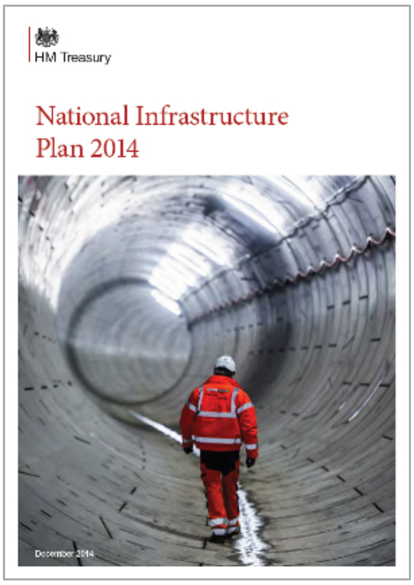
This short report focuses upon the methodology adopted to represent the NIP projects and the results of the assessment. Further details of the NISMOD-LP modelling system and the accompanying NISMOD-DB national infrastructure database and visualisation tools, can be found in: Hall, J.W., Tran, M., Hickford, A.J. and Nicholls, R.J. (2016) *The Future of National Infrastructure: A System of Systems Approach*, Cambridge University Press.

Introduction

This report presents the results of a collaboration between members of the Infrastructure Transitions Research Consortium (ITRC), with Infrastructure UK (IUK), using tools developed by ITRC to assess the benefits of investment in the National Infrastructure Plan (NIP). This study was funded by EPSRC through Impact Acceleration Account awards to the universities of Oxford, Southampton and Newcastle.

1.1 Background to the NIP and the pipeline

The National Infrastructure Plan (NIP)[1] was first published in 2010, setting out the challenges facing UK infrastructure, and outlining the Government's vision and approach for the key economic infrastructure sectors of energy, transport, water, waste, communications, flood defence, and science. Since then, the NIP has been revised annually, continuing to develop and refine its approach in response to investors and other stakeholders, to ensure the NIP is a maturing, integrated plan for UK infrastructure provision.



The NIP is supplemented by the infrastructure pipeline, which sets out details of major commitments for investment in important infrastructure projects to 2020 and beyond. In the NIP 2014, this pipeline consisted of around 550 infrastructure projects and programmes with a total budget of £466 billion for the next decade. As projects are completed, the pipeline is updated, and in 2015 the pipeline consisted of 560 projects and programmes with a budget of £411 billion. Further details of the NIP pipeline are given in Section 3.

1.2 Background to ITRC and NISMOD

The ITRC is a collaboration of scientists, engineers, economists and social scientists, funded by the UK's Engineering and Physical Sciences Research Council (EPSRC) to analyse the long-term dynamics of interdependent infrastructural systems. In academia, the consortium comprises seven universities (Oxford, Cambridge, Newcastle, Leeds, Cardiff, Southampton and Sussex), supported by more than 60 partners in government and industry[2].

The programme has developed and demonstrated a new generation of system simulation models and tools to inform analysis, planning and design of national infrastructure. The research programme has assessed energy, transport, water, waste and ICT systems at a national scale[3], developing new methods for analysing their performance, risks and interdependencies.

The ITRC programme has provided a virtual environment in which to test strategies for long-term investment in infrastructure and to understand how alternative strategies perform with respect to

[1] Further documentation on the National Infrastructure Plan can be found at https://www.gov.uk/government/collections/national-infrastructure-plan

[2] For more information, and access to other ITRC publications, visit www.itrc.org.uk

[3] ITRC outputs have focused on Great Britain (GB), comprising England, Scotland and Wales

policy constraints such as reliability and security of supply, cost, carbon emissions, and adaptability to demographic and climate change. The assessment of the NIP pipeline presented here is one example of how this virtual test environment can be adapted to assess a particular range of infrastructure investments.

A major output from the ITRC programme has been the development of a series of pioneering models, known collectively as the National Infrastructure System Model (NISMOD) family, with a supporting database, as well as visualisation and reporting tools. There are four main components to the NISMOD suite, as follows:

NISMOD-LP	**NISMOD-LP** A national model of the long-term performance of interdependent infrastructure systems
NISMOD-RV	**NISMOD-RV** A national model of risk and vulnerability in national infrastructure systems
NISMOD-RD	**NISMOD-RD** A model of regional development and how it adapts to infrastructure provision
NISMOD-DB	**NISMOD-DB** A national database of infrastructure networks, demand and performance

The assessment of the performance of the NIP investments was undertaken with NISMOD-LP (LP for Long-term Performance), which combines national scenarios of population change, economic growth and climate change with detailed modules of the capacity of energy, transport, water, waste and ICT sectors. This allows assessment of the amount of service that could be delivered by a given set of investments, the cost and associated impacts. In the assessment of the NIP, our focus has been upon energy (electricity and gas), transport (road and rail) and water supply only. Further details of the socio-economic scenarios are given in Section 2.3.

NISMOD is underpinned by a unique database architecture populated by several hundred national infrastructure network datasets (NISMOD-DB). As well as hosting all the necessary infrastructure data, NISMOD-DB hosts the results of each step in the modelling process, manages the information flows and provides an audit trail for the provenance of results. NISMOD-DB also enables visualisation of the data and simulations held in the database, using bespoke visualisation tools which were further developed as part of this collaboration.

A further overview of the NISMOD suite is given in Section 2.1, and details of how the reporting and visualisation tools have developed is given in Section 2.6.

1.3 Objectives of the study

The study is intended to inform the work of the Major Infrastructure Tracking (MIT) team within IUK by conducting an assessment of the potential impact of the latest national infrastructure pipeline, as set out in the 2014 National Infrastructure Plan. The MIT's work has focused upon the cost, finance, timing and implementation of the national infrastructure pipeline, with less explicit analysis of the system performance benefits that would be achieved by investing in these infrastructures. Assessment of benefits will have been carried out in individual project appraisals, but to date, the MIT has not had access to evidence about the future performance of infrastructure investments at a system scale. NISMOD-LP provides that evidence, in terms of a consistent set of metrics and based on a consistent set of assumptions. Throughout the collaboration, any ambiguities or gaps in the pipeline data were verified through consultation with IUK officials. The aim of the study therefore is to provide evidence of the impacts and performance benefits of investment in the national infrastructure pipeline, compared to the counterfactual in which no investment takes place.

The pipeline was updated during the collaboration, resulting in the inclusion in this assessment of a revised 2015 pipeline list; an overview of those projects included in the assessment is given in Section 3 with further details given in Appendix B.

The pipeline assessment includes results across the energy, transport and water sectors, testing and comparing the impact of the NIP pipeline projects with a ‘No Build’ future, in which the investments set out in the NIP pipeline are assumed not to have been undertaken (although projects under construction at the outset of the study were assumed to have been completed). The results are also compared across three contrasting socio-economic future pathways, with different levels of growth in population and the economy. For the water sector, further analysis of the effect of climate change scenarios was also undertaken.

Using NISMOD-LP to assess the NIP pipeline

This section gives an overview of the NISMOD suite, and focuses on the assessment process using the sector models and scenarios of future change embedded within NISMOD-LP.

1.4 Overview of the NISMOD suite

Figure 1 shows the overall design of NISMOD-DB. In addition to the database itself, it also has a series of related extension modules for analysis and visualization. The database also links to the modelling software of NISMOD-LP (the modelling of the long term capacity and demand of critical infrastructure systems) and NISMOD-RV[4] (the modelling of interdependent infrastructure systems risk and vulnerability). NISMOD-DB is able to represent the spatial (geographic/location) characteristics of infrastructure systems as well as their aspatial properties.

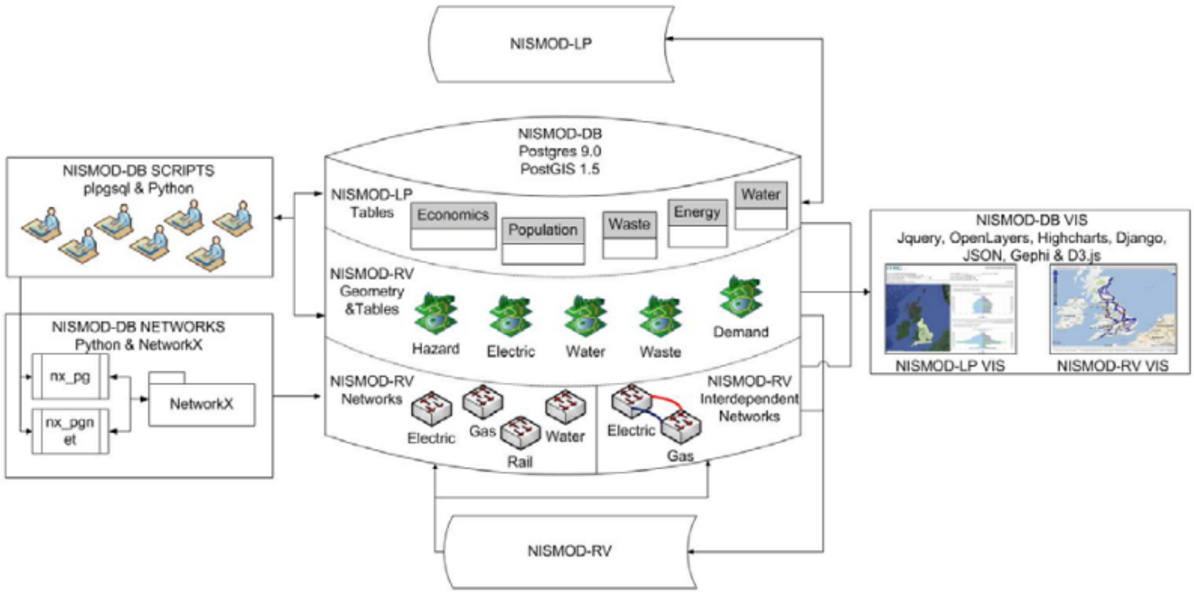


Figure 1: Overall organisation of the NISMOD-DB spatial database, analysis and visualisation framework

In the database, tables are organized and grouped in terms of their use within ITRC and then in terms of infrastructure system. In the case of the long term capacity/demand modelling of NISMOD-LP, standard relational tables representing the required inputs and results of the modelling undertaken are stored and organised by economic, population (demographic), energy, water (clean and waste), transport and solid waste sectors.

1.5 Assessment framework

The assessment framework for the IUK collaborative study is based on that used throughout the wider ITRC assessment, and is shown in Figure 2.

[4] NISMOD-RV is not used in this assessment; outputs from a series of risk-based assessments can be found at www.itrc.org.uk

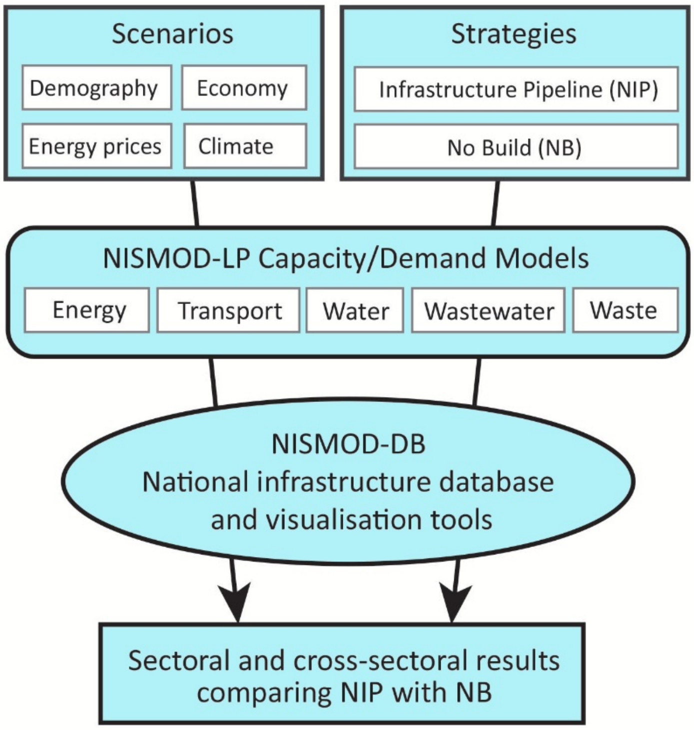


Figure 2: Overview of the NIP assessment framework

The assessment is designed to compare the impact of the NIP pipeline investments with an alternative 'No Build' future where such infrastructure investments are assumed not to have happened[5]. These alternative investment strategies can be assessed for different growth scenarios of demographic, economic, and climate change, which are considered to be exogenous inputs to the suite of models within NISMOD-LP.

A summary of the NIP pipeline and parameterisation process is given in Section 3.

1.6 Socio-economic scenarios

An important part of the ITRC programme was the development of a series of detailed geographical population growth scenarios, based on the Office for National Statistics (ONS) population projections[6]. National Population Projections are available, together with variant projections based on alternative assumptions of future fertility, mortality and migration.

In view of the uncertainties associated with longer timescales, these projections have been refined to provide an extended set of spatially explicit demographic projections of the British population over the next century, where the three broad drivers of long-term demographic change are characterised as the level of economic prosperity, social attitudes to sustainability, and the political effects of isolation (in particular the importance of spatial political integration and international migration policies).

[5] Note that infrastructure projects completed prior to the study were included in this 'No Build' future.
[6] Further details of ONS National population projections can be found here: http://www.ons.gov.uk/ons/rel/npp/national-population-projections/2012-based-projections/

For the subsequent analyses, three scenarios are assessed which represent two extremes of change, together with a ‘central’ growth scenario. Each population scenario has different implications for rates and locations of population change, as shown in Figure 3. For instance, the highest growth scenario assumes high levels of migration, as prosperity increases and isolationism decreases. However, much of this growth is in the regions around London, rather than concentrated within the capital. The Central growth scenario has lower levels of migration coupled with higher birth rates, resulting in more London-centric growth.

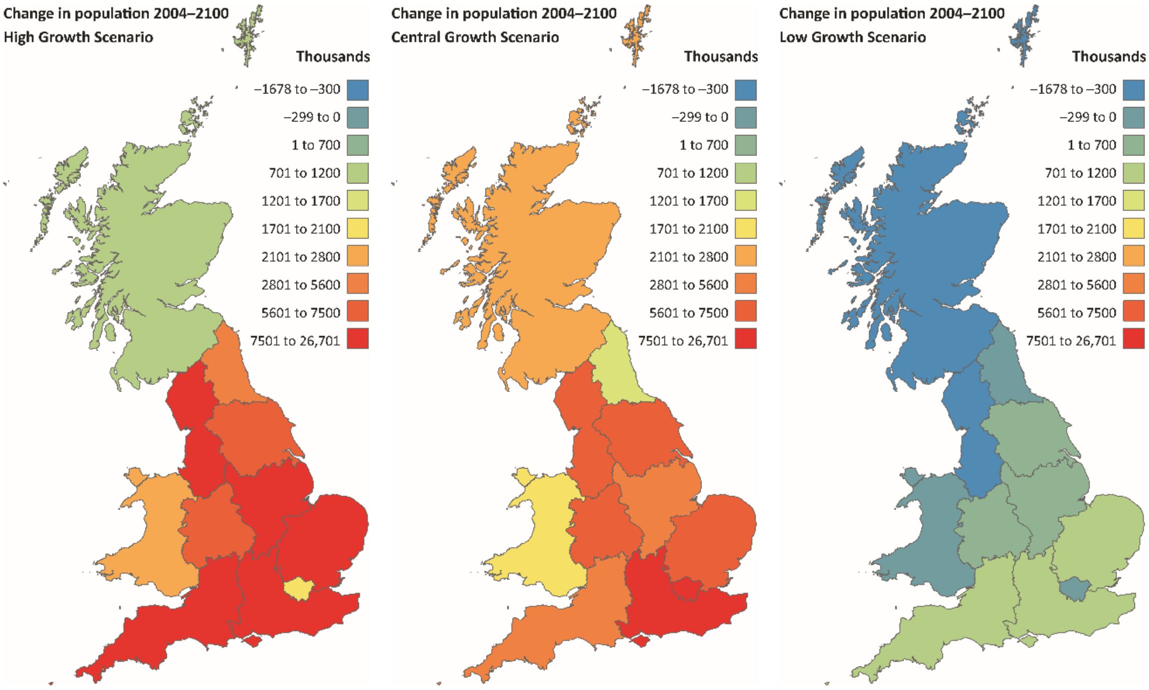


Figure 3: Change in population for High, Central and Low growth scenarios between 2004 and 2100

Each of the demographic scenarios is then coupled with an associated economic growth scenario[7], dependent both on these regional population changes and changes to global economies and fossil-fuel costs. These economic scenarios give a range of Gross Domestic Product (GDP) and employment profiles, together with regional and sectoral[8] breakdown of Gross Value Added (GVA).

Thus, the scenarios are characterised as follows:

High growth: High population variant, with the GB population approaching 100m people by 2050; high rate of global economic growth[9]; low energy costs.

Central growth: Broadly, a ‘central’ population projection, with the GB population growing to almost 80m in 2050; central global economic growth[10]; central energy costs.

[7] The economic projections use the Multi-sectoral Dynamic Energy-Environment-Economy (MDM-E3) model, which projects key indicators (such as output, prices, employment and components of demand) separately for each industry sector and region.
[8] Sectors are: Public services, Private services, Construction, Utilities, Manufacturing, and Agriculture & mining
[9] High global economic growth: average 4% pa over 2010-20, rising to 5-6% over 2020-50

Low growth: Low population variant with initially slow growth followed by mild decline, resulting in almost no change in GB population in 2050; global economic growth[11]; high energy costs.

1.7 Summary of sector models

Each of the sector models in NISMOD-LP that are used in this assessment (comprising energy, transport and water) is briefly described below.

1.7.1 Energy

For energy, coupled spatially explicit models of demand and supply are employed in this analysis of the NIP energy system investments, as shown in Figure 4. The analyses focus on the two major energy carriers, electricity and gas, with significant network infrastructures both in the context of current and future energy systems in Great Britain.

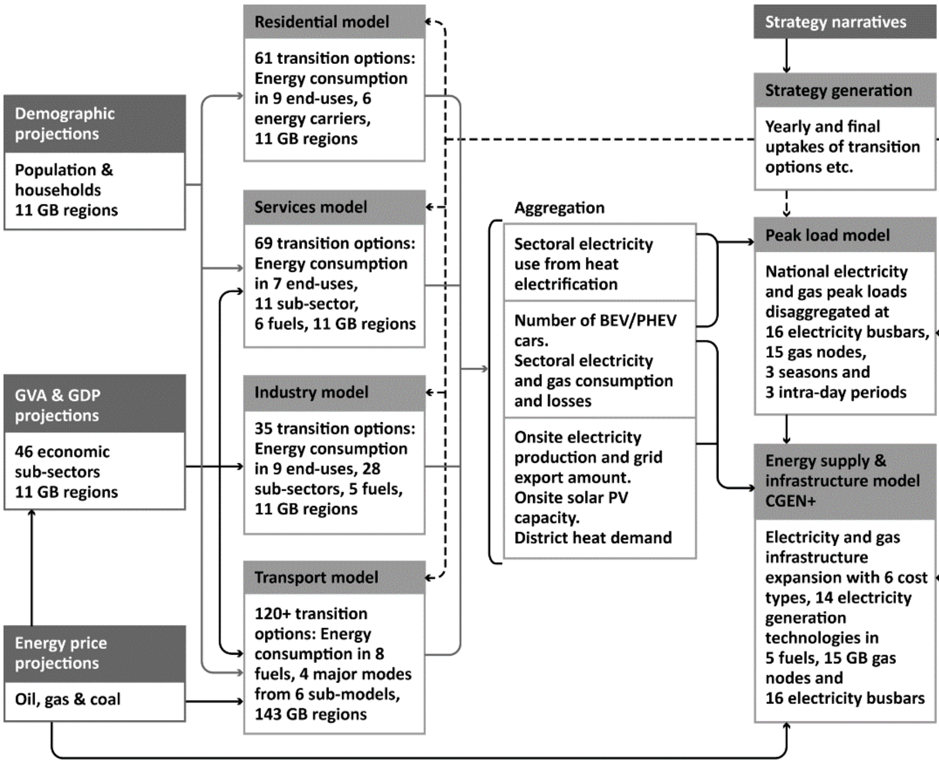


Figure 4: Schematic of the energy modelling framework and inter-model data-links

The energy modelling framework contained in NISMOD-LP couples eight separate models to provide an analysis of the energy system in Great Britain and its alternative futures. Residential, services and industry sector energy consumption, as well as electricity and gas peak loads, are estimated by bespoke models. Transport energy consumption is modelled from transport services demand estimated by the transport model described below. Electricity supply analysis is carried out with a cost optimisation model, CGEN+ (Combined Gas and Electricity Network model). The CGEN+ model has been validated and reproduces the characteristics of today's energy supply and transmission

[10] Central global economic growth: average 3.5% pa over 2010-20 and 4-5% pa over 2020-50
[11] Low global economic growth: average 2% pa over 2010-20 and growth of 3-3.5% pa to 2050

infrastructure in Great Britain and has been extensively compared with alternative longer term energy scenarios.

1.7.2 Transport

The transport model forecasts transport demand (and its relationship with transport capacity) by road and rail within and between 144 zones (based on local authorities) covering the whole of Great Britain. The model uses a set of elasticities to adjust demand and capacity utilisation levels, based on changes in both exogenous (population, GVA and energy costs) and endogenous (fuel mix, fuel efficiency, speed/delays, and actual and effective infrastructure capacity) variables.

The model is made up of six simulation sub-models, covering inter-zonal (between zones) and intra-zonal (within zones) road and rail traffic, as well as air passenger and seaborne freight traffic. Inter-zonal traffic is allocated to an infrastructure system made of single aggregated links connecting each pair of adjacent zones, with intra-zonal traffic modelled at the aggregate level. The model differs from most aggregate transport models in that it neither contains nor imputes an origin-destination matrix, as the key point of interest is the volume of traffic on particular links or within individual zones. The model does not include urban congestion disaggregated by road link or detailed consideration of urban public transport systems.

Capacity enhancements are specified in the model inputs prior to the commencement of a model run. Exogenous changes in population, the economy and fuel costs are taken from the set of scenario files detailed in Section 2.3. The model produces forecasts on a yearly basis for the period 2011-2100, but considers much smaller time intervals during the forecasting process (for example to allow a more accurate representation of road congestion). The model generates outputs giving demand, infrastructure capacity utilisation, carbon emissions and fuel consumption for each mode and each time step.

1.7.3 Water supply

The water supply systems model relies on a simplified reconstruction of the existing regional water resource management arrangements in Britain. Every area in the model falls within a water resource zone (WRZ). Due to the large size of the territory managed by Scottish Water the company's 'mega-zones' are treated as WRZs.

Simple sub-models capturing the hydrology and the water availability of each WRZ are implemented to determine values for potential water yield (deployable output), as shown in Figure 5. The sub-model components include river intakes, reservoir intakes and groundwater, with each component present or absent depending on what is reported by the water company for that zone. A single reservoir and river intake are included in each WRZ and represent the summed dimensions of the existing WRZ infrastructure. All increases in reservoir capacity are represented as an increase in the capacity of the existing reservoir. Where river intakes and/or reservoirs are present, a relevant catchment where river flows are gauged is identified from the National River Flow Archive[12], with recorded flow proportionally adjusted to the representative river intake flow or reservoir watershed on the basis of sub-catchment area. Reservoirs are modelled as a single storage location with

[12] For further details of the National River flow Archive, see here: http://www.ceh.ac.uk/data/nrfa/

maximum capacity set to the total capacity for reservoirs in the WRZ. Where a river and reservoir both exist, the operating rule is to remove as much as possible from the river within licenced conditions and, where this is not greater than yield, to remove deficit water from the reservoir. Groundwater is taken as a steady state input which is subtracted from yield. The maximum sustainable yield is determined as the maximum abstraction which can be removed from the system without causing a breach of the lowest return period level of service for the WRZ.

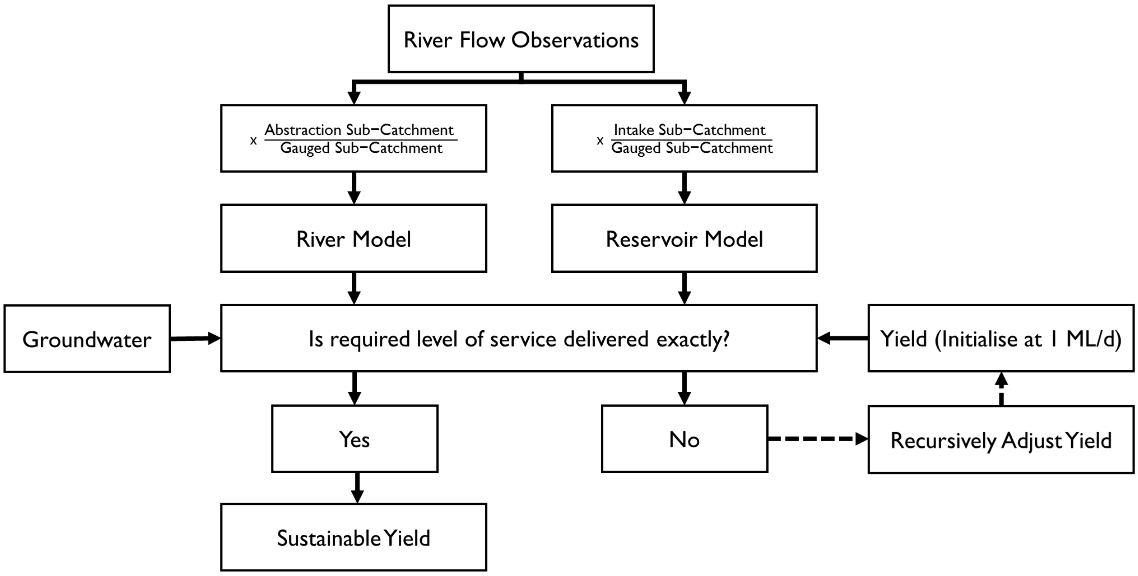


Figure 5: Methodology used to generate the water yield estimates for each water resource zone

Demand for each WRZ is the sum of domestic and non-domestic demand. Domestic demand for a WRZ is determined by multiplying the projected population of the WRZ in the given socio-economic growth scenario by the average per capita water demand (PCD) for the WRZ. A range of possibilities for PCD can be adopted, dependent upon the scale of demand management efforts. Non-domestic demand is calculated as a percentage of domestic demand for a given WRZ based on the regional break-up of non-domestic demand and the industrial and agricultural activity in the WRZ.

1.8 Reporting metrics

A number of metrics are used to evaluate the use of infrastructure systems, and the impact that investments in new infrastructure might bring. Those used in this report are summarised in Table 1.

For energy and water supply, we have developed projections of infrastructure service delivery, i.e. the amount that the infrastructure system is projected to be used. Services delivered are calculated by sector specific models and are therefore measured by sector level metrics as follows: energy (MWh/yr), water supply (ML/yr), and transport (vehicle km/yr).

Table 1: Metrics used in this report

	Units
Energy	
Electricity capacity	GW
Electricity peak load	GW
Gas capacity	mcm/day
Gas demand	TWh
Transport	
Traffic flows (links)	PCU (passenger car units)
Road vehicle km	mn vehicle km
Traffic speed	km/h
Interzonal rail traffic	Number of trains
Rail delay index	No units
Water	
Water demand	ML/yr
Supply-demand balance	ML/yr
Cross-sector	
Carbon emissions	MT

Whilst 'Service Delivered' is an interesting metric in its own right, it is more informative to decision-makers when combined with a metric of system capacity. By comparing these two quantities i.e. the amount of infrastructure service that a system can deliver (Capacity) with the amount that it is projected to actually deliver (Service Delivered) we generate a non-dimensional metric of Capacity Margin. Capacity Margin is defined as the ratio between total available capacity and service delivered:

$$Capacity\ Margin = \frac{Capacity - Service\ Delivered}{Service\ Delivered} . 100\%$$

Capacity Margin assesses the difference between available capacity and demand at a given time for a given sector, representing security of supply and system redundancy. Capacity Margins are a well-developed approach traditionally used in energy demand and water supply.

The concept is less familiar in the context of transport; because of the need for spatial averaging in the transport sector, this metric is adapted to represent Capacity Utilisation, which measures the use of each link/node in the transport network. The Capacity Utilisation of each link/node is the predicted throughput (in terms of vehicles per hour, trains per hour) as a percentage of the maximum capacity of the link/node for the given infrastructure configuration. The aggregate figure is the passenger-weighted combination over all links/nodes. The aggregate figure for the whole transport system is the passenger-weighted combination over the two networks considered, accounting for mode share (road ~90%, rail ~10%). Given the fairly stable modal split we assume that this split does not change dramatically in the future. Alternative scenarios might explore modal switching, possibly up to 15% on rail.

1.9 Development of the reporting tool

NISMOD-DB has been explicitly designed and developed for the storage of all NISMOD-LP data, including all model inputs and outputs. This ensures that the NISMOD-LP models are parameterised in a consistent manner in terms of inputs (e.g. demographic and economic data). It also provides a mechanism by which the provenance of results produced from NISMOD-LP can be tracked. Such high-level management functionality of NISMOD-DB has been augmented with a novel reporting tool and associated reporting tables within NISMOD-DB. Reporting tables are populated from the main output tables when a model run is completed. The web enabled reporting tool then dynamically links to the required reporting tables in NISMOD-DB allowing real time querying and reporting of the result-sets generated.

Within the reporting tool, results for individual infrastructure sectors can be displayed through a range of specific metrics. Added functionality enables the representation of certain sector results in terms of a sub-national level geography such as in Figure 6 where the value of electricity generated by the wastewater sector for each government level region is shown.

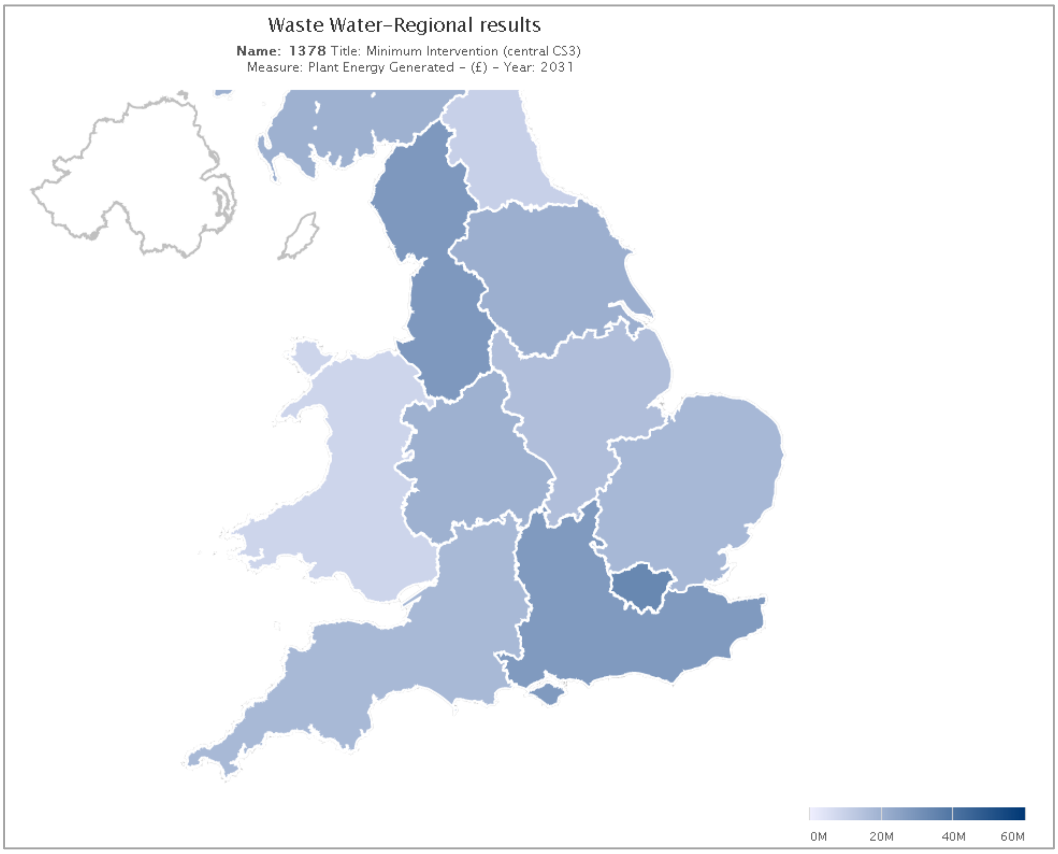


Figure 6 Example output showing the value of electricity generated by the wastewater sector in 2031 for each government office region

In order to model the NIP, a number of further developments to the NISMOD reporting tool were required. The significant NIP-related developments undertaken were:

- **Key date overlays**: to allow for key dates, such as when capital investments were due to take place, to be overlaid onto charts to ease interpretation of results.
- **New sector-specific metrics**: new metrics that more closely correspond to those used by IUK, such as capacity utilisation of roads (as a match to capacity utilisation of motorways).

Key NIP date overlays were added as a standard feature to all single-sector plots. These took the form of the ability to overlay a dotted line for each of the years when NIP-related investments were planned, allowing their impact in terms of the particular sector projections under investigation to be assessed (an example of this feature can be seem in Figure 9). For mapped results at a sub-national level the ability to more clearly present the areas directly affected by the NIP projects was added allowing the spatial impacts of investments to be ascertained (Figure 7) while for charts, alternative versions were generated to distinguish between affected and unaffected areas.

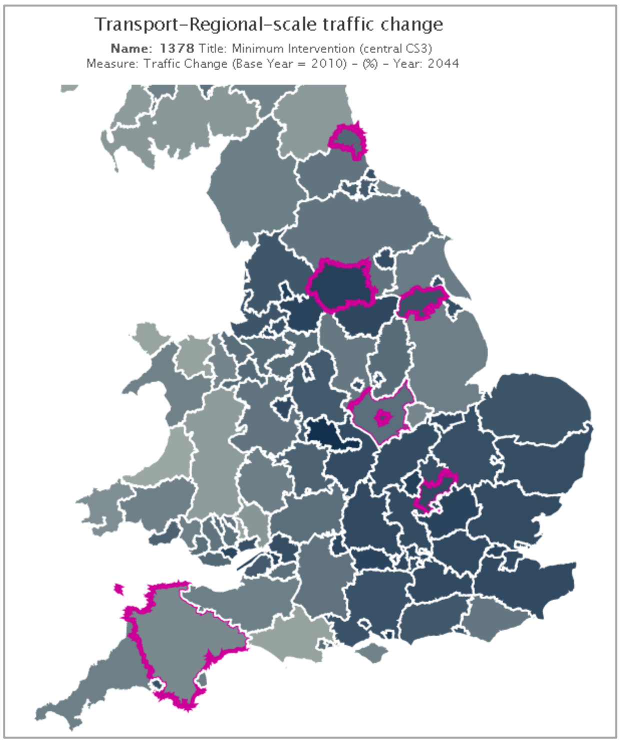


Figure 7 Example output showing the percentage traffic change from baseline levels for traffic zones in 2044, with highlighted zones those affected by investments

To allow for a greater understanding of the results from the NIP analysis new metrics were introduced which better matched those used by IUK for the assessment of sector performance. One such example is the creation of a capacity utilisation metric for transport sectors (i.e. road, rail, air and sea) to achieve a similar set of metrics as those used by IUK to assess the utilisation of transport capacity. These new metrics were generated by developing a post-modelling set of database functions that derived the new metrics and recorded them within the NISMOD-DB reporting tables; thus, the metrics were added without changing any of the NISMOD-LP models or the raw output tables. These additional metrics allow for comparisons to be made to previous work undertaken by IUK and thus increase relevance and potential impact.

The NIP pipeline

The infrastructure pipeline provides a bottom-up assessment of planned investment in infrastructure, across both the public and private sectors. The pipeline enhances visibility and certainty for investors and the supply chain and allows government to plan more effectively to ensure that the UK's current and future infrastructure needs are met.

The pipeline includes large capital projects and programmes of investment worth £50 million or more. Programmes represented in the pipeline may consist of a number of smaller projects grouped together. These are often rolling investments, such as national programmes of ongoing repair and maintenance of our utilities networks and regional flood defence programmes.

The pipeline provides a strategic overview of the level of planned infrastructure investment. The pipeline is not a statement of need or a commitment to undertake all of the projects shown. The publicly funded elements of the infrastructure pipeline represent announced projects. In privately funded sectors, the decision to go ahead with individual projects will be determined by the market. However, the pipeline for regulated sectors is consistent with regulatory settlements, where agreed.

To support delivery of its objectives in each sector, since 2011 the government has set out its 'Top 40 priority infrastructure investments'. This allows the government to focus on the delivery of those investments which either make the most significant contribution towards achieving a particular objective or carry the most risk should they fail, both strategically and in value for money terms.

Given the scale of the government's infrastructure commitments, the Top 40 is necessarily diverse and spans both the public and private sectors, and includes projects both currently under construction and some which are still in the scoping stages, with delivery milestones stretching beyond 2020.

Top 40 priority investments, are selected on the basis of three main criteria:

- potential contribution to economic growth
- nationally significant investment that delivers substantial new or replacement infrastructure with enhanced quality, sustainability and capacity
- projects that attract or unlock significant private investment.

1.10 Summary of the current pipeline portfolio

The value of the refreshed 2015 infrastructure pipeline is £411 billion, consisting of projects and programmes from within the Energy, Transport, Waste, Flood Defence, Communications, Water and Science and Research sectors, as set out in Table 2, along with some key statistics about the pipeline.

This study has focused on energy, transport and water, which represents over 90% of the overall investment, but NISMOD-LP is also capable of modelling changes to the solid waste and wastewater systems. In the NIP pipeline, there are 16 projects related to solid waste (an investment value of £1bn) ranging from the building of specific assets (seven energy-from-waste plants are listed), and investments in longer-term contracts for regional waste disposal. There are also programmes relating to sewage services as part of the Asset Management Programmes (AMP6) for ten water and sewage companies. Due to the short timescale of this study, these projects were not included in the assessment.

Table 2: The National Infrastructure Pipeline 2015 investment summary

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

Some key statistics regarding the pipeline are as follows:

- The pipeline annual spending figures are expected to average around £48 billion over the next 5 years (2015-2019)
- There are 564 projects and programmes in the pipeline (265 programmes and 299 projects)
- £264 billion (64%) of the pipeline is expected to be funded solely by the private sector. Private sector funding comes from a range of sources, including i) user charges and ii) external financing contributions
- £46 billion (11%) of projects have mixed private/public funding, with the remaining £101 billion (25%) of the pipeline publicly funded (by taxpayers)
- The two largest sectors, Energy (£245 billion, 60%) and Transport (£127.4 billion, 31%) account for 91% of the pipeline's total value
- 60% of the projects and programmes within the pipeline are either in construction or part of an active programme
- £199 billion (49%) of projects and programmes are monitored as part of the government's Top 40 priority infrastructure investments
- 53% of key projects and programmes within the Top 40 priority infrastructure investments are either in construction or part of an active programme

1.11 Analysing the pipeline in NISMOD

In order to begin the assessment of the National Infrastructure Pipeline, it was first necessary to determine which of the projects could feasibly be incorporated into the assessment. The process is slightly different for each of the sectors, but a general overview of the process is shown below, outlining the three main stages involved in the basic parameterisation.

Stage 1: Identification of project types which can be parameterised within NISMOD
Not all projects in the NIP pipeline can be parameterised within NISMOD; generally those projects that add capacity (generation capacity for energy, new road lanes and rail track km for transport, changes to the water supply system) can be included; projects that fund buildings (e.g. station improvements) rather than infrastructure network assets are excluded from these analyses, as are those that are focused on maintenance or research.

Stage 2: Prioritisation of acceptable projects
Due to the fact that some smaller investments are likely to have minimal impact on a national scale, it was decided to only including the 'Top 40' priority projects and high investment projects where applicable. For energy, transport and water, all 'Top 40' projects are included in the assessment (where they can be translated into NISMOD inputs). For transport, some of the higher impact projects outside the Top 40 are also included.

Stage 3: Translation of project details to NISMOD inputs
The final stage of parameterisation involved determining the specific input variables in NISMOD that needed to be modified to reflect the NIP changes to each of the networks. Examples for energy and transport are given in Appendix A.

1.11.1 Energy

For energy, the No Build strategy includes all current and 'in construction' generation capacity as well as any planned decommissioning as per the published DECC schedule. The NIP strategy includes the 'No Build' existing energy supply and transmission assets plus all projects provided by IUK in the 2014 and 2015 National Infrastructure pipeline listings. These projects amount to around 25GW of additional generation capacity at a cost of around £44bn with an additional 8.7GW of capacity being provided through new interconnectors with Europe (Table 3). A more detailed list of the energy generation projects is provided in Appendix B.

Table 3: Summary of new energy generation infrastructure projects in the 2014 and 2015 NIP

Generation type	Total cost	Capacity	Lifespan
Wind	£13.2bn	9.5 GW	30 years
Nuclear	£26bn	9.4 GW	60 years
Interconnectors	Not given	8.7 GW	40 years
CCGT	£1,345	2.8 GW	30 years
Biomass	£2.3bn	1.5 GW	30 years
CCS	Not given	784 MW	30 years
Energy from Waste	£946	157 MW	30 years
Solar	£39m	39 MW	30 years

The timing of the additional of 33GW of capacity in the NIP can be seen through a comparison of Figure 8 and Figure 9. Figure 8 presents the generation capacity in the No Build strategy by year while Figure 9 presents the NIP strategy which includes the additional 33GW summarised in Table 3. It should be noted that the steep decline in generation capacity in 2035 represents an unrealistic scenario; it is not expected to happen in practice as the NIP also contains a significant budget for additional generation projects beyond 2030 that have yet to be defined, and so are not included in this assessment.

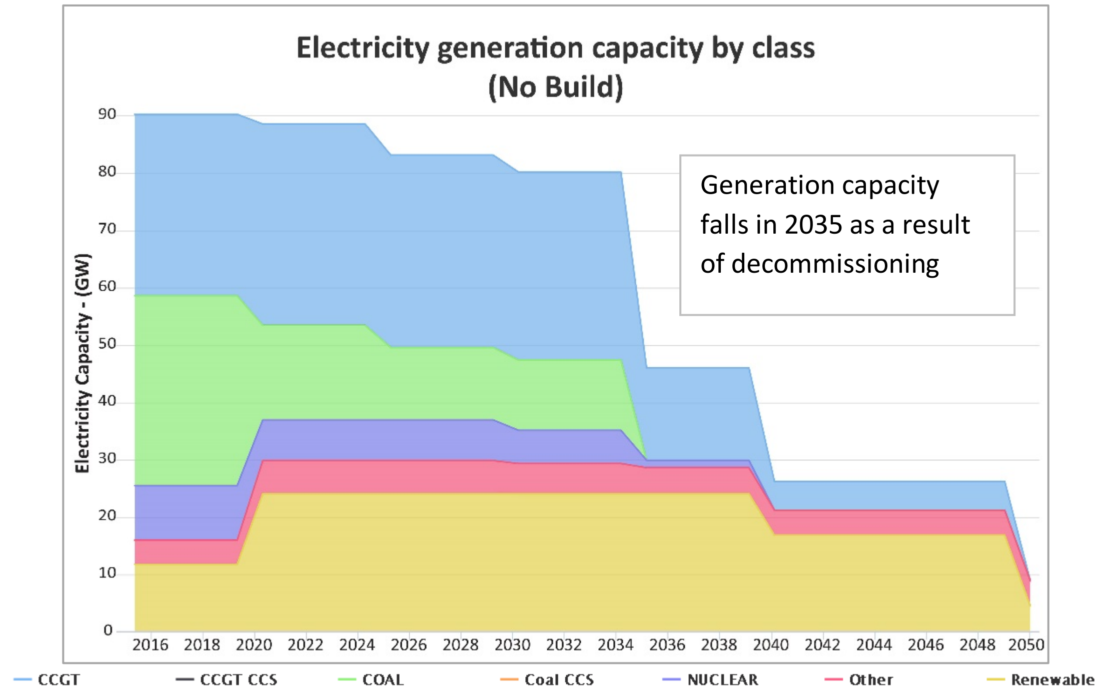


Figure 8: Generation capacity in the No Build scenario which includes all current and 'in construction' capacity and any planned decommissioning

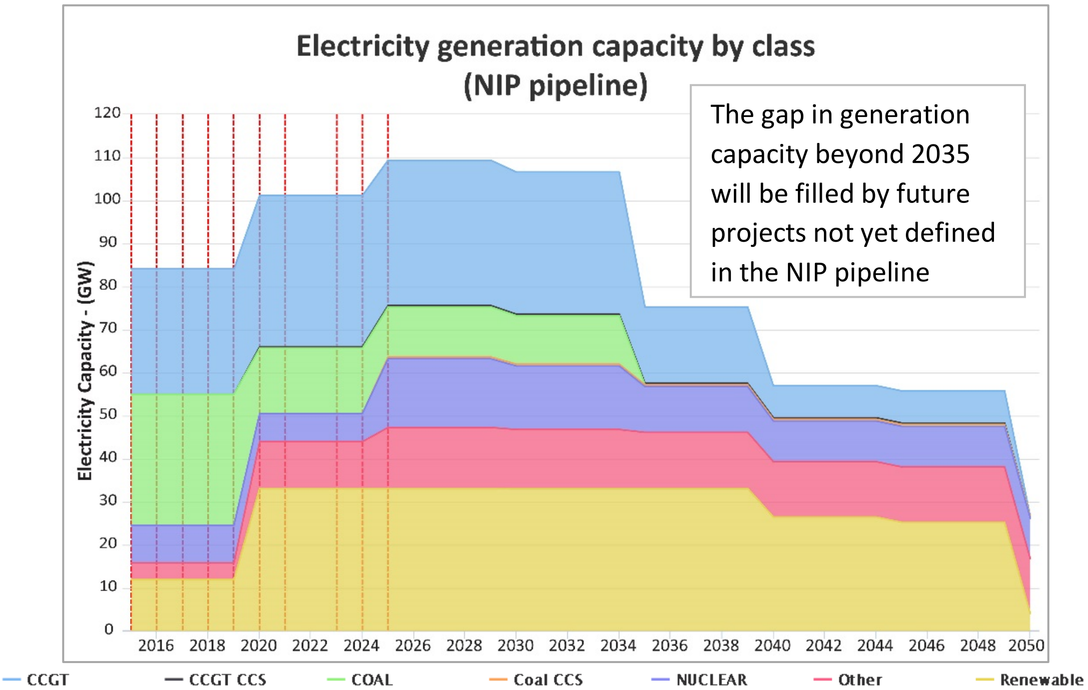


Figure 9: Generation capacity in the NIP scenario which includes all existing infrastructure assets in the No Build scenario plus the addition of the 33GW in the 2014/15 NIP. The dotted red lines represent the years in which new infrastructure is scheduled to be built in the NIP

1.11.2 Transport

In the transport assessment, there are 24 of the 32 'Top 40' road-based projects in the NIP that can be translated into NISMOD-LP model inputs. There are 6 of the 10 Local Authority Major projects and 18 of the 22 Highways England Major projects. The model also assesses a further 29 road-based projects outside the 'Top 40', including 12 Smart Motorway projects. A full listing of projects included in the assessment is given in Appendix A.

Project types that are not included in the assessment are those concerned with metro systems (which are currently not represented in NISMOD-LP), junction improvements and general maintenance programmes and smaller scale local projects outside the Top 40 priority list which would have little impact on a national scale.

Table 4 gives an overview of the additional lanes between zones which are assumed to be built as a result of the NIP investments, together with the number of additional lane kilometres within zones

Table 4: Road lanes and lane km added in this assessment

Inter-zonal flow lane (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%
Intra-zonal 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[13]	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%

Thus, the NIP assessment aims to quantify the effect of adding 52 new inter-zonal flow lanes, which is an additional 1.3%, and 1746 intra-zonal lane km (including 861km of managed motorway/all lane running), which is an additional 0.22%.

For rail, all seven electrification projects are included in the assessment (as set out in Appendix A), as well as an assessment of the impact of HS2, which is assumed to affect a small number of inter-zonal rail links, as shown in Figure 10.

[13] Negative values indicate where e.g. single carriageway roads are converted to dual carriageway.

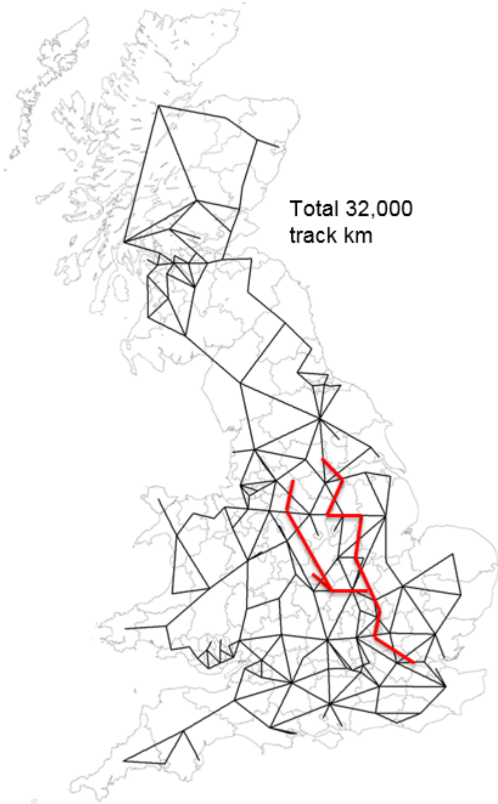


Figure 10: The inter-zonal links (red) affected by HS2

Phase 1 of HS2 is assumed to add 384 km of new high-speed track (192 km length, double track), linking Britain's busiest urban hubs. This increases the total length of the entire rail network by 1.2%. Phase 2 is assumed to add a further 700km (a further 2.2%).

1.11.3 Water supply

The NIP projects and programmes listed under the NIP 2015 for the water sector consist primarily of the investments over the next five years (2015-2020) contained in each of the water companies' Water Resource Management Plans (WRMPs) for Asset Management Programme 6 (AMP6). The only exception is the Thames Tideway Tunnel which is not modelled in this study and deals principally with stormwater overflow and wastewater management. Included within each of the WRMPs are estimates of population growth, changes in per capita demand, and levels of non-household demand (agriculture and industry). In this assessment we use the consistent NISMOD population scenarios (as described in Section 2.3 above) alongside water company projections of per capita demand for each WRZ through to 2050. Also included in both strategies are a series of 'sustainability reductions' listed in each WRMP, which are reductions in licenced water withdrawals that have been mandated by the UK government through the Environment Agency (Table 5). Our results have assumed that the yields of each affected WRZ have been reduced by the full amount attributed to the sustainability reductions. However, not all of these sustainability reductions will necessarily result in decreases in supply, as not all abstraction licenses are currently being fully exploited. Having said this each water company must consider the sustainability reductions in their future investment plans and thus we have included them in full in our modelling results.

Table 5: List of Sustainability Reductions by Water Company and Water Resource Zone (WRZ) including the year reductions commence and their quantity

Company	WRZ	Start Year	Reduction (ML/year)
Anglian	East Lincolnshire	2025	13505
Anglian	Hunstanton	2025	475
Anglian	Fenland	2025	7300
Anglian	Ely	2025	548
Anglian	North Norfolk Coast	2020	475
Anglian	Norwich and the Broads	2020	18944
Anglian	West Suffolk	2025	3577
Anglian	Newmarket	2025	913
Bristol	Bristol	2015	3687
Cambridge	Cambridge	2020	1643
Portsmouth	Portsmouth	2020	2190
Severn	Grid	2020	16425
Severn	North Staffordshire	2025	365
Severn	Shelton	2025	10585
South East	WRZ4	2020	2489
South Staffs	South Staffordshire	2020	3650
South West Water	Roadford	2020	2540
Southern	South	2020	39055
Thames	SWOX	2018	4015
Thames	London	2020	3285
United	West Cumbria	2022	13688
United	Integrated	2020	1825
Welsh Water	Brecon Portis	2015	172
Wessex	Wessex	2018	9490
Yorkshire	Grid	2018	986

Each of the WRMPs were searched for any major investments designed to enhance yield (summarised in Table 6). These investments constitute the only difference between the No Build and NIP strategies presented in this analysis. The total expected yield from these investments amounts to approximately 132,900 ML/year or around 18% of the total estimated yield for 2015. The majority of these investments are in leakage reduction which will provide an increase in 71,680 ML/year of water supplied to end-users, which amounts to around 6% of estimated total leakage in 2015.

Table 6: Summary of projects and their potential yield extracted from each of the water company's Water Resource Management Plan

	No of projects	Total exp. (£m)	Yield (ML/yr)
New abstractions	3	73+	23,140
Licence variations	2	5+	7,700
New reservoir	1	103	5,950
Leakage reduction	28	260+	71,680
Transfers	6	2+	22,460
New groundwater	2	6+	1,970
Total	42	449	132,900

Analysis of the performance of the NIP pipeline

1.12 Energy

In addition to the NIP investments and 'No Build' (NB) comparison, which have already been introduced, we also report an investment strategy referred to as 'Minimum Intervention' (MI) in the energy modelling. The Minimum Intervention (MI) strategy has been modelled using the CGEN+ model's optimisation capability to plan a 'least cost' approach to maintaining capacity margins. On the demand side, the MI strategy assumes minimal energy efficiency, conservation and fuel switching in the energy system. This represents a strategy of meeting both gas and electricity demands at minimum costs without regard for considerations such as carbon emissions or energy security.

Modelled demand for gas and electricity is focused upon 'peak load' demand and calculated from future projections of population and economic growth and their impacts on residential, services, industry and transport demand for energy. The projected peak load demand for electricity under the low, central and high socio-economic growth scenarios is presented in Figure 11. Estimated transitions towards newer and more efficient technologies are responsible for the curved inflections in these peak demand graphs.

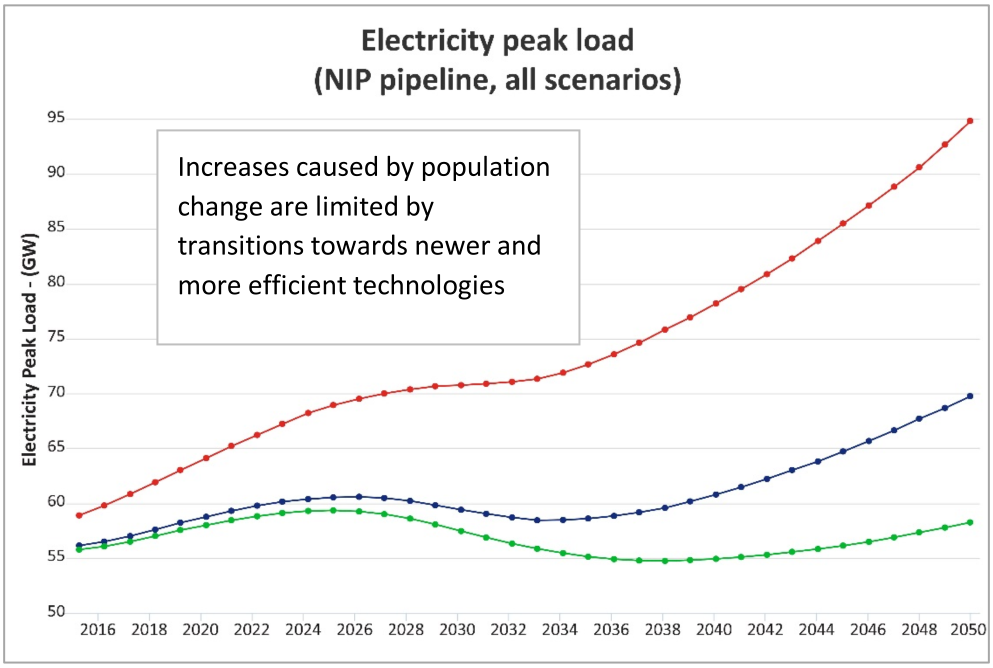


Figure 11: Estimated NIP pipeline peak load demand for electricity under the low (green), central (blue) and high (red) socio-economic growth scenarios

1.12.1 Electricity

The ability of each of the three strategies to meet this future demand for electricity can be captured using the 'capacity margin' metric (described in Section 2.5) which represents the percentage of capacity available over and above the estimated peak load. A capacity margin below zero suggests that the generation capacity for a strategy will not be able to meet peak demand in that year.

The capacity margins for each of the three strategies in the central socio-economic growth scenario is presented in Figure 12. The sudden drop in 2035 for the 'no build' and NIP strategies is due to reduction in generating capacity at the end of the life of existing plant, given that further investments have not yet been specified beyond that date. The diagram suggests that current capacity (No Build) will not be able to meet peak demand beyond around 2024. The NIP projects provide a capacity margin of close to 20% until 2035 when new generation projects that have yet to be defined in the NIP should provide additional capacity. By design the minimum intervention strategy maintains the capacity margin above 20% for the modelled period.

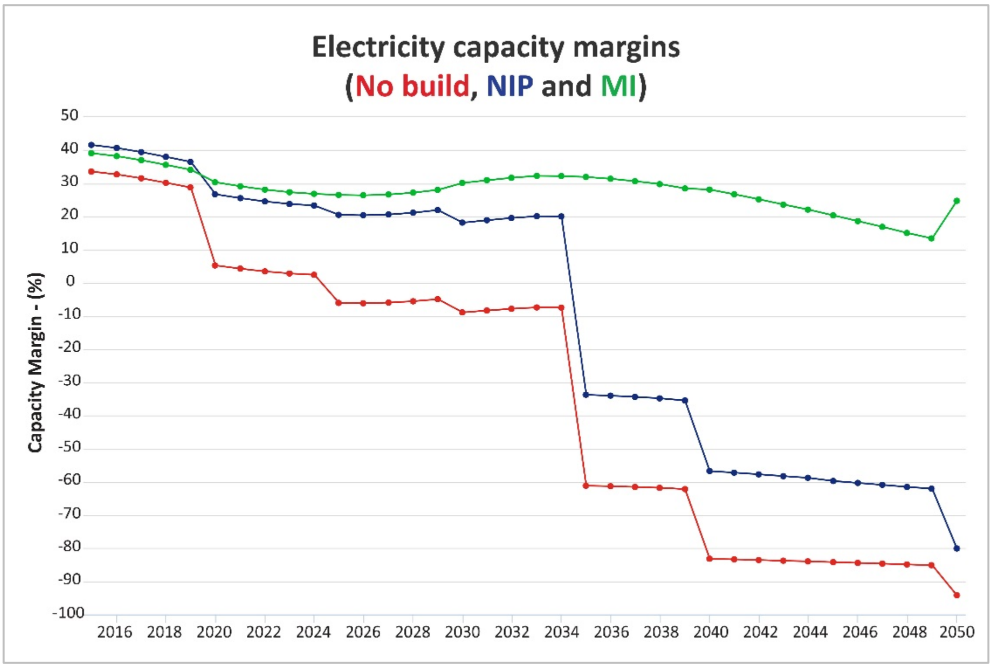


Figure 12: Capacity margin (central growth scenario) for the No Build (red), NIP (blue) and Minimum Intervention (green) strategies

Figure 13 presents the capacity margin for the NIP projects under the low, central and high socio-economic scenarios. This diagram suggests that a higher population scenario could result in a much lower capacity margin, but that the NIP projects should still be able to meet modelled demand up to 2030.

There are a number of important points to be considered in the modelled capacity margins presented here. Firstly, the NIP projects include a significant amount of new wind generation capacity. As is customary in energy modelling, wind generation facilities are de-rated to 15% of their maximum capacity when calculating the capacity margin in order to account for the intermittency of energy supplies from wind. Secondly, the decommission dates of existing plants in each of the strategies represented in these diagrams are those provided by DECC (See Appendix A). However, each of these plants could feasibly be maintained beyond their reported decommissioning date if required and if such an option proves cost-effective.

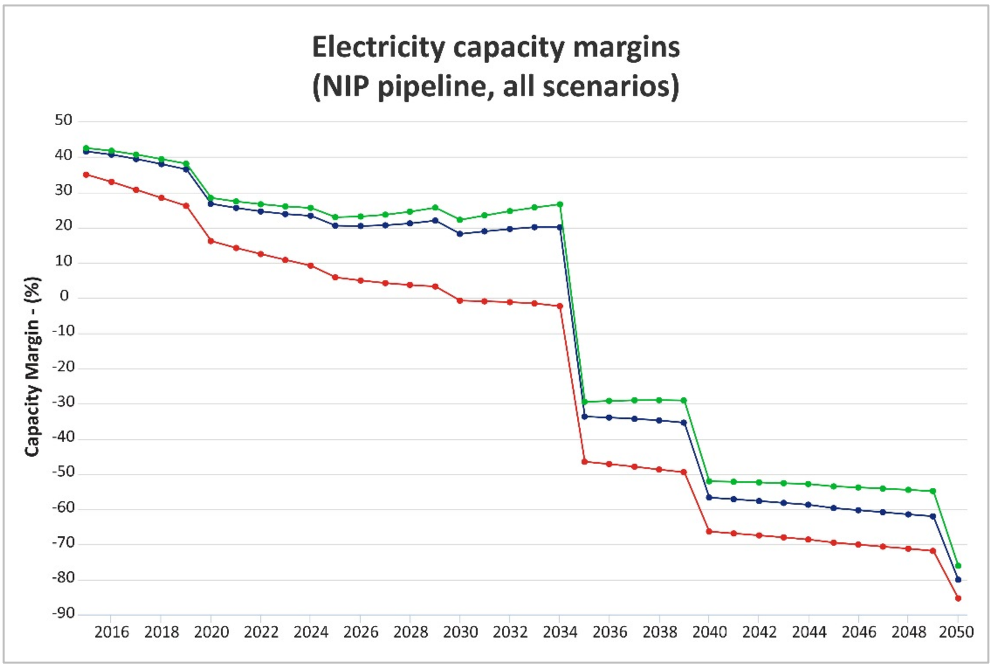


Figure 13: Capacity margin for the NIP projects under the low (green), central (blue) and high (red) growth scenarios

A further final caveat worthy of note is that the capacity margin results presented in Figure 12 and Figure 13 above are based on a conservative set of assumptions about the uptake of electrification of heat and transport. In an alternative demand strategy titled ‘electrification of heat and transport’ we test the impact of a more highly electrified future in the NIP projects. Figure 14a and 15b present this alternative demand future contrasted with the ‘standard assumptions’ for a central socio-economic growth scenario (shown in Figure 12 and Figure 13). The key differences appear to involve a significant increase in peak demand over the entire period when the electrification of heat and transport is included, which is reflected in Figure 14b as a concomitant decrease in the capacity margin estimated for the NIP projects. Such a result suggests that any anticipated policy promoting the electrification of heat and transport may need to include the provision of additional electricity generation capacity.

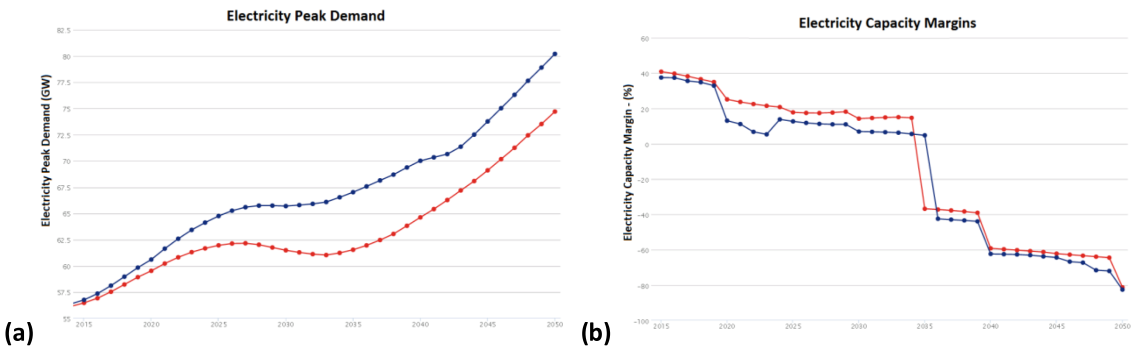


Figure 14: (a) Contrasting the ‘standard assumptions’ energy demand (red) with the estimated demand from the alternative 'electrification of heat and transport' demand strategy (blue) and (b) the effect of these alternative demand strategies on the capacity margin for the NIP projects (central growth scenario)

1.12.2 Gas

The NIP projects do not include any increase in gas capacity. The gas supply capacity for Great Britain is presented in Figure 15 showing the only change being a gradual decrease in domestic supplies over time. The estimated demand for gas supplies over the same period under the low, central and high socio-economic scenarios is shown in Figure 16.

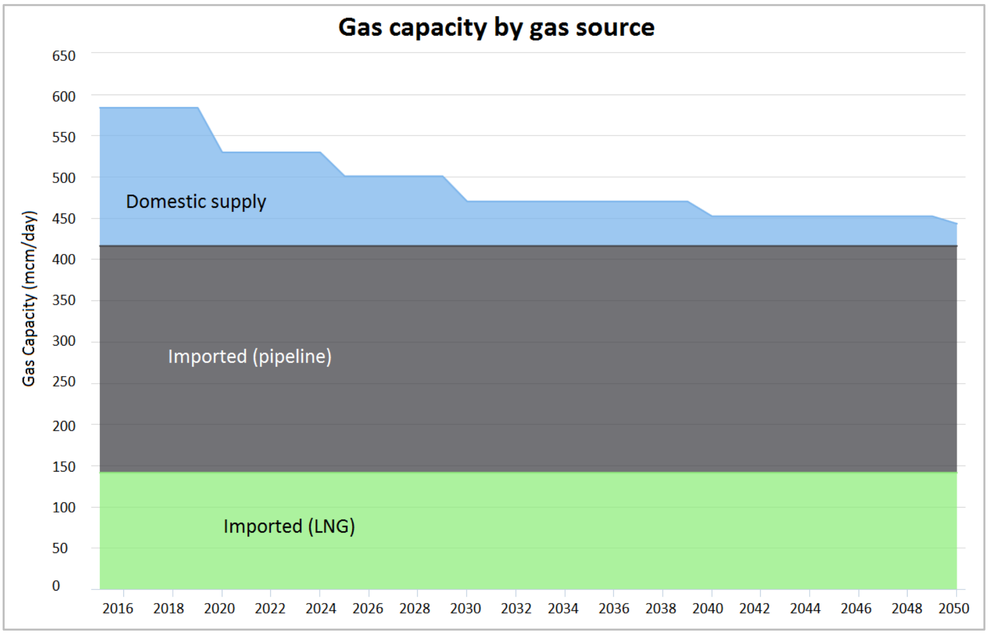


Figure 15: Gas supply capacity in Great Britain showing domestic supply (blue), gas imported by pipelines (grey) and imported LNG liquefied natural gas (green)

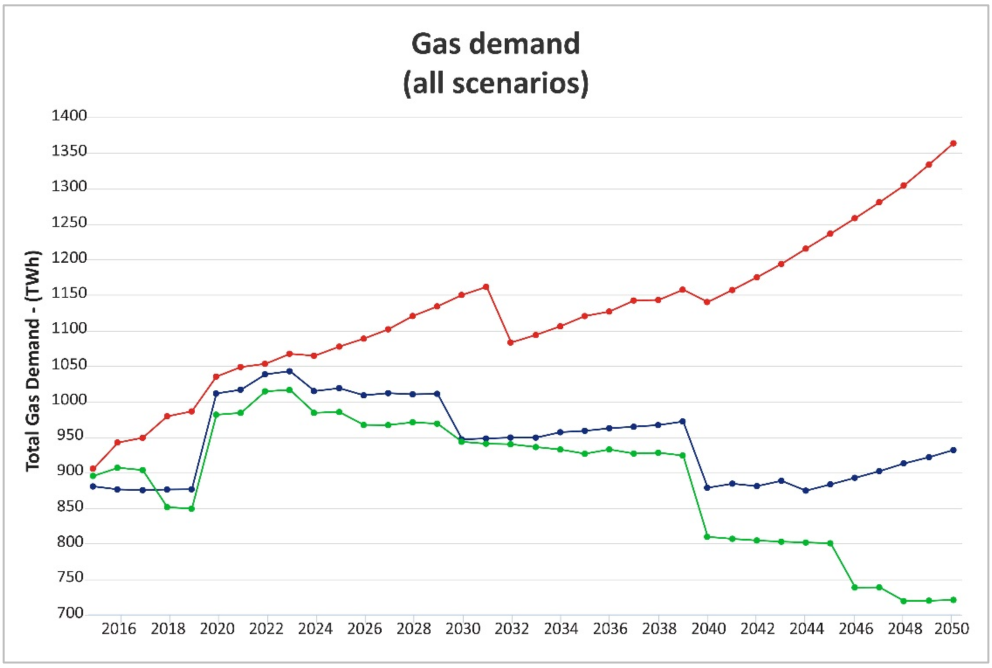


Figure 16: Total demand for gas supplies for the low (green), central (blue) and high (red) socio-economic growth scenarios

To evaluate the ability of the current unenhanced gas supply capacity to meet long term demand we calculate a gas capacity margin which provides the capacity above peak demand, excluding storage. Despite the decline in domestic gas supplies the current gas infrastructure is able to ensure sufficient capacity in the gas network over the period from 2015 to 2040 without new capacity investment, under all growth scenarios, as shown in Figure 17. Only in the high-growth scenario is there a danger of the gas capacity margin dropping below zero beyond 2040.

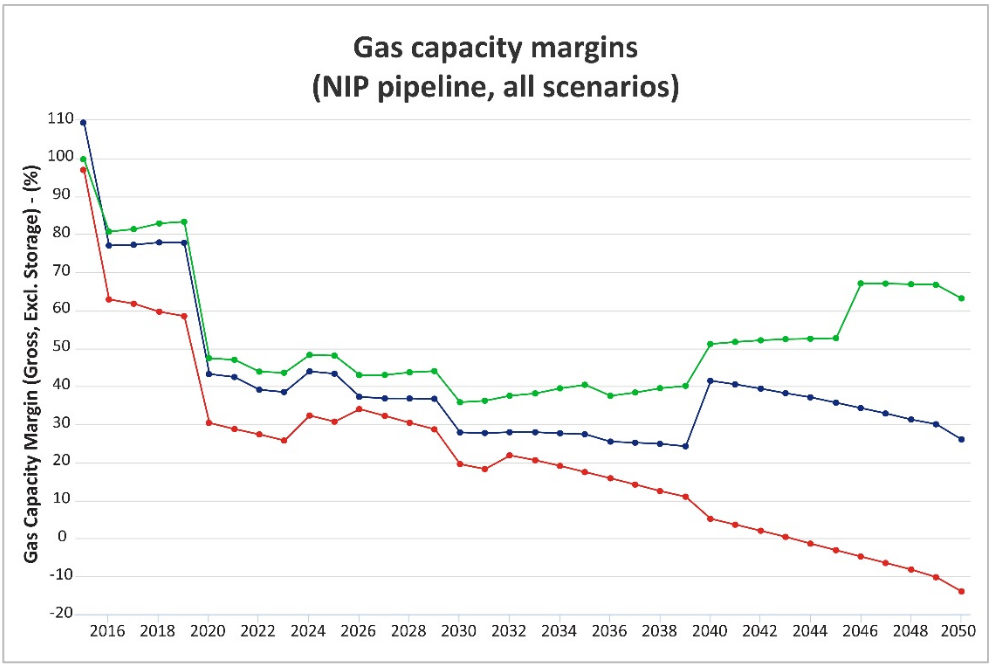


Figure 17: Capacity Margin for gas supplies from the NIP strategy under the low (green), central (blue) and high (red) socio-economic growth scenarios

Note that the stepped increases and decreases in demand for gas shown in Figure 17 and 18 are a result of the CCGT demand for gas in the production of electricity. The dramatic shifts in use of CCGT are in part due mostly to commissioning and decommissioning of plants but also in part due to the switching of electricity generation between different generator types due to the workings of the cost minimisation algorithms used by the energy supply model.

1.12.3 Greenhouse gas emissions

A final means by which the NIP projects can be assessed is in the estimated greenhouse gas emissions produced by this strategy. Figure 18 provides these estimates for the No Build, NIP projects and Minimum Intervention strategies. From this perspective the NIP projects can be seen to provide significant improvements over the least cost Minimum Intervention strategy. The decline beyond 2035 reflects the decommissioning of plants (and consequent negative capacity margin) beyond that point (as shown in Figure 8 and Figure 9). The actual anticipated emissions beyond that point will depend on the nature of the new supply infrastructure that is built in the meantime. Note that embodied carbon is not included in these analyses which would increase the carbon costs of all save the No Build strategy.

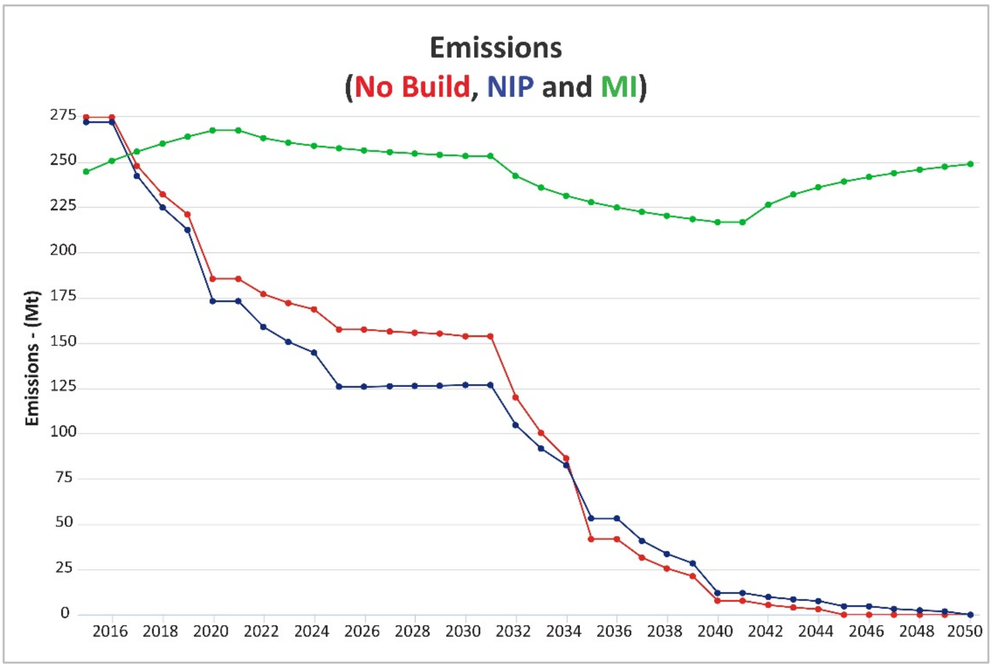


Figure 18: Greenhouse gas emissions (central growth scenario) for the No Build (red), NIP (blue) and Minimum Intervention (green) strategies

1.13 Transport

Changes to the transport infrastructure are necessarily spatial in nature; additional motorway lanes and railway tracks have start and end points. For projects involving motorway widening and hard-shoulder running, these are additional lanes alongside an existing link, whereas for HS2 these are newly built railway tracks. These new transport infrastructures are represented in NISMOD as additional lanes or tracks between neighbouring zones, or between a series of neighbouring zones for those projects which span a number of boundaries (such as large 'smart motorway' widening schemes).

Although the transport model calculates the traffic flows within zones (inter-zonal), and between zones (intra-zonal), it was originally designed to display aggregate change at a national scale, but the largely local nature of the investments in the infrastructure pipeline mean that such change might be 'lost' within the national picture. One resultant adaptation to the model and reporting tools was to display results only for those links or zones affected by newly added infrastructure. Changes to the use of the transport system are more visible using these distilled model outputs, and the following analyses have used this facility where appropriate.

1.13.1 Road transport

Figure 19 shows the growth in road traffic (in PCUs, passenger car units[14]) between neighbouring zones where infrastructure has been added as part of the NIP pipeline, comparing those same links without the additional lanes for No Build strategy (central growth scenario).

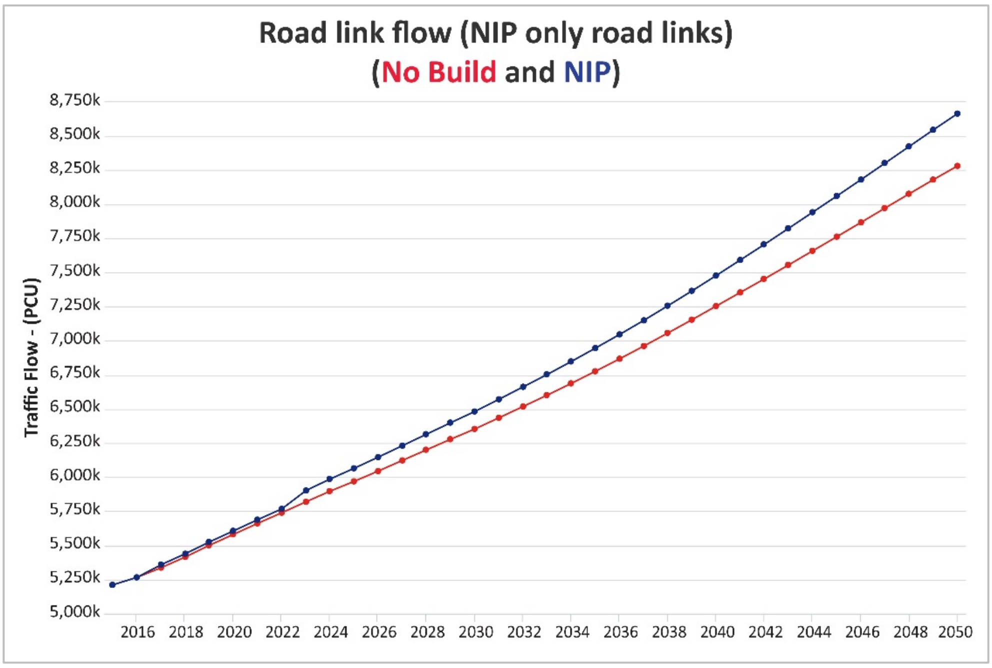


Figure 19: Inter-zonal traffic flow (affected links, central growth scenario) for No Build (red) and NIP (blue)

The reason for the growth in transport is due to latent demand; elasticities within the model imply that demand is released when congestion levels are eased, as can be seen here. By 2030 there is 2% more traffic (compared to No Build) using the network links where NIP investments are planned, increasing to an additional 4.6% traffic in 2050.

[14] A Passenger Car Unit represents the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car. Typical values of PCU are: private car (including taxis and LGV) 1; motorcycle 0.5; bicycle 0.2; bus, HGV 3.5

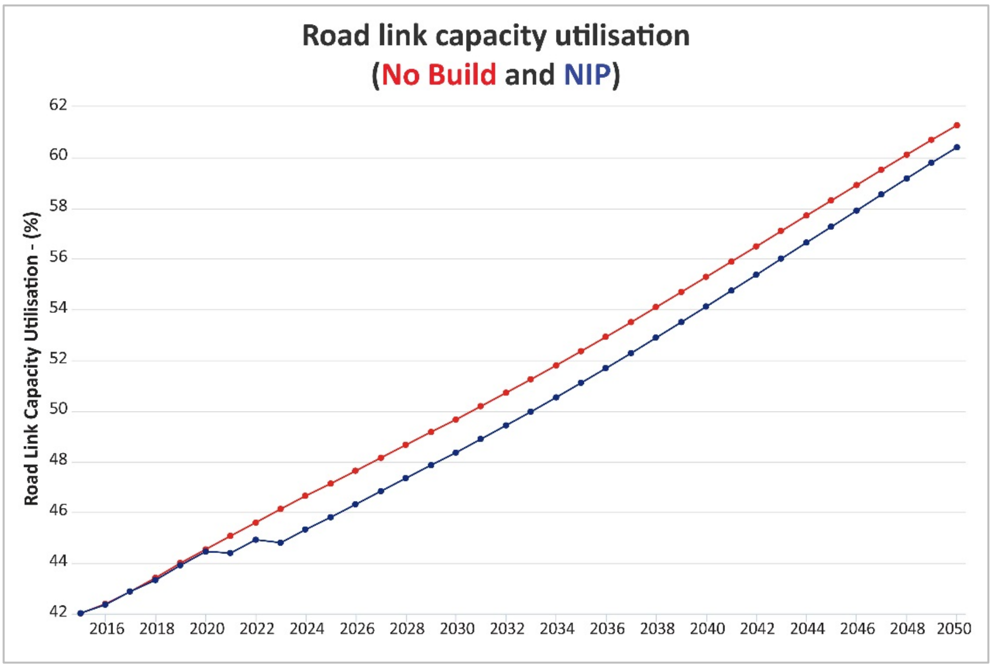


Figure 20: Road link capacity utilisation (central growth scenario) for No Build (red) and NIP (blue)

As can be seen from Figure 20, even though traffic levels have increased, there is a reduction in capacity utilisation. From the definition of capacity utilisation (CU) for transport given in Section 2.5, we would expect CU to decrease as capacity increases (e.g. double the number of lanes for the same flow, CU is halved). Thus, additional lanes increase capacity, release latent demand, but still enable a reduction in capacity utilisation. Reduced capacity utilisation at peak times implies reduced congestion.

In regards to the impacts of local network changes within each of the affected local authority zones (intra-zonal), Figure 21 and Figure 22 display a similar profile to the inter-zonal impact. The amount of traffic increases slightly as more lane km become available for use (by 0.65% in 2030 compared to No Build), but without affecting speeds (which are 4.3% higher for NIP affected zones than for those same zones under a No Build future).

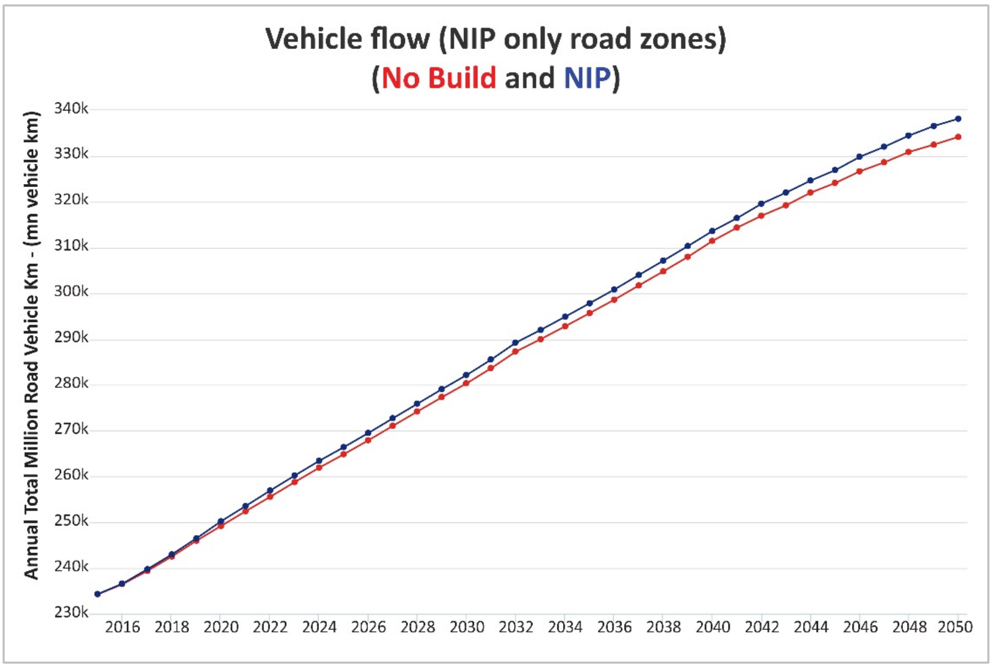


Figure 21: Intra-zonal road vehicle km (affected zones, central growth scenario) for No Build (red) and NIP (blue)

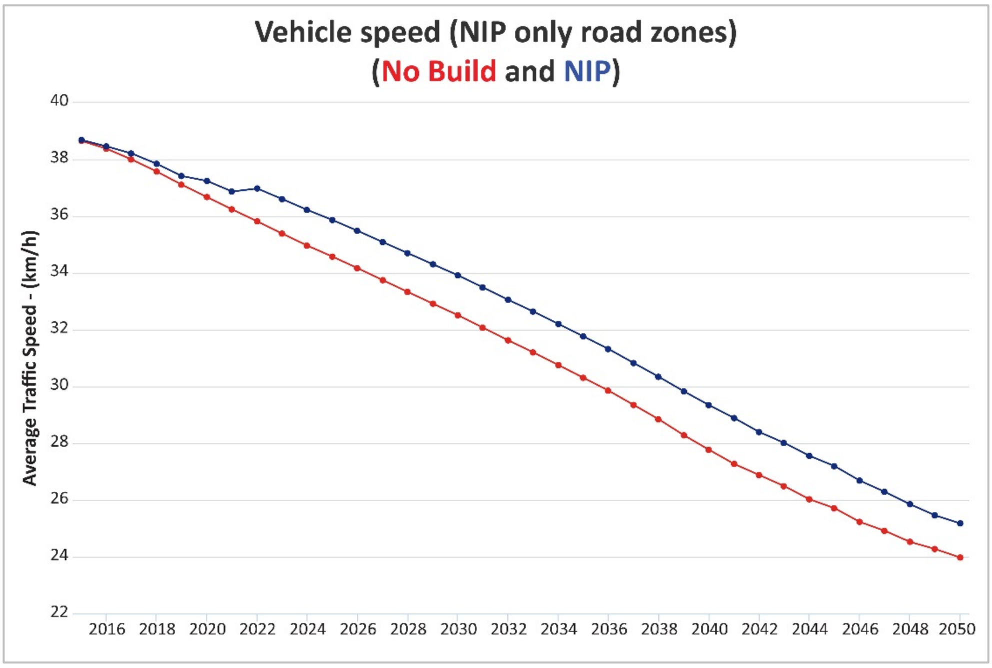


Figure 22: Intra-zonal road vehicle speeds (km/h, central growth scenario) for No Build (red) and NIP (blue)

1.13.2 Rail

A similar picture emerges when considering how wide-scale electrification, and the subsequent opening of HS2, will impact on the rail network across these affected links. Figure 23 shows demand increasing in 2018 as electrification expands across the network[15]. The opening of Phase 1 of HS2 in 2026 provides capacity for a large number of extra trains, with a further increase in 2034 when Phase 2 is assumed to open. Note that the rail model displays *numbers of trains* as opposed to *passenger numbers*, since the base model is aligned to the timetabled rail service between zones. The number of trains increases with demand (population growth), and it is assumed that there is sufficient flexibility within the baseline timetable to provide such extra capacities in the No Build and NIP futures.

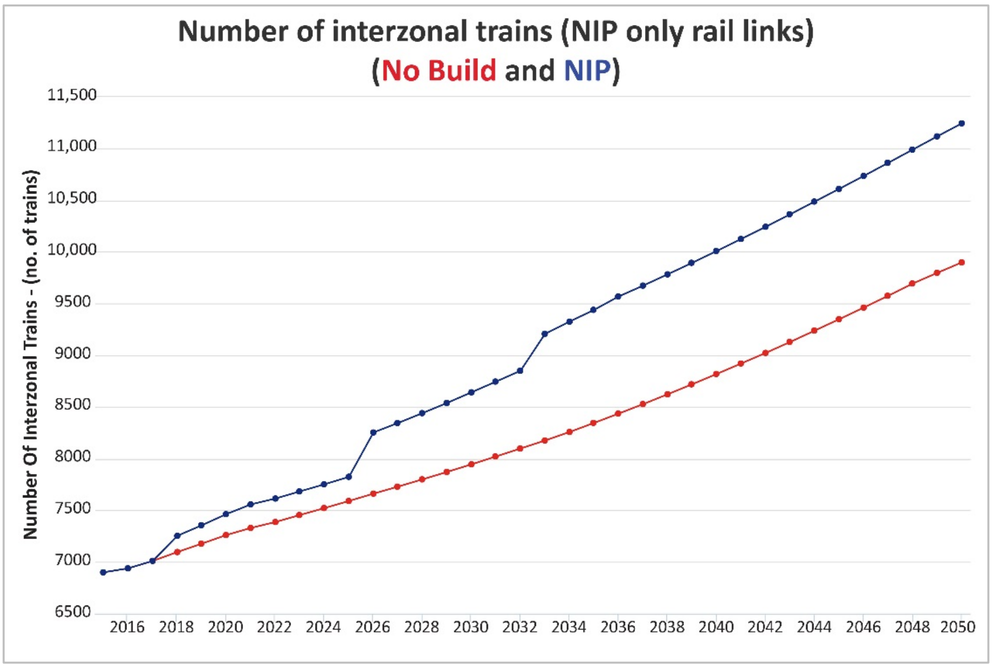


Figure 23: Impact of HS2: Number of inter-zonal trains (central growth scenario) for No Build (red) and NIP (blue)

Figure 24 shows an index of the expected delays (2010=1), where rail congestion is eased considerably by the introduction of HS2.

[15] Note that the introduction of electric trains is assumed to result in greater demand, and more trains. As a result of the programme of rail electrification in the NIP pipeline, the amount of diesel used nationally reduces by 35% by 2022, while electricity use increase over the same period.

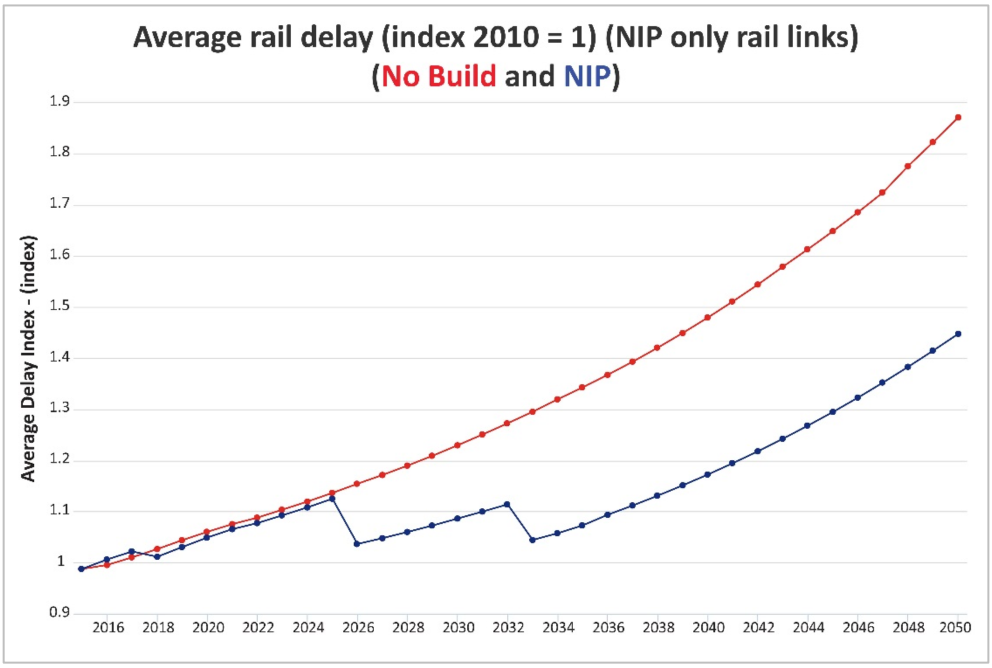


Figure 24: Impact of HS2: Index of rail delay for NIP (blue) and No Build (red) (central growth scenario)

1.14 Water supply

The socio-economic scenarios (high, central and low growth) outlined in Section 2.3 are employed to assess the relative performance of the NIP projects. In addition, the possible impact of climate change on water availability is assessed through the use of the Future Flows[16] hydrological scenarios for each WRZ. Of the 11 published Future Flows scenarios, examples of increasing, median and decreasing water availability are identified (scenarios 'afixh', 'afixc' and 'afixk', respectively) and these are used in this study to represent high, central and low water flow scenarios[17].

Incorporating the changes in demand from the WRMP (see Section 3.2.3) and the three main population scenarios (for the central climate change scenario), a wide range of possible outcomes are produced for Great Britain as a whole, from a reduction in demand in the low population/per capita demand scenario to a 20% increase in total demand by 2050 in the high population/per capita demand scenario (Figure 25).

[16] For further information of Future Flows Hydrology, see here: http://www.ceh.ac.uk/services/future-flows-maps-and-datasets

[17] Note that although the three scenarios are differentiated based on their aggregated national water availability levels (high, central and low), each has the potential of affecting individual companies differently and not necessarily in the same direction as the national aggregate.

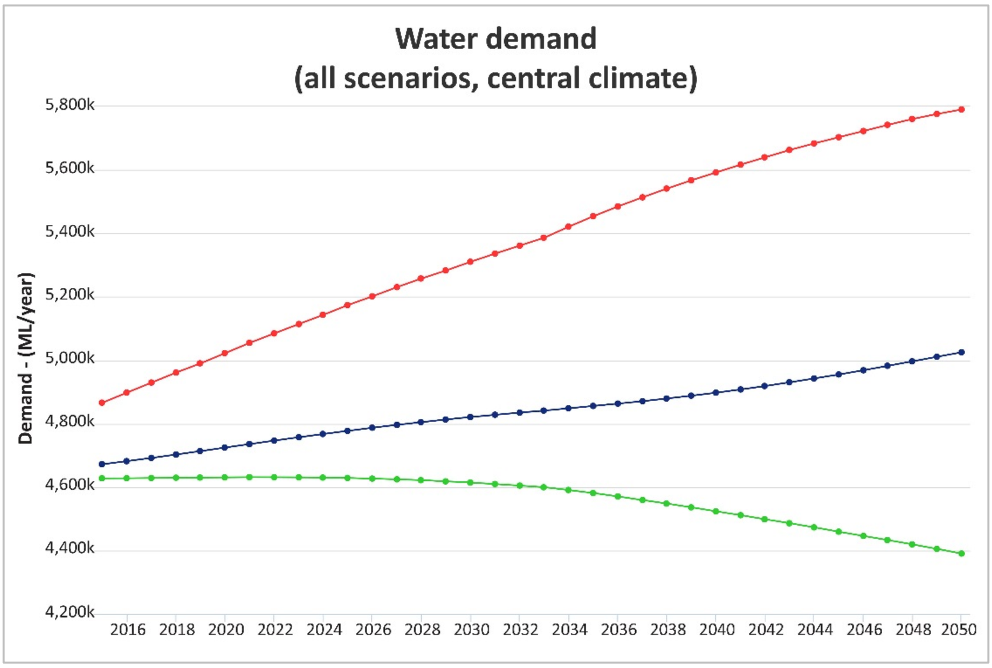


Figure 25: Changes in demand for water for Great Britain under central climate and low (green), central (blue) and high (red) population growth scenarios

The calculated water balance for Great Britain under the central population and climate scenario for each year from 2015 to 2050 is presented in Figure 26. The water balance is calculated for each WRZ as the water available for supply less the household and non-household demand and estimated leakage in that WRZ. As shown in Figure 26, the NIP investments amount to an 18% increase in water availability for Great Britain. This increase in supply is countered by a potentially larger decrease in yield from reductions in water abstractions that are mandated to restore the aquatic environment ('sustainability reductions') which amount to around a 22% decrease in supply levels by 2025. The steady decline in supply-demand balance following 2025 is the result of population increases and median level declines in water availability due to climate change.

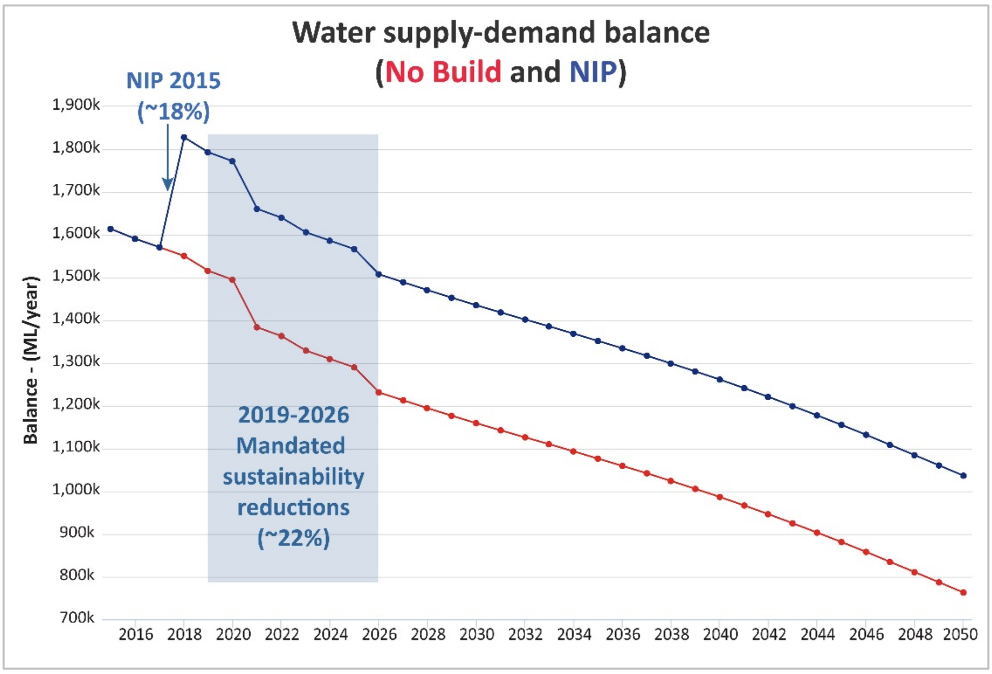


Figure 26: Changes in water supply-demand balance (supply less demand) for Great Britain under a central population and climate scenario. Percentages in parentheses show the estimated percent change in water supply resulting from the NIP investements and sustainability reductions

The positive national water balance shown in Figure 26 is not spread evenly over the nation. Figure 27 shows the water balance for each water company in 2030 in the No Build and NIP strategies under the central population and central climate scenario. As shown, the NIP projects do much to alleviate potential water shortages, with most companies showing a positive balance in the NIP strategy in 2030 with the exception of Sussex and Essex which shows a slight negative balance. It should be remembered that these figures do not necessarily reflect the total water available for extraction, but rather the water available given the current and NIP infrastructure. Companies such as Thames Water, Scottish Water and Dwr Cymru (Welsh Water) all have considerable potential for increasing water supply through additional abstractions and the construction of more infrastructure assets.

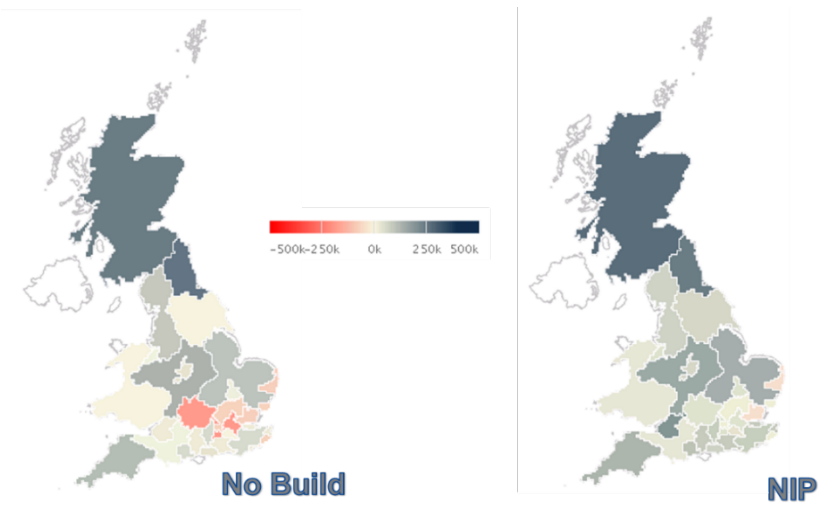


Figure 27: A comparison of water balance (ML) in 2030 (central growth, central climate scenarios) for each of the water company regions in the No Build and NIP strategies

Climate change is expected to manifest as changed patterns of average and extreme rainfall and evaporation. Climate change therefore has the potential to increase or decrease water availability for the various water company regions. When combined with expected population growth the impact on available water can be substantial. Figure 28 presents the effects of both the NIP projects and the sustainability reductions on total water balance in Great Britain under the combined scenarios of low population with wetter climate, central population and central climate, and high population with a drier climate. This diagram provides an insight into the large range of uncertainty associated with socio-economic and climate change. By 2030 the water balance for Great Britain could either be at a similar level to 2015 in the best-case scenario or 60% lower in the worst-case scenario.

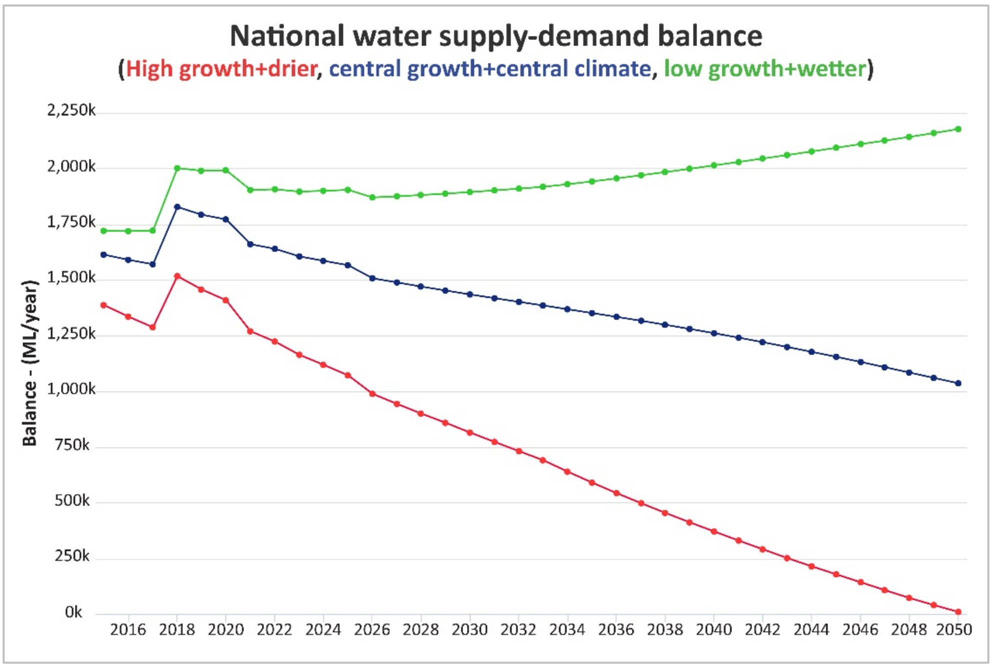


Figure 28: Water supply-demand balance (ML/year) for all of Great Britain showing both the NIP projects and the sustainability reductions across three scenarios of low population wetter climate (green), through central population and central climate (blue), to high population and drier climate (red)

As discussed earlier, climate projections of precipitation are highly uncertain, showing the potential for both positive and negative change. Figure 29 provides a graphical representation of this uncertainty through a presentation of the impacts on the water balance for each of the water company regions in 2050 under the 11 Future Flows scenarios. The low, central and high climate scenarios are the 4th, 3rd and 7th scenarios from the top left, as indicated.

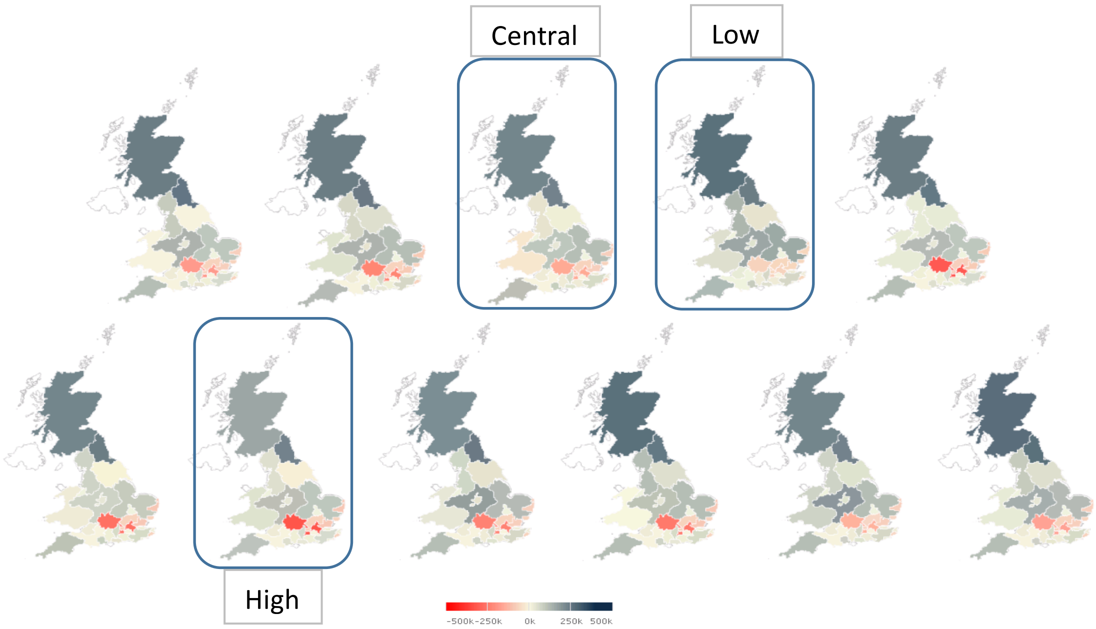


Figure 29: Water balance (ML) for each of the water companies in 2050 under the 11 Future Flows[18] climate scenarios for the central growth demand scenario ('Low', 'Central' and 'High' climate scenarios are indicated, other scenarios have a range of characteristics)

[18] For further information of Future Flows Hydrology, see here: http://www.ceh.ac.uk/services/future-flows-maps-and-datasets

Discussion and conclusions

Undertaking this collaborative study has demonstrated the functionalities of the NISMOD system in being able to evaluate the long term performance of national infrastructure plans against a range of population, economic and demand scenarios. This has provided insights into how well current plans for infrastructure investments in energy, transport and water supply might perform in both the short and longer-term. An integrated perspective on investments in each of these major infrastructure sectors provides important insights for policymakers. The study has also delivered a number of new database and visualisation tools which enable scrutiny of the results both geographically and through time.

For energy, if we assume no additional investment in generation capacity over the next few years, the expected moment at which capacity margins drop below 20% is 2020. The electricity supply investments included in the NIP add around 33GW of new energy generation capacity over the next five years, which delays the moment at which the electricity capacity margin falls below 20% by 15 years to 2035 if population growth follows the central projection, and to 2030 if population growth is high. That said, it should be noted that the NIP also contains a significant budget for additional generation projects beyond 2030 that have yet to be defined, which is likely to alleviate any future energy shortfall. This analysis shows the importance of such future investments in energy as well as the importance of considering GHG emissions of these investments if the UK is to meet its Climate Change Act obligations.

The future for gas seems more robust; despite the decline in domestic gas supplies (which may have implications for future new investments in LNG), the current gas infrastructure is projected to keep the gas capacity margin above zero over the period from 2015 to 2040 without new capacity investment, under all growth scenarios. Only in the high-growth scenario is there a danger of the gas capacity margin dropping below zero beyond 2040.

For road transport, the NIP investments in this assessment are a very small proportion of the overall asset base; there is little effect at an aggregate national scale, but these investments can be seen to relieve local congestion hotspots. Nevertheless, increasing road capacity may not be enough to manage continued growth in demand, and the analysis suggests that more aggressive policy responses (in terms of investment and/or demand management) will be required.

For rail transport, the rollout of electrification schemes across the country will obviously have substantial impacts on the fuel mix used throughout the network, with around 20% of current diesel use switching to electricity by 2030.

The opening of Phase 1 of HS2 in 2026 is assumed to release a large number of extra trains along those affected links, with a further increase as Phase 2 opens in 2034. However, while there are more trains using the network, there will not be any overall impact on rail congestion. The amount of delay on those rail links drops to 2015 levels, against a background of continued growth in rail use.

For the water sector, changes in demand are estimated from water companies' Water Resource Management Plans, and future projections of demand produce a wide range of possible outcomes for Great Britain as a whole, from a reduction in demand in the low population/per capita demand scenario to a 20% increase in total demand by 2050 in the high population/per capita demand scenario.

The NIP investments amount to an 18% increase in water availability for Great Britain. However, this increase in supply is countered by a potentially larger decrease in yield from sustainability reductions which amount to around a 22% decrease in supply levels by 2025. In the central growth scenario, there follows a steady decline in supply-demand balance due to population and climate change. While the NIP investments help to alleviate potential problem in regional supply-demand balance when compared to a No Build future, there may still be shortages for specific regions.

Overall, this study has successfully identified the impacts of a large number of investments in future infrastructure for energy, transport and water. While the range of investments included in this assessment will provide some alleviation to current challenges for electricity capacity margins, road and rail congestion, and water supply-demand balances across Great Britain, there will inevitably be a need to reconsider how best to target future investments in new capacity and demand management, particularly against a background of population growth and climate change.

APPENDIX A

Translating from NIP to NISMOD: Examples of parameterisations

Example: Hinckley Point C

MinP = minimum power output (MW)
MaxP = maximum power output (MW)

BusNum (15) = SW England and Wales
(16 busbars overall see ES_LU_BusData)

AddCapex = user-defined project

GenID	GenNum	GenName	GenType	Type	BusNum	MinP	MaxP	Year	Retire	Connect	AddCapex	Residual
….	500	Hinkley Point C	Nuclear EPR	4	15	0	3200	2023	2083	0	1	0

Type (4) = Nuclear European Pressurised Reactor
(20 types overall – see ES_LU_GenType)

Image and logo taken from *"Hinkley Point C An Opportunity to Power the Future", February 2013.* Available at: https://www.edfenergy.com/sites/default/files/edf-energy-hinkley-point-c.pdf. Copyright

Year = year connected to grid
Retire = year of asset retirement
(fixed lifetime 60 yrs – see ES_I_NewGen_Base)

Example: M4 J3-J12 'Smart' Motorway

Year	Project	Zone1	Zone2	MLaneChange	DLaneChange	SLaneChange
2015	TR-118 M6 Junctions 10a to 13 Managed Motorway - Cost £55.3m	Staffordshire	West Midlands	2	-	-
2015	TR-119 A453 Widening - Cost £53.2m	Derbyshire	Nottinghamshire	-	2	-
2015	TR-119 A453 Widening - Cost £53.2m	Nottingham	Nottinghamshire	-	2	-
2017	TR-110 M1 Junctions 28 to 31 Managed Motorway - Cost £135.2m	Derbyshire	South Yorkshire	2	-	-
2019	TR-105 A6 Manchester Airport Relief Road - Cost £211.1m	Cheshire East	G. Manchester	-	4	-
2020	TR-106 Lower Thames Crossing - Cost £181.5m	Kent	Medway Towns	-	4	-
2022	TR-102 M4 J3 - J12 Managed Motorway - Cost £576m	Greater London	Slough	2	-	-
2022	TR-102 M4 J3 - J12 Managed Motorway - Cost £576m	Buckinghamshire	Slough	2	-	-
2022	TR-102 M4 J3 - J12 Managed Motorway - Cost £576m	Buckinghamshire	Windsor & Mhead	2	-	-
2022	TR-102 M4 J3 - J12 Managed Motorway - Cost £576m	Maidenhead	Wokingham	2	-	-
2022	TR-102 M4 J3 - J12 Managed Motorway - Cost £576m	Reading	Wokingham	2	-	-
2022	TR-102 M4 J3 - J12 Managed Motorway - Cost £576m	Reading	West Berkshire	2	-	-

APPENDIX B

Details of pipeline projects included in the assessment

Energy (NIP15) - only Top 40 projects assessed

	IUK Top 40		NISMOD NIP40		IUK All NIP projects		NISMOD NIP (same as NIP40)	
Sub-sector	**No. of projects & programmes**	**Total (£m)**	**No. of projects & programmes**	**Total (£m)**	**No. of projects & programmes**	**Total (£m)**	**No. of projects & programmes**	**Total (£m)**
Electricity Distribution	0	£0.00	0	£0.00	14	£18,363.80	0	£0.00
Electricity Generation (2 no cost info)	50	£81,210.00	46	£62,186.90	52	£140,292.40	46	£62,186.90
Electricity transmission (7 no cost info)	13	£4,627.10	7	£0.00	35	£18,633.60	7	£0.00
Gas Distribution (1 no cost info)	0	£0.00	0	£0.00	10	£6,094.00	0	£0.00
Gas Importation (2 no cost info)	0	£0.00	0	£0.00	2	£0.00	0	£0.00
Gas storage (3 no cost info)	0	£0.00	0	£0.00	4	£254.60	0	£0.00
Gas Transmission	0	£0.00	0	£0.00	5	£1,219.70	0	£0.00
Nuclear Decommissioning	0	£0.00	0	£0.00	33	£19,353.20	0	£0.00
Oil & Gas (1 no cost info)	2	£34,344.40	0	£0.00	2	£34,344.40	0	£0.00
Smart meters	1	£6,311.60	0	£0.00	1	£6,311.60	0	£0.00
Grand Total	66	£126,493.10	53	£62,186.90	158	£244,867.30	53	£62,186.90

Electricity generation (NIP15)

	IUK Top 40		NISMOD NIP40		IUK All NIP projects		NISMOD NIP	
Sub-sector	**No. of projects & programmes**	**Total (£m)**	**No. of projects & programmes**	**Total (£m)**	**No. of projects & programmes**	**Total (£m)**	**No. of projects & programmes**	**Total (£m)**
Advanced conversion technologies	3	£347.30	2	£285.70	3	£347.30	2	£285.70
Biomass	3	£1,233.60	3	£1,233.60	3	£1,233.60	3	£1,233.60
Biomass conversion	2	£717.70	2	£717.70	2	£717.70	2	£717.70
Capacity Market Auction	0	£0.00	0	£0.00	1	£257.70	0	£0.00
CCS commercialisation (2 no costs)	3	£919.20	2	£0.00	3	£919.20	2	£0.00
Energy from waste with CHP	2	£598.30	2	£598.30	2	£598.30	2	£598.30
Gas	3	£1,874.90	2	£1,257.90	3	£1,874.90	2	£1,257.90
Nuclear	3	£45,768.40	3	£45,768.40	3	£45,768.40	3	£45,768.40
Other generation investment to 2030	0	£0.00	0	£0.00	1	£58,824.70	0	£0.00
Other renewable investment to 2020	1	£17,425.20	0	£0.00	1	£17,425.20	0	£0.00
Photovoltaics	3	£39.40	3	£39.40	3	£39.40	3	£39.40
Wind offshore	9	£10,834.00	9	£10,834.00	9	£10,834.00	9	£10,834.00
Wind onshore	18	£1,462.00	18	£1,462.00	18	£1,462.00	18	£1,462.00
Grand Total	50	£81,220.00	46	£62,197.00	52	£140,302.40	46	£62,197.00

The following table shows which of the 'Top 40' energy projects and programmes are included in the NISMOD energy assessment.
Note that 'Date in service' and Cost information is taken from the National Infrastructure Pipeline 2015.

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
Electricity Generation	ENE148	Advanced Conversion Technologies	BHEG Walsall	2018/19	Yes	145.6
	ENE149		Energy Works (Hull)	2017/18	Yes	140.0
	ENE029	Biomass	Tees Renewable Energy Plant	2018/19	Yes	1,077.6
	ENE030		Ferrybridge Multifuel 1 ('C') Power Station	2015/16	Yes	89.5
	ENE031		Speyside Biomass CHP	2015/16	Yes	56.5
	ENE032		Drax Biomass Conversion	2016/17	Yes	541.4
	ENE033		Lynemouth Biomass Conversion	2017/18	Yes	176.3
	ENE037	CCS Commercialisation	Peterhead CCS project	TBC	Yes	-
	ENE038		White Rose CCS project	TBC	Yes	-
	ENE151	Energy from Waste with CHP	Wren Power and Pulp	2018/19	Yes	314.1
	ENE150		K3 CHP Facility	2018/19	Yes	284.1
	ENE182	Gas	CCGT - Trafford Power Station	2017/18	Yes	1,138.5
	ENE034		CCGT - Carrington Power Station	2015/16	Yes	119.4
	ENE040	Nuclear	Hinkley Point C	2023/24	Yes	16,294.9
	ENE041		Wylfa B	2024/25	Yes	15,276.5
	ENE042		Moorside	2025/26	Yes	14,197.0
	ENE153	Photovoltaics	Charity Farm	2016/17	Yes	14.9
	ENE152		Netley Landfill Solar	2016/17	Yes	12.2
	ENE154		Triangle Farm Solar Park	2016/17	Yes	12.2
	ENE051	Wind Offshore	Hornsea	2020/21	Yes	2,883.0
	ENE156		EA 1, Phase 1*	2017/18	Yes	1,745.2
	ENE052		Walney Offshore Wind Farm Extension	2019/20	Yes	1,735.8
	ENE047		Beatrice Wind Farm	2019/20	Yes	1,536.8
	ENE157		Neart na Gaoithe	2018/19	Yes	1,095.0
	ENE048		Dudgeon Offshore Wind Farm	2017/18	Yes	959.0
	ENE050		Burbo Bank Extension	2017/18	Yes	648.4
	ENE049		Westermost Rough	2015/16	Yes	120.7
	ENE054		Humber Gateway Offshore Wind Farm	2015/16	Yes	110.1
	ENE160	Wind Onshore	Dorenell Wind Farm	2017/18	Yes	270.4
	ENE057		Pen Y Cymoedd	2016/17	Yes	256.6
	ENE167		Kype Muir Wind Farm	2017/18	Yes	158.9
	ENE165		Clocaenog Forest Wind Farm	2017/18	Yes	146.7
	ENE172		Middle Muir Wind Farm	2019	Yes	91.7
	ENE169		Brenig Wind Farm - Brenig Wind Limited	2016/17	Yes	68.7
	ENE158		Mynydd Y Gwair Wind Farm	2017/18	Yes	61.1

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
Electricity Generation (contd.)	ENE163	Wind Onshore (contd.)	Nanclach Wind Farm	2018/19	Yes	59.7
	ENE159		Solwaybank Wind Farm	2018/19	Yes	57.3
	ENE171		Sneddon Law Community Wind Farm	2017/18	Yes	57.3
	ENE055		Strathy North	2015/16	Yes	51.9
	ENE161		Coire Na Cloiche Windfarm	2018/19	Yes	45.8
	ENE164		Bad a Cheo Wind Farm	2018/19	Yes	45.7
	ENE166		Tralorg Wind Farm	2018/19	Yes	30.6
	ENE168		Moor House Wind Farm	2018/19	Yes	25.1
	ENE162		Achlachan Wind Farm	2018/19	Yes	15.3
	ENE056		Heckington Fens	TBC	Yes	10.0
	ENE170		Common Barn Wind Farm	2018/19	Yes	9.4
Electricity Transmission	ENE083	Interconnectors	NEMO	2019	Yes	-
	ENE084		FABlink	2021	Yes	-
	ENE085		Eleclink	2017	Yes	-
	ENE086		IFA2	2020	Yes	-
	ENE087		NSN	2020	Yes	-
	ENE088		Viking	2021	Yes	-
	ENE089		Greenlink	2021	Yes	-

The following projects and programmes are not included in the NISMOD energy assessment:

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
Electricity Generation	ENE185	Advanced Conversion Technologies	Enviroparks Hirwaun Generation Site	2017/18	Yes	61.6
	ENE036	CCS Commercialisation	CCS Commercialisation Programme	2019/20	Yes	919.2
	ENE035	Gas	Other gas investment	2020/21	Yes	617.0
	ENE045	Other renewable investment to 2020	Other renewable investment to 2020	2020/21	Yes	17,425.2
Electricity transmission	ENE075	Electricity transmission	West Coast HVDC link	2012	Yes	288.8
	ENE072		London Power Tunnels	2015-2019	Yes	241.6
	ENE064		Western HVDC link UC-NA2883	2017	Yes	165.8
	ENE068		TIRG - Beauly-Denny 400kV line UC-5920042	2016	Yes	95.1
	ENE061		Beauly-Denny 400kv line	2015	Yes	57.4
	ENE082	Interconnectors	Interconnector Investment	2021	Yes	3,778.4
Oil & Gas	ENE146	Shale Gas Exploration	Shale Gas Exploration	TBC	Yes	-
Smart meters	ENE147	Smart meters	Smart meters rollout	2020	Yes	6,311.6

Transport (NIP15)

	IUK Top 40		NISMOD NIP40		IUK All NIP projects		NISMOD NIP	
Sub-sector	No. of projects & programmes	Total (£m)	No. of projects & programmes	Total (£m)	No. of projects & programmes	Total (£m)	No. of projects & programmes	Total (£m)
Airports	8	£3,653.40	0	£0.00	21	£6,001.20	0	£0.00
Crossrail	1	£5,658.20	0	£0.00	1	£5,658.20	0	£0.00
High Speed Rail	2	£49,685.00	1	£40,623.00	2	£49,685.00	1	£40,623.00
LA Majors (2 no cost info)	10	£991.60	6	£610.20	83	£13,524.70	12	£809.80
London (1 no cost info)	6	£4,456.10	0	£0.00	39	£14,531.10	1	£33.00
Ports (7 no cost info)	14	£673.70	0	£0.00	14	£673.70	0	£0.00
Potholes Fund	0	£0.00	0	£0.00	0	£0.00	0	£0.00
Rail (6 no cost info)	25	£5,903.20	7	£2,755.50	51	£23,171.10	10	£3,261.80
Roads - HE Majors (excl RIS) (15 no cost info)	17	£2,234.60	17	£2,234.60	51	£7,332.40	40	£2,701.00
Roads - HE Majors (RIS) (16 no cost info)	5	£0.00	4	£0.00	21	£2,463.90	4	£0.00
Roads - HE pinchpoints	0	£0.00	0	£0.00	9	£192.60	0	£0.00
Roads - HE Renewals	0	£0.00	0	£0.00	1	£4,046.40	0	£0.00
Roads - LA pinchpoints	0	£0.00	0	£0.00	9	£160.20	0	£0.00
Grand Total	69	£73,255.80	32	£46,223.30	270	£127,440.50	66	£47,428.60

NOTE: Where no cost profile is provided in NIP, NISMOD provides estimated costs using aggregate costs per type of capacity increase (which may differ from IUK estimates)

The following table shows which of the 'Top 40' energy projects and programmes are included in the NISMOD energy assessment.
Note that 'Date in service' and Cost information is taken from the National Infrastructure Pipeline 2015.

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
High Speed Rail	TPT023	High Speed Rail	National high speed rail network (Phase 1&2)	2033	Yes	14,503.4
Rail	TPT156	East-West Rail and Electric Spine	Electric spine	2021	Yes	806.6
	TPT155		East West Rail	2019	Yes	269.9
	TPT157	Great Western Programme	Great Western Electrification	2018	Yes	673.4
	TPT158		Welsh Valleys electrification	2019	Yes	289.7
	TPT160	Midland Main Line Programme	Midland Mainline Electrification	2020	Yes	460.1
	TPT196	North of England Programme	North Trans Pennine Electrification	TBC	Yes	160.4
	TPT193		North West Electrification	2018	Yes	95.3
LA Majors	TPT078	LA Major	Mersey Gateway	2017	Yes	238.4
	TPT063		A6 to Manchester Airport Relief Road	31/10/2017	Yes	141.7
	TPT060		Norwich Northern Distributor Road	31/12/2017	Yes	71.6
	TPT065		Heysham to M6 Link Road	30/06/2016	Yes	52.0
	TPT064		Kingskerswell By-pass (Devon/Torbay A380)	31/12/2015	Yes	12.2
	TPT076		Sunderland Strategic Corridor	01/12/2017	Yes	94.3
Roads - HE Majors	TPT203	AS 2011 (Growth Scheme)	M1 / M6 Junction 19 Improvement	Q3 2016/17	Yes	89.9
	TPT204		A453 Widening	Q2 2015/16	Yes	7.3
	TPT207		M3 Junctions 2 to 4a	Q1 2017/18	Yes	117.9
	TPT208		M6 Junctions 10a to 13	Q3 2015/16	Yes	14.8
	TPT212	AS 2012 (Funded for Delivery)	A1 Leeming to Barton	Q1 2017/18	Yes	205.9
	TPT209	AS 2012 (Funded for Delivery)	A5-M1 Link Road	Q1 2017/18	Yes	114.1
	TPT211	AS 2012 (Funded for Delivery)	A1 Lobley Hill (A1 Coal House to Metro)	Q1 2016/17	Yes	35.3
	TPT210	AS 2012 (Funded for Delivery)	A30 Temple Carblake	Q3 2016/17	Yes	20.9
	TPT202	AS14 (Feasibility Schemes in RIS)	A303/A30/A358 corridor	TBC	Yes	-
	TPT277a	AS14 (Feasibility Schemes in RIS)	A1 North of Newcastle	TBC	Yes	-
	TPT215	AS14 (Major Projects Pipeline Schemes)	Lower Thames Crossing	TBC	Yes	-
	TPT276c	AS14 (RIS 1 Period)	A30 Chiverton to Carland Cross	TBC	Yes	-
	TPT276j		M42 Junction 6	TBC	Yes	-
	TPT219	SR10 committed starts	M60 J8 to M62 J20	Q2 2017/18	Yes	139.5
	TPT217		A556 Knutsford to Bowdon	Q4 2016/17	Yes	125.3
	TPT221		M1 Junctions 28 to 31	Q4 2015/16	Yes	50.9
	TPT220		M1 Junctions 39 to 42	Q3 2015/16	Yes	38.6

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
Roads - HE Majors (contd.)	TPT222	SR13 Funded for Delivery	A14 Cambridge to Huntingdon	2020/21	Yes	1,206.1
	TPT214		A160 / A180 Immingham	2016/17	Yes	67.8
	TPT223		M4 J3 - J12 Managed Motorway	2021/22	Yes	-
	TPT230		A2 Bean & Ebbsfleet	2022/23	Yes	-
The following projects and programmes are not in the 'Top 40', but are included in the NISMOD transport assessment:						
Rail	TPT119	London Overground	Gospel Oak to Barking - electrification	2018		33.9
	TPT164	Network Rail	West Coast and Midlands CP5 scheme	2019		52.7
	TPT178	Network Rail - electrification	Scotland - Electrification	2019		147.8
	TPT179	Network Rail - Other	Edinburgh Glasgow Improvement Programme	2019		305.9
LA Majors	TPT097	LA Major	Lincoln Eastern Bypass	31/05/2018		74.8
	TPT061		Bexhill-Hastings Link Road	30/09/2015		12.8
	TPT027	Local Growth Funding (Transport)	Crewe High Growth City - Congleton Link	2019		41.4
	TPT037		Preston Western Distributor	TBC		28.0
	TPT025		M6 Junction 10	2019		27.3
	TPT034		Grantham Southern Relief Road	2017		15.4
Roads - HE Majors	TPT205	AS 2011 (Growth Scheme)	A45 / A46 Tollbar End	Q3 2016/17		33.4
	TPT206	AS 2011 (Growth Scheme)	A14 Kettering Bypass	Q1 2015/16		- 1.8
	TPT213	AS 2012 (Funded for Delivery)	M25 Junction 30	Q1 2017/18		61.3
	TPT216	SR10 committed starts	M1 Junctions 32 to 35a	Q4 2016/17		74.8
	TPT226	SR13 Funded for Delivery	A63 Castle Street	2020/21		142.2
	TPT228		M20 Junction 10a	2018/19		61.4
	TPT231		A19 Testos	2020/21		50.4
	TPT227		A21 Tonbridge to Pembury	2016/17		44.7
	TPT224		M5 J4a-6	2017/18		-
	TPT225		M6 J16-19	2018/19		-
	TPT234		M54 / M6 / M6 Toll	2021/22		-
	TPT235		M23 J8-10	2019/20		-
	TPT236		M6 J13-15	2021/22		-
	TPT237		M1 J13-19	2021/22		-
	TPT238		M1 J24-25	2017/18		-
	TPT239		M20 J3-5	2019/20		-
	TPT240		M6 J21a-26	2019/20		-
	TPT241		M6 J2-4	2019/20		-
	TPT242		M27 J4-11	2020/21		-
	TPT243		M3 J9-14	2021/22		-

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
Roads - HE Majors (contd.)	TPT244	SR13 Funded for Delivery (contd.)	M56 J6-8	2021/22		-
	TPT245		M62 J10-12	2022/23		-
	TPT246		M60 J24-27 & J1-4	2019/20		-
The following 'Top 40' projects and programmes are not included in the NISMOD transport assessment:						
Airports	TPT010	Airports	Heathrow Capital Investment Programme Q6	2019	Yes	2,475.2
	TPT003		Gatwick CIP Q6 - Asset Stewardship	2020/21	Yes	458.5
	TPT001		Gatwick CIP Q6 - remainder	2020/21	Yes	321.6
	TPT004		Gatwick CIP Q6 - Pier Service in N.Terminal	TBC	Yes	152.7
	TPT007		Gatwick CIP Q6 - HBS Replacement	TBC	Yes	107.1
	TPT006		Gatwick CIP Q6 - South Terminal IDL Capacity	TBC	Yes	58.6
	TPT005		Gatwick CIP Q6 - North Terminal IDL Capacity	TBC	Yes	57.4
	TPT002		Gatwick CIP Q6 – S.Terminal Baggage & Pier 1	TBC	Yes	22.5
Crossrail	TPT021	Crossrail	Crossrail	2019	Yes	5,658.2
High Speed Rail	TPT022	High Speed Rail	Rolling Stock - HS2	TBC	Yes	7,765.6
LA Majors	TPT077	LA Major	Leeds New Generation Transport	31/07/2021	Yes	211.6
	TPT066		Croxley Rail Link (Watford)	31/05/2018	Yes	160.7
	TPT059		Midland Metro	31/12/2015	Yes	9.1
	TPT058		Nottingham NET2	30/09/2015	Yes	-
London	TPT101	Crossrail	Crossrail - new trains and depot works	2020/21	Yes	973.1
	TPT111	Station Upgrades	Bank - station upgrade	2021	yes	430.1
	TPT126	The Tube - Line upgrades	Sub-surface Railway Upgrade	2022	Yes	1,388.3
	TPT125		Northern Line Extension	2020	yes	807.9
	TPT124		Northern Line Upgrade 2 & 3	2022	yes	595.3
	TPT122		World Class Capacity	2020	yes	261.4
Ports	TPT129	Biomass Terminal	Liverpool Biomass Terminal	01/07/2016	Yes	-
	TPT130	Cargo and Logistics	Port of Dover – W.Docks and Marina Areas	2020	Yes	105.5
	TPT131		Forth Ports	TBC	Yes	-
	TPT134	Container ports	Liverpool2	2015	Yes	89.7
	TPT133		Port Salford Terminal	TBC	Yes	48.2

Sub-Sector	MIT identifier	Sub-Group	Project / Programme Name	Date in Service (Actual/Projected)	Top 40 Priority	2015/16 onwards (£m constant)
Ports (contd.)	TPT132	Container ports (contd.)	Felixstowe South	2015	Yes	16.4
	TPT135		Bristol Port	2021	Yes	-
	TPT136		Teesport	2017	Yes	-
	TPT137	Fishing	Peterhead port - Harbour Development	TBC	Yes	-
	TPT138	Fishing & Oil	Lerwick investment programme	2016	Yes	24.5
	TPT139	Mixed Ports investments	AB Ports Capital Investment Programme	various	Yes	357.1
	TPT140	Oil	Aberdeen Harbour	TBC	Yes	-
	TPT141	RoRo and Cargo	Port of Tyne	TBC	Yes	-
	TPT142	RoRo, Cargo, Cruise, Heritage	Port of Dover - capital investment plan	2016	Yes	32.4
Rail	TPT153	Airport/Port Connectivity - Rail	Rail Access - Ports and Airports	2018	Yes	49.3
	TPT154	East Coast Mainline	East Coast Connectivity	2019	Yes	249.9
	TPT159	Great Western Programme	Reading Station Area Redevelopment	2015	Yes	33.3
	TPT161	Midland Main Line Programme	Derby Station Area Remodelling	2017	Yes	64.8
	TPT162		Remainder of Midland Mainline programme	2019	Yes	25.0
	TPT176	Network Rail	European Rail Traffic Management System	2020	Yes	187.7
	TPT180	Network Rail - Other	Thameslink	2018	Yes	1,286.3
	TPT184	Network Rail - Other	Intercity Express Programme - Infrastructure	2017	Yes	230.7
	TPT182	Network Rail - Other	Strategic freight network	2019	Yes	167.8
	TPT188	Network Rail - Stations	Bristol Temple Meads	2018	Yes	32.1
	TPT189	Network Rail - Stations	Birmingham New Street	01/09/2015	Yes	10.5
	TPT190	Network Rail - Stations	Manchester Victoria	2015	Yes	-
	TPT194	North of England Programme	Northern Hub	2018	Yes	440.8
	TPT197	South West Route Capacity	Waterloo station and surrounding works	2019	Yes	313.7
	TPT198		South West Route Capacity: Remainder	2017	Yes	56.0
	TPT199	Strategic Rail Freight Interchange	E.Midlands Intermodal Park	TBC	Yes	-
	TPT200		E.Midlands Gateway Rail Freight Interchange	TBC	Yes	-
	TPT201		Daventry International Rail Freight Terminal	TBC	Yes	-
Roads - HE Majors	TPT276f	A514 (RIS 1 Period)	A5036 Port of Liverpool	TBC	Yes	-

Water supply (NIP15)

Sub-sector	NISMOD NIP40 No. of projects & programmes	Total (£m)	Yield (ML/yr)
New abstractions	3	**£73+**	23,140
Licence variations	2	**£5+**	7,700
New reservoir	1	**£103**	5,950
Leakage reduction	28	**£260+**	71,680
Transfers	6	**£2+**	22,460
New groundwater	2	**6+**	1,970
Grand Total	**42**	**£449+**	**132,900**