Scotland

National Needs Assessment (NNA)

Demand drivers

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1. Introduction

This report provides an update on the collaborative work being carried out by members of the Infrastructure Transitions Research Consortium (ITRC), with the Institution for Civil Engineers (ICE), using methods and tools developed by ITRC to assess Great Britain's long-term infrastructure needs. This report builds on previous work used by the ICE to inform the UK National Needs Assessment (NNA), and is focused on Scotland.

The report initially gives an overview of ITRC (Section 1.1) and the assessment framework (Section 2). Section 3 sets out the demand drivers for each of the sectors under consideration (energy, transport, digital communications, water and waste), firstly by assessing historical trends in demand, then giving a brief overview of the likely impacts of the main drivers of demand in the future, as well as any policies or plans which may affect demand for infrastructure services.

1.1 Background to the 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 numerous partners in government and industry.

The first 5-year research programme (ITRC) 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, digital communications, water and waste systems at a national scale, 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 policy constraints such as reliability and security of supply, cost, carbon emissions, and adaptability to demographic and climate change. The assessment of infrastructure needs carried out for the NNA for Great Britain, and subsequently informing the National Infrastructure Commission's ongoing work is one example of how this virtual test environment can be adapted to assess a particular range of infrastructure investments and choices.

A major output from the programme has been the development of a series of pioneering models, known collectively as the National Infrastructure System Model (NISMOD) family, with supporting database, 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 future changes in demand and supply of infrastructure services has been undertaken for Great Britain 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 water, solid waste and digital communications 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 for the NNA, the focus of the study will be upon energy (electricity and gas), transport (road, rail, airports and ports), digital communications, water supply, wastewater treatment and solid waste. In addition, new insights will be provided on flood risk management thanks to collaboration with the Environment Agency.

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 of the provenance of results. NISMOD-DB also enables visualisation of the data and simulations held in the database.

1.2 The role of ITRC in previous NNA work

NISMOD-LP and the associated datasets provide unique capability to analyse long term performance of national infrastructure strategies, thereby providing analytical capability to support the NNA. For the previous study with ICE, the ITRC analysis comprised of three main tasks:

1. **Analysing the future drivers of demand for infrastructure services, to give a sense of the scale of necessary future provision.**
2. **Specifying possible strategies for national infrastructure provision** in conjunction with the Executive Group at ICE, developing a long-term vision for national infrastructure, comprising a timeline and series of choices, and a sequence of interventions which were subsequently tested in the NISMOD-LP model.
3. **Testing alternative strategies for national infrastructure provision** using the NISMOD-LP system, providing analysis of their performance with respect to a range of possible future scenarios.

This report provides initial analysis of the scale of future demand for national infrastructure services, set out in Task 1 above. Obviously the magnitude of demand depends also on the nature and cost of services that are available, so demand cannot be analysed in isolation. The projections contained herein therefore all contain a wide range of uncertainties, above all because they are contingent on future policy interventions. Nonetheless, understanding of the drivers of change and consequent possible scale of demand for infrastructure services helps to ground a national infrastructure strategy in quantitative terms.

2. Overview of ITRC's long-term infrastructure assessment framework

This section of the report introduces the assessment framework that underpins NISMOD-LP, which was used to inform the NNA for Great Britain.

Three important aspects of the assessment framework include:

i) *Strategies* are sets of choices, or rationales for taking choices, about the provision of infrastructure services. Strategies will typically involve investment in the provision of infrastructure combined with instruments to manage infrastructure demand. They extend across infrastructure sectors (energy, transport, digital communications, water, flooding and waste), so are built up of strategic options from each of the sectors;

ii) *Scenarios* describe the main factors that are outside the direct control of infrastructure decision-makers, which influence the future performance of strategies. They include changes in population, the economy, global energy prices and the climate. The processes that determine what scenarios will materialise are outside the scope of our sector modelling systems, so are said to be 'exogenous'. Future changes in these phenomena are uncertain, so we test a wide range of possible scenarios to analyse the sensitivity of future infrastructure performance to those scenarios; and,

iii) *Systems models* are used to analyse the performance of strategies in the context of given scenarios. The system models take as inputs the current state of the infrastructure system and the demands placed upon it, strategies for each infrastructure sector and scenarios of exogenous changes. The models output projections of infrastructure performance, given those input conditions.

Figure 1 provides an overview of the assessment framework, including the relationships between exogenous scenarios, endogenous strategies and the sector infrastructure systems models. All aspects of the assessment have been developed with input from government and industry.

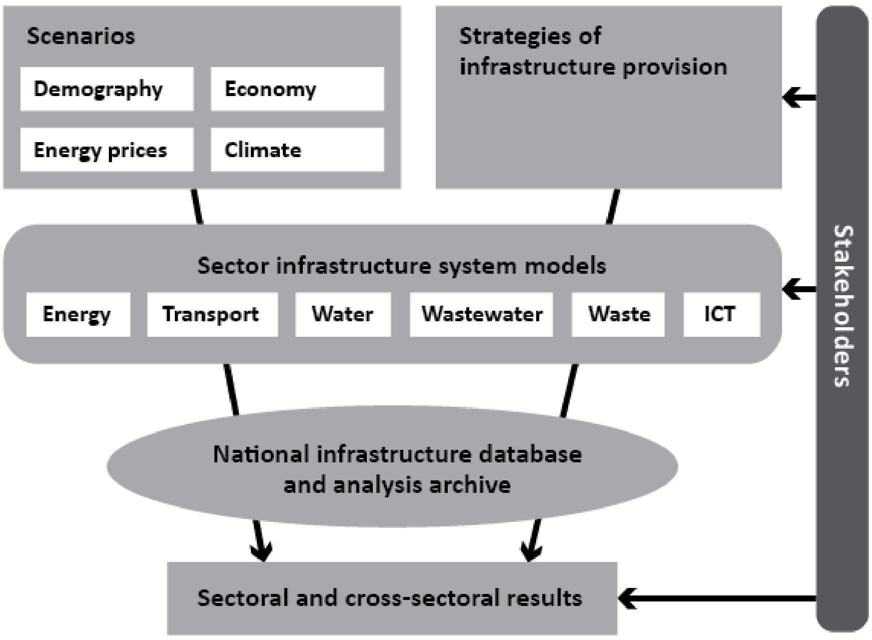

Figure 1: Overview of the assessment framework

3. Drivers of demand for infrastructure services

This section of the report introduces the key *drivers of demand for infrastructure services* in Scotland. For the GB assessment, these drivers provided key information to help construct scenarios (exogenous demand drivers) and strategies (endogenous demand drivers) used for the NNA assessment.

3.1 Introduction

The nature and scale of demand for national infrastructure services is driven by long-term changes in population, the economy, technology, society and the environment. However, how those factors affect the longer-term demand for infrastructure is not straightforward. Investment in infrastructure will be challenged by a number of fundamental long-term trends that include demographic developments (e.g. migration, ageing, household fragmentation and urbanisation), increasing constraints on public finances, environmental factors (e.g. climate change), technological progress (especially in the area of information and communication technology, as well as efficiencies in transport and energy), trends in governance (particularly decentralisation), an expanding role for the private sector, and an increasing need to maintain and upgrade existing infrastructures (OECD, 2007).

The following sub-sections provide an overview of the most important demand drivers, highlighting those that are endogenous to the system (forming the NISMOD-LP strategies) and exogenous to the system (forming the NISMOD-LP scenarios). Given their uncertain nature, we organise exogenous drivers into scenarios that represent a set of plausible future conditions for infrastructure planning, which provide a consistent and crosscutting framework for the analyses of demand and supply of the different infrastructure sectors.

Starting with a summary of historic demand trends, the section then outlines the likely trajectory for demand of infrastructure services by sector. Projections are completed for a range of different future conditions (scenario and strategy) highlighting the important interplay between different demand drivers.

3.2 Scenario-related demand drivers

3.2.1 Demography

The ITRC population projection model has been used to extend the range of ONS projections and disaggregate those projections to a high enough resolution to be used for infrastructure planning. The population model is driven by three components: fertility (birth rate), mortality (death rate) and migration. These three drivers of population change are interdependent. To explore the range of potential demographic futures a consistent framework is required to determine how each component should be varied relative to the others. Scenarios have been specified by combining parameter settings (‘high’ or ‘low’) of these three model drivers (fertility, mortality and migration), taking account of co-dependency between them. Cutting across these drivers is a ‘prosperity’ dimension which has a positive influence in population. For example, low mortality would be expected under a high prosperity scenario, with the opposite occurring with low prosperity.

For the previous studies, three scenarios were developed, each with a high and a low dimension resulting in a total of 8 different scenario combinations, allowing for a future assessment of i) population growth, ii) ageing, and iii) urbanisation and the implications for future infrastructure demand in the UK. However, previous modelling work did not include Scotland specifically, so for simplicity, this report adopts the ONS principal projection for Scottish population (National Records for Scotland, 2017, 2018) which has been extended to 2050 (using the average change between 2030 and 2040 to estimate the change from 2041 to 2050). These figures provide the basis of the Baseline projection for this study, against which future change is compared.

Population growth

As shown in Figure 2, population growth in Scotland is not inevitable. The extended ONS principal projection for Scotland assumes a change of 5.3% in total population between 2016 and 2041 (6.2% growth to 2050). The highest rate of growth (assuming higher rates of fertility, longevity and migration) is 13.2% to 2041 (17.3% to 2050), while the low estimate gives a decrease of -3.3% in 2041 (-6.4% in 2050). The range of estimated population in 2050 is between 5.06 and 6.34 million, with the principal projection of 5.74 million. This following analyses are based on the principal projection, a growth of 6.2% population to 2050, which will have direct and significant implications in terms of demand for infrastructure services, across all sectors.

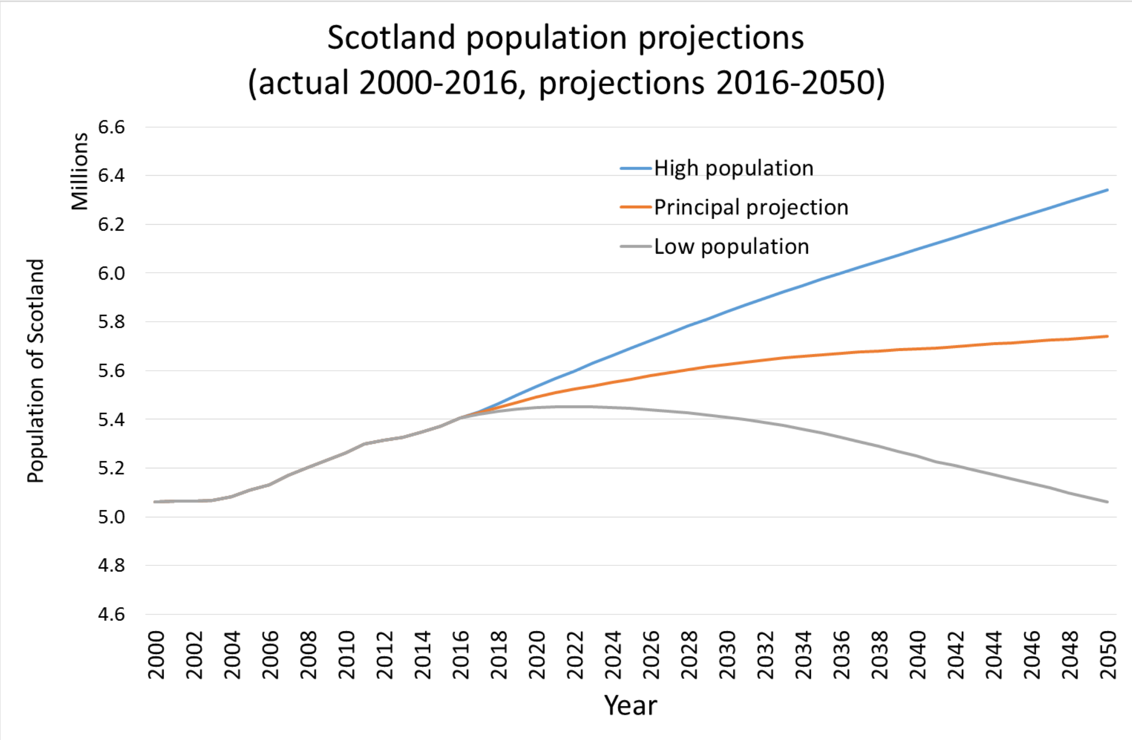

Figure 2: Projected total population of Scotland, under the 2016-based principal, high and low variant projections, 2006-2050 (Source: adapted from National Records of Scotland, 2019)

At the LAD level, the (principal projection) population change between 2016 and 2026 can be seen in Figure 3. Council areas projected to decrease in population are concentrated in the west of Scotland, while much of the expected growth occurs in the northeast of Scotland, and around Edinburgh and the region near the southern coast of the Firth of Forth. According to the National Records of Scotland report (2018), the two main components driving these changes are natural change (i.e. the number of births minus the number of deaths) and net migration. Most of the projected growth is attributable to migration – between 2016 and 2026 Midlothian (+10.9%), East Lothian (+8.3%) and East Renfrewshire (+7.9%) are projected to experience to highest increases in population from net migration.

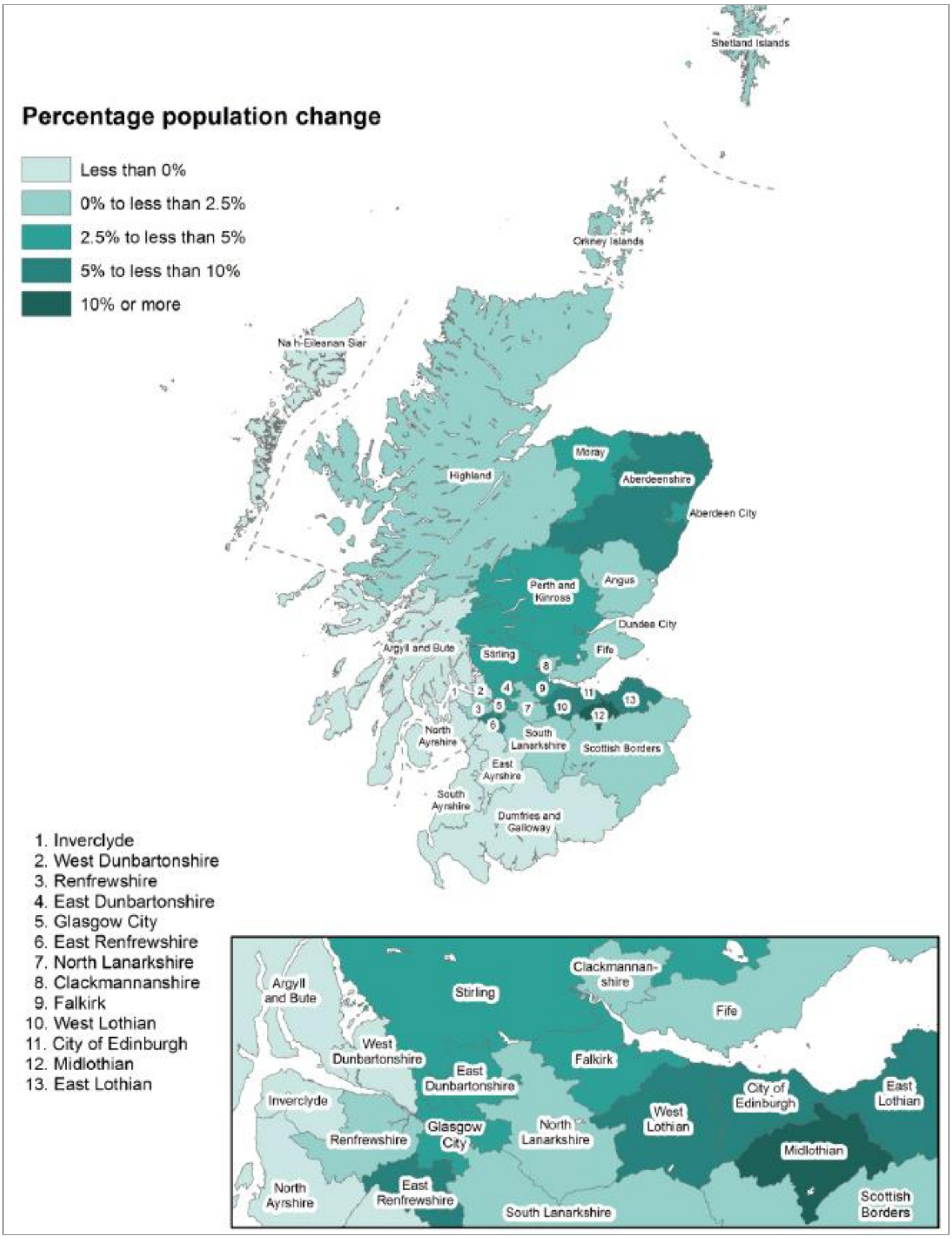

Figure 3: Projected percentage change in population, buy council area, 2016 to 2026 (from National Records of Scotland (2018, Figure 2b, p12))

Aging

Across the UK, the population structure is expected to age markedly in all future scenarios, and a population pyramid showing the projected numbers by age comparing 2015 and 2014 is shown in Figure 4. A more elderly population has important policy impacts in terms of the kinds of transport services that need to be provided (e.g. investment in appropriate public transport) but also in relation to varying patterns of consumption for energy, water and waste.

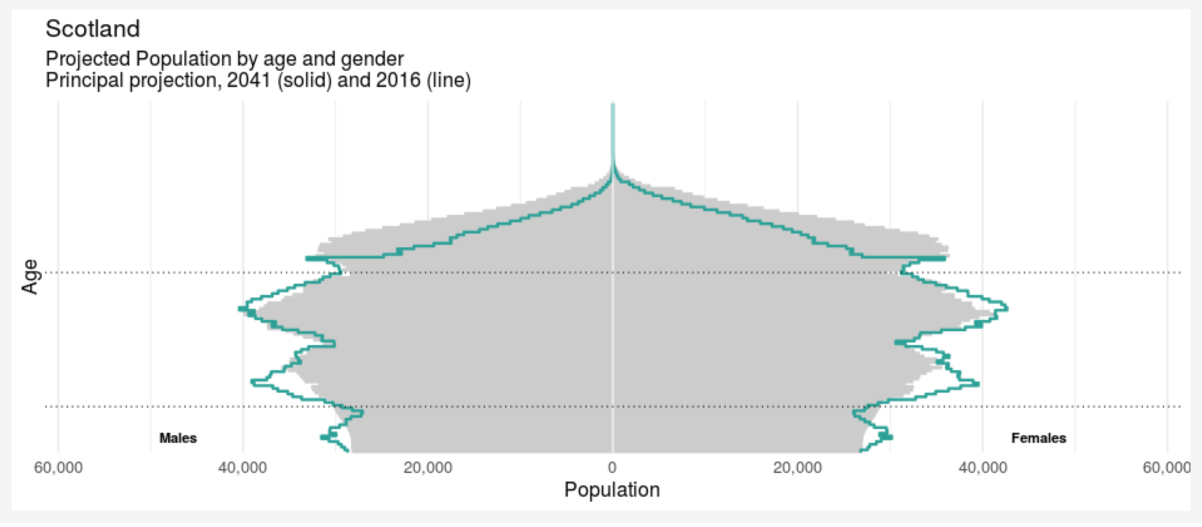

Figure 4: Population pyramid comparing 2016 and 2041 principal projection (Source: National Records of Scotland, 2019)

The relatively slow uptake of information technology amongst more elderly consumers is also important for example, by not leveraging the full potential of efficiency improvements such as accessing integrated transport services or energy demand management in households.

Urbanisation

Figure 3 shows that the prospects for urbanisation vary markedly across the regions of Scotland. The balance of demographic growth between rural and urban areas is an important question with potentially profound implications for infrastructure policy. For example, counter-urbanisation might be relatively favourable for the future provision of waste sites and would take the pressure off congested urban road networks; conversely, it might encourage use of space for the construction of larger properties with greater household energy and water requirements, and increase the demand for transport between rural and urban areas.

Urbanisation also has governance implications. Throughout the UK, local authorities have become increasingly active in some infrastructure sectors (e.g. energy), whilst in others they have traditionally played a central role (e.g. waste and transport). This has opened up opportunities for more co-ordination of infrastructure development at a local level, albeit in the context of severe limitations on local government finances.

3.2.2 Economy

World economic growth (i.e. outside of the UK) affects UK and Scottish economic performance through changes in prices and patterns of trade. Meanwhile, an increase in population tends to increase the total level of household expenditure and different regional demands for infrastructure services. If the infrastructure stock is to meet the needs of a growing economy it is essential to forecast how the demand for each of the key sectors of infrastructure may change. Economic scenarios for the UK have been generated from Cambridge Econometrics' (CE's) MDM-E3 model of the UK economy. These scenarios are based on the following key sets of assumptions:

- UK population by region – these used the 8 demographic scenarios discussed above (Section 3.2.1) as direct inputs for generating economic scenarios;
- World economic growth – these were developed by CE to represent a range of world economic conditions that affect UK international trade with the rest of the world. Three variants are used:
  - Central: a baseline view with non-UK economic growth averaging 3.5% p.a. over 2016–2020, and 4–5% p.a. over 2020–2050;
  - High: average non-UK economic growth of 4% p.a. over 2016–2020, rising to 5–6% over 2020–2050;
  - Low: non-UK economic growth of 2% p.a. over 2016–2020 and growth of 3–3.5% p.a. from 2020–2050.
- Fossil fuel prices – these are based on the UK Department for Energy and Climate Change (DECC) fossil fuel-price assumptions from the most recent Updated Energy and Emissions Projections publication extended to 2050 (DECC, 2012). Three nominal price variants are used shown in Figure 5.

	Central	High	Low
Oil ($/bbl)	245	496	204
Gas (p/therm)	183	263	105
Coal (£/tonne)	199	313	126

Source: DECC Updated Energy and Emissions Projections, CE calculations.

Figure 5: Fossil fuel price assumptions in 2050 (nominal)

The three assumption sets outlined above represent the complete scenario space of economic projections. Combining all variations results in a possible 72 scenario projections.

Economic trends

The direct effect of an increase in population is an increase in the level of household expenditure, principally on services rather than manufacturing. While some of the ITRC population scenarios are similar in their projections of total population, their corresponding demographic structures are not. These structural differences (i.e. proportion of working age) introduce supply-side differences in the availability of labour, altering wages and household incomes. The scenarios indicate that throughout the UK, services will continue to dominate GVA by 2050, with most activity in London and the surrounding regions, a reflection of the continued dominance of these regions in the underlying population projections.

	GVA per capita (£)	Total GVA (£m)	Share of UK total GVA
England	26,159	1,433,164	86.0
Northern Ireland	18,584	34,410	2.1
Scotland	23,685	127,260	7.6
Wales	18.002	55,788	3.3

Table 1: Economic statistics for UK regions (Source: ONS)

Our macro-economic modelling projects UK GDP in the range £2.7–3.7 trillion by 2050. Scotland contributes around 8% to this total (see Table 1 for GVA). We have explored a range of projections for the structure of the UK economy and patterns of employment, though in all cases London and the surrounding regions continue to dominate, with a corresponding requirement for infrastructure services in this part of Britain.

Economic change will affect the population's ability to utilise infrastructure services, where higher GDP is likely to result in higher demand for infrastructure services, as people tend to consume more energy and travel further and more often. Economic growth may also affect governmental and infrastructure owners' ability to invest in infrastructure systems.

3.2.3 Energy prices

Global fossil-fuel costs affect operating costs and transport costs in particular. Increased costs will therefore reduce levels of demand for services. National policy measures such as carbon taxes may affect these costs, but these are generally assumed to be exogenous to the models.

3.2.4 Climate change

Climate change will affect infrastructure systems differently depending on which climate variable (temperature, precipitation etc.) is under consideration. For example, a general increase in winter temperatures is expected to reduce energy demand used for heating during these times. Conversely, warmer summers will require more energy for cooling purposes.

Climate change will also affect the availability of water resources and the potential for extreme loads on infrastructure systems. The supply-demand balance is a key measure of water resource sustainability. This balance is highly uneven across Scotland with much of the demand for water in the drier east. Agricultural irrigation is increasing in many areas, linked to land use change and requirements for high-quality produce. Brown et al. (2012) developed maps showing climate risks to Scottish catchment areas in 2050 (based on the regional climate model used in the UKCP09 projections and integrated with the supply and demand models to estimate potential future change). As seen in Figure 6, the projected reduction in summer flows, particularly in East Scotland, makes it unlikely that increased demand can be met by additional abstraction without negative environmental impacts.

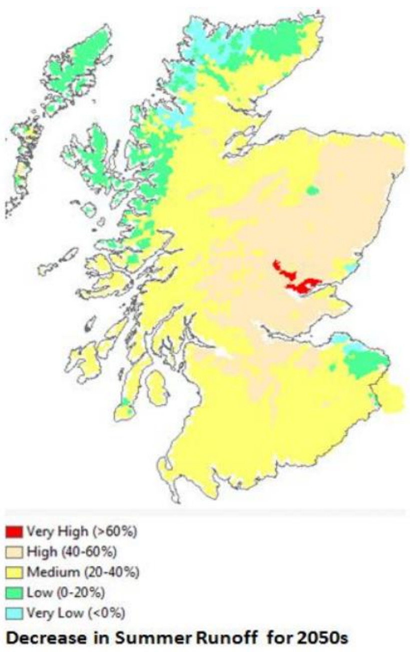

Figure 6: Climate change risks for Scottish water catchment areas (Source: Brown et al. (2012))

By the 2030s, climate change impacts on the amount of water available for public water supply could affect nearly a quarter of Scotland's water resource zones (Wallingford, 2015), although the northern most catchment areas of Scotland are projected to maintain a high level of water availability under all the future scenarios (Wallingford, 2015).

3.3 Strategy-related demand drivers

In practice, the partitioning between factors under the control of decision-makers (strategies), and external changes over which they have no control (scenarios) is not clear-cut. Behavioural change and technological change in particular lie on the boundary between controllable and uncontrollable factors.

3.3.1 Technology

We broadly assume that choices about the uptake of technology lie within the strategic choices available to decision-makers, whilst acknowledging that technological development, more broadly, is a global process, and is therefore out of control of a national decision-maker. Nonetheless, the large-scale nation-wide application of a specific technology (e.g. smart meters, domestic energy storage, shale-gas extraction, district heating, carbon capture and storage, desalination, ubiquitous road user charging, autonomous vehicles) is within the authority of national legislation and regulation, whereas some external technology-related factors, such as global energy prices, are considered to be exogenous.

3.3.2 Behaviour

Similarly, there are many processes of behavioural change that are largely outside the control of decision-makers. For example we assume demographic changes like household size or internal migration to be outside the control of infrastructure decision-makers, even though these issues will profoundly change the demand for future infrastructure services. These are exogenous variables in our analysis. On the other hand, instruments that are intended to directly influence the demand for infrastructure services, such as road-user charging and energy 'demand response', are taken as being part of the infrastructure strategy and have an assumed effectiveness.

3.4 Demand outlook by infrastructure sector

Since no modelling results were available relating specifically to Scotland for this sectoral analysis, the future demand assessments below rely on assumptions based on the previous results for Great Britain.

3.4.1 Energy

Historical demands for energy in Scotland

Historically, for the UK as a whole, electricity consumption has steadily increased over the whole period of recent history due largely to the penetration of electrical equipment and increasing numbers of end uses for electricity in buildings. Gas consumption has grown at a much greater pace, spurred by the oil shocks and discovery of the oil and gas resources in the North Sea in the 1960s/1970s, and has been further accelerated by market liberalization in the 1990s, which has made gas the fuel choice for power generation.

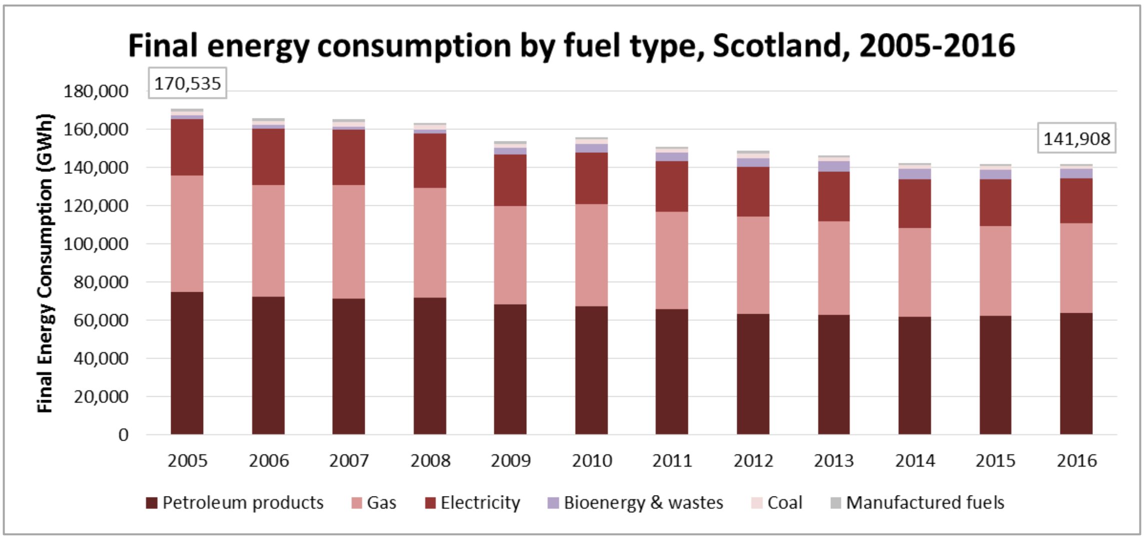

Figure 7: Fuel consumption by fuel type in Scotland 2005-2016 (Source: Scottish Government (2018), BEIS (2018))

Total energy consumption in Scotland has been decreasing over the past 10 years. In 2016 total energy consumption in Scotland was 17% lower than that in 2005 (see Figure 7) with over 20% reduction in consumption of energy derived from electricity, gas and coal.

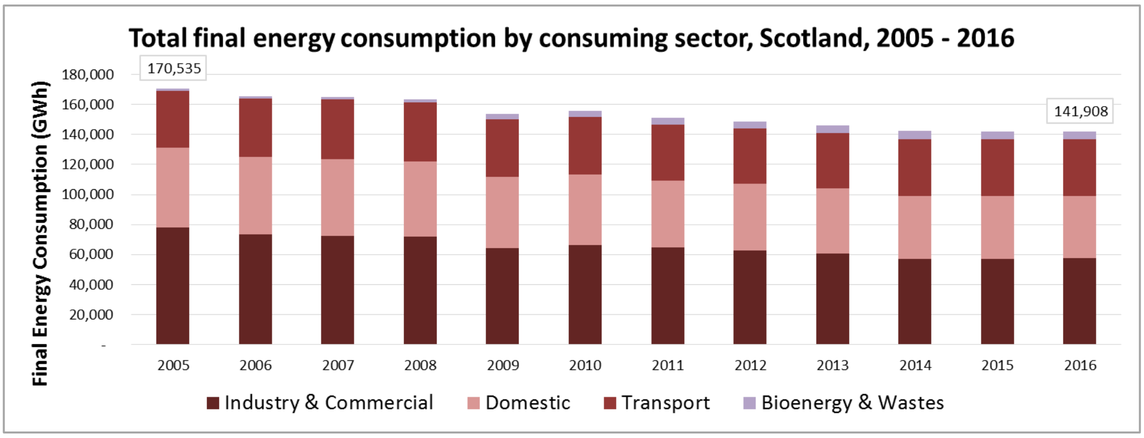

Figure 8: Fuel consumption by sector in Scotland 2005-2016 (Source: Scottish Government (2018), BEIS (2018))

The majority of total consumption is for industry (40% of total use) and domestic uses (30% of total), although the consumption for both sectors has reduced since 2005 by over 20%. Transport, however has remained largely unchanged over the period, with 37,879 GW energy used in 2005 compared with 37,818 GW in 2016, as shown in Figure 8.

The final use of energy consumed in Scotland in 2016 was split between electricity (23% of total energy consumed in 2016), heating (53% in 2016) and transport (24% in 2016) (Scottish Government, 2018). Unsurprisingly, total energy consumption is highest around urban and industrial centres, as shown in Figure 9.

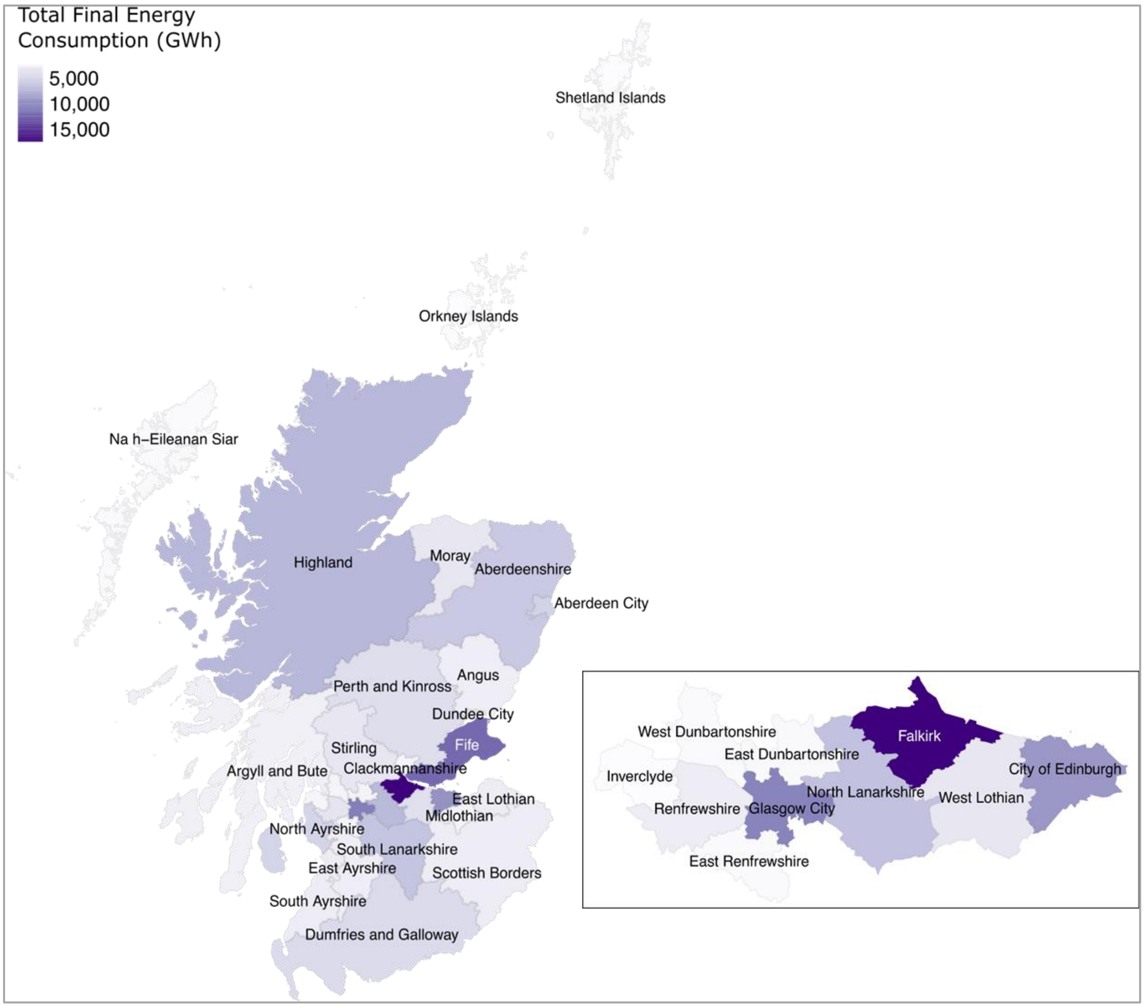

Figure 9: Total final energy use in Scotland, 2016, by LAD (Source: Scottish Government (2018), BEIS (2018))

Average domestic electricity use in Scotland has decreased by over 25% between 2005 and 2017, and domestic gas consumption by 31% (BEIS, 2018, 2019). The historical data for per household electricity and gas consumption is shown in Figure 10 and Figure 11. Factors quoted in the BEIS report which may have contributed to these reductions are: weather conditions; energy efficiency improvements such as increased levels of insulation, new boilers and more energy efficient appliances; increased prices; changes in building regulations; increases in solar photovoltaic self-generation by household, and household composition. Generally, households in the north of Scotland use more electricity than those in central or southern Scotland, possibly due to higher demands for heating in particular.

However, these recent reductions are unlikely to continue indefinitely and are likely to plateau at some lower limit in the near future, and indeed electricity demand and peak demands are likely to rise significantly due to the electrification of transport and heating in the future, according to National Grid future scenarios (National Grid, 2018).

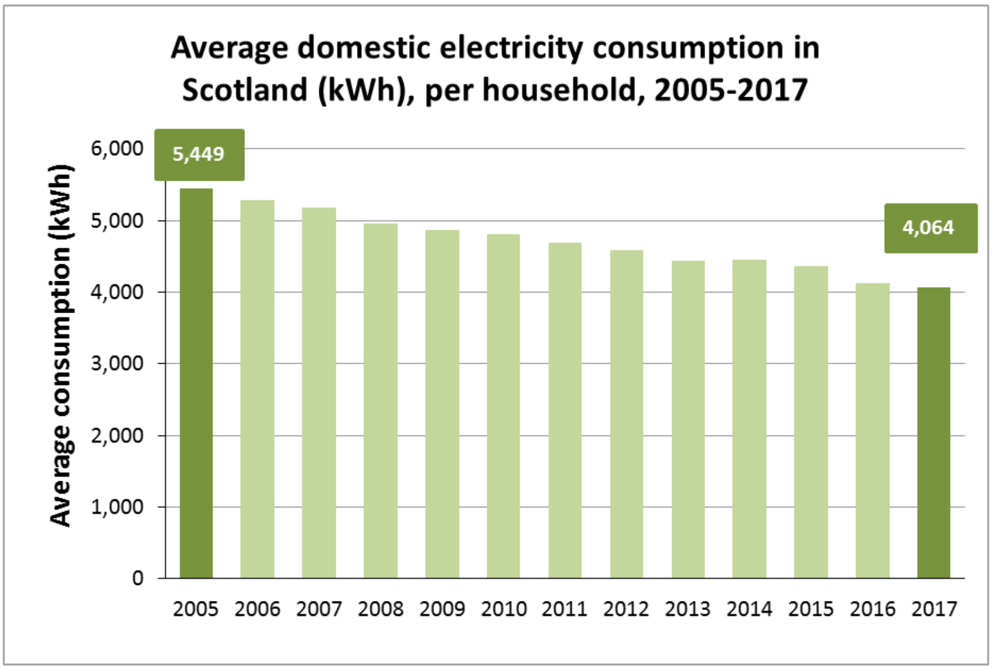

Figure 10: Average domestic electricity consumption (kWh) in Scotland per household 2005-2017 (Source: Scottish Government (2018))

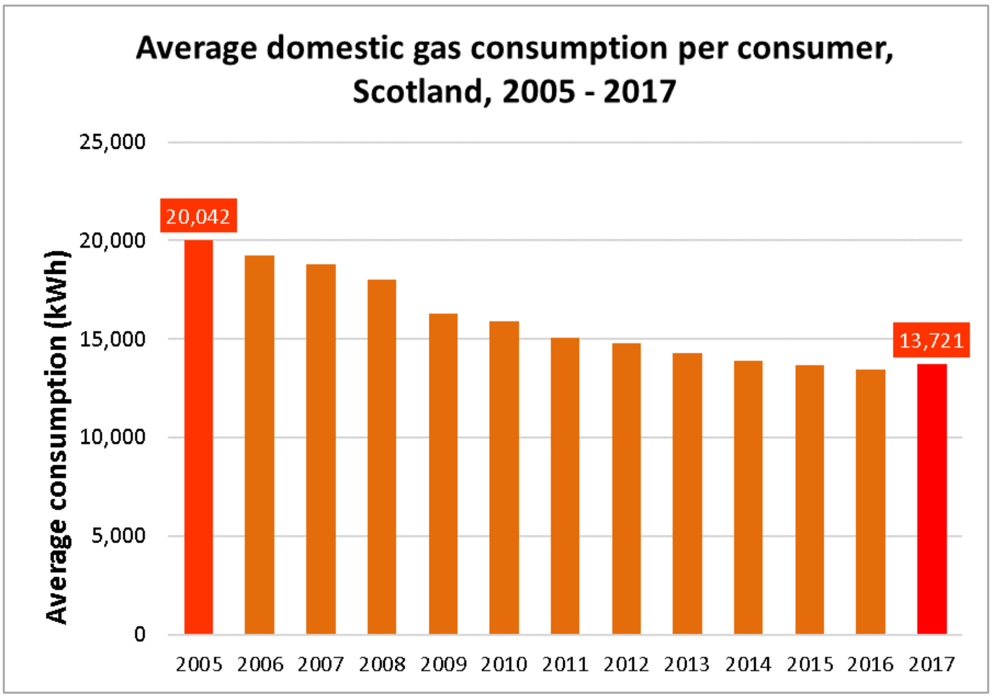

Figure 11: Average domestic gas consumption (kWh) in Scotland per consumer 2005-2017 (Source: Scottish Government (2018))

The more remote northwest regions and islands of Scotland tend not to be connected to the gas network, as shown in Figure 12. These locations rely on a resilient electricity network to provide their energy needs, or use alternative fuel sources.

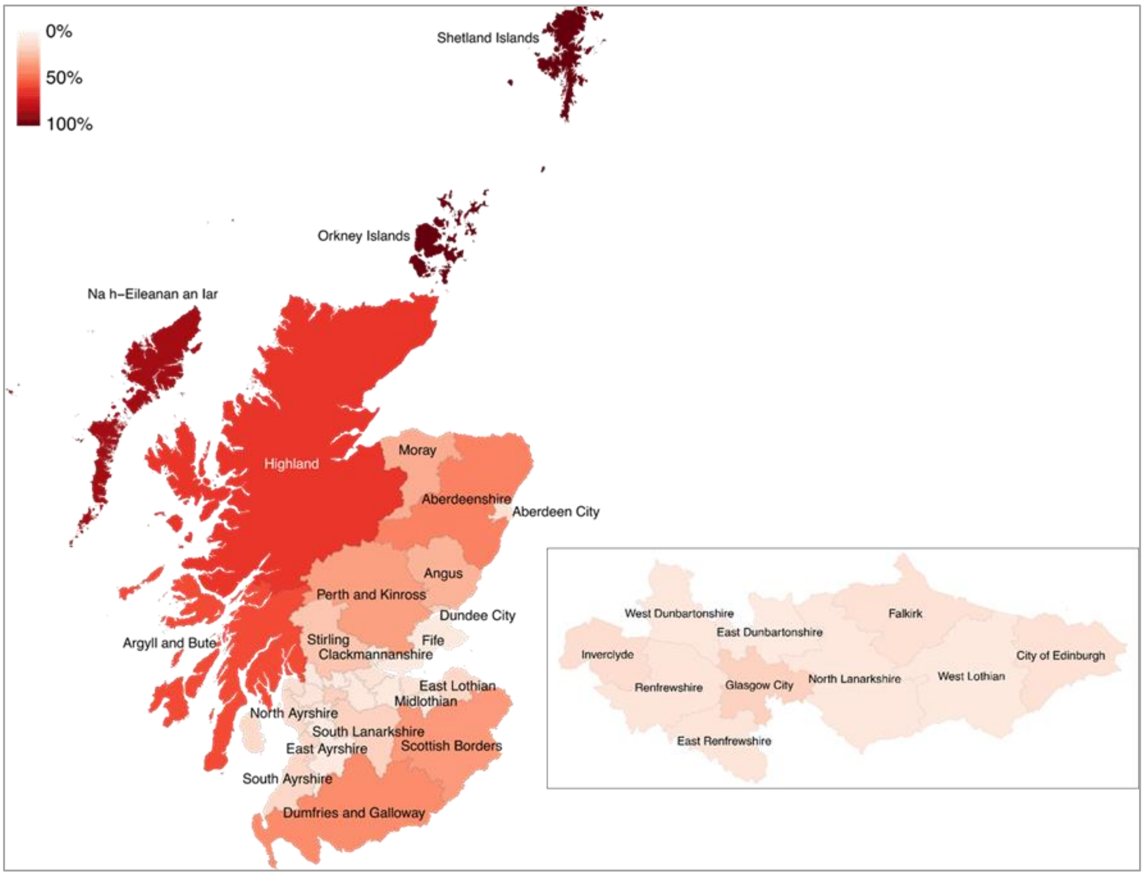

Figure 12: Proportion of households not on the gas grid by local authority (estimates), Scotland, 2016
(Source: BEIS (2018))

In terms of energy generation, as a result of the Scottish Government adopting the Electricity Generation Policy Statement (Scottish Government, 2013) and the 2020 Renewable Energy Routemap (Scottish Government, 2011) in June 2013, there has been a well-defined approach to changing the role of renewable electricity and fossil fuel thermal generation (coal, gas, oil) in Scotland's future energy mix. Figure 13 shows how the share of renewable electricity has increased substantially in recent years, and was 70% in 2017. This equated to 16% of Scotland's energy needs coming from renewable sources, higher than the UK average of 9.3%, but still short of Scandinavian countries such as Sweden (53%) and Finland (39%) (Scottish Government, 2018).

In 2017, renewables delivered 25,000 GWh of electricity (22,000 GWh of which were from wind and hydro), nuclear energy accounted for 17,800 GWh, and gas generated 4,300 GWh of electricity. A further 1,350 GWh came from pumped hydro (573 GWh), oil (663 GWh) and coal (116 GWh). The installed capacity of generating site has increased from 4.37 GW in 2010 to 10.5 GW in 2018, the majority from wind and hydro (Scottish Government, 2018). Looking to the future, there are renewable energy projects under construction which will bring an additional 1.3 GW to the generation capacity, with a further 7.3 GW from projects which have been agreed but awaiting construction. Additional, there are projects at the planning stage which would bring a further 3.4 GW capacity, resulting in a renewable generation capacity of 22.5 GW if all these projects are completed (Scottish Government, 2018).

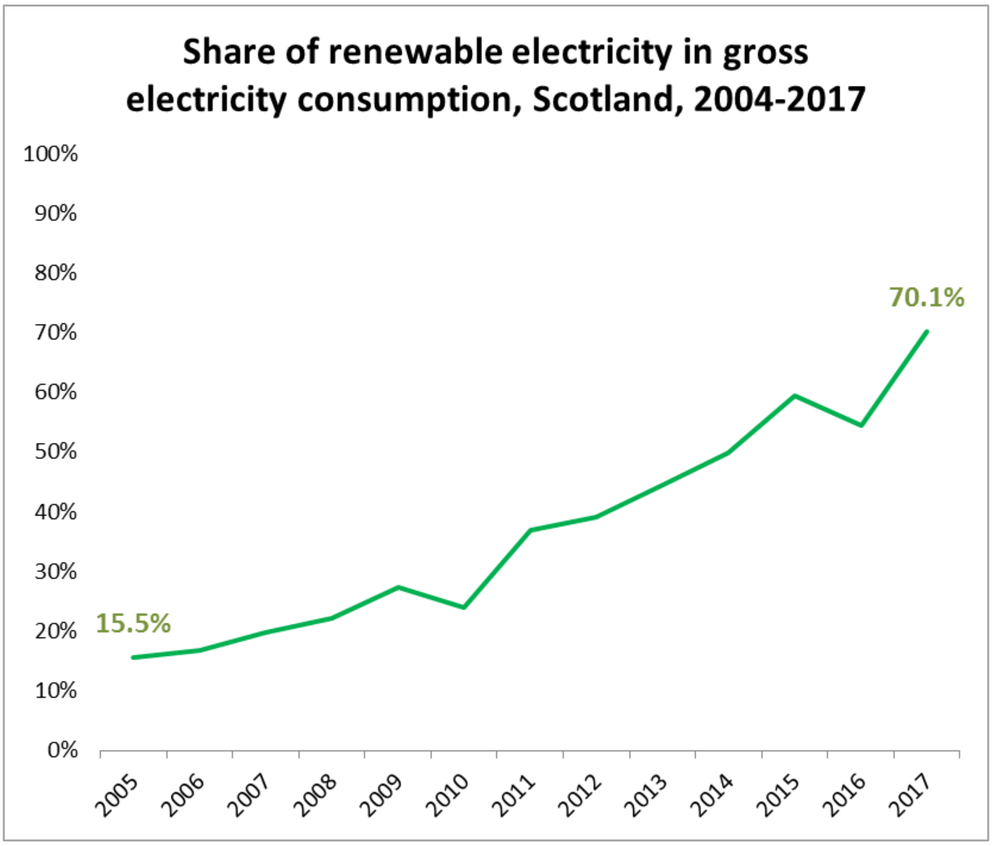

Figure 13: Share of renewable electricity in gross electricity consumption, Scotland, 2004-2017 (Source: Scottish Government (2018))

Future demands for energy

Table 2 gives examples of the main demand drivers for future energy demand, along with the expected effect on demand into the future. Population is projected to grow under the principal and high ONS scenarios, which will increase the demand for electricity and heating services, although slow growth in the principal projection could result in a short-term drop in demand, as has been seen in recent years. However, a growing population together with increasing numbers of home appliances and consumption of electronics means that electricity demand will increase over the long term. The economic structure of the UK generally is shifting from energy-intensive to higher value (lower energy intensity) manufactures, which if similar in Scotland will drive down energy use from industry. By contrast, a larger population holding jobs in services and professional and managerial occupations will lead to greater potential to telework and flexibility. This will change the pattern of demand away from shared offices to (potentially less efficient) individual homes.

Smart grids and meters will contribute to decreasing demand by providing greater flexibility and shaping consumer behaviour, and in 2017 smart meters were installed in 18% of Scottish homes, up from 10% in 2016 (Scottish Government, 2018). Similarly, energy efficiency (such as set out in the ‘Energy Efficient Scotland’ programme (Scottish Government, 2019)), demand response and stronger interconnections will help in decreasing peak demand. Although ultra-low emission vehicles (ULEVs) currently only account for less than 0.5% of vehicles on Scotland’s roads (there were 10360 licensed ULEVs in Q3 2018 (Transport Scotland, 2018)), but numbers will inevitably grow as costs decrease and charging points become more prevalent. System transition strategies such as those set out in the 2020 Renewable Energy Routemap involving high levels of electrification of transport and heat, are attractive for the decarbonisation agenda, and will likely require very large increases in electricity generation capacity (relying on increased levels of renewable generation, or gas-fired power generation) to meet peak demand. Conversely, distributed generation with storage will serve to decrease electricity peak loads.

These effects are dependent on the future strategies adopted to decarbonise electricity generation, transport and heating, as well as the uptake of distributed generation and storage as new technologies become more efficient and cost effective.

Table 2: Demand drivers for energy

Main energy demand drivers	Effect on energy demand
Population growth (Principal projection)	↑
Growth in economic wealth	↑
Policies and technologies promoting efficiencies	↓
Policies, technologies and behaviours promoting demand management	↓
Electrification of heat and transport	↑
Distributed generation with storage	↓

3.4.2 Transport

Historical demands for transport in Scotland

Demand for transport infrastructure has grown dramatically over the last 60 years for a variety of reasons, including economic growth combined with relatively low costs making travel affordable for most, population growth and societal changes such as increasing numbers of female drivers. There were three million motor vehicles licensed in Scotland in 2017 (up from 0.9 million in 1964), travelling an estimated 48 billion vehicle kilometres on Scotland's 56,364 kilometres of public roads. (Transport Scotland, 2018)

In 2017, there were 67 million tonnes of freight handled by Scotland's ports. Exports accounted for 31 million tonnes of these at major ports, although exports had been nearly twice that amount in 1997, rising to 68 million tonnes in 2002, before steadily falling to 31 million tonnes in 2017 (a 32% fall in tonnage in the last ten years). Imports in 2017 totalled 10.6 million tonnes, considerably less than the volume of exports. Scottish airports saw half a million aircraft movements, and were used by 28.8 million passengers in 2017, three-quarters of which travelled to or from Edinburgh or Glasgow. Passenger numbers had increased by 39% between 2001 and 2007 reaching a peak of 25.1 million before falling 17% to 20.9 million in 2010, since when they have risen 38 per cent. (Transport Scotland, 2018).

On the rail network, ScotRail passengers numbered 97.8 million in 2017, an increase of 31% since 2007, with over 90% of trips having a destination within Scotland. (Transport Scotland, 2018)

Throughout Great Britain, there is recent evidence that this growth has levelled off for car trips. Demographic and economic changes, such as younger adults moving towards cities and older adults moving out, saturation of growth in female driving license holding and car ownership, and company car use decline, and other trends like the relationship between vehicle speeds and constant travel time budgets and the declining marginal utility of additional destinations, may have caused this 'peak demand' (Millard-Ball & Schipper, 2010). However, there is still debate whether peak demand has actually occurred (DfT, 2013). For instance, in the last five years, there have been increases in car (+7.2%), air (+29.8%), rail (+17.4%) and ferry (+5.7%) passenger numbers, while there has been a fall in bus passengers (-7.6%) and distance cycled (-6.5%).

Future demand for transport and travel

Table 3 sets out the main demand drivers of transport and travel in the future, and their likely effect on demand. Any population growth predicted in coming decades means that total travel demand will almost certainly increase despite any slight decline in travel per person. Replacing travel with technological options such as home-working and greater workplace flexibility may have the potential to ease congestion at peak commute times, but such flexibility may also mean that a larger proportion of the workforce will have more than one job, which may lead to increased levels of commuting. In addition, as the population ages, the number of some peripatetic jobs like social care will also increase, driving upwards the demand for transport services.

Increase in economic wealth means that more transport services will be needed to move people and goods around. However, regional differences in economic development mean that major urban centres around Edinburgh, Glasgow and the surrounding regions will continue to face most of the pressure on infrastructure.

Conversely, policies promoting modal shifts not only towards traditional public transport but also towards short range electric vehicles for urban use, light rail and tram systems, in addition to promoting active travel (walking and cycling) will relieve stress across transport networks. However, for such systems to be commercially successful, they are likely to be limited to denser urban areas, which means a large proportion of the country may be unsuitable for such options.

The impact of digital communications and information technologies may help establish successful demand management techniques, such as promoting car sharing or smart planning of trips (or trip replacement by adopting technological advances such as virtual meetings) will also have a substantial impact on demand reduction.

Transport economics may also play a substantial role in decreasing demand. Transport costs are linked closely to energy price changes and therefore to both energy supply policy and changes in energy demand elsewhere. This could place future supply of affordable transport at risk, if for example the transition away from 'conventional' fuels for road transport was unsuccessful, and future fossil fuel supplies were to dwindle while demand for such fuels increases in other industry sectors and countries. Pricing policies, such as road user charging or workplace parking levies, can also increase costs and reduce demand.

Table 3: Demand drivers for transport and travel

Main transport demand drivers	Effect on travel demand
Population growth (Principal projection)	↑
Ageing of population	↑
Growth in economic wealth	↑
Policies promoting modal shift	↓
Policies promoting demand management techniques	↓
Pricing policies (congestion charges, parking levies)	↓

3.4.3 Digital communications

Historical demands for digital communication in Scotland

The UK has a very advanced digital communication infrastructure comprising communication (fixed and mobile telephony, broadband, television and navigation systems) and computation (data and processing hubs). Much of this infrastructure has been provided in a relatively short space of time compared to other more traditional forms of infrastructure. For instance, while the US maintained the largest Internet penetration rate throughout the 1990s, the UK has rapidly caught up in the first decade of the twenty-first century (Figure 14). There are differences in performance between urban and rural areas, particularly regarding broadband speeds, since 87% of premises in urban areas can access 'superfast' broadband over 30 megabits per second (Mbits/s), while only 56% of premises in rural areas can do so. According to Ofcom, urban users can expect an average of 46 Mbits/s, compared with 20 Mbits/s in rural Scotland. In 2017, 5.3% of properties in Scotland had broadband speeds slower than 10Mbits/s, and 1.1% received slower than 2 Mbits/s (Ofcom, 2017). In 2017, 38% of premises in Scotland had access to broadband speeds of at least 100 Mbit/s (compare with 50% of premises in England). These higher broadband speeds are provided by Virgin Media, but the majority of premises in rural Scotland rely on BT's 'Openreach' network and are not covered by Virgin Media's cable network. This explains why only 3% of rural Scotland can achieve speeds of at greater than 100Mbit/s, compared to 45% in urban areas (Ofcom, 2017).

In terms of mobile services, Ofcom's report states that the most important findings for mobile services in Scotland are:

- mobile voice services from all four operators now cover 87% of indoor premises in Scotland;
- geographic voice and data coverage from all four operators has improved but still significantly lags behind the rest of the UK;
- there remain large areas of Scotland's landmass where it is not possible to receive a mobile voice (22%) or mobile data (33%) service;

- geographic 4G coverage in Scotland has increased to 17% from 6% but still significantly lags behind the rest of the UK; and
- challenges remain in delivering mobile coverage to consumers on the move, with only 46% of Scotland's A&B roads covered by mobile voice services.

Because of the complexity and rapid innovation compared to other physical infrastructure sectors, digital communication systems' future is highly uncertain, therefore making it challenging to analyse their prospective direction.

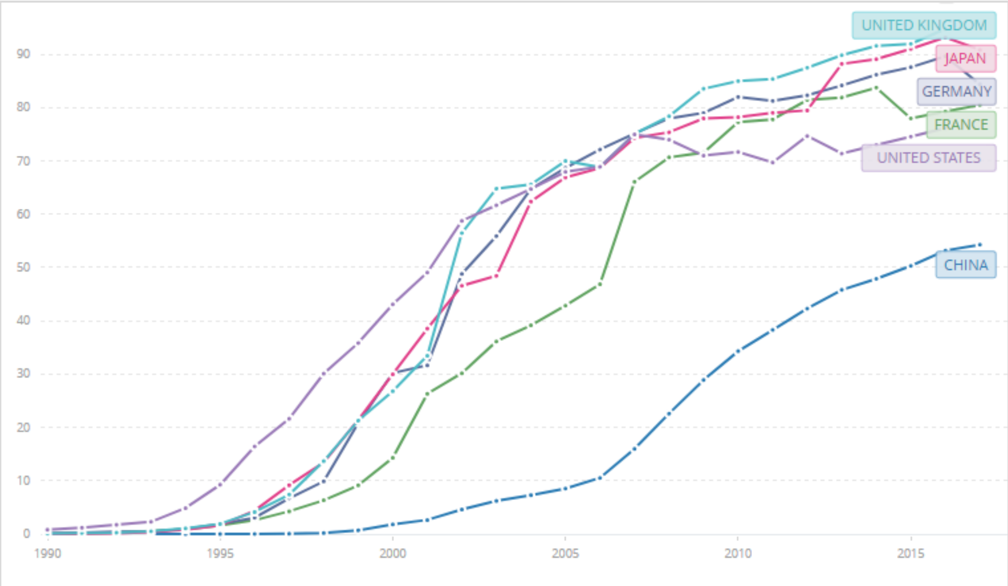

Figure 14: Internet penetration rate (per 100 people) for the top six economies 1990-2016. (Source: World Bank)

Future demands for digital communication

Table 4 shows the main demand drivers for digital communications in the future, with an indication of the likely effect on demand. Population growth and high purchasing power of consumers and businesses will translate to higher demand of digital communication services. A shift in the focus of policy from basic access to *access quality,* represented by the European Commission's Digital Agenda for Europe to provide Internet access speeds to all EU citizens of 30 Mbit/s, with over 50% of citizens subscribing to a connection over 100 Mbit/s, by 2020 will drive up demand. The Scottish Government is seeking to extend the availability of superfast broadband infrastructure to 100% of premises in Scotland by 2021 through its 'Reaching 100% Programme' (Ofcom, 2017).

Continued development of the digital economy will increase consumption of digital communication services: Britain is one of the top economies in Europe for the proportion of sales arising from e-commerce. The adoption of digital communication in businesses has led to 20% of total turnover in 2013 being attributable to e-commerce, amounting to an estimated £557 billion (ONS, 2014).

Shifting cultural and work habits will play an important role by further driving demand (e.g. working remotely). 'The internet of things' concept is increasingly being integrated into business and personal life in the UK, with a £6million project 'IoT Scotland' launching in 2019 (BusinessCloud, 2019; Davidson, 2018). The wide-area wireless sensor network will allow data to be collected from and exchanged between compatible electronic devices and appliances across much of Scotland, changing services consumption modes and lifestyles.

Table 4: Demand drivers for digital communications

Main digital communication demand drivers	Effect on IT demand
Population growth (Principal projection)	↑
Growth in economic wealth	↑
Regulation to provide minimum and better quality access to digital communication	↑
Development of the digital economy	↑
Cultural and work habits	↑
Increasing integration of 'the internet of things' into business and personal life	↑

3.4.4 Water

Historical demands for water in Scotland

Demand for water can be divided into domestic and non-domestic uses. Non-domestic demand for water comes from industry, power generation, primary production and commerce. In 2015, mean per capita water demand in Scotland was 150 litres per person per day (l/p/d). The usage of around 150 l/p/d is in line with the demand of other GB and European countries although an increase in efficiency is possible (Scottish Water, 2010).

In detail, between 2002 and 2009, estimated raw water abstractions by Scottish Water decreased by 13% to 2,165 Ml/d. Between 2010 and 2015, using improved data and methodology, the volume of raw water abstracted decreased by 12.6% to 1,831 Ml/d. Between 2004/05 and 2015/16, treated water produced fell by 598 Ml/d (25%) to a new low of 1,780 Ml/d. There has been a slight increase of 89 Ml/d (13%) in domestic water consumption between 2004/05 and 2015/16, while non-domestic water consumption has decreased by 98 Ml/d (19%) over the same period. However, there has been relatively little change in all water consumption overall (domestic, non-domestic and operational use) between 2004/05 and 2015/16 (Scottish Government, 2016a).

As shown in Figure 15, the decrease in public water supply is almost entirely due to a reduction in leakage of 608 Ml/d (53%) between 2004/05 and 2015/16, in response to Scottish Water's 'Leakage Management Strategy 2010-2015' (Scottish Water, 2010). There has been an increase during that period in domestic water consumption, partly reflecting an increase in the number of households, household size and usage patterns. The decrease in non-domestic water consumption partly reflects the introduction of the retail market, where retailers offer customers advice on how to reduce their water and sewerage bills (Scottish Government, 2016a).

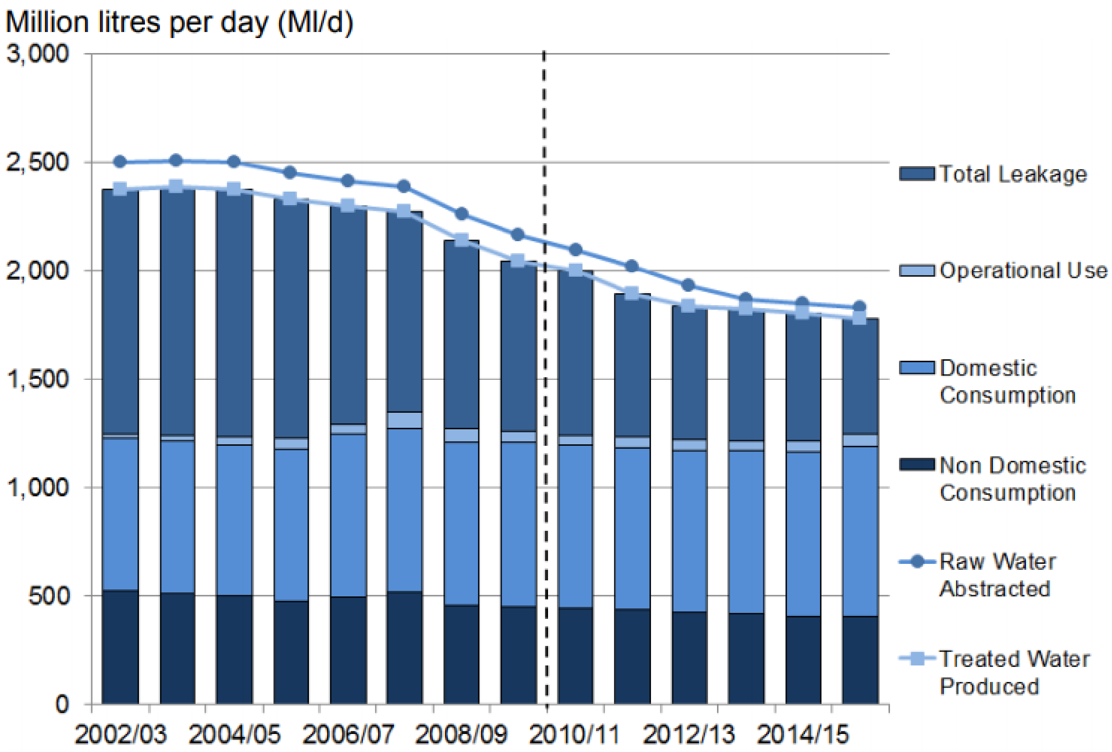

Figure 15: Public water supplies – water abstracted and supplied: 2002/03-2015/16 (Source: Scottish Government (2016a))

Future demands for water and strategies for demand reduction

Table 5 shows the main drivers of demand for water, and the likely effect those drivers will have on demand. Demand for water is expected to increase with growing population and economic wealth, with demand in large industrial and urban areas growing most rapidly owing to a high concentration of population and economic activities. This is likely to put those areas under water stress since high population density results in lower mean per capita precipitation.

Water metering improves system efficiency and reduces water consumption, but is controversial because seen as a limit to personal freedom. Domestic metering typically reduces PCD by 15 l/p/d (Walker, 2009). Similarly, water charges also decrease consumption, but the pressure on low-income households caused by rising water bills coupled with the unacceptability of disconnecting households from the water supply even if they cannot or will not pay bills (Walker, 2009) make increasing the cost of water increasingly impracticable.

Leakage reduction has been the main focus of Scottish Water to reduce overall demands for water (Scottish Government, 2016a) and will continue to be so for the next few years as long as it is economically viable (Scottish Water, 2015). Reducing leakage reduction since 2005 has resulted in a saving of 600 Ml/day, however, many water companies argue that leakage reduction has already reached a level where it is not economical to reduce leakage further.

Regulation (i.e. building and plumbing codes) and educational policies could also contribute to demand reduction. Holistic practices to manage the water sector’s interdependencies with other sectors, especially energy, has a big potential to improve efficiencies and better manage demand.

Table 5: Demand drivers for water

Main water demand drivers	Effect on water demand
Population growth (Principal projection)	↑
Growth in economic wealth	↑
Metering mechanisms	↓
Charging mechanisms	↓
Leakage reduction	↓
Regulation and educational policies	↓
Management of water sector's interdependencies with other sectors (particularly energy)	↓

3.4.5 Wastewater treatment

Historical demands for wastewater treatment in Scotland

A program to improve waste treatment has been in place in Europe since the early 1990s, driven by legislation to improve environmental quality in rivers and coastal waters. The result in Scotland has been the minimisation of untreated and primary treated sewage discharged into the environment, as well as the increase of tertiary treatment from around 15% of the population connected to treatment facilities in 2001 to nearly 30% in 2009 (Figure 16).

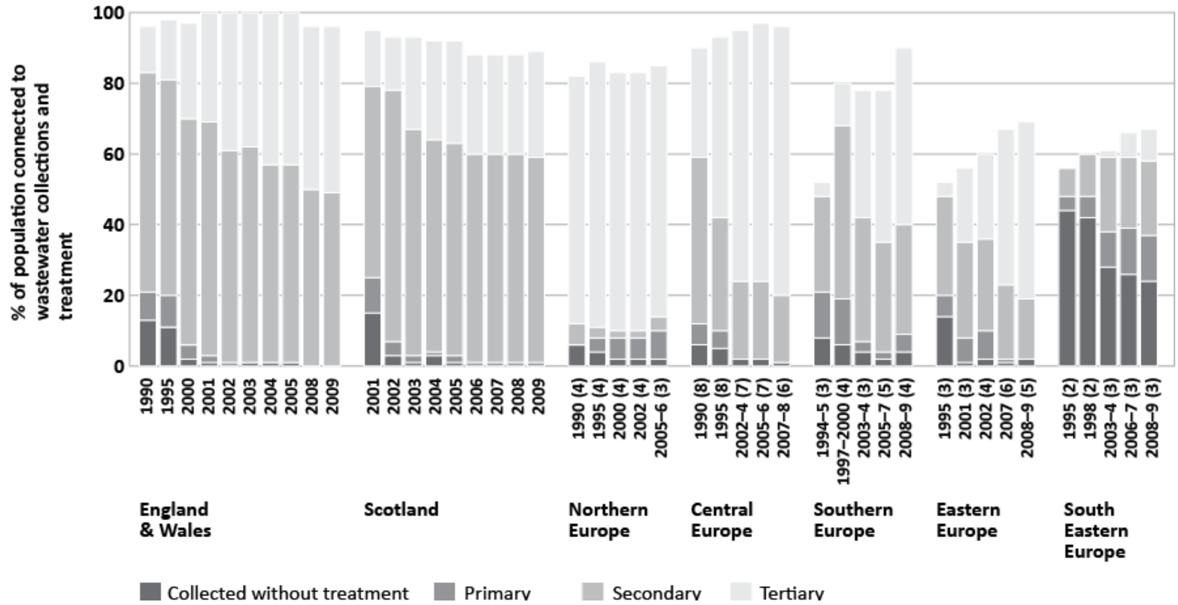

Figure 16: **Improvement in the standards of wastewater treatment across Europe 1990-2009. (**Source: Hall et al. (2016))

The volume of wastewater treated reflects per capita daily water use, currently about 150 l/day in Scotland, most of which is returned to the sewerage system. In 2018 Scottish Water estimate 930 million litres of wastewater was treated (Scottish Water, 2018). However, demand is also affected by effluents of industrial users and urban surface runoff that are collected by the sewerage system. Each of these additional sources bring difficulties; industrial users may discharge pollutants that are difficult to remove from the wastewater, whereas urban runoff increases liquid volumes that must pass through the sewers, which is especially problematic at times of severe storms and flooding.

Future demands for wastewater treatment

Table 6 provides examples of the main drivers of demand for wastewater treatment, and the likely effect those drivers will have on demand. Population increase will require more sewerage and treatment capacity, impacting both network size and capacity requirements, with the potential need for expanded trunk sewer capacity to accommodate increased wastewater volumes. Climate change, by changing patterns of average and extreme rainfalls, will also put pressure to increase volumetric requirements if sewer surcharging and flooding of foul water are to be avoided (this occurs because the sewer system conveys both domestic wastewater and surface runoff, and the volume to be accommodated can swell considerably during storms).

Meeting environmental standards, coupled with population growth, will drive wastewater treatment demand upwards since there is a limit to the capacity of receiving waters in the environment to assimilate the waste for a given effluent standard. Thus, even for effluents treated to current regulatory standards, there is a limit to the population size able to be supported by available receiving waters.

Conversely, sustainable drainage systems, such as reed beds, swales and infiltration ditches to permeable paving and allowing for discharge directly to the ground where possible, will decrease demand. These are all measures that permit the detention of runoff and its absorption close to its source. An alternative strategy for reducing demand is reduction of household water use by harvesting rainwater and reusing grey water.

Table 6: Demand drivers for wastewater treatment

Main wastewater treatment demand drivers	Effect on wastewater treatment demand
Population growth (Principal projection)	↑
Climate change altering patterns of average and extreme precipitation	↑
Increasing environmental standards	↓
Sustainable drainage systems	↓
Household water demand reduction	↓

3.4.6 Solid waste

Historical demands for solid waste in Scotland

Over the last two to three decades, waste management in the industrialised world has gradually shifted from providing safe disposal of unwanted materials, often by entombing the waste in a sophisticated, engineered landfill, to recovering materials and value from that which is no longer needed through reuse, recycling, composting and energy recovery.

Recycling and composting have increased from very low levels in the 1990s to nearly 45% of municipal waste treatment in 2015 (Figure 17). Results of a household survey aiming to determine the types of items that have been recycled show that since 2003, the percentage of households recycling waste from all item types increased (the gaps in the chart are due to changes in the survey techniques and definitions). Between 2011 and 2015, there was little change in the percentage of households recycling each type of item, except for plastic bottles which increased by 7 percentage points to 82%. In 2015, the recycling rate was highest for paper and card at 87% and lowest for glass at 77% (Scottish Government, 2016a).

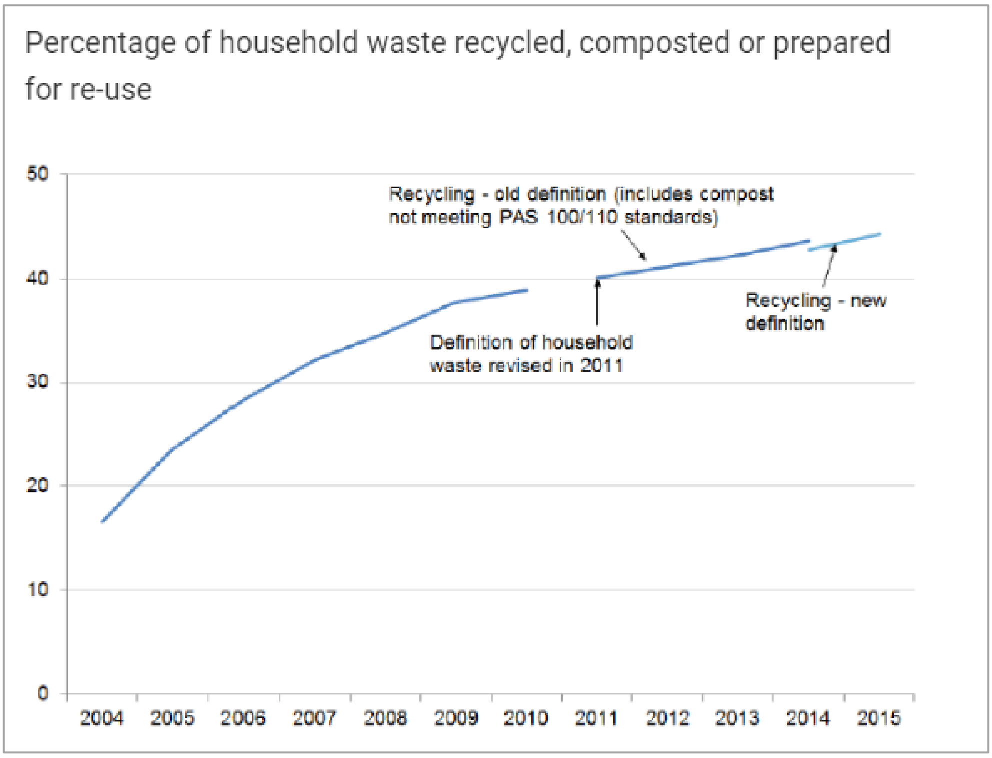

Figure 17: Household waste recycling, Scotland, 2004-2015 (Source: Scottish Government (2016a))

Increased recycling rates and reduced generation of waste has resulted in significant reductions in the amount of waste going to landfill since 2005 (Figure 18). In 2014, 4.03 million tonnes of waste generated in Scotland were sent to landfill, a reduction of 42% compared with the 7.01 million tonnes sent to landfill in 2005. The amount of Biodegradable Municipal Waste (BMW) landfilled in Scotland was 1.06 million tonnes in 2014, a reduction of 51% compared with 2005.

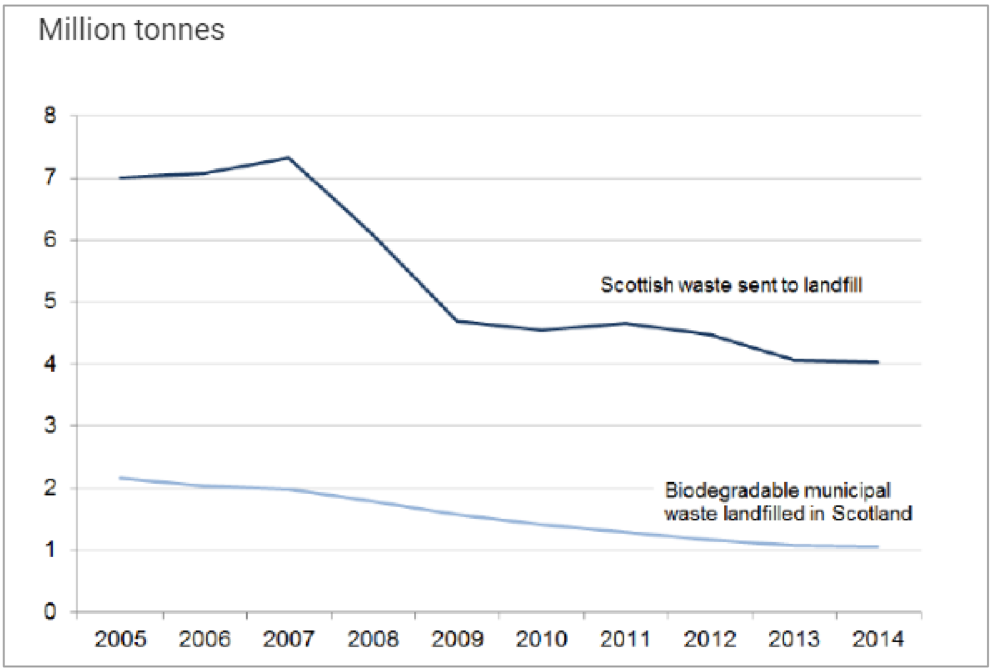

Figure 18: Waste sent to landfill, Scotland 2005-2014 (Source: Scottish Government (2016a))

These changes are likely to have partly been the result of the increases to landfill taxes. Landfill tax is intended to encourage waste producers to produce less waste, and promote recycling and waste recovery. The 2008 recession occurred alongside a sharp reduction in tonnage sent to landfill, which may be due to the reduction in the construction industry. Methods of food waste disposal can also have an impact on the tonnage of biodegradable waste sent to landfill.

Future demands for solid waste and strategies for demand reduction

Table 7 shows the list of drivers which are expected to contribute most to future changes in demand. A growing population and relative economic wealth contributes to generating solid waste; however, publications on resource security (Defra, 2012), resource efficiency (European Commission, 2011) and sustainable materials management (OECD, 2012) suggest that there is a move away from the linear view of resource management towards embracing the idea of a circular economy. Indeed, The Scottish Government's circular economy strategy, 'Making Things Last', sets out priorities for moving towards a more circular economy. One of the priority areas is construction and the built environment. According to the strategy, "construction accounts for about 50% of all waste in Scotland and is a major influence on efficient use of resources" (Scottish Government, 2016b). The strategy also includes a new Scottish food waste reduction target, the first of its kind in Europe. This target, to cut food waste by a third by 2025, aims to establish Scotland as an exemplar in tackling food waste and is in line with the UN Sustainable Development Goal target 6 related to food waste.

Other aspects of the strategy related to waste include 'Zero Waste Scotland'[1], which sets out priorities for managing and reducing waste as follows: (i) improving resource efficiency through actions such as discouraging use of single-use materials; (ii) taking action to reduce and recycle food waste; (iii)

[1] https://www.zerowastescotland.org.uk

introducing a deposit return scheme for drinks containers; (iv) helping deliver progress tackling litter and fly-tipping; and (v) delivering the New Plastics economy global commitment.

The targets set out for reducing waste and increasing recycling by 2025 are: (i) to reduce total waste arising in Scotland by 15% against 2011 levels; (ii) to reduce food waste by 33% against 2013 levels; (iii) to recycle 70% of the remaining waste; and (iv) to send no more than 5% of remaining waste to landfill. The targets also aim to match the EU ambition for all plastic packaging to be economically recyclable or reusable by 2030.

Other European directives and national regulations have continually played an important role in increasing the demand for services to recycle or reuse solid waste. The possible banning of the disposal of all biodegradable municipal waste to landfill in the next decade may require additional new infrastructure.

Waste that is disposed of to landfills is taxed according to the Scottish Landfill Tax (a standard rate of £91.35 per tonne in 2019 to 2020, with a lower rate for less polluting materials (referred to as qualifying materials) of £2.90 per tonne in 2019 to 2020). This has the effect of making landfill the most expensive form of waste treatment, and hence making investment in other forms of treatment and disposal financially viable. It is clear that such tax has had and will continue to have an effect in reducing disposal to landfill.

Table 7: Demand drivers for waste treatment

Main waste treatment demand drivers	Effect on waste treatment demand
Population growth (Principal projection)	↑
Growth in economic wealth	↑
European directives and national regulation	↓
Landfill tax	↓

3.5 Interdependencies between sectors

The NISMOD-LP modelling framework couples sector models for each of the infrastructure sectors addressed above. This enables the effects of inter-sectoral infrastructure demands to be modelled.

In the future, the most influential of these interactions (in terms of total sector demand) is likely to be the potential for large increases in electricity demand through widespread uptake of electric vehicles. The Scottish Government has pledged to phase out new petrol and diesel cars by 2032, resulting in further investment in charging points across Scotland (Scottish Government, 2017).

The energy requirements of the water sector may reduce into the future, since more than 70 of Scottish Water's water and waste water treatment works are either fully or partly self-sufficient in their power requirements. Not only does this reduce the energy requirements of the sector, but leads to lower operating costs, smaller carbon footprint, and a more sustainable business (Scottish Water, 2018).

In ‘Making Things Last’, the Scottish Government suggest that there is an ambition “to have an energy from waste infrastructure that effectively manages the ‘leakage’ from a more circular approach to the economy in Scotland without creating demand for materials that could otherwise be kept in higher value use. We want to ensure that energy recovered from waste supports, directly, high quality heat and power schemes”, either through anaerobic digestion of organic materials which retains nutrients as part of a circular economy, or through the creation of heat and energy through thermal treatment of non-recyclable waste (Scottish Government, 2016b).

These and other potential interdependencies in sector demand have not been specifically addressed in this report but could be addressed as part of future subsequent modelling work.

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