NATIONAL INFRASTRUCTURE COMMISSION
Better infrastructure for all

Distributional Analysis Technical Annex

Infrastructure consumption patterns vary significantly across different people and places, and while distributional analyses commonly analyse the impact of policy changes across the income distribution, other important characteristics – such as ethnicity, gender or geography– are less frequently examined. These characteristics may be important in shaping how households use and experience infrastructure, so for the Assessment the Commission has conducted comprehensive distributional analysis of its recommendations across a suite of household characteristics. In the context of the cost of living crisis, this analysis can help us understand how households actually experience infrastructure costs and design policies that better take account of nuanced variation between groups.

This note summarises the experimental approach we use to quantify the distributional impacts of the Commission's infrastructure recommendations and presents our preliminary results. The analysis considers the impact of the Commission's recommendations across income, regions, urban-rural split, gender, ethnicity, marital status, age, and disability. The analysis finds that for all groups infrastructure costs will consistently fall over the period 2022-2050, with variation in the amount of decline different groups experience.

This is experimental work that differs significantly from the majority of distributional analyses conducted. The main difference between the Commission's work and others is that the Commission conducts its analysis at the household level, rather than the individual level, because households—not individuals—pay infrastructure costs (like electricity or water bills). This involved constructing household-level variables aggregated up from information about the individuals in these households. The analysis is based on projections of aggregate spend on infrastructure from the Commission's modelling, and assumes no behavioural changes or changes in income. This is a relatively novel approach to distributional analysis in the infrastructure sector with large simplifying assumptions, and the Commission hopes that by undertaking this analysis it can set a foundation for future work that maps in more detail and more comprehensively the impact of infrastructure on different groups.

Methodology

Data sources

Our distributional analysis uses household consumption data from the Living Costs and Food Survey (LCFS)[1]. The LCFS is an annual survey published by the ONS to measure household expenditure on goods and services, as well as gather information about the income of

[1] https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/bulletins/familyspendingintheuk/previousReleases

household members. The data contains observations at the household level, with a supplementary dataset at the individual level that can be linked to the household data.

The analysis used data from 2016/17, 2017/18 and 2018/19, combining the data to create a pooled cross-section of over 16,000 observations. This was done to improve statistical power[2]. Spend from all years is inflated to put all figures in 2022 price terms.

Approach overview

The Commission used pooled data from the LCFS to identify spend at the household level, combined with data on individuals to construct household-level groups. Results are expressed as a percentage of total household expenditure, as is standard in distributional analysis. The Commission's own analysis is used to project infrastructure spending into the future, but total household consumption is held constant. This is done because it means the Commission does not need to make assumptions about future income trends, and because it enables a view of policy impacts on today's world. However, this does mean that results may exaggerate the effects of changes in infrastructure spending, as no account is made for future wage growth. The analysis also does not take into account behavioural responses to changing infrastructure prices, nor long term changes in consumption habits and infrastructure needs. These will vary between the groups analysed. As such, the Commission's distributional analysis results charts are best interpreted as demonstrating the amount a given group would need to spend in order to maintain their current level of consumption given changing infrastructure prices, rather than a strict projection or estimate of infrastructure costs across different groups.

Scope

The analysis focuses on the three infrastructure sectors expected to see significant changes in costs compared to today: transport, energy, and water. Digital is also included when assessing overall infrastructure costs, though the Commission does not expect major changes in the cost of digital infrastructure services over the period 2022-2054.

The geographic scope of the distributional analysis work aligns with UK government competence, respecting devolved responsibilities for economic infrastructure.

Unit of analysis and constructing household characteristics

The analysis was conducted at the household level. This is because several key infrastructure sectors (i.e. energy, water and digital) are provided and paid for at the household level, not by individuals. Our analysis is of the distributional impact of the Commission's recommendations across income level, regions, urban-rural split, gender, ethnicity, marital status, age, and disability status. These groups were chosen because they are protected characteristics under the Equality Act 2010 and the LCFS records them.

The nature of aggregating individual-level characteristics like gender or ethnicity to the household level involves an unavoidable trade off between precision and generalisability. At one end of the scale, every possible household configuration could be considered: for example, for a

[2] This approach is taken in other distributional analyses, e.g. by the IFS (2010) *The distributional effects of the UK government's tax and welfare reforms in Wales: an update*
https://ifs.org.uk/sites/default/files/output_url_files/bn150.pdf

household consisting of two adults, there are 25 possible combinations of ethnicities from the five categories the LCFS records, not to mention further combinations for households with more than two adults. At the other end of the scale, households could be grouped into simple binaries, for example, on marital status, whether they contain a married couple or not. When deciding on how to construct variables the analysis aims to balance this trade off, generating categories that are sufficiently broad as to cover a significant number of households, but specific enough to identify important differences between them.

There are two other primary approaches that were considered. The first is based on using the Household Reference Person (HRP), which is how the ONS report spending metrics from the LCFS by age. The HRP "provide[s] an individual person within a household to act as a reference point for producing further derived statistics and for characterising a whole household according to characteristics of the chosen reference person"[3], with the HRP either being the person in whose name the household's accommodation is owned or rented, or the person with the highest income in the household. As such, one approach could have been to take the HRP as representative of the household and conduct distributional analysis accordingly. This approach presents some issues. Firstly, by only looking at the named homeowner or highest earner, the analysis would likely be systemically biased by characteristics over-represented among these individuals. For example, of the 1,727 people receiving disability benefit in the sample, only 1,056 are the HRP for their household. Had it used the HRP method, the analysis would not have taken into account the effect of infrastructure costs on the remaining 671 individuals, nor how their household's experience of infrastructure may differ compared to other households.

Another approach was considered of splitting household costs evenly among individuals, and then conducting the analysis at the individual level. The household-level analysis was preferred because of the Commission's aim to analyse infrastructure costs as they are actually experienced, and because it does not require an assumption that households split bill costs evenly among individuals.

For each group a coding schema was created based on the characteristics of household members. These are set out below.

Income group

The analysis calculates each household's income group by splitting households into ten deciles based on their equivalised income. This is a measure of household income that takes into account household size and composition. The OECD-modified scale is used to equivalise income as set out by the ONS[4].

[3] https://analysisfunction.civilservice.gov.uk/policy-store/household-reference-person/

[4] https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/compendium/familyspending/2015/chapter3equivalisedincome
NB that household expenditure is used to measure spend on infrastructure services, but equivalised income deciles are used to categorise households' income levels.

Sex

The analysis defines five categories for gender based on the ratio of adult women to adult men. These are all women households, all men households, households containing an equal number of men and women, households containing more men than women (but at least one woman), and households containing more women than men (but at least one man).

Disability

The analysis uses a binary schema for disability. Households are coded as 'contains a disabled member' if they receive any disability allowance[5], or 'non-disabled' otherwise. This approach means our analysis cannot measure effects of self-reported disability.

Marital status

The analysis uses the marital status of the household reference person (HRP) to code for marital status. There are four categories based on the HRP's status: married, single, cohabiting (i.e., non-married couple) and civil partnership. In this case the HRP is used because their marital status is inherently connected to that of the other adults in the household, so by constructing the variable based on them the analysis very likely takes account of the whole household.

Age

To code for age the analysis uses the average age of adults in the household, segmenting these age groups into households with and without children, depending on whether the household also contains an individual younger than 18. Households are grouped into 18-34, 35-49, 50-64 and 65+. Children are excluded from the average age because this would conflate older households with children with younger households without children.

Ethnicity

For ethnicity, the analysis uses the ethnicity of the 'first two' adults in the household, defined as the HRP and their partner. In the case that the HRP does not have a partner, the HRP's ethnicity is used. The analysis is limited by ethnic groups that are provided in the LCFS: Asian, Black, White, Mixed Race and Other.

The analysis codes a household as a given ethnicity (for example, Asian) if both the HRP and their partner (or just the HRP in a single household) are that ethnicity. When there are two adults with different ethnicities, it is coded as 'mixed ethnicity'. These codes are general enough to allow adequate sample sizes such that the analysis has suitable statistical power, but fine-grained so it can recover substantive differences between groups.

Urban/rural

Households are grouped based on their urban-rural status as per the 2011 census rural-urban classification. While this is over a decade old, urban-rural status is generally stable over time.

Region

Households are grouped into regions based on their regional location. This includes the nine International Territorial Levels (ITL) regions in England as well as Scotland, Wales, and Northern Ireland.

[5] Personal Independence Payment (PIP), Disability Living Allowance (DLA) for self-care and mobility, and Attendance Allowance (AA).

Calculating infrastructure spend per group

With the household groups defined as set out in the previous section, the next step is to aggregate households into these groups, and calculate how much they spend on infrastructure services and how this will be affected by the Commission's recommendations. This is the heart of the distributional analysis which allows inferences to be made about the impact of the Assessment across different groups and regions.

Current infrastructure spend

To calculate current infrastructure spend for each group in a given sector, first a new variable is created for each household corresponding to the total spend in that sector. Table 1 shows the subsector breakdown for each sector.

Table 1: Subsectors included in distributional analysis

Sector	Subsectors
Water	Water, waste water
Energy	Heating, electricity
Transport	Bus, train, car, bike
Digital	Mobile, fixed

Then the mean spend is calculated in each sector across each group. There are four sectors and nine groups, making a total of 36 different group-sector average spend outputs.

Rather than weighting each household equally in the mean calculations, households are assigned weights to ensure the overall sample is representative of the UK population. These weights are calculated by the ONS by a process detailed in the LCFS documentation[6].

The impact of recommendations

Calculations of the impact of recommendations are based on modelling of the overall change in infrastructure spending undertaken by the Commission. For example, the Commission estimates that spending on infrastructure services by an average household should fall from today's level of around £7,300 per year, to between £5,500 and £6,600 by the mid-2030s and £5,100 to £6,100 by 2054. The distributional analysis is based on making assumptions about how this reduction in overall spend will affect households differently.

For each subsector, each household is assumed to consume a constant share of the aggregate spend, so as aggregate spend changes, a given household's spend changes proportionally.

In effect, this assumes a constant distribution of spending with zero behavioural effects (perfect inelasticity) from price changes, where households will continue to consume the same quantity of a good or service even if the price changes. It demonstrates the level of spending required to maintain households' current standard of living with respect to infrastructure services. Changes in the spending distribution between households over the time horizon are then driven exclusively by changes in the cost of infrastructure.

[6] Office for National Statistics (2023), Family spending in the UK: April 2021 to March 2022

The Commission presents spend on infrastructure services and related investments for each group as a percentage of total annual expenditure. Across current and future periods, the analysis holds total annual expenditure at the level reported during the survey period. That is, it assumes that changes in spending on bills are paid for by cutting back spending or increasing spending elsewhere, with total expenditure remaining constant. This avoids the need for assumptions about future income trends and the distribution of future wealth, and enables a view of policy impacts on today's world.

Sector-specific approach: transport

The major change in the transport sector described in the Assessment is the switch to electric vehicles in place of petrol and diesel powered vehicles. This will change dynamics in fuel spending because electric cars are cheaper to run than petrol or diesel cars. While the method described above is used to analyse changes to spending on train and bus fares, a different approach is required to analyse spending on electricity for cars; current data on the relatively few households with electric cars today is unlikely to be representative of the wider population in future. In order to analyse the distributional effects of future changes in transport costs, the analysis needs to model which households will switch to electric vehicles and when. The analysis does not capture the impact of purchasing electric vehicles, assuming instead that the costs incurred by these purchases will be the same as costs from purchasing petrol and diesel vehicles. This assumption is consistent with modelling undertaken for the economic remit in the Assessment.

The approach for this is based on modelled changes in the vehicle stock from the Society of Motor Manufacturers and Traders that predicts what percentage of vehicles on the road in the UK will be electric vehicles. The analysis calculates how many households will need to switch to electric vehicles in a given year to line up with the overall modelled vehicle stock, and predicts the characteristics of these households based on current car-purchasing habits. With electric vehicle ownership modelled, the analysis only takes into account the effects of the transition on fuel spending.

To do this, the analysis fits a logit model that predicts a household's likelihood of purchasing a car in the last year. It then ranks all households according to this likelihood. Next, yearly modelled uptake of EVs is used to assign the top x per cent ranked households as EV switchers, where x is the share of the total car stock that is electric in a given year. The years used in the analysis are 2025 and 2035, where modelled EV share of the vehicle stock in these years is eight per cent and 55 per cent respectively, so the top ranked eight per cent of households are assigned to the EV group in 2025, and the top 55 per cent to the EV group in 2035. These figures come from modelled changes in the vehicle stock from the Society of Motor Manufacturers and Traders[7]. For households that are assigned to the EV group, the analysis assumes all their petrol/diesel spend is replaced with electricity spend. It assumes constant miles travelled, so to obtain the value of electricity spend it divides petrol and diesel spend in the LCFS period by the unit cost of petrol and diesel in that time to get the litres of fuel purchased.

[7] https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-new-car-market-and-parc-outlook-to-2035-by-powertrain-type-11-06-21.pdf

This is then converted to kWh using a standard conversion factor between kWh and litres of petrol[8], and the predicted unit cost of electricity used in these years to calculate spend on electricity for EVs. For a given distance travelled, electric vehicles are cheaper to run than petrol or diesel cars at current and projected electricity prices. This approach is a simple method to approximate the characteristics of households who we might expect to switch to EVs first. It relies on the assumption that households who are most likely to buy a car now will be the first ones to switch to EVs, and it also assigns EVs at the household level, meaning households are assumed to switch all their cars at once, which concentrates the transition in those most likely to buy a new car. These are simplifying assumptions which allow the analysis to provide a reasonable indication of the approximate distributional impacts of the EV switch.

Results

In the following section, the results of our distributional analysis are presented in a series of charts. This analysis examines the impacts of changing infrastructure costs on household expenditure across various protected characteristics, as well as by region, income, and urban/rural split. The impacts are presented as a percentage of total household expenditure. 95 per cent confidence intervals are presented for all 2019 data, but as future projections are based on external modelling individual to each sector, rather than sampling from a population, confidence intervals are not appropriate for other years.

Differences in the experience of protected groups largely follow their household income, with urban-rural dynamics also an important driver of overall trends. Below there is a brief commentary on the headline results across each of the sectors as well as for the overview results. It is important to note that this is a first attempt at distributional analysis of spend on infrastructure services across income and protected groups. Therefore, the methods discussed in previous sections and results should be considered experimental and should be interpreted with caution. They are indicative of potential outcomes following the Commission's recommendations based on projections of future bills and other costs.

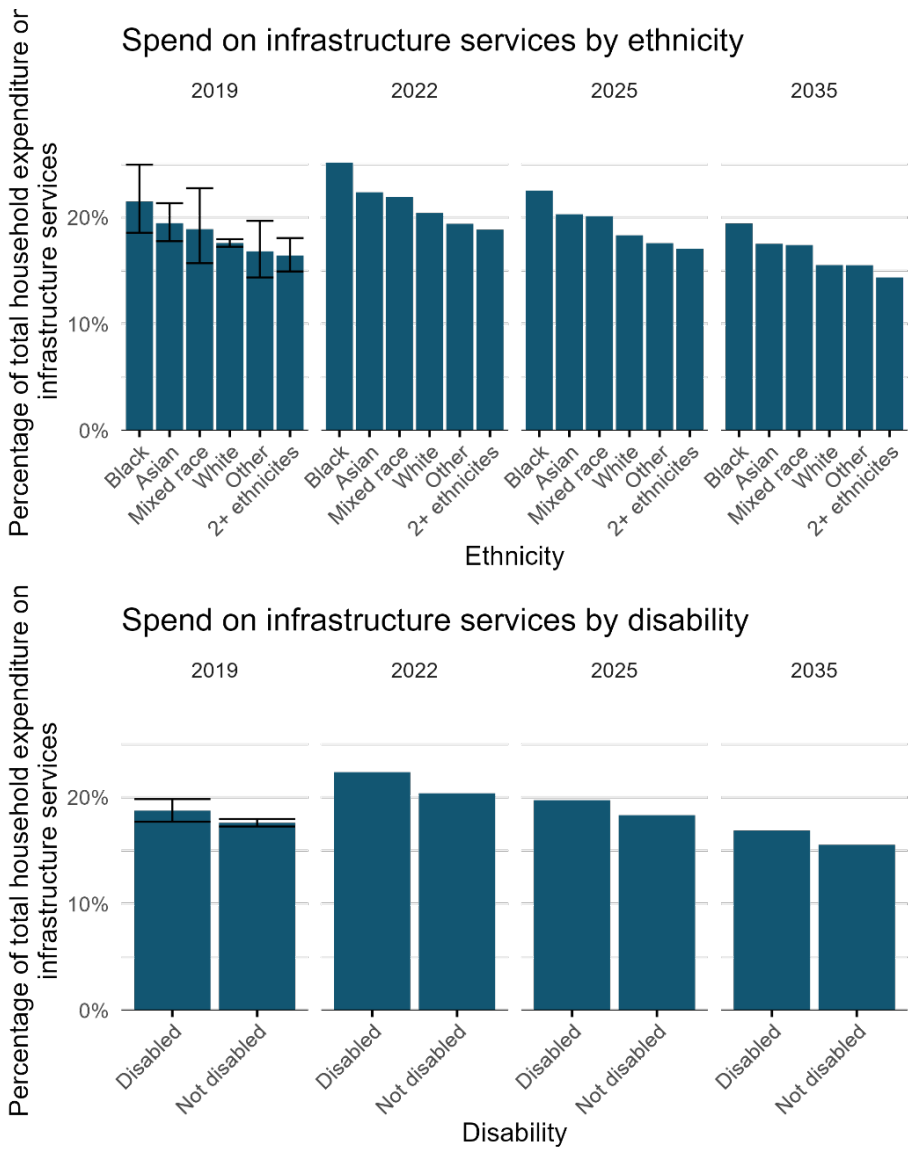
This analysis should therefore serve as a starting point for understanding how infrastructure costs effect different types of households. The Commission welcomes feedback on the methods and results.

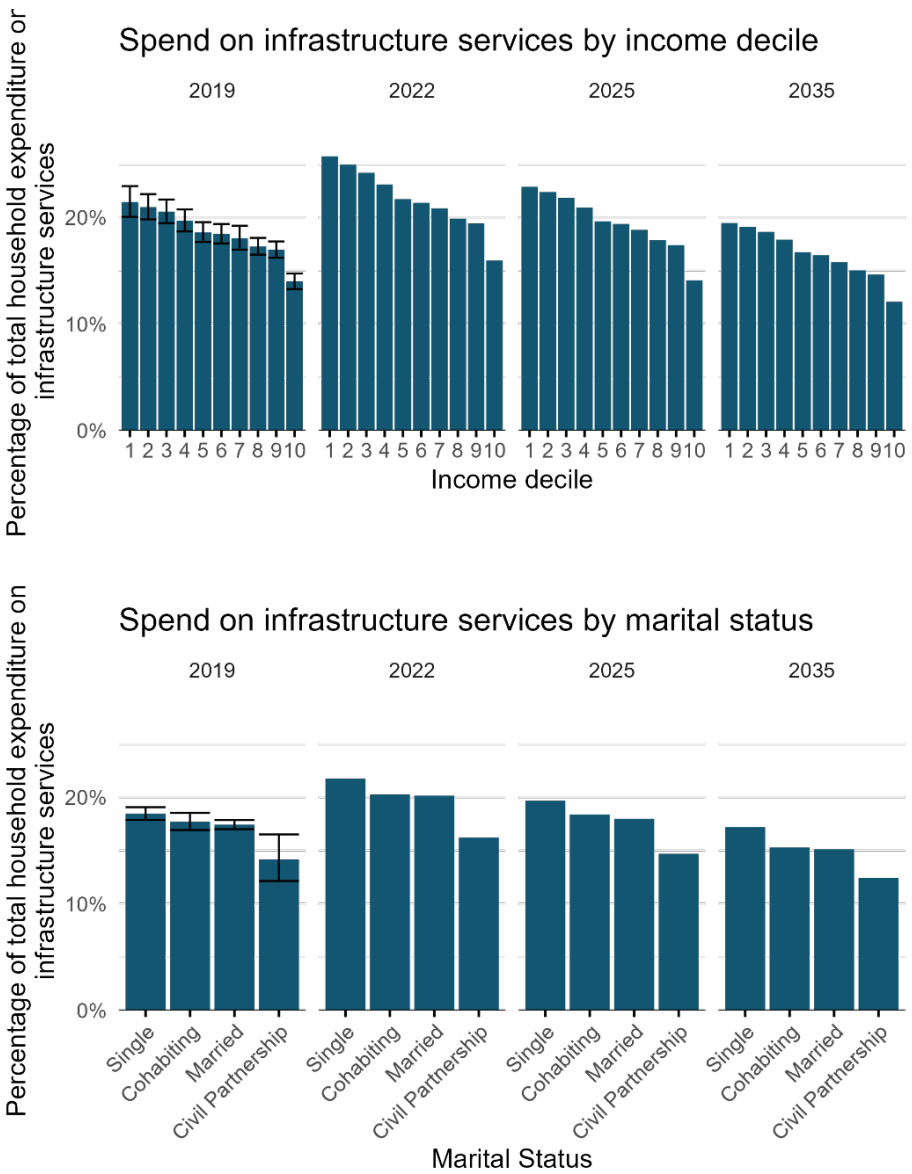
[8] https://nepis.epa.gov/Exe/ZyPDF.cgi/P100BAV0.PDF?Dockey=P100BAV0.PDF

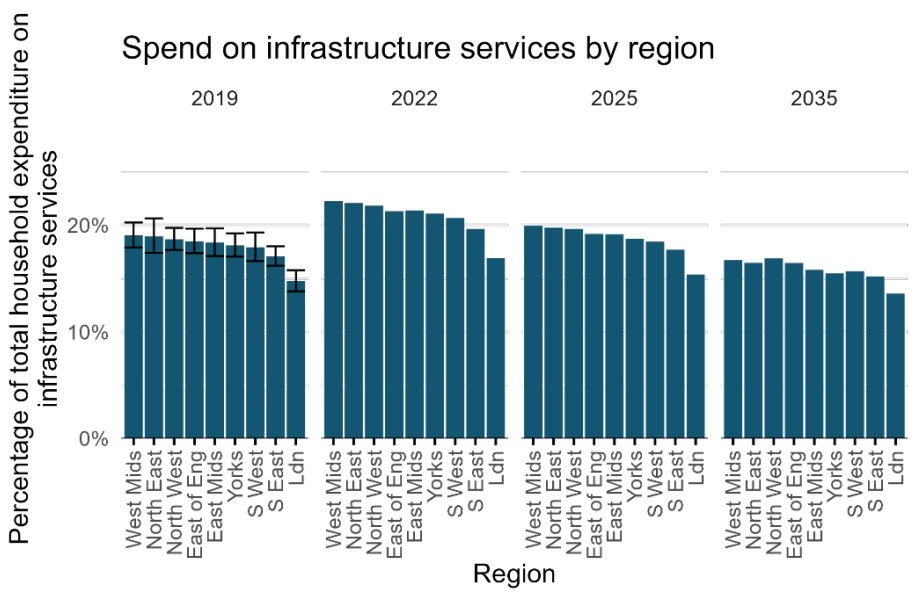
Total infrastructure spend

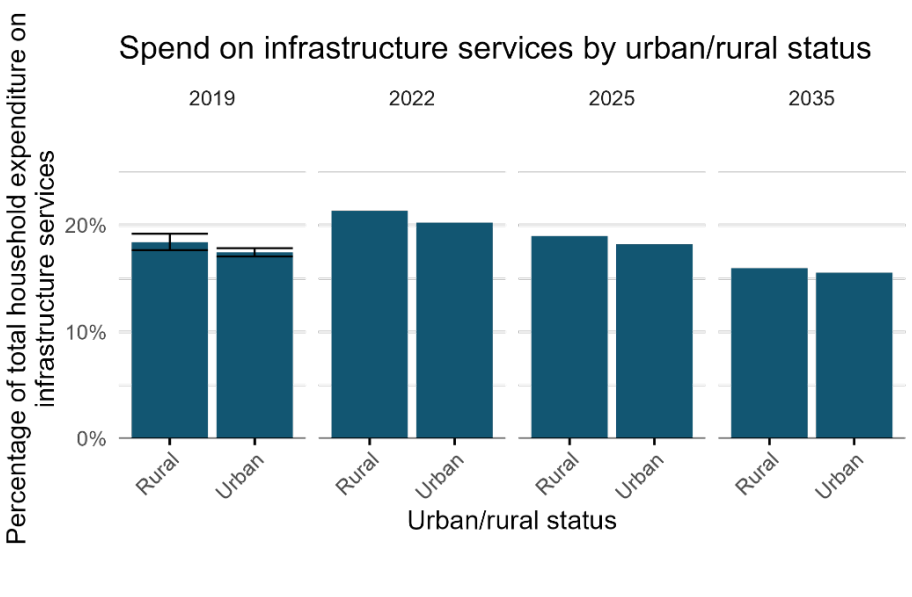
The following charts illustrate the projected impacts of bills across infrastructure sectors (energy, transport, digital, and water) for each protected characteristic/group. The focus is on the period leading up to 2035, spanning the sixth carbon budget's requirements for decarbonising much of the transport sector and domestic heating.

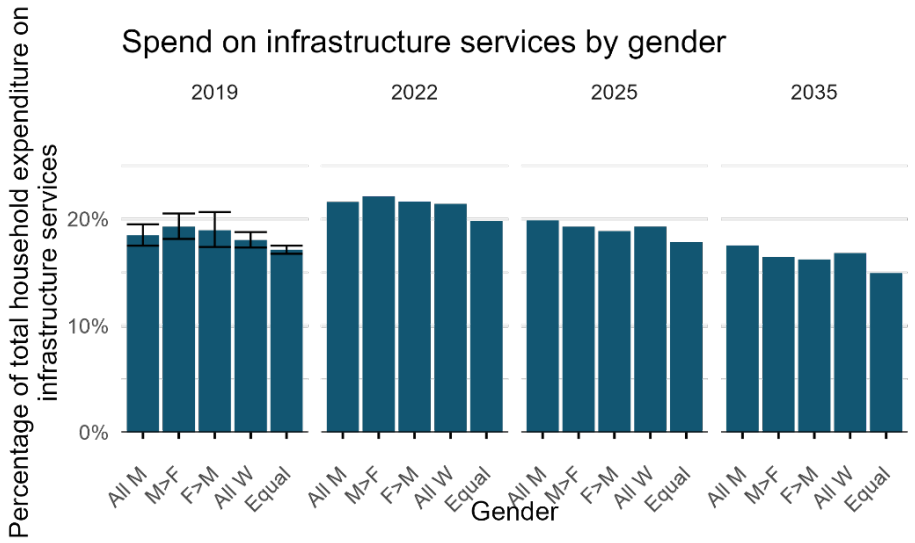
The findings indicate that average bills are expected to decrease consistently for households across all groups. This decrease is primarily driven by anticipated reductions in energy costs, which are expected to offset increases in water bills, and the falling cost of driving as motorists switch to electric vehicles (which are cheaper to run than petrol or diesel cars). This means the households that stand to benefit the most are those that allocate more of their spending to energy and fuel for driving.

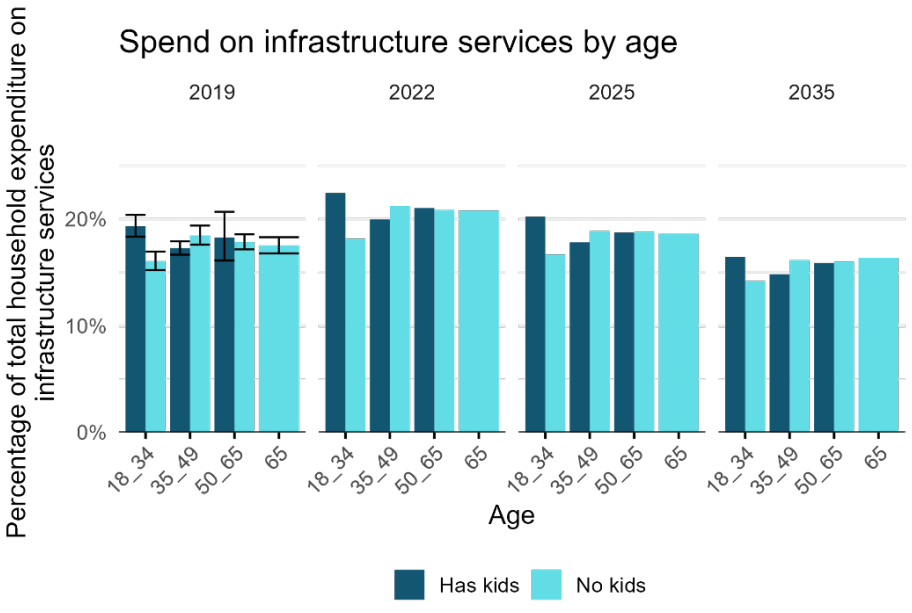










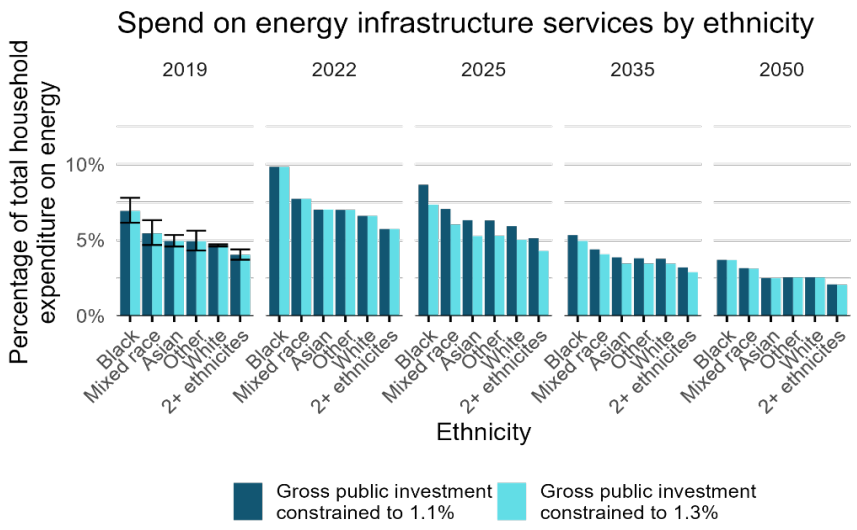


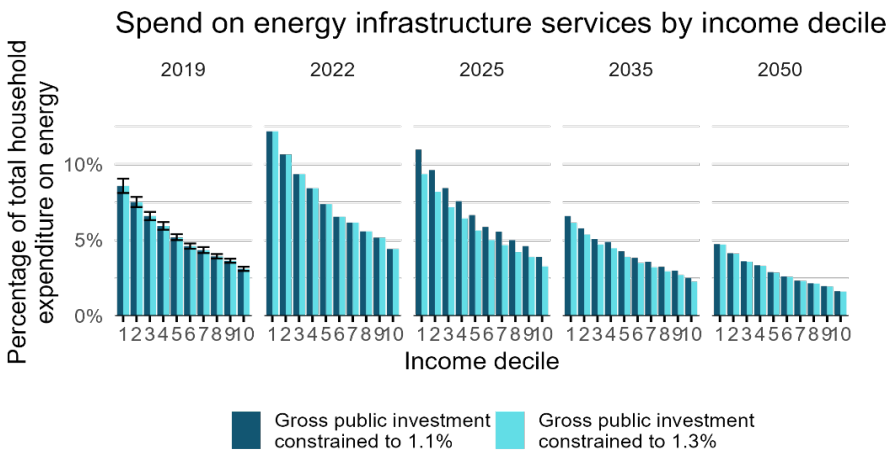
Impacts of future energy bills

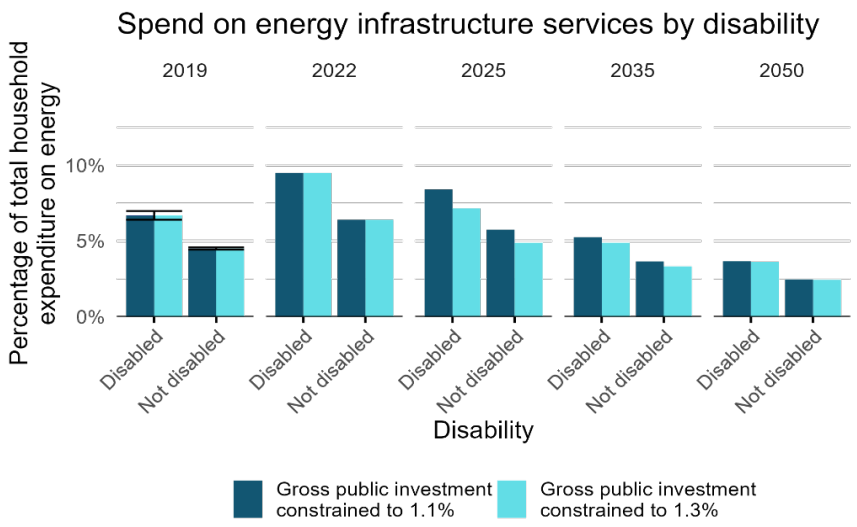
Our analysis of the impacts of changing energy bills takes into account expenditure on gas and electricity bills, as well as costs associated with heat infrastructure, including heat pumps and subsidies, and boilers. The analysis anticipates a decrease in costs across all groups due to lower electricity unit costs and the increased efficiency of low-carbon heating.

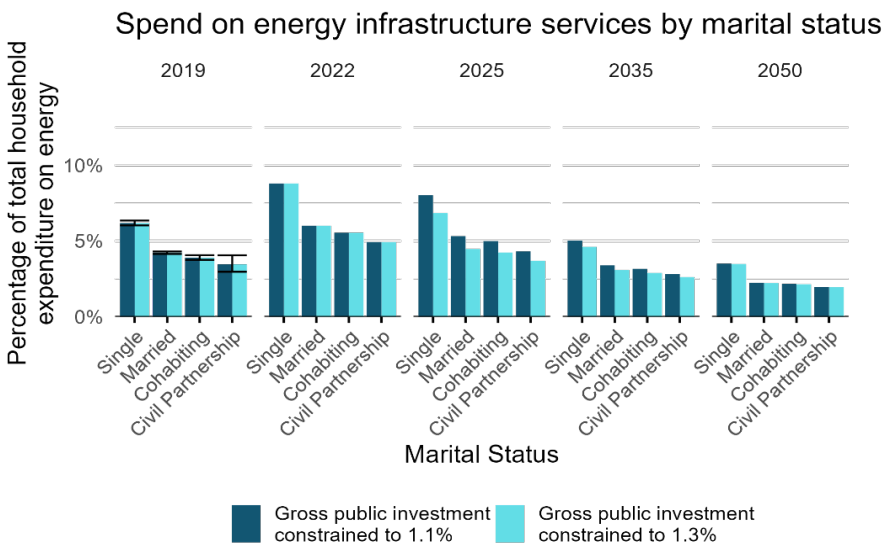
Energy spend as a percentage of total household expenditure is proportionally higher for lower income households. With the reduction in electricity costs and the introduction of a heat subsidy package aimed at providing targeted support to low-income households, our analysis expects energy bills for lower income households to decrease over the next 30 years.

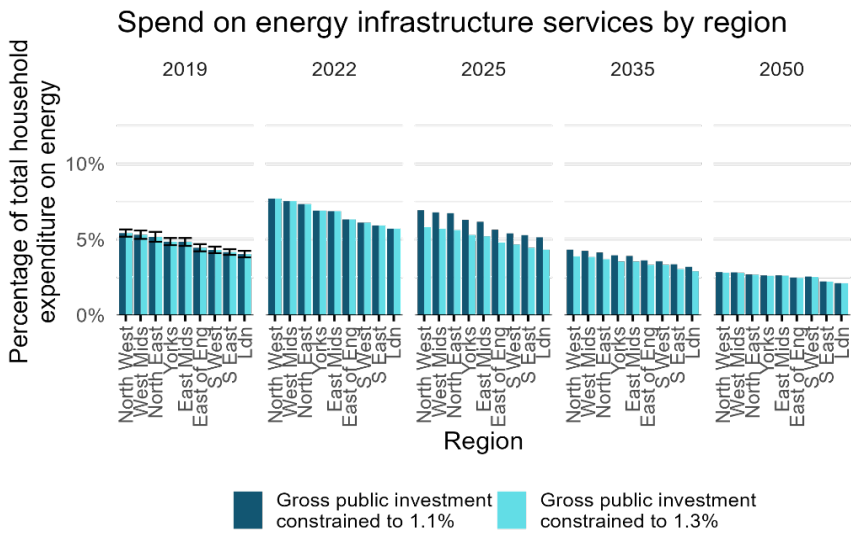
In the charts below, two sets of results are presented side-by-side. The first presents the impacts of the Commission's recommended package of interventions in the Assessment, whilst the second presents an alternative package which the Commission is required to develop and puts a relatively higher burden on households in exchange for a lower burden on government. The recommended package would cost government around 1.3 per cent of GDP in gross public investment, whilst the alternative would cost 1.1 per cent of GDP. The charts demonstrate that every group faces higher costs in 2025 and 2035 under the 1.1 per cent package, with the largest difference experienced by low-income households.

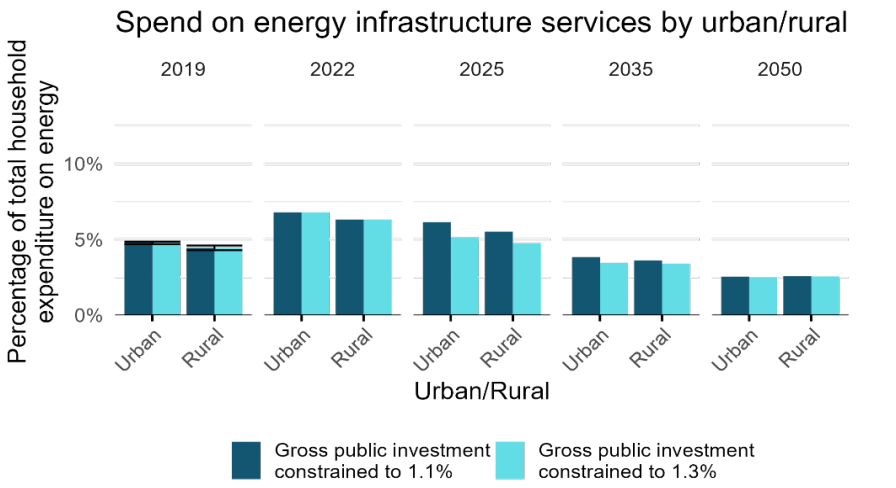


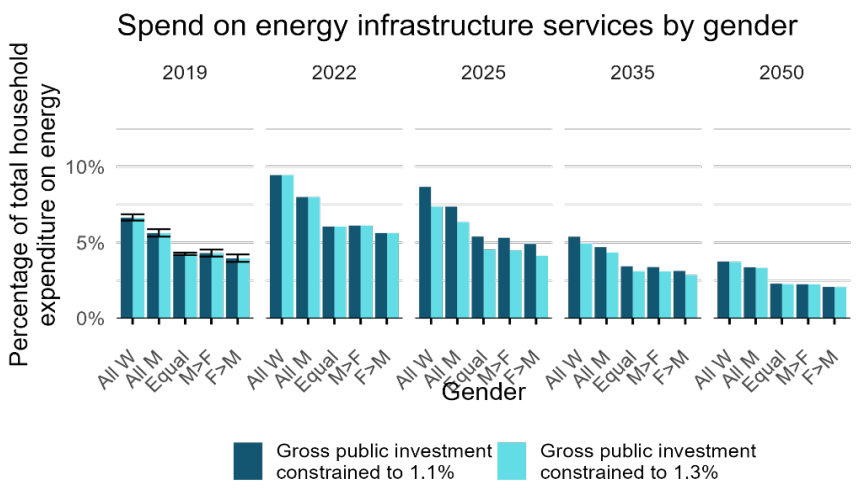


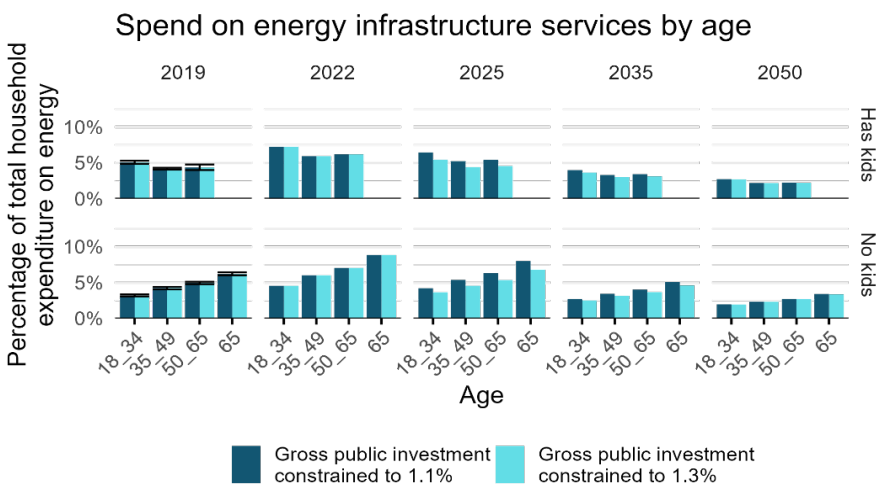






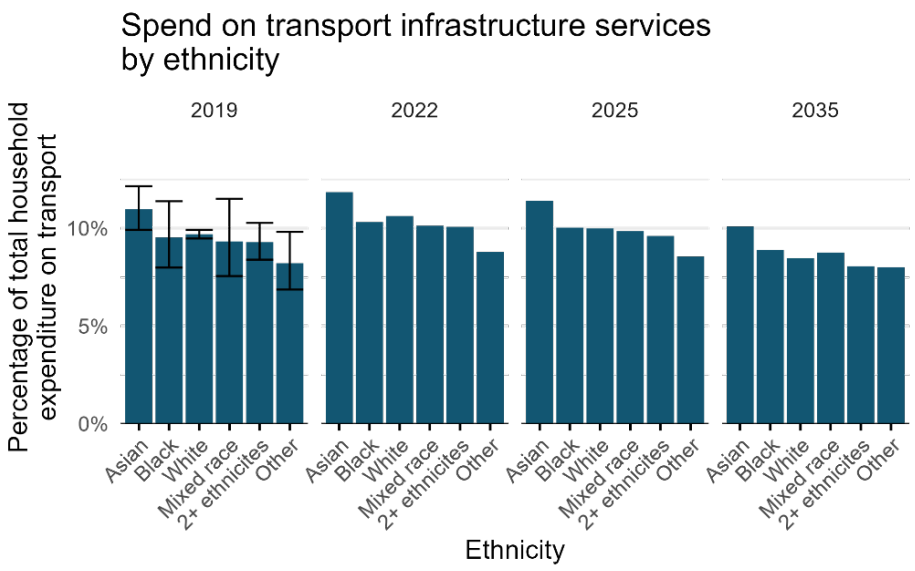


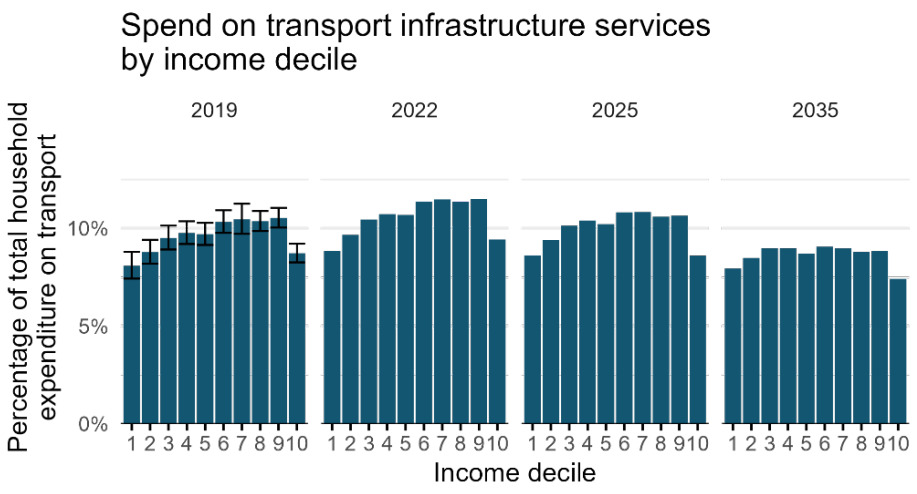


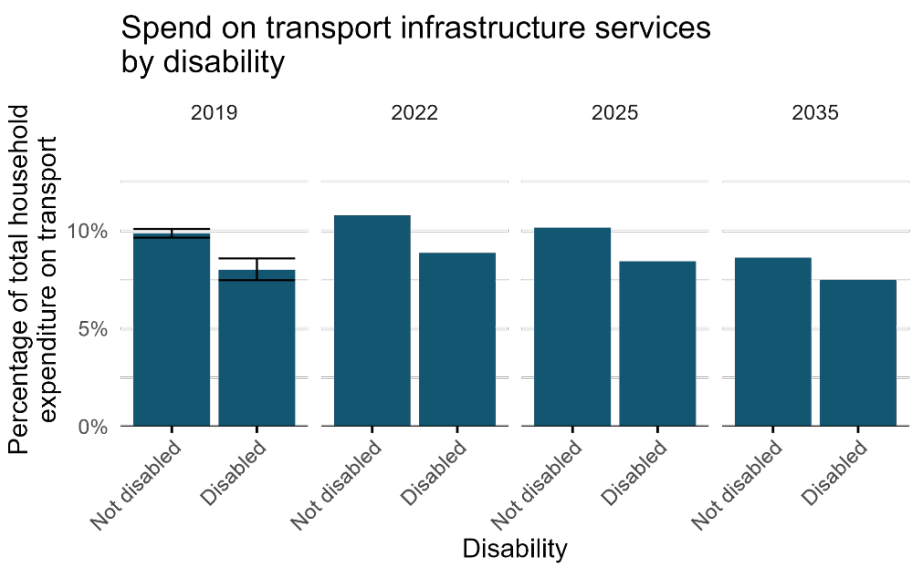


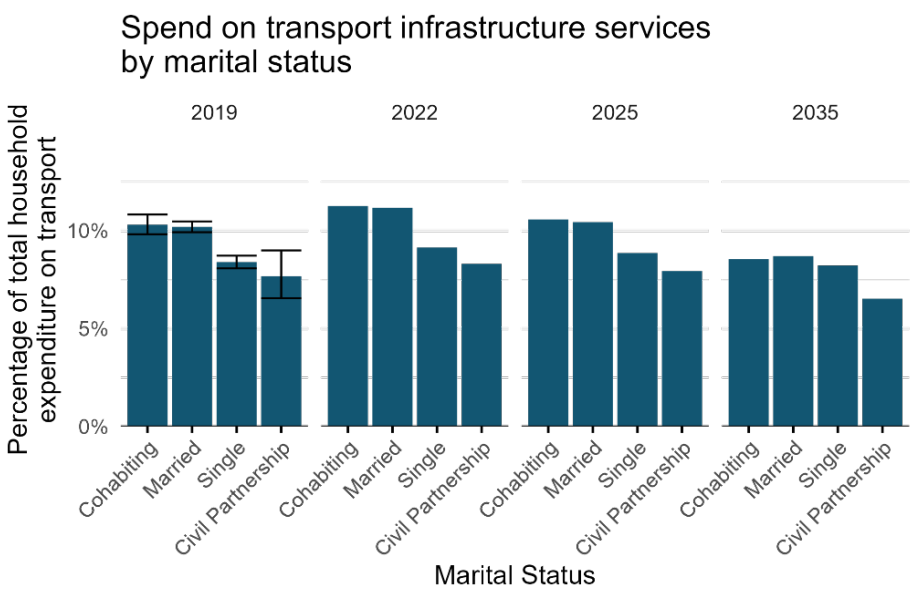
Impacts of future transport costs

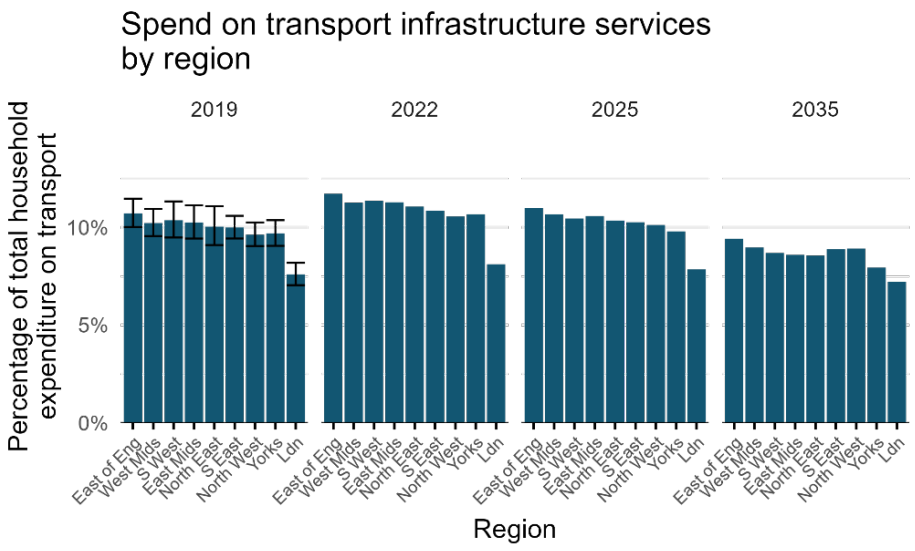
Across most groups, the analysis anticipates a decrease in transport costs as the transition to electric vehicles reduces spending on fuel and electricity. This decline will be most pronounced for households that currently allocate a larger portion of their expenditure to fuel and those that switch to EVs sooner. Currently, higher-income households generally allocate more of their expenditure to transport than those with lower incomes. These higher spenders are more likely to switch to EVs first, so stand to benefit sooner. Regionally, households in London currently spend significantly less on transport than those in other regions, primarily due to lower car usage, as do urban households more generally. This trend may flatten out over the time horizon. There are also significant disparities in transport spend by gender and disability status, also expected to flatten over the time horizon.

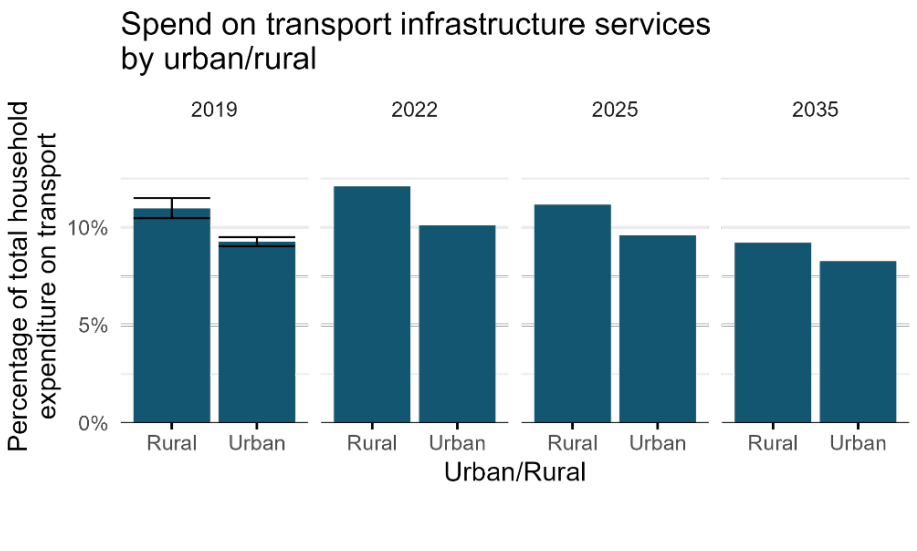


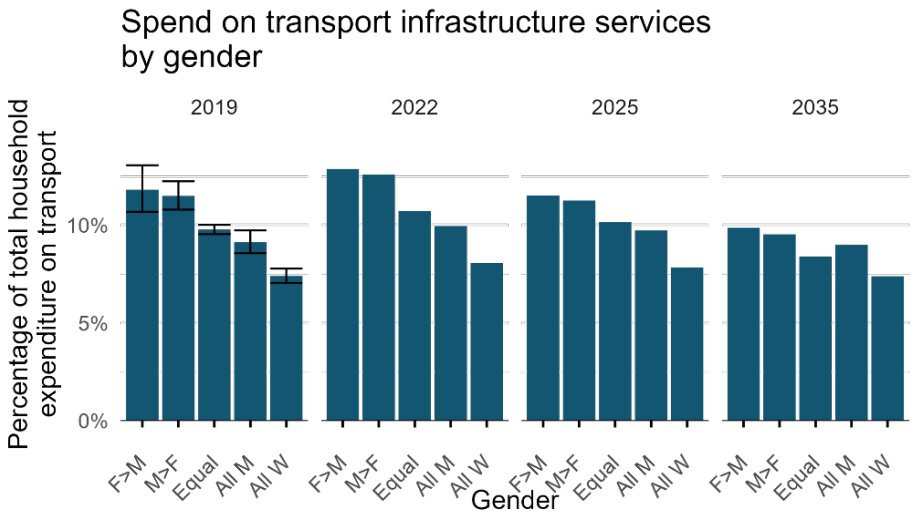


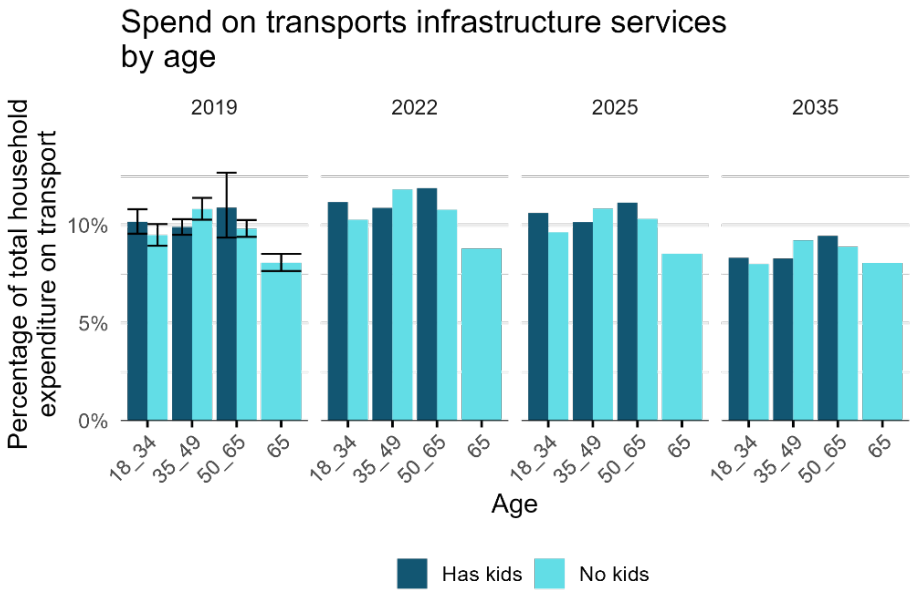












Impacts of future water bills

Water bills are expected to rise for all households across all groups. Water consumption is relatively less income elastic, resulting in lower-income groups spending a proportionally higher percentage of their income on water. Consequently, the current distribution of water bills among income deciles is likely to worsen as prices increase.

In 2019, significant variation in water spend is present across all characteristics analysed, with especially large differentials between groups in income, marital status, gender, ethnicity and region. These disparities will likely worsen if water bills increase as expected.