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The distributional effects of pathways to net-zero and the implications for fuel and transport poverty

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Executive summary

Achieving a just transition

A key challenge associated with the transition to net-zero is how to fairly spread the costs and benefits of policies used to achieve decarbonisation across all aspects of society. A so-called 'just' transition can be achieved if, at the same time as reducing emissions across the economy, all people, places and communities are supported, benefits from the transition are fairly shared and no-one is 'left behind'. This report explores whether new inequalities may emerge, or existing inequalities worsen within UK society, because of policies designed to transition the UK to a net-zero economy and society. It specifically considers the vulnerability of different types of representative households to fuel and transport poverty as a result of three different policy approaches to achieving net-zero.

The 2022 cost-of-living crisis has exacerbated fuel and transport poverty

At the time of its publication, the findings of this report are highly relevant; the 2022 cost-of-living crisis, partly driven by rocketing global gas prices, has made the issues of fuel and transport poverty, and the need to address increasing inequalities, ever more pertinent. Much higher proportions of the UK population are expected to fall into hardship and difficult daily decisions about energy and transport will be further exacerbated as household finances are put under increasing pressure.

How should the Government respond?

The 2022 cost-of-living crisis has brought about fresh dilemmas about how best to support households with rising costs, while still achieving other Government priorities including climate goals and levelling up. A challenge now faced by policymakers is how to continue the pathway to net-zero, without further adding to the financial pressures faced by households, particularly vulnerable households who are less 'able to pay'.

In this report we argue that decarbonisation policies could be used to both partly address the cost-of-living crisis while also delivering progress towards net-zero. It is clear that strategies to decarbonise the UK should not make the incidence of, or degree of, fuel and transport poverty worse. Through the distributional outcomes of hypothetical scenarios of differing policy pathways, this report provides greater understanding of who could be vulnerable to fuel and transport poverty in the UK's transition to net-zero, to what extent, and why. It unveils societal groups and specific household archetypes who may be at particular risk and considers the implications for developing effective and supportive policy, which reduces inequalities and promotes a fair and just transition.

The objectives of this research

The research presented in this report forms part of the 'Fuel and transport poverty in the UK's energy transition' (FAIR) project, funded by the Centre for Research into Energy Demand Solutions (CREDS) (CREDS, 2022). The overall objectives of the FAIR project are to:

- Examine who and where is vulnerable to fuel and transport poverty in the UK, to what extent, and why.
- **Unveil how vulnerability to fuel and transport poverty shapes the UK's energy transition**.
- Propose policies for an energy transition that promotes a more just society.

This research contributes primarily to the second objective by considering whether new inequalities may emerge, or existing inequalities worsen, as a result of policies designed to transition the UK to a net-zero economy. Through a combination of macroeconomic modelling with Cambridge Econometrics' well-established E3ME model[1] and additional household archetype distributional analysis, the research aims to demonstrate how policies associated with the UK's low-carbon transition may impact upon vulnerable groups within society.

Macroeconomic modelling

The first stage of the research modelled three core scenarios exploring alternative net-zero pathways for the UK economy, using Cambridge Econometrics' E3ME model.

Three core modelling scenarios

The three scenarios aimed to explore the impacts of alternative pathways to net-zero for the UK economy. Results for these three scenarios are compared against a 'business-as-usual' baseline, in which there is no change to currently implemented policies.

- The first scenario was designed to replicate major climate policies and targets included in the UK Government's Net Zero Strategy (NZS) (BEIS, 2021c). When the NZS was modelled in E3ME, it did not achieve net-zero emissions by 2050.

Meanwhile, two further scenarios outlined two alternative pathways to net-zero (with both of these achieving higher emissions reductions than the NZS scenario):

- One using a range of regulatory measures to achieve emissions reductions.
- Another relying on a market-based instrument (MBI), to incentivise the decarbonisation of the economy.

The macroeconomic modelling findings demonstrate that **all the net-zero policy pathways modelled lead to better outcomes for GDP and employment in the UK compared to the 'business-as-usual' baseline**, with the more ambitious MBI and Regulation scenarios leading to higher GDP and (to a lesser extent) employment than the NZS scenario.

1 See www.e3me.com

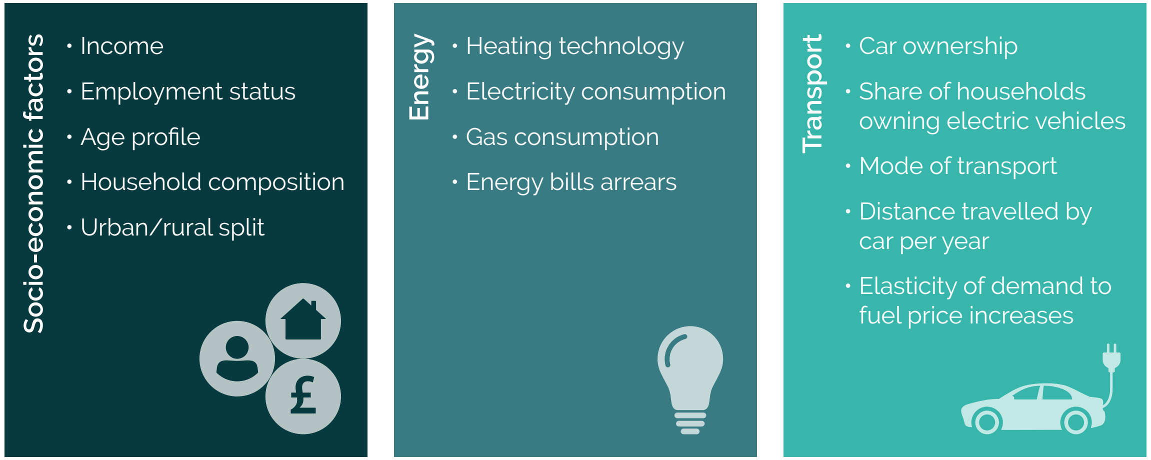
The macroeconomic results of the scenario modelling demonstrate two important findings:

- **Climate policy generates favourable outcomes for the environment, economy and society as a whole**, creating a win-win situation in which emissions are reduced, while at the same time the economy grows, and new employment opportunities are created.
- **More ambitious climate action (in terms of emissions reductions) can lead to even greater gains for the environment, economy and society**.

The impacts of net-zero pathways on different household archetypes

A set of household archetypes with different socio-economic backgrounds, energy attributes and transport behaviours were then developed to represent UK society, building on the energy consumer archetypes produced by Ofgem in 2020 (Centre for Sustainable Energy, 2020), which segments the population of Great Britain[2] into a set of thirteen household archetypes. The household archetypes developed are further enriched with quantitative and qualitative data on transport behaviours, mainly extracted from an extended literature review and from the National Travel Survey (Department for Transport, 2021), that provides data on personal travel patterns by residents of England.

2 The archetypes in this report are assumed to represent UK society. While the Ofgem archetypes are based on the population of Great Britain, it is deemed a reasonable assumption that the characteristics of these archetypes may be extended to represent the UK, since the population of Great Britain constitutes approximately 97% of the UK population (see Population estimates for the UK, England and Wales, Scotland and Northern Ireland | Office for National Statistics.



Summary of household archetype characteristics.

Transport characteristics included in the framework refer to car ownership, main mode of transport, average distance travelled by car and elasticities of demand to fuel price increases (see figure, above).

The household archetypes framework was further expanded by developing a 2035 version of the archetypes, for each of the scenarios considered in this research. This involved estimating how the uptake of heat pumps and electric vehicles (EVs) changes across archetypes as a result of decarbonisation policies, and the potential behavioural responses across different households.

The findings of the deep-dive into the effects of the policy scenarios on a set of UK household archetypes shows that there can be 'winners' and 'losers' in each of the policy pathways. The three modelled scenarios show that in 2035:[3]

Vulnerable households will be disproportionately affected

- When considering equity-weighted energy bills,[4] the highest household bills are paid by **low-income households**, particularly from **ethnic minorities, living in social housing predominantly in urban areas**.
- Similarly, **pensioners with disabilities and long-term health conditions**, with either average or low-incomes, are also expected to pay high energy bills[5] in all the modelled scenarios.
- Historically, low-income groups spend a greater proportion of their income on household energy, and the findings of this research show that this **inequality is exacerbated** in all three modelled scenarios. As a proportion of income, the archetype spending the most on energy bills is mainly composed of **ethnic minority households on a low income and living in social housing**. By 2035, these households will spend between 10% and 13% of their income on energy, which is more than double the proportion spent by families on a high income (between 3% and 5%). Similarly, by 2035 **young (i.e. age 16–34), low-income renters** spend between 9% and 13% of their income on energy bills, which is double the proportion spent by those with similar socio-economic characteristics but earning high incomes. Households comprised of **pensioners, typically on disability benefits**, also pay a large proportion of income on energy bills.
- In addition, **young (i.e. age 16–34) households on a low income, ethnic minorities and pensioners with disabilities** tend to have the highest expenditure on motor fuel in all the three modelled scenarios.
- When considering expenditure as a proportion of income, **vulnerable households tend to spend a greater proportion of their income on motor fuel expenditure**. The **policy pathways explored in this analysis all have regressive impacts in terms of motor fuel expenditure**. In the medium-term vulnerable groups are likely to be affected negatively by policies aimed at decarbonising the transport sectors, since they are less likely to be able to make the switch to EVs, and therefore benefit from lower fuel costs.

3 The analysis in this report uses energy prices in line with historical trends, and does not reflect the sharp increase in energy prices that occurred in the late part of 2021 and through 2022 to date. Such high energy prices, if they were to persist into the future, would further tip both the economic and distributional impacts of policy in favour of accelerated decarbonisation, and in particular in favour of measures which do not further increase the energy costs faced by households.

4 As recommended by Green Book guidelines on distributional analysis (HM Treasury, 2022b), our analysis applies 'equity weights' to estimate household bills. Equity-weighting places a higher social value on costs or benefits for lower income households than the equivalent costs or benefits for higher income households. The rationale behind this is the economic principle of the diminishing marginal utility of income which says that the value of an additional £1 of income is greater for low-income households than for high-income groups.

5 The term 'energy bills' used throughout this report reflects energy use within the household (i.e. for heating and utilities) and the use of transport fuels by consumers outside of the house (i.e. petrol, diesel and electricity).

While at the same time:

- **Retired couples and families on average incomes, as well as young households (i.e. age 16–34) and middle-aged households (i.e. age 45–64) on a high income tend to pay substantially lower annual household energy bills (when equity-weighting is taken into account, and a proportion of income) compared to vulnerable households**.
- **Wealthy and less vulnerable groups are expected to benefit widely from the transition to electric vehicles (EVs)**.
- In the NZS and Regulation scenarios, regulatory policy leads to sales of new internal combustion engine (ICE) vehicles being phased out by 2030 (NZS) or 2022 (Regulation), which results in a substantial shift to EVs, particularly amongst high-income households who can afford the up-front costs. **While both scenarios lead to savings in motor fuel expenditure for all household archetypes, the results are regressive since the largest savings are achieved by the least vulnerable households**.

The findings of this research are consistent with earlier work in the FAIR project which identified the groups most vulnerable to fuel and transport poverty (see Figure 1.1 in Chapter 1), as well as other work carried out by CREDS.[6] **Households on a low income, households with children, ethnic minority households and households with health and/or mobility difficulties** are all predisposed to experience energy and transport poverty combined, and **our research shows that, without appropriate support, these groups are indeed vulnerable to financial hardship when it comes to paying their energy and transport costs in the UK's energy transition**.

6 See Curbing excess: high energy consumption and the fair energy transition | CREDS.

When the modelling findings point towards any savings in 2035 (i.e. the NZS and Regulation scenarios lead to savings on motor fuel expenditure), the largest savings are made by the least vulnerable archetypes. Without appropriate policy that recognises the potential 'winners' and 'losers' of the transition to net-zero, worsening inequalities may emerge.

What kind of policy could be used to support vulnerable households, and alleviate fuel and transport poverty?

The following policies could be effective and supportive measures to achieve both progress towards net-zero, while reducing inequalities, thereby promoting a fair and just transition:

- Speed up the pace at which:
  - **The UK decarbonises its energy system (with the dual benefit of reducing the cost of generating electricity and increasing the UK's energy security) and**;
  - **The UK prioritises electrification and reduces its demand for energy**. In practice this means that at the same time as greater deployment of renewable energy sources, the focus should be on the mass retrofit of homes and improving the energy efficiency of the UK's housing stock through installing insulation, double-glazing and low-energy heating technologies such as heat pumps. While greater deployment of renewable energy sources and moving away from expensive fossil fuel powered sources should reduce the costs of generating electricity, the other aforementioned energy efficiency and low-carbon measures together reduce energy demand, allowing for warmer, more comfortable homes at more affordable running costs.

- A mass retrofit programme should be **targeted first towards the societal groups most vulnerable to fuel poverty, often living in the most inefficient homes and who are least 'able to pay'**.
- **Investing in a high quality, low-cost, integrated public transport system** will not only help to address transport poverty, particularly for vulnerable households such as those in rural areas who have difficulties accessing convenient and affordable public transport, but also increase connectivity and economic growth through increased investment.
- **Policy should take account of the intersectional vulnerabilities certain groups face**. Best available evidence and enhanced data on household composition and spatial characteristics could be used to better target those who are vulnerable.
- Broader **taxation and spending policies associated with the climate transition will have significant distributional impacts**. Fiscal decisions will have important distributional effects on consumption, and therefore on fuel and transport poverty. **If tax revenues raised through decarbonisation were used to promote energy efficiency in fuel-poor households, the Government could drive a progressive transition**, while still generating wider economic benefits for the UK, and also ensuring continued reductions in emissions.

1 Introduction

1.1 The concepts of fuel and transport poverty and a just transition

Achieving a just transition

A key challenge associated with the transition to net-zero is how to fairly spread the costs and benefits of policies used to achieve decarbonisation across all aspects of society. A so-called 'just' transition can be achieved if, at the same time as reducing emissions across the economy, all people, places and communities are supported, benefits from the transition are fairly shared and no-one is 'left behind'.

The Climate Change Committee (CCC)'s Sixth Carbon Budget report notes that while it is expected that the transition will bring many benefits to UK households, there is the risk of costs falling unevenly across society, creating 'winners' and 'losers'. The CCC recommends that decarbonisation policy 'should aim to limit increases in costs to those that are able to pay, while sharing the benefits broadly' (Climate Change Committee, 2020).

Fuel and transport poverty

Throughout the transition to a net-zero economy and society, when energy and transport policy will influence the availability, characteristics and prices of household energy and transport, attention should be given to ensuring that everyone has access to affordable energy and transport to meet their every-day needs.

Particular consideration should be given to protecting those who are the most vulnerable to rising energy and transport costs, living in, or at risk of, fuel and transport poverty. These concepts can be broadly defined as:

- **Fuel poverty**: the inability to attain sufficient levels of domestic energy services (e.g. heating, cooking, showering, washing etc.) (Bouzarovski & Petrova, 2015).
- **Transport poverty**: the inability to attain a socially- and materially- necessitated level of transport services (be that due to lack of affordability, mobility or access) (Simcock et al., 2021).

Earlier work in the CREDS Fuel and transport poverty in the UK's energy transition (FAIR) project identified groups who are particularly at risk to fuel and transport poverty (as shown in Figure 1.1). Households composed of older, retired people and those living in older and inefficient homes are at particular risk of fuel poverty. In addition, groups of people who have fewer choices about the home they live in, the energy system or energy efficiency measures installed, or the type of fuel or tariff they are connected to are also at risk as they have less opportunity to improve the energy efficiency of their home and the costs of heating it. These groups include those living in the private rented sector, students and young people, asylum seekers and refugees.

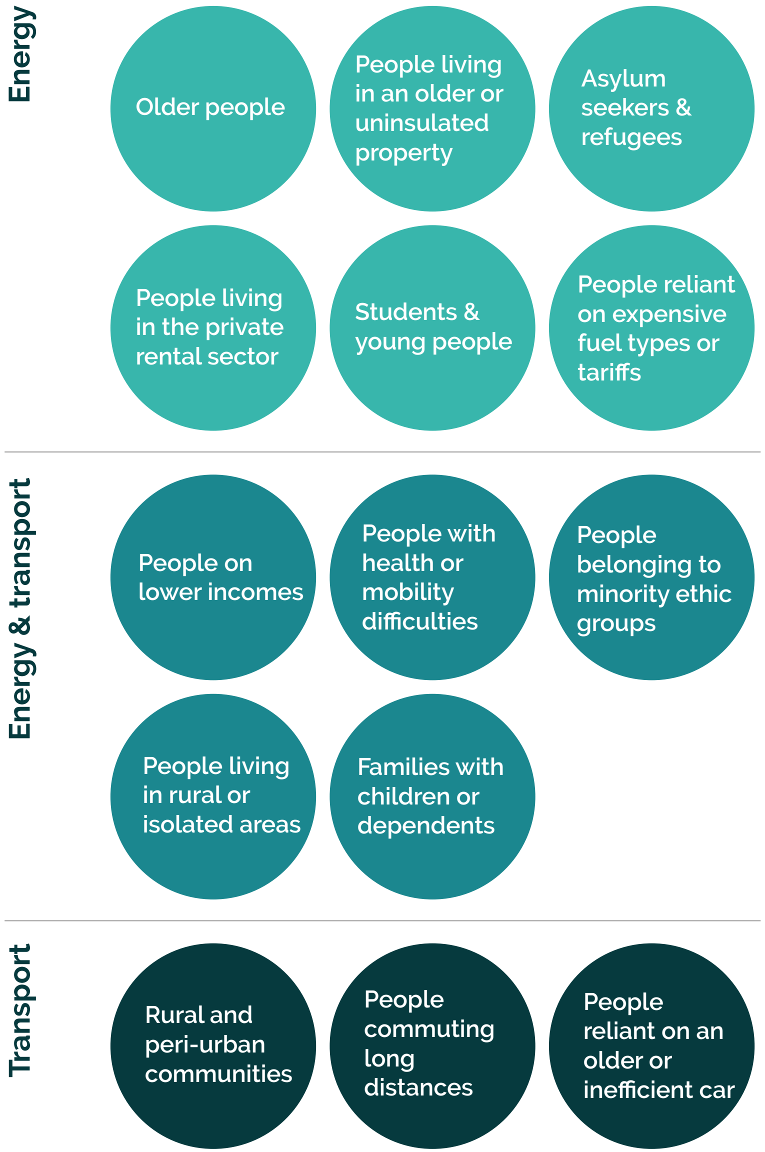


Figure 1.1: The groups of people vulnerable to fuel, fuel and transport, and transport poverty. Source: Martiskainen et al., 2021; Simcock et al., 2021.

Some of the groups who are at risk of fuel poverty are also most at risk of experiencing transport poverty simultaneously. Households with low incomes, people from ethnic minorities, households with children or people with health and/or mobility difficulties, and those living in rural or isolated areas are particularly at risk. Transport poverty can be a particular problem within rural and peri-urban communities, because amenities, places of work and social spaces may be located far from home and public transport links may be limited. Households may therefore be more dependent upon their car, while at the same time running a private car may be unaffordable for some.

What do we mean by vulnerability?

The analysis presented in this report considers the distributional impacts of policies to decarbonise the UK's economy and transition to net-zero, and whether households across UK society will be more or less vulnerable to fuel and transport poverty as a result of these policies.

Box 1.1 sets out what we mean by 'vulnerability' in this context.

Box 1.1: Concepts of vulnerability to fuel and transport poverty

Vulnerability to fuel and transport poverty is comprised of three interlinked factors:

- **Exposure**: the likelihood that a household will experience fuel and/or transport poverty.
- **Sensitivity**: the extent to which fuel and/or transport poverty will be harmful to the well-being of individuals or households.
- **Adaptive capacity**: the extent to which households are able to plan, adapt and respond to fuel and/or transport poverty.

Source: Thomson et al., 2019.

1.2 What consideration has already been given to the distributional impacts of decarbonisation policy?

Net Zero Strategy

The Government's Net Zero Strategy claims to have fairness and affordability at the heart of its approach (BEIS, 2021c). In the context of households and vulnerability to fuel poverty, this means that while households will need to play their part in decarbonising their buildings, the NZS should ensure that the costs of doing so fall fairly across society. The NZS acknowledges the need to continue supporting those most in need throughout the transition to net-zero, particularly in the decarbonisation of buildings. To meet statutory fuel poverty targets,[7] Scotland, Wales and Northern Ireland have their own fuel poverty targets (Department for Communities, Northern Ireland, 2011; Scottish Government, 2022; Welsh Government, 2021)), the NZS outlined continued financial support for vulnerable households through increased investment in the Home Upgrade Grant and Social Housing Decarbonisation Fund schemes, which provide support for low-income households when installing energy efficiency measures and low-carbon heating technologies.

In addition, to further ensure that the transition to net-zero is fair and affordable, and the distribution across society of potential costs does not fall disproportionately on vulnerable groups, the NZS sets out commitments to assessing the distributional impact of the Government's net-zero policies.

Heat and Buildings Strategy

Similarly, the Government's Heat and Buildings Strategy (BEIS, 2021a) also claims that fairness and affordability are at the heart of the approach to decarbonise buildings as part of economy-wide efforts to achieve net-zero by 2050. Investment in energy efficiency measures has the potential to reduce energy bills for all households and the Heat and Buildings Strategy focuses support on households who need it the most, those who are not 'able-to-pay' and may be experiencing fuel poverty. The support measures outlined are the same as those in the NZS – the Government will support low-income households with the costs of paying for energy efficiency improvements and low-carbon heating through the Home Upgrade Grant and Social Housing Decarbonisation Fund.

To increase the affordability of low-energy heating technologies such as heat pumps, the NZS outlines what the Government will do to reduce the costs of such technologies. Measures include working with industry to accelerate innovation and reduce the costs of heat pumps by at least 25-50% by 2025, bringing costs in line with conventional fossil-fuel boilers by 2030, and £5,000 Boiler Upgrade grants for consumers installing air source heat pumps (£6,000 is available for installing ground source heat pumps). In addition, the NZS aims to ensure that, ultimately, the running costs of heat pumps should be no more than conventional fossil-fuel boilers.

7 In England the target is for fuel poor households to be living in a home rated EPC Band C or better by 2030 (BEIS, 2021b).

HM Treasury's Net Zero Review

In 2021, at the recommendation of the Climate Change Committee (CCC), HM Treasury undertook the Net Zero Review to determine how the transition to net-zero will be funded and where costs will fall across the economy and society and how the benefits will be distributed (HM Treasury, 2021). As recommended by the CCC, following on from this review, HM Treasury should develop a strategy for funding a transition that is fair (Climate Change Committee, 2019). The CCC has commented that there are some shortcomings to the Net Zero Review and does not believe all its recommendations have been considered. It notes that the Review recognises the multiple challenges faced in funding the transition to net-zero, and 'now the Government must start to map out the solutions. The Committee will continue to develop analysis on the merits and risks of different decarbonisation delivery mechanisms and funding options, particularly with consideration to their distributional impacts' (Climate Change Committee, 2021, p. 22).

While some aspects of 'fairness' have been acknowledged in the Government's decarbonisation strategies, more work is needed to understand who is vulnerable to fuel and transport poverty, how to support these people appropriately and to develop policy accordingly so that a just transition can be achieved.

1.3 The intersections between the affordability of energy and the transition to net-zero have been highlighted by the cost-of-living crisis

High energy prices are driving the UK's cost-of-living crisis

The incidence of fuel poverty in the UK has become exacerbated and therefore an increasingly urgent issue in recent months, driven by rising energy prices and the broader cost-of-living crisis. Since the latter part of 2021 gas prices in the UK have continued to rise steeply, and these rises have been compounded by multiple economic, infrastructural and geopolitical factors. It is expected that energy bills will continue to climb throughout 2022 in line with increases to the UK's energy price cap (Centre for Sustainable Energy, 2022). At a BEIS Committee meeting in May 2022, the Chief Executive of Ofgem signalled that the price cap is likely to increase to around £2,800 a year from October 2022, while some experts predict that by October the cap could be as high as £3,000 (Morison, 2022). It should be noted that the price cap is not a hard cap on bills; but instead a cap on the costs that can be paid by the 'average' consumer, and final household bills still vary with consumption.

Rising global oil and gas prices not only have an impact on the costs of heating a home, but also increase the costs of running a petrol or diesel car, and the costs of weekly food shops and other essentials such as clothing because higher energy prices are feeding into higher production and transportation costs associated with these goods.

Fuel poverty is becoming more widespread

Increases in household energy costs will add to the rising cost-of-living in the UK, affecting all households, but particularly severely vulnerable households who are already experiencing, or are at risk of falling into, fuel poverty. For many vulnerable households who have low incomes and live in inefficient homes and/or have disabilities, an increase in their energy bill will force them to make difficult daily decisions about whether to heat their home, what food they can afford to buy, which meals they can afford to cook, and how often they can wash clothes or take a hot shower or bath. The evidence is clear that fuel poverty is becoming more widespread across the UK; the national fuel poverty charity National Energy Action (NEA) estimates that the April 2022 increase in the energy price cap plunged a further 2 million households into fuel poverty, taking the total number in the UK to 6.5 million, representing a quarter of all UK households, and a 50% increase in just over six months (NEA, 2022).

The future outlook could be even worse – Citizens Advice estimates that 14.5 million, over half of all UK households, will be unable to afford their energy bills from October 2022 (Bullard T. et al., 2022). And throughout 2022, the costs of essential goods and services are expected to keep increasing, as businesses grapple with their own costs and profitability, and put up prices. For many households, difficult decisions about energy and transport will be further exacerbated as household finances are put under increasing pressure.

How should the Government respond?

With the growing cost-of-living crisis in the UK perpetuated not just by the rising energy prices but also tax rises and general price increases, urgent consideration should be given to where this leaves vulnerable households and how the Government should respond. The cost-of-living crisis has brought about fresh questions about how best to support households with rising costs, while still achieving other Government priorities including decarbonisation and levelling up. To help with the immediate difficulties faced by households in 2022, the Government introduced the Energy Bills Rebate in February followed by a revised set of support measures in May (HM Treasury, 2022a). The revisions in May offered more targeted support for vulnerable households than the original Energy Bills Rebate package, but once again did not address other major priorities like decarbonisation, of homes in particular. It could be argued that longer-term solutions to the crisis should instead go hand-in-hand with an accelerated and fair approach to net-zero, an approach which could also reduce the UK's dependence on fossil-fuels, thereby increasing energy security and vulnerability to global oil and gas price volatility.

The pathway to net-zero should avoid exacerbating fuel and transport poverty further and should instead be an opportunity to reduce or eradicate these problems through improved energy efficiency, reduced energy use and reduced energy costs. Since the policy choices included in a pathway can have implications for how the costs and benefits of the transition are distributed across society, the challenge now faced by policymakers is how to continue the transition without further adding to the financial pressures faced by households, particularly households who are less 'able to pay'.

1.4 Objectives of this research

The research presented in this report forms part of the FAIR project, funded by CREDS (CREDS, 2022). The overall objectives of the FAIR project are to:

- Examine who and where is vulnerable to fuel and transport poverty in the UK, to what extent, and why
- **Unveil how vulnerability to fuel and transport poverty shapes the UK's energy transition**
- Propose policies for an energy transition that promote a more just society

This research contributes primarily to the second objective by considering whether new inequalities may emerge, or existing inequalities may worsen, as a result of policies designed to transition the UK to a net-zero economy. Through a combination of macroeconomic modelling with Cambridge Econometrics' well-established E3ME model and additional household archetype distributional analysis, the research aimed to demonstrate how policies associated with the UK's low-carbon transition may impact upon vulnerable groups within society. The research consisted of two distinct stages, to build up a clear picture of the economic and societal outcomes of three hypothetical decarbonisation policy scenarios:

- **Macroeconomic modelling of policy scenarios**: the three scenarios exploring alternative net-zero pathways for the UK economy were modelled, using Cambridge Econometrics' E3ME model.[8] This stage of the research estimated the impacts of the scenarios on macroeconomic indicators including GDP, employment and consumption, thereby 'setting the scene' by describing the high-level socio-economic impacts of the policy pathways. This part of the research also produced scenario outputs which are used in the second part of the research, including growth rates in energy prices and household income, and estimated shares of heating and transport technologies.
- **Assessment of the costs and benefits experienced by different household archetypes**: in this part of the research a mixture of quantitative and qualitive analysis of the costs and benefits a set of household archetypes may experience as a result of the policy scenarios was carried out. This second stage of the research used outputs of the E3ME modelling and comprised a deep-dive into the effects of policies on those most vulnerable in the UK to fuel and transport poverty, considering vulnerability not just based on the income characteristics of households, but additional characteristics which are also 'risk-factors'.

8 See www.e3me.com.

1.5 The structure of this report

This rest of this report presents the findings of the research, and is structured as follows:

- Chapter 2 presents the macroeconomic impacts of the three decarbonisation scenarios, representing three alternative policy pathways to achieve net-zero. The purpose of this chapter is to 'set the scene', from which the more detailed socio-economic effects can be built.
- Chapter 3 explores the distributional effects of the decarbonisation scenarios by considering how different types of households might react to decarbonisation policy, how their energy and transport spending might be affected, and consequently their vulnerability to fuel and transport poverty. This analysis considers how not only income levels, but other household characteristics such as household composition, age, household heating systems, spatial characteristics and transport modes and behaviours might determine the effects of the decarbonisation scenarios on a particular household.
- Finally, in Chapter 4, conclusions of the research are drawn, and the policy implications of the findings are set out.

2 Macroeconomic impacts of net-zero pathways

2.1 Macroeconomic modelling approach

The first stage of the research modelled three core scenarios exploring alternative net-zero pathways for the UK economy, using Cambridge Econometrics' E3ME model. The macroeconomic results from these modelling scenarios are then used as inputs into the later stages of the research, described in Chapter 3, which provides a distributional analysis of the impacts of the net-zero pathways.

E3ME is a macroeconometric simulation model, which importantly allows for integrated modelling of the interactions between the energy system, the economy, and policies that affect both of these. These features enable a detailed analysis of the impacts of the net-zero transition on jobs, incomes, and CO_2 emissions, among other indicators. For more information on E3ME, see Appendix A.

2.2 Scenario and sensitivity design

Three core modelling scenarios

Three core modelling scenarios were developed, which aimed to explore the impacts of alternative pathways to net-zero for the UK economy. Results for these three scenarios were compared against a 'business-as-usual' baseline, in which there is no change to currently implemented policies.

- The first scenario was designed to replicate major climate policies and targets included in the UK Government's Net Zero Strategy (NZS) (BEIS, 2021c).

Two further scenarios outline two alternative pathways to net-zero:

- One using a range of regulatory measures to achieve emissions reductions (Regulation)
- Another relying on a market-based instrument (MBI), to incentivise the decarbonisation of the economy.

The Regulation and MBI scenarios are designed to represent opposing approaches to decarbonisation. In reality, a likely policy outcome will see both policy types implemented as complementary measures. However, considering the different 'extreme' scenarios is a useful exercise to explore the specific economic and distributional outcomes of these types of policies.

An overview of the policies included in each scenario is provided in Table 2.1. Note that the policy levers assessed in these scenarios do not include explicit additional energy efficiency measures affecting the building envelope, such as insulation. While these types of measures will certainly have an important role in decarbonising the UK economy, they are not included in our modelling and could be an area for subsequent research.

Table 2.1: Scenario policies and targets

Sector	NZS	Regulation	MBI

Power generation	• 40GW offshore wind capacity by 2030
	• Fossil fuel shut down by 2035
	• £500m public investment in nuclear & offshore wind
		• Phase out of new capacity additions:
		  • Oil & coal by 2022
		  • Gas by 2028
		• Fossil fuel shut down by 2050
			Carbon price reaching £500/tCO_2 by 2030 (in 2020 GBP), rising with inflation thereafter

Transport	• Phase out new vehicle sales:
	  • Internal combustion engine vehicles (ICE) by 2030
	  • Hybrids by 2035
	• Net-zero rail by 2050
		• Phase out new vehicle sales:
		  • ICE by 2022[9]
		  • Hybrids by 2030
		• Biofuel mandate for vehicles: 50% by 2035, 100% by 2050	

Heating	• Phase out gas boiler sales by 2035
	• Mandate incentivising 600k annual heat pump installations by 2028; 1.7m by 2035
		• Phase out sales of new gas boilers from 2022[10]
		• Mandate incentivising 600k annual heat pump installations by 2028; 1.7m by 2035
		• Renewable heating capital subsidy:
		  • 75% until 2030
		  • Falling to 0% by 2050	

Others	• Capture 20-30 MtCO_2 per year by 2030 across the economy
	  • Including 6 MtCO_2 industrial CCS
	  • Including 5 MtCO_2 engineered GGRs
	• Halving emissions from oil and gas sector by 2030
	• Plant 30,000 ha of trees per year by 2025
	• £11.4bn public spending commitments from 2020-30
		• Energy efficiency investments (all sectors except residential, transport & steel)
		• Forced switching from fossil fuels to industry (other final use/other industry)
		• Biofuel mandates	

9 While we recognise that such an ambitious policy could not be delivered by today, given the focus exclusively on regulation-based policy in this scenario such ambitious phase-out dates were required to achieve the targeted emission reductions.

10 See www.e3me.com.

The ambition of policies in the 'Regulation' and 'MBI' scenarios were adjusted through an iterative process to ensure that both achieved a net-zero emissions outcome by 2050.[11] For instance, experimentation with the carbon price in the MBI scenario revealed that a carbon price rising to £500/tCO_2 by 2030 (in 2020 GBP and rising with inflation thereafter) could achieve a net-zero-consistent CO_2 emissions outcome by 2050.[12]

On the other hand, the 'NZS' scenario is designed to replicate policies from the Net Zero Strategy, and when these policies are implemented in E3ME, the level of emissions in 2050 differ to that in the 'Regulation' and 'MBI' scenarios. As a result, emissions in the NZS scenario are slightly higher than in the other two scenarios, as can be seen in Figure 2.1. Accordingly, comparisons of results between the NZS scenario and the other two scenarios should be interpreted with appropriate caution.

The E3ME modelling suggests that the emissions reductions achieved in the NZS scenario are not sufficient to meet net-zero by 2050. This finding is in line with other research which suggests similar outcomes, for example CREDS work on the role of energy demand reduction in achieving net-zero in the UK finds that 'there is a significant gap between our current trajectory and the pathway necessary to achieve our net-zero goal.' (Barrett et al., 2021).

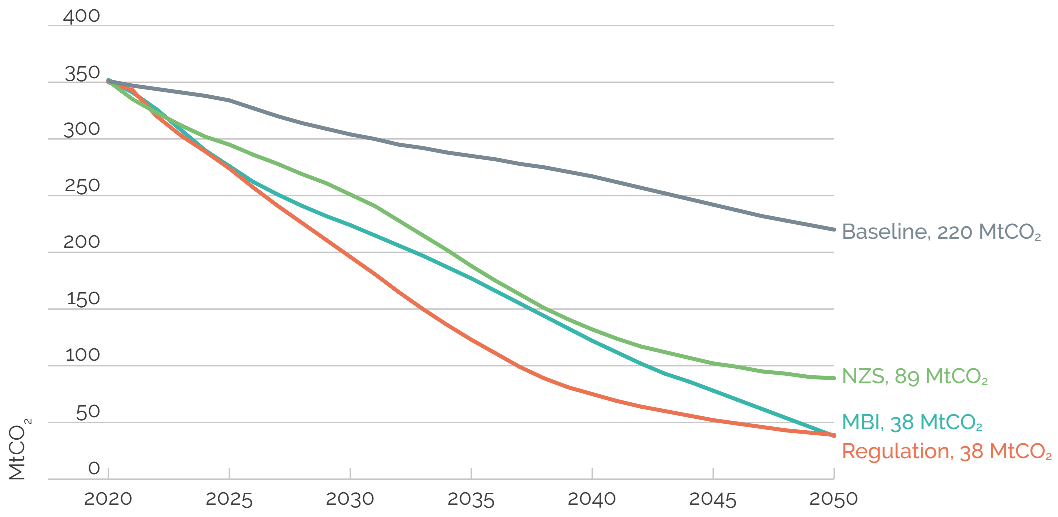


Figure 2.1: CO_2 emissions by scenario, MtCO_2, 2020-50. Note: Includes CO_2 emissions from energy use and industrial processes only. The scenario outcomes put UK within range of net-zero once carbon removals from agriculture, forestry and land-use (AFOLU) and engineered removals are taken into account.

Sensitivity analysis

Different pathways for decarbonising the economy can be expected to have different implications for public finances. If public spending is increased to fund investments and subsidies for clean energy technologies, then Governments may need to raise taxes in the economy to pay for this spending. Conversely, the Government can expect to raise revenues from carbon taxes and must decide whether to 'recycle' these through increased spending or rebates to taxpayers, or alternatively to use the funds to pay down the national debt.

11 While the emissions outcome is the same in the 'Regulation' and 'MBI' scenarios, the cumulative emissions are not exactly the same, due to the difficulty of replicating identical trends through different policies in a simulation model – but they are sufficiently similar to be considered comparable.

12 The £500/tCO_2 assumption is a relatively extreme policy measure, and the fact that the model suggests that this is what is required for a carbon price alone to drive a net-zero outcome underlines the fact that a market-based instruments approach will not be sufficient, and a range of policies will be required to achieve net-zero.

To account for these fiscal policy uncertainties, two sensitivities are used covering different levels of 'revenue recycling' in the MBI scenario: in the core scenario, 100% of carbon revenues are recycled, while the sensitivities explore alternative versions of the core scenario in which this rate is reduced to 50% or 0%.

Note that 100% revenue recycling is the default assumption across all scenarios. This can more broadly be framed as 'budget-neutral' climate policy. So, in the NZS and Regulation scenarios, where Government spending on climate investments and subsidies is greater than receipts from carbon pricing, the 'revenue recycling' in this case implies that direct tax and VAT rates are raised in order to balance the budget.

In reality, Government revenues from a particular tax stream are not typically ringfenced for a particular purpose in this way. Spending of Government revenues are subject to competing policy priorities and attempts to ensure that spending commitments are 'budget neutral' are rare. However, as a modelling exercise, making clear and explicit assumptions about the fiscal balance aids the interpretation of the results.

Table 2.2: Revenue recycling sensitivities (MBI scenario)

Scenario/Sensitivity	Revenue recycling policy
MBI (core)	100% of carbon tax revenues recycled through reductions in direct taxes and employees' social security payments.
MBI (50% RR)	50% of carbon tax revenues used to reduce direct taxes and employees' social security payments.
MBI (0% RR)	0% of carbon tax revenues recycled.

2.3 Limitations of the macroeconomic modelling

This modelling exercise consists of scenario analysis and is not an attempt to forecast the future pathway of the UK economy. We analyse the likely macroeconomic outcomes *assuming* certain conditions, without assessing the likelihood of these conditions being met in the first place.

In general, our scenarios explore the impacts of fiscal measures and energy sector policies at a macroeconomic level. With the exception of sectors covered by its 'Future Technology Transformations' (FTT) submodules (power generation, steel, road transport and residential heating), E3ME is not designed to replicate the dynamics of specific sectors at a microeconomic level. As such, the modelling of policies such as tree-planting and investment in public transport are limited to the macroeconomic impacts of fiscal measures, and the assumed impacts on energy use and emissions.

In addition, the replication of policies in the Net Zero Strategy is in some cases limited by the lack of policy detail in that document. In many cases, a key element of the transition is framed as a target outcome, without any indication of the specific measures which will ensure that outcome is achieved. In these cases, we have either made assumptions about which policies will achieve these outcomes, or made off-model assumptions that allow these outcomes to be achieved.[13]

13 In particular, the NZS targets a strong uptake of heat pumps (1.7m installs per year by 2035), without identifying which policy measures will drive this outcome. In the modelling, we have replicated this outcome through an external assumption. This produces a strong and early decarbonisation of the housing sector relative to the other scenarios, which suggests that the target may be regarded as somewhat implausible without additional policy measures.

The modelling only considers the impacts of policies affecting emissions of CO_2 from energy use and industrial processes. Emissions from waste, agriculture, forestry, and land-use, as well as of non-CO_2 greenhouse gases, are effectively assumed off-model, and the macroeconomic impacts of these measures are not analysed.

It should also be noted that the analysis considers the impacts of a net-zero transition in the UK *alone*. A global climate transition is expected to produce positive externalities which benefit the UK, due to learning-by-doing effects which advance the rate of technological development and bring down the costs of low-carbon technologies sooner. Although E3ME is a global model, the scenarios do not consider the decarbonisation of the rest of the world, and its potential impacts on the UK.

Finally, energy prices within the model start off based on historical data, and then evolve based on extraction/production costs and how these change as energy production scales up to meet demand. The analysis therefore starts off with energy prices in line with historical trends, and does not reflect the sharp increase in energy prices that occurred in the late part of 2021 and through 2022 to date. Such high energy prices, if they were to persist into the future, would further tip both the economic and distributional impacts of policy in favour of accelerated decarbonisation, and in particular in favour of measures which do not further increase the energy costs faced by households.

2.4 Macroeconomic impacts

Summary

The macroeconomic modelling results summarised in this section demonstrate that **all the net-zero policy pathways analysed lead to better outcomes for GDP and employment in the UK compared to the 'business-as-usual' baseline**, with the more ambitious MBI and Regulation scenarios leading to higher GDP and (to a lesser extent) employment than the NZS scenario.

The macroeconomic results of the scenario modelling demonstrate two important findings:

- **Climate policy generates favourable outcomes for the environment, economy and society as a whole**, creating a win-win situation in which emissions are reduced, while at the same time the economy grows, and new employment opportunities are created.
- **More ambitious climate action (in terms of emissions reductions) can lead to even greater gains for the environment, economy and society**.

GDP

The GDP results, displayed in Figure 2.2, show an improvement compared to the baseline in every scenario. This suggests that achieving net-zero is a boon for UK policymakers: decarbonisation of the UK economy can be achieved, while also delivering economic growth.

Furthermore, in all scenarios, the UK economy benefits from a shift in spending away from imported fossil fuels towards domestically produced goods and services, thus improving energy security.

The main driver of the positive economic outcomes depends on the pathway and the policy tools used. **In the Regulation and NZS scenarios, the main driver of growth is investment** in energy efficiency, renewable energy capacity, and the installation of heat pumps. These investments are front-loaded at the beginning of the scenario period, which is why the outcomes show initial gains relative to the baseline, which then plateau after a few years, as the higher costs of the low-carbon investments are repaid.

In contrast, **an important driver of economic growth in the MBI scenario is a boost in consumer expenditure**, as carbon tax revenues are recycled back to consumers through lower direct tax rates and social security contributions.

The MBI scenario outcomes assume that the carbon tax revenues are recycled in this way. Two sensitivities assess how the results are affected if only half of these revenues were recycled ("50% RR"), or if none of them were ("0% RR"), with the remainder used to pay down historic Government debt. The results of these sensitivities (Figure 2.3) show that the **recycling of these carbon tax revenues is critical to the positive outcomes of the MBI scenario**: if all revenues were instead used to pay down the national debt, we estimate that the impact of an MBI net-zero pathway would in fact lead to worse economic outcomes than in the baseline.

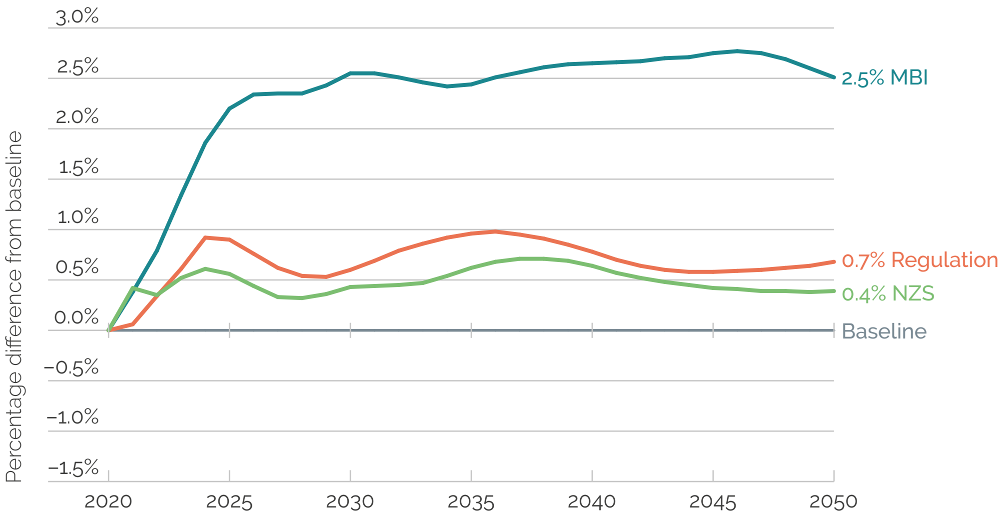


Figure 2.2: GDP by scenario, relative differences from baseline, 2020-50.

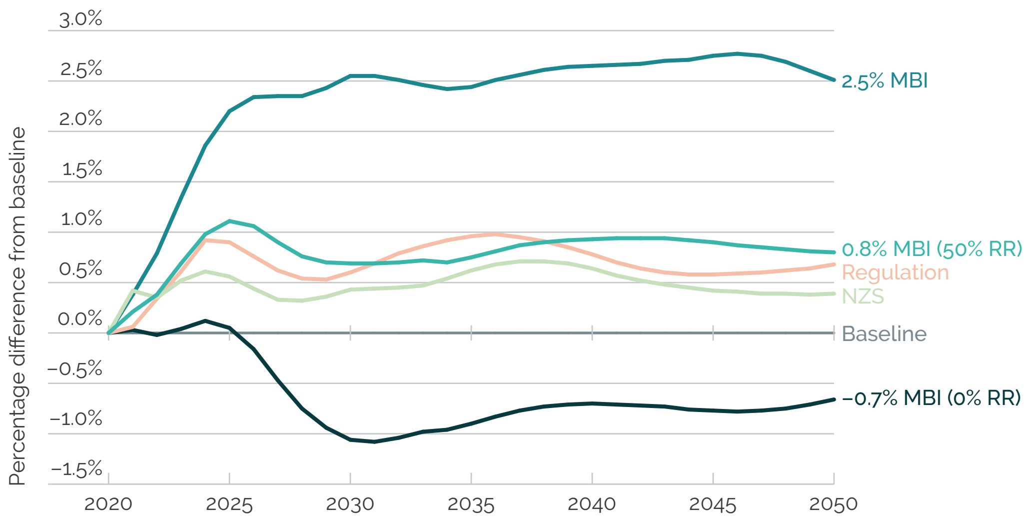


Figure 2.3: GDP by MBI revenue recycling sensitivity, relative differences from baseline, 2020-50.

Employment

The employment results (Figure 2.4) follow a similar pattern to GDP: **all scenarios show positive results relative to the baseline, and outcomes are especially strong in the MBI scenario**. This pattern in the MBI scenario can be mainly attributed to the increase in aggregate consumption (from lower direct tax rates as a result of recycled carbon revenues), much of which is spent on services, which are domestically produced and relatively labour intensive. This increased employment also creates an induced demand effect, whereby higher employment and incomes lead to higher consumption, which in turn boosts employment and incomes, and so on.

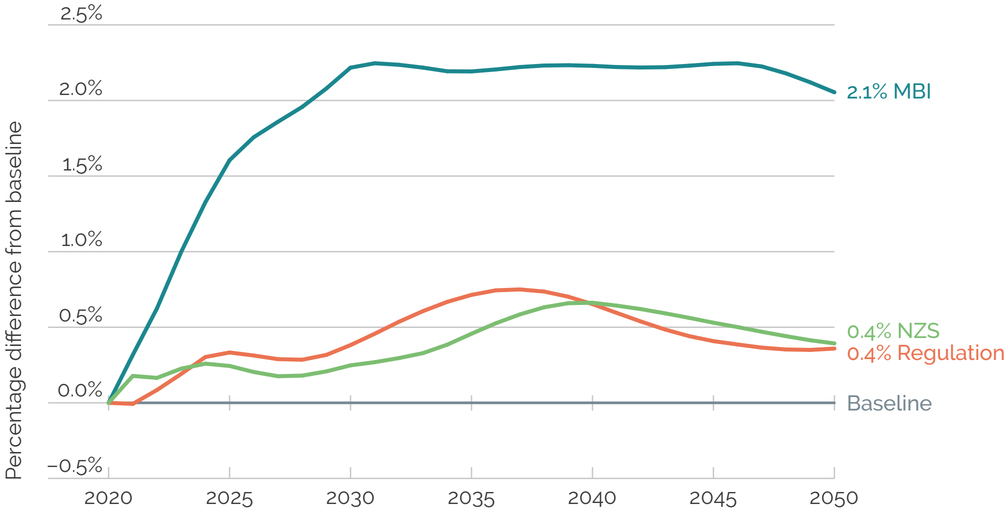


Figure 2.4: Aggregate employment by scenario, relative differences from baseline, 2020-50.

3 Impacts of net-zero pathways on different household archetypes

Policy pathways towards net-zero will have multiple impacts on different groups in society, and these will vary based upon more than just income attributes. Assessing the impacts of decarbonisation on different household types is crucial to determine how the costs and benefits of policies are distributed across society. Indeed, policy options may lead to unintended adverse outcomes on vulnerable groups in society.

3.1 Approach to the household archetypes analysis

Analysing the effects of the policy scenarios described earlier on a set of household archetypes allows us to identify which groups in society are at risk of experiencing energy and transport poverty in the transition to net-zero.

Enriching existing household archetypes

A set of household archetypes with different socio-economic backgrounds, energy attributes and transport behaviours have been developed building on the energy consumer archetypes produced by Ofgem in 2020 (Centre for Sustainable Energy, 2020), which segments the population of Great Britain[14] into a set of thirteen household archetypes with different income levels, tenure, age profiles, household composition, urban/rural split, health conditions, energy consumption, heating fuels, and electric vehicle ownership. The household archetypes are further enriched with quantitative and qualitative data on transport behaviours mainly extracted from the UK National Travel Survey (Department for Transport, 2021) and an extended literature review. Transport characteristics included in the framework refer to car ownership, main mode of transport, average distance travelled by car and elasticities of demand to fuel price increases (Figure 3.1).

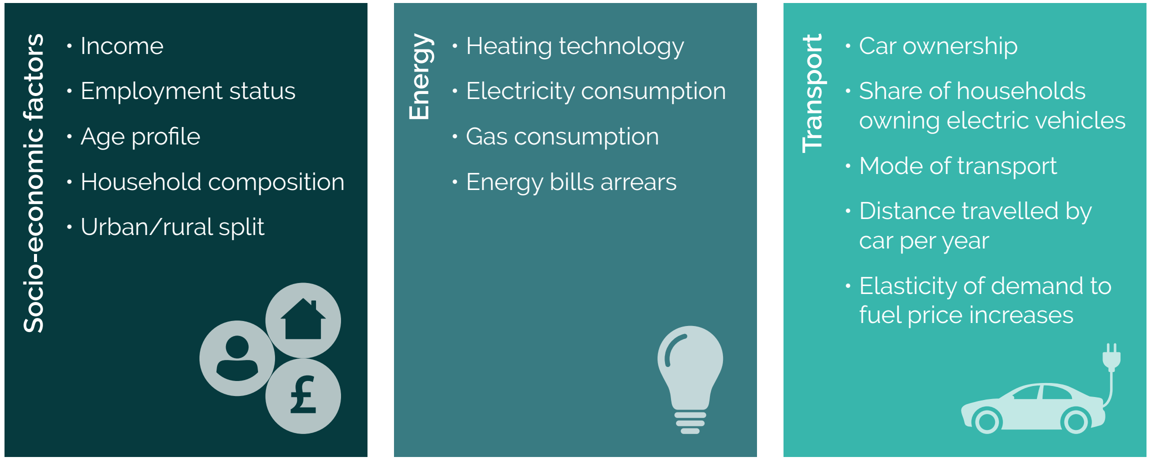


Figure 3.1 Summary of household archetypes characteristics.

14 The archetypes in this report are assumed to represent UK society. While the Ofgem archetypes are based on the population of Great Britain (England, Scotland & Wales), it is deemed a reasonable assumption that the characteristics of these archetypes may be extended to represent the UK, since the population of Great Britain constitutes approximately 97% of the UK population (see Population estimates for the UK, England and Wales, Scotland and Northern Ireland – Office for National Statistics | ons.gov.uk).

Development of future archetypes

The household archetypes framework was further expanded by developing a 2035 version of the archetypes, for each of the scenarios considered in this research. This involved estimating how the uptake of heat pumps and EVs changes across archetypes as a result of decarbonisation policies, and the potential behavioural responses across different households. Further information on the methodology used to develop the household archetypes framework is provided in the Appendix B: Household archetypes analysis methodology.

3.2 How different households are impacted by different net-zero policy pathways

Household heating bills

The analysis shows that there is great variation in annual energy bills across the scenarios depending on socio-economic characteristics.

Our analysis is consistent with the Green Book guidelines on distributional analysis (HM Treasury, 2022b), with equity weights applied to estimated households bills. The rationale behind using equity-weighting is that the value of an additional £1 of income is greater for low-income households and lower for high-income groups. Furthermore, when analysing households' bills as a proportion of income, we applied the equivalisation technique in order to derive distributional impacts that take into account the different structure of households. More details on the Green Book methodology adopted are provided in Box 3.1.

Box 3.1 Methodology for income equivalisation and equity-weighting of bill

Equity-weighted bills refer to household's bills that were recalculated to consider the fact that the burden of an additional £1 in bills is greater for low-income groups than for high-income recipients. This technique allows higher weights to be applied to bills paid by low-income households. The reasoning for this relies on the economic principle of the diminishing marginal utility of income, stating that the value of an additional pound declines more quickly relative to increases in income.

Equivalised income is a measure of household income that has been recalculated to take into account the differences in household's size and composition. Equivalisation consists of applying a scaling factor to household income to adjust for composition factors (i.e. age profile, income, size). This technique allows for a consistent comparison in welfare terms between households with different structures. The figure below provides an illustrative example of the methodology used for income equivalisation.

Score value: First adult, 0.67 | Second adult, 0.33 | Children 14 yrs & older, 0.33 | Children under 14 yrs, 0.2

Source: (HM Treasury, 2022b).

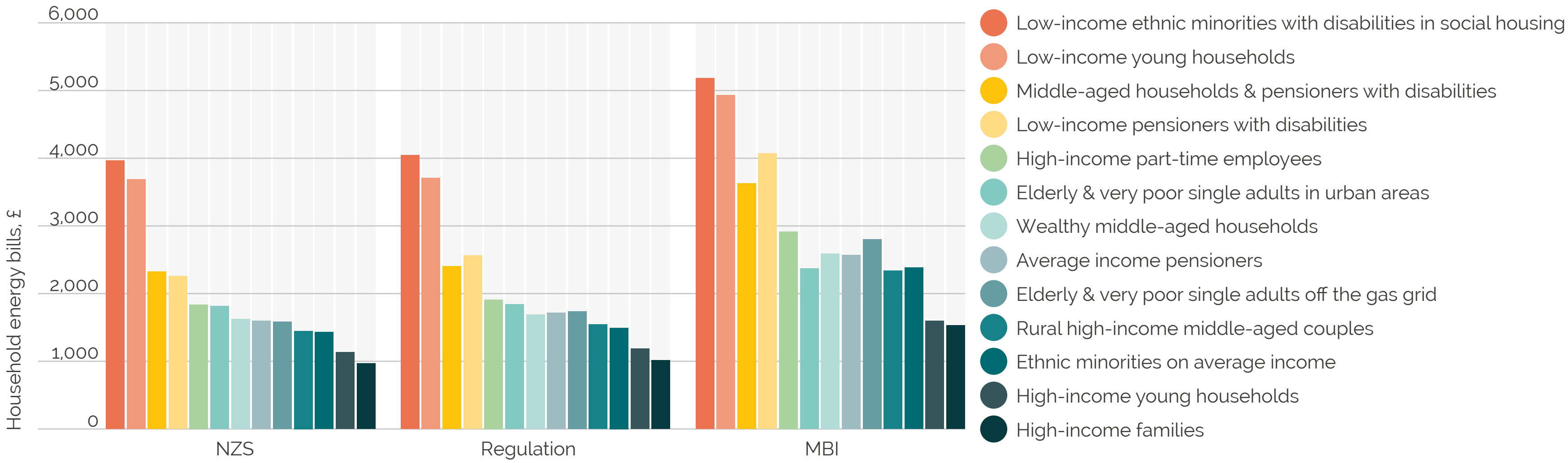


Figure 3.2 Annual equity-weighted energy bills by household archetypes, 2035 (£).

Energy bills weigh most heavily on households with low incomes, from ethnic minorities and renting in social housing

The highest household energy bills occur in the MBI scenario (see Figure 3.2). Indeed, the MBI scenario assumes the highest increase in energy prices by 2035, resulting from the implementation of carbon pricing mechanisms. Therefore, the spike in energy prices leads to higher energy bills for all household archetypes compared to the NZS and Regulation scenarios. However, in all the three modelled scenarios once equity-weighting is applied, the highest relative energy bills are paid by low-income households, particularly from ethnic minorities, living in social housing predominantly in urban areas. These households are either part-time workers or unemployed, and likely to face difficulties in paying their bills. In 2035 their annual energy bills range from £3,600 in the NZS scenario to about £5,000 in the MBI scenario. By 2035, pensioners with disabilities and long-term health conditions, with either average or low-incomes, are also expected to pay high energy bills in all the modelled scenarios.

Some of these households are not on the gas grid and rely heavily on inefficient electric heating and oil boilers, and are at risk of being in arrears on electricity and gas bills due to inefficient heating systems and high energy costs.[15] Their annual energy bills range from £2,200 in the NZS scenario to £4,000 in the MBI scenario. On the other hand, retired couples, families and young households on a high income tend to pay significantly lower annual energy bills, ranging from £970 in the NZS to £1,600 in the MBI scenario. This is mainly due to these households having higher uptakes of heat pumps, contributing to reduced energy consumption, and tending to live in more energy efficient homes .

15 The UK Government has recognised the risks that households off the gas grid are likely to face due to the phase out installation of fossil fuel heating systems and opened a consultation to set out various options for the decarbonisation of off-grid properties (Phasing out the installation of fossil fuel heating in homes off the gas grid | GOV.UK).

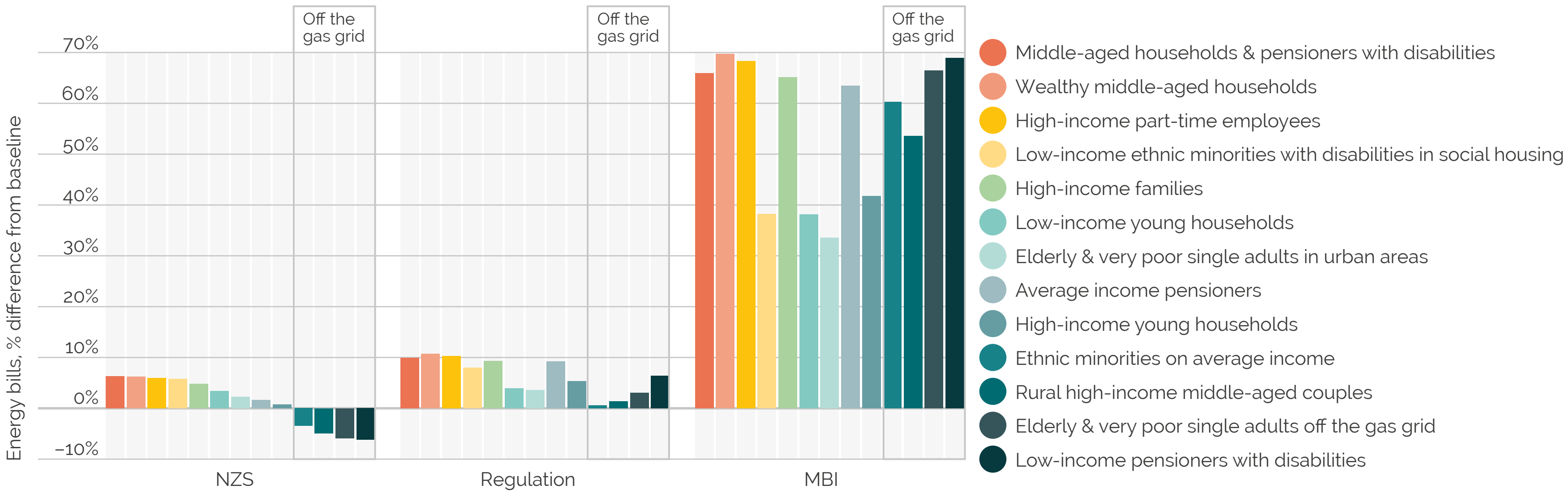


Figure 3.3 Annual equity-weighted energy bills by household archetype, 2035 (% difference from the baseline).

The MBI scenario brings the highest increase in energy bills

Figure 3.3 shows that by 2035 the highest increase (relative to the baseline scenario) in annual energy bills is reached in the MBI scenario, resulting from the introduction of carbon pricing.

Although the increase in energy bills is widespread across all household archetypes, the spike in energy prices strongly affects households with very high energy consumption, that by 2035 face a 68% increase in annual energy bills on average compared to the baseline. Indeed, these are typically high-income households, living in large houses which require more energy for heating. However, the increase in energy bills for these households is not expected to substantially affect their quality of life nor expose them to fuel poverty. The analysis also shows that by 2035 households off the gas grid face a 62% increase in annual energy bills on average in the MBI scenario.

Many of these households are on a low income, many living in rural areas, and heavily reliant on inefficient oil boilers. Therefore, these households are particularly vulnerable to fuel poverty and at risk of deprivation of other essential resources.

NZS brings savings to households initially off the gas grid

The NZS scenario leads to an increase in energy bills for households that were previously reliant on mains gas as a source of heating. The NZS assumes a substantial shift to heat pumps, that are more efficient than gas boilers (i.e. require less energy to operate).

However, heat pumps are powered by electricity, which is more expensive than gas on a per unit basis and hence can lead to higher bills, as seen in this scenario.[16] Conversely, households that are off the gas grid see their energy bills reduced by 5% on average by 2035, due to a shift away from oil and inefficient electric heating systems and towards more efficient heating technologies (i.e. heat pumps). Some of these households live in social housing and benefit from an ambitious deployment of heat pumps thanks to the Social Housing Decarbonisation Fund, which provides financial support for the installation of heat pumps in such homes.

High energy consumers are hit the most in the Regulation scenario

The Regulation scenario assumes an ambitious shift away from fossil fuel heating and towards wider adoption of heat pumps, due to stringent rules on the phase out of fossil fuel boilers. Heat pumps are indeed much more efficient than fossil fuel boilers, as they require less energy to operate. This leads to a larger use of electricity in heating, which in this analysis results in higher energy bills for all households, since electricity is relatively more expensive than fossil fuels on a per unit basis. The increase in energy bills is more pronounced for pensioners with disabilities and long-term health conditions as well as high-income households with high energy consumption.

16 There is substantial uncertainty around the future relative costs of heat pumps versus gas boilers, while only changes in fuel costs are explored across the scenarios in this analysis. In particular, the relative efficiency of both gas boilers and heat pumps depends upon the quality of the specific components used, and how well the technology is installed, in individual cases. For example, in some cases well installed heat pumps could already offer bill savings compared to older and poorly installed gas boilers before the 2021/22 increase in energy prices. In addition, the Heat and Building Strategy aims to address the current cost gap.

People from ethnic minorities, those renting in social housing, and pensioners with disabilities spend the highest proportion of income on energy

Figure 3.4 shows that the proportion of income spent on energy bills differs substantially across different archetypes. The difference is exacerbated in all the three scenarios. The archetype spending the highest proportion of income on energy is mainly composed of ethnic minority households on a low income and living in social housing. By 2035, these households spend between 10% and 13% of their income on energy, which is more than double the amount spent by families with children on a high income (between 3% and 5%). Although their electricity and gas consumption are below the national average, their energy bills represent a disproportionately large share of their income. Therefore, they are likely to experience difficulties in paying their bills and be vulnerable to fuel poverty.

Similarly, by 2035 young low-income renters spend between 9% and 13% of their income on energy bills, which again doubles the amount spent by an archetype with similar socio-economic characterises but earning high incomes. These households are mainly composed of part-time workers and unemployed adults living below the poverty line. Their precarious employment status exposes them to the risk of facing arrears on energy bills. Moreover, the presence of young couples with children makes it difficult to reduce the overall energy consumption of the households, which stands below the national average.

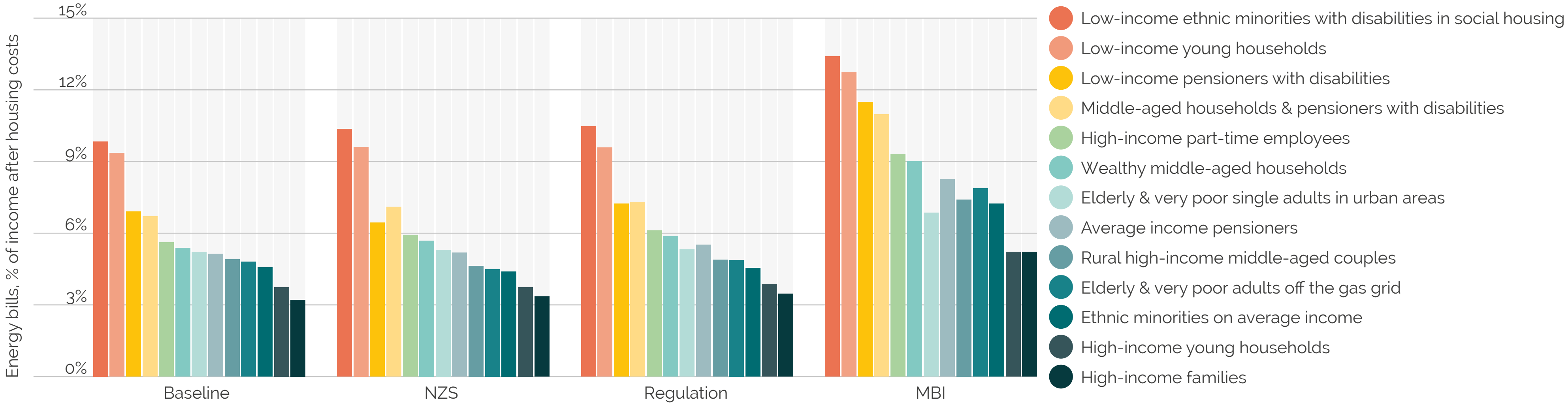


Figure 3.4 Annual energy bills as a proportion of equivalised income after housing costs, 2035 (%)

Households comprised of pensioners, particularly those on disability benefits, also pay a large proportion of income on energy bills. Among these are rural households, that rely heavily on oil boilers for space heating, that are highly inefficient compared to heat pumps. Therefore, in all the modelled scenarios, the increase in fossil fuel prices and the continued reliance on fossil fuel boilers leads to a large increase in energy bills for these households in the medium term. Moreover, archetypes spending a high proportion of their income on energy bills have larger household sizes (i.e. families with children, households comprised of multiple adults, students and young professionals in shared houses). This means that their energy consumption tends to be much higher compared to archetypes with single adults or small household size.

People on low-incomes are the most negatively affected

The analysis also shows that low-income households tend to spend a higher proportion of their income on energy bills, compared to medium- and high-income households.[17]

17 The baseline scenario is broadly in line with other analyses of energy bills produced by Joseph Rowntree Foundation and Centre for Sustainable Energy. For instance, the analysis from Joseph Rowntree Foundation found that households on low incomes spent on average 12% of their income after housing costs on energy bills in 2019/20, whereas middle-income households spent on average 4% of income on energy bills (Anderson, 2022). Similarly, a study from Centre for Sustainable Energy shows that 'isolated pensioners' spend 12.4% of their income on energy bills, compared to 6% for 'wealthy families' (Centre for Sustainable Energy, 2022).

This means that a potential increase in fuel prices is expected to have a stronger, disproportionately negative impact on low-income groups, leading to an increased risk of fuel poverty and ultimately to deprivation of other essential services as a knock-on effect. The regressive effect of higher energy bills is exacerbated in all the three scenarios. The reason for this is attributable to two main factors:

- First, all the three scenarios foresee an accelerated deployment of heat pumps, leading to a shift away from gas and heating oil and towards higher electricity use, being relatively more expensive than fossil fuels.
- Second, higher fossil fuel prices, that spike substantially in the MBI scenario, place a burden on low-income households, as they are late adopters of heat pumps and by 2035, they will still be reliant on the use of fossil fuels for heating.

The highest impact on energy bills as a proportion of income is associated with the MBI scenario, where by 2035 carbon pricing leads to the highest energy prices, that hits low-income households and people from ethnic minorities disproportionally, as they will be spending on average 13% of their income after housing costs on energy bills compared to 5% for high-income households.

The Regulation and NZS scenarios assume an ambitious deployment of heat pumps. However, this is skewed towards high-income households, that are able to afford the high upfront cost of installing them. This means that in the medium term, high-income households will benefit from increased energy efficiency and reduced energy consumption, while low-income households will continue to be mostly reliant on fossil fuels and will bear the cost of higher energy bills resulting from inefficient heating technologies.

The transition to heat pumps has great potential to provide benefits in terms of efficiency and energy bills savings to all households. Indeed, heat pumps are much more efficient than fossil fuel-based heating technologies and minimise the amount of energy required for heating. However, heat pumps require a wider use of electricity to operate, which in some cases leads to higher energy bills, since electricity is more expensive than gas on a per unit basis. This means that vulnerable households, typically on lower incomes, are likely to be affected the most by the shift to heat pumps. Without additional support mechanisms, vulnerable households will not afford the high upfront cost of installing heat pumps, and will possibly face serious risks of fuel poverty, with adverse consequences on health and wellbeing.

Motor fuel expenditure

Our analysis also considers motor fuel expenditure associated with driving internal combustion engines (ICE) and EVs but does not consider the cost of transport that households incur through travelling by rail and public transport (due to data availability). The analysis relies on assumptions made on the distance travelled by car by each household archetype based on data from the National Travel Survey (Department for Transport, 2021).

Young households, social renters, and pensioners with disabilities on a low income pay the highest car fuel bills

Motor fuel expenditure varies largely across household archetypes. Figure 3.5 shows that by 2035 young households (i.e. age 25-34) on a low income, people from ethnic minorities and pensioners with disabilities tend to have the highest expenditure on motor fuel in all the three modelled scenarios. This is mainly due to these households owning old and inefficient vehicles, which are relatively more expensive to drive.

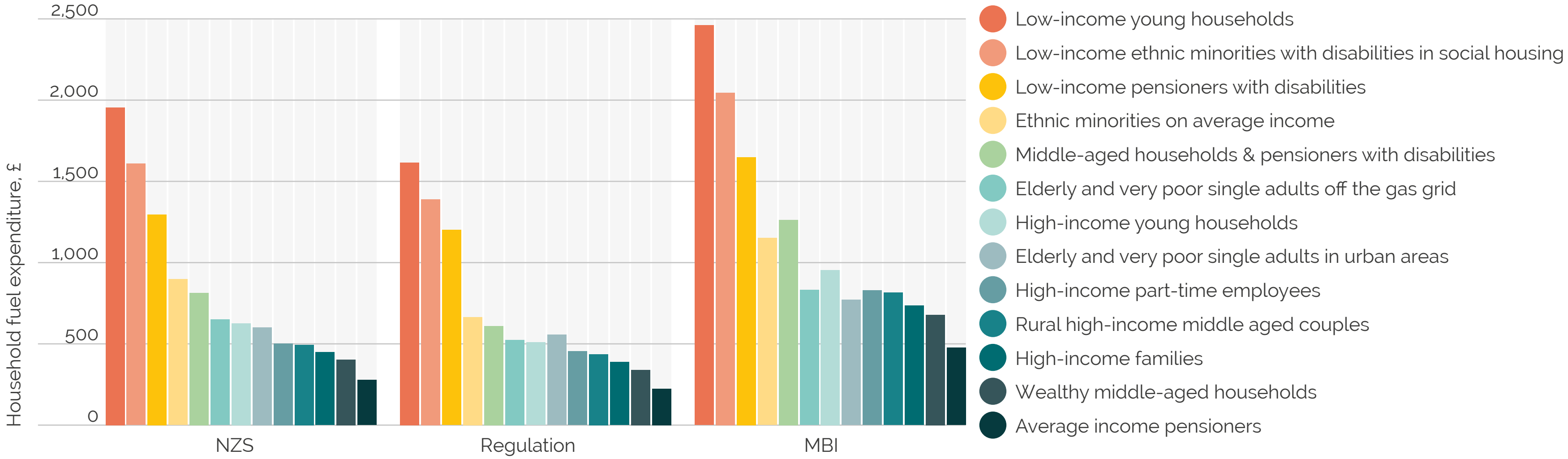


Figure 3.5 Annual equity-weighted fuel expenditure by household archetypes, 2035 (£).

Some of these households live in rural areas and are in 'forced car ownership' due to disability and long-term health issues affecting their day-to-day activity; combined with the lack of public transport in many rural areas, this means that most of the time they have no convenient alternative to the use of private cars. It is important to note that motor fuel expenditure is adjusted using equity weights, as defined by the Green Book (HM Treasury, 2022) (for further details on the methodology refer to Box 3.1). This allows us to account for the fact that the burden of an additional £1 on fuel consumption is greater for low-income groups than for high-income recipients.

The MBI scenario leads to a spike in fuel bills

The MBI scenario is associated with the highest level of expenditure on motor fuels, due to the spike in fossil fuel prices. Due to carbon pricing and soaring fossil fuel prices, by 2035 motor fuel expenditure increases for all household archetypes in the MBI scenario (Figure 3.6). Young couples (i.e. age 25-34) on a high income are expected to face a 36% increase in motor fuel expenditure in the MBI scenario, although this is not expected to expose them to transport poverty nor compromise their quality of life. Meanwhile, the much higher fossil fuel prices lead to an average 29% increase in fuel expenditure for people from ethnic minorities (both on low and average incomes) and older people (i.e. 65+ years old) on low incomes living in either urban or rural areas, or living with a disability. A proportion of these households have long-term health conditions related to their age and live in rural areas, factors which would make them even more vulnerable to experiencing transport poverty.

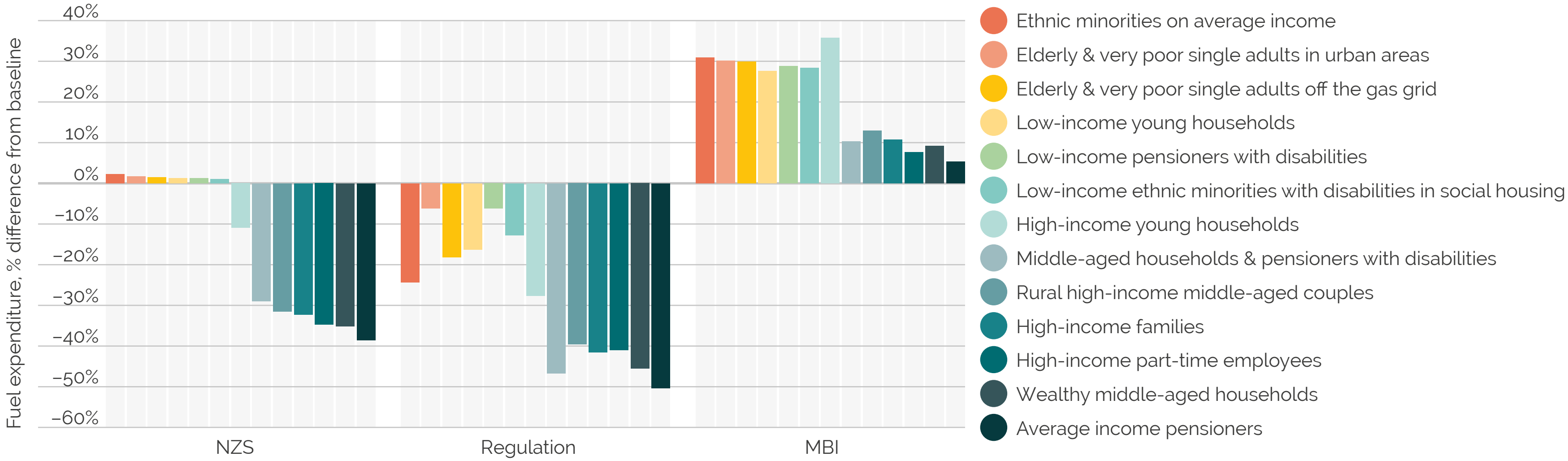


Figure 3.6 Annual equity-weighted fuel expenditure by household archetype, 2035 (% difference from the baseline).

...the NZS scenario brings savings in fuel bills to less vulnerable groups...

The NZS scenario assumes a phase out on sales of new ICE vehicles by 2030 and hybrid vehicles by 2035, which results into a substantial shift to EVs amongst high-income households who can afford the up-front costs, predominantly living in urban areas. This leads to regressive outcomes, since high-income households have the potential to achieve greater savings in fuel expenditure, due to a large shift towards EVs that are more efficient and relatively cheaper to drive.[18] Indeed, household archetypes on the highest income levels are expected to face average savings of 36% on their fuel expenditure in the NZS scenario. Conversely, low-income groups are late adopters of EVs because of the lack of affordability of a new (or used) EV, and by 2035 they will be mainly reliant on old ICE vehicles.

This leads to a slight increase (1% to 2%) in motor fuel expenditure by 2035 for households that are vulnerable to transport poverty, which again are mainly composed of adults from ethnic minorities, single female adults on a low income and elderly households. Therefore, the NZS is largely beneficial for high-income households, whereas it does not bring any improvement in costs for vulnerable groups.

18 While it is possible that future tax regime changes (e.g. the introduction of road charging) will reduce this cost gap, such policies should be technology neutral, i.e. applied to all powertrains, and if this was done the lower cost of EVs would be preserved.

…and the Regulation scenario leads to savings in fuel expenditure for all household archetypes.

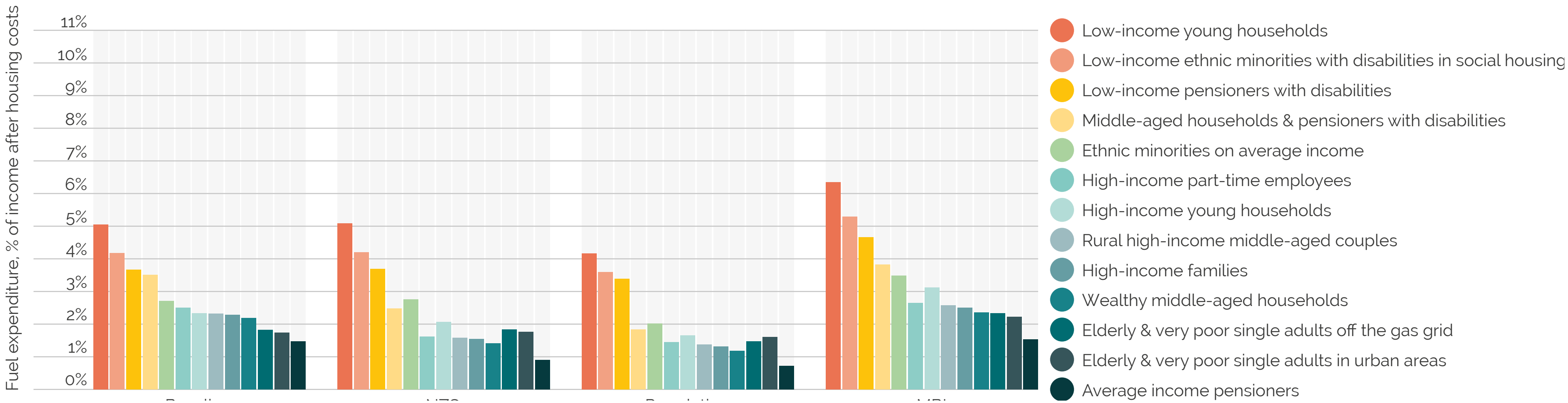
In the Regulation scenario the phase out of new ICE vehicle sales is brought forward to 2022 – essentially an instant ban on the sale of ICEs. This is done to illustrate the potential impact on demand of a very immediate ban, although we recognise that this could not be delivered at such speed. This leads to an ambitious uptake of EVs for all household archetypes. Although the shift to EVs is skewed towards high-income archetypes who can afford them, low-income households that are heavily reliant on the use of private cars are also nudged to buy more efficient EVs. This results in substantial savings in fuel expenditure for all household archetypes. However, the largest savings are achieved by the least vulnerable households. Middle-aged households on average income face an average reduction of 50% in fuel expenditure by 2035. Indeed, most of these households shift to EVs due to their higher purchasing power, which leads to higher reliance on private cars. Similarly, high-income households living in urban areas save 42% on average on fuel expenditure by 2035. In contrast, by 2035 the fuel expenditure savings for people from ethnic minorities, single female adults and elderly households is on average 17%. Therefore, the Regulation scenario is particularly effective in incentivising the shift towards EVs and reducing motor fuel expenditure, although the largest savings are achieved by the least vulnerable archetypes.

The results are broadly in line with previous Cambridge Econometrics analyses, stating that by 2030 the cost of running a car is reduced by 40% on average due to a significant shift to electric propulsion vehicles (Cambridge Econometrics, 2015).

Vulnerable households spend the highest proportion of income on fuel bills

In the business-as-usual scenario, by 2035 households spend between 1% and 5% of their income on driving their private car (Figure 3.7).[19] The share of income spent on driving increases in the NZS and the MBI scenarios, due to higher motor fuel expenditure, whereas it decreases in the Regulation scenario for all archetypes. This is because the Regulation scenarios foresees an ambitious shift to EVs across all household archetypes due to stringent rules on the use of ICEs, which ultimately leads to substantial savings in motor fuel expenditure. The highest increase in expenditure is associated with the MBI scenario, where carbon pricing leads to a large increase in fossil fuel price. Even though there are small differences across household archetypes in the share of income spent on fuel bills, vulnerable households tend to spend higher proportions of their income on fuel expenditure. Again, these are young households (i.e. age 25-34) on a low income, ethnic minorities and pensioners with disabilities and health conditions, which spend between 4% in the Regulation scenario to 6% in the MBI scenario (Figure 3.7).

19 All income figures used in this analysis refer to income after housing costs (AHC) and are based on data from Ofgem energy consumer archetypes (Centre for Sustainable Energy, 2020). Based on the Green Book guidelines, the equivalisation technique was adopted to account for different households' structures (HM Treasury, 2022b). Equivalisation consists of applying scaling factors to household income and allows to make consistent comparisons between households with different compositions.



Therefore, the policy pathways explored in this analysis all have regressive impacts. This means that in the medium-term vulnerable groups are likely to be affected negatively by policies aimed at decarbonising the transport sectors, whereas wealthy people and those less vulnerable are expected to benefit widely from the transition to electric vehicles. To achieve a just transition, vulnerable groups need to be provided with additional financial support measures to cover the high upfront costs of shifting to low-carbon technologies. This is also crucial to avoid incurring unintended outcomes in the medium term leading to transport poverty, and ultimately deprivation of other essential resources as a knock-on effect.

Figure 3.7 Annual fuel expenditure as a proportion of equivalised income after housing costs, 2035 (%).

3.3 Qualitative assessment

Table 3.1 Quantitative & qualitative impacts on different household archetypes

High-income families		
Number of households	2.8 million	**Commentary**
Main attributes	• High income (£54,927) • Predominantly urban • Working age families with children • Owner occupied • Low energy consumption • Full-time employment	Despite high levels of income (£54,927), about 50% of these households are couples with children that may find it difficult to install energy efficiency measures, as this involves substantial disruption in the households' day-to-day activities. This means that the uptake of heat pumps is not as high as in other archetypes with a similar income profile. Although there is a small increase in energy bills by 2035, in both the NZS and the Regulation scenarios, these households are not vulnerable to fuel poverty, due to their high income.
Energy bills in 2035 (difference from Baseline)	NZS 5% Regulation 9% MBI 65%	In all scenarios, reliance on private cars remains high for leisure and personal business, due to high incomes and inflexible lifestyles of this archetype. This results in a relatively large uptake of EVs in all scenarios, although the largest transition occurs in the NZS and Regulation scenarios due to stringent rules on the sale of ICE cars. Due to the large uptake of EVs, substantial savings in fuel bills are achieved by 2035 in the NZS and Regulation scenarios. In the MBI scenario, this archetype faces increased motor fuel expenditure, due to soaring fuel prices and relatively lower uptakes of EVs. The increase however does not represent a disproportionate share of their income. Furthermore, these are middle-class households, many living in urban areas and are likely to intensify their 'active travel' in the NZS scenario, due to the construction of new routes for cycling and walking in urban areas. In general, this archetype is not vulnerable to transport poverty, due to high income and accessibility to different transport modes.
Motor fuel expenditure in 2035 (difference from Baseline)	NZS −32% Regulation −42% MBI 11%	

Wealthy middle-aged households

Number of households	2.9 million	
Main attributes	• High income (£64,731) • Predominantly urban • Middle-aged couples with children • Owner occupied • High energy consumption • Full-time employment	
Energy bills in 2035 (difference from Baseline)	NZS	6%
	Regulation	11%
	MBI	70%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS	–35%
	Regulation	–46%
	MBI	9%

Commentary

This archetype is on a high income (£64,731) and has strong environmental concerns and is therefore characterised by the highest uptake of heat pumps and EVs across all the household archetypes, in all the three modelled scenarios. The shift to more efficient heating technologies is also justified by the large energy consumption of this archetype, possibly attributable to big houses and the use of numerous electrical appliances and devices (i.e. TVs, games consoles, big fridges). The substantial shift to heat pumps, together with the increase in electricity prices, leads to higher energy bills on average in all the three scenarios, since electricity is more expensive than gas. The highest increase in energy bills is associated with the MBI scenario, due to much higher electricity prices. In general, this archetype benefits from improved energy efficiency in all scenarios, resulting from the transition to heat pumps that require less energy to operate. The increase in energy bills is due to a wider use of electricity compared with the baseline and does not expose this archetype to fuel poverty.

This archetype is likely to be one of the hardest to shift onto different transport modes and change their transport behaviours. Despite strong environmental concerns, attitudes towards reduced energy use and frequency of private car use remain unchanged due to a 'wealthy' lifestyle (Cass et al., 2022). In all scenarios, this archetype continues to rely on private cars for transport, especially for non-commuting purposes. The average motoring costs for this archetype are reduced in the NZS and Regulation scenarios due to a substantial shift to EVs, whereas the MBI scenario leads to a slight increase in fuel expenditure due to soaring fossil fuel prices. Therefore, this archetype benefits largely form the shift to more efficient vehicles and is not vulnerable to transport poverty, due to high income, high rates of car ownership and more efficient vehicles .

Average income pensioners		
Number of households	3.7 million	
Main attributes	• Average income (£37,603) • Predominantly urban • Mostly couples above 55 years old • Owner occupied • High energy consumption • Pensioners	
Energy bills in 2035 (difference from Baseline)	NZS	2%
	Regulation	9%
	MBI	63%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS	-39%
	Regulation	-50%
	MBI	5%

Commentary

This archetype has strong concerns about the environment, which leads to a moderate uptake of heat pumps and EVs. This leads to higher energy bills by 2035 in all the three scenarios, due to a larger use of electricity in heating (which is relatively more expensive than fossil fuels). Being retired, on average incomes (£37,603), and having no children, these households have flexible lifestyles and are likely to take behavioural steps to reduce their energy consumption, especially in the MBI scenario that is characterised by much higher fossil fuel prices (Torriti & Yunusov, 2020). Although not vulnerable to fuel poverty, these households offset the higher energy prices with a reduction in energy consumption, that does not affect their quality of life.

A moderate shift to EVs leads to substantial savings in motor fuel expenditure in the NZS and the Regulation scenarios. The increase in fuel prices in the MBI scenario does not affect transport behaviours for this archetype, as pensioners rely more on concessionary travel on public transport (which is inelastic to fuel price increase) for personal business and to access basic services. However, being retired, and not having to commute to work, these households are quite flexible with their transport behaviours, and are likely to make use of free bus passes which become available from the age of 60 and/or from pension age across the UK. It follows that these households are likely to intensify the use of public transport as a result of upgrades in the national bus system in the NZS scenario or in response to increased motoring costs in the MBI scenarios. Although this archetype is not vulnerable to transport poverty, a large increase in fuel prices in the mid-term leads to a higher use of public transport and a moderate shift away from the use of private cars.

High-income part-time employees

Number of households	2.3 million
Main attributes	• High income (£49,152) • Predominantly urban • Mostly working age couples • Owner occupied • High energy consumption • Part-time employed
Energy bills in 2035 (difference from Baseline)	NZS 6% Regulation 10% MBI 68%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS –35% Regulation –41% MBI 8%

Commentary

This archetype has above average levels of environmental behaviours and is characterised by a high uptake of heat pumps. These households are predominantly couples without children with part-time jobs, so these are the most likely group to be willing to be flexible with their energy use over the course of the working week. Indeed, these households take behavioural steps to reduce their energy footprint (i.e. using lighting and appliances less, turning down the thermostat), without risking compromising their quality of life. By 2035, energy bills increase in all scenarios, due to larger use of electricity in heating (which is relatively more expensive than gas and heating oil) and higher energy prices. Despite the increase in energy bills and reduced energy consumption, this archetype is not vulnerable to fuel poverty due to their relatively high income.

Part-time workers living in urban areas are more likely to be using public transport for commuting (as this is easily accessible, less expensive, and more sustainable than using a private car). Their use of public transport is also expected to intensify in the NZS scenario, where buses become more frequent and reliable thanks to investments in the National Bus Strategy. Most households shift to EVs (as they require less energy to run), which results in large savings in fuel expenditure by 2035 in the NZS and Regulation scenarios. These households are quite flexible with their transport behaviours, due to the fact that they live in predominantly urban areas and can rely on both public transport and private vehicles. This means that the large increase in petrol and diesel prices in the MBI scenario can be offset by substantial reductions in the use of private cars for leisure and private business. Despite the small changes in the mode of transport, this archetype is not exposed to transport poverty, due to the adoption of more efficient vehicles and wide accessibility to public transport.

Elderly and very poor single adults in urban areas

Number of households	1.9 million	
Main attributes	• Very low income (£17,727) • Predominantly urban • Mostly single pensioners above 75 years old • Social housing • Health issues	
Energy bills in 2035 (difference from Baseline)	NZS	2%
	Regulation	4%
	MBI	34%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS	2%
	Regulation	-6%
	MBI	30%

Commentary

In the absence of financial support from the Government, this archetype is the least likely to shift to heat pumps and EVs, due to very low incomes, elderly age, and long-term health conditions. However, in the NZS scenario, households living in social houses benefit from the Social Housing Decarbonisation Fund, which facilitates the uptake of heat pumps. This results in improved energy efficiency, which can lead to better health conditions (i.e. reduced risk of respiratory conditions and diseases associated with dampness). Although this archetype has low energy consumption, these households still face increases in energy bills in all the three scenarios. The particularly high energy prices in the MBI scenario led to a disproportionate share of income spent on energy bills, which expose this archetype to fuel poverty. This leads to reductions in energy consumption to avoid fuel debts and a potential cut in spending for other essential goods as a knock-on effect.

These households are also mostly lacking sufficient availability of cars and relying on concessionary public transport; therefore they are relatively unaffected by the phase out on ICE cars and see little impact on their transportation costs in the NZS and Regulation scenarios. Moreover, the use of bus transport intensifies in the NZS scenario, thanks to investment in and improvement of public transport. Consistently higher prices in the MBI scenarios leads to a large increase in fuel expenditure, especially for those households reliant on the use of private cars due to long-term health conditions (albeit many households don't have access to such vehicles in this group). In general, this archetype has limited vulnerability to transport poverty, due to the wide accessibility of public transport and concessionary travel. However, increases in fuel prices hits disproportionally households that are forced to use private cars due to health conditions (Mattioli G., 2017), hence exposing them to some degree of transport poverty.

Low-income ethnic minorities with disabilities in social housing		
Number of households	1.5 million	**Commentary**
Main attributes	• Low income (£18,264) • Predominantly urban • Mostly working age single adults • People from ethnic minorities • Social housing • Experienced fuel debt • Mostly unemployed • Health issues and disabilities	These households mainly live in social housing, hence benefitting from the increased Social Housing Decarbonisation Fund which makes energy efficiency improvements and the installation of heat pumps more affordable in the NZS scenario – although it is clear that further funding is required above that available in this scenario. This involves a wider use of electricity for heating, which is relatively more expensive than gas and heating oil. This ultimately leads in the analysis to an increase in energy bills, representing a disproportionate share of income for this household archetype, even though energy consumption for this archetype is below the national average. The uptake of heat pumps in the Regulation and MBI scenarios is relatively small. Further increases in energy bills therefore occur in the Regulation and MBI scenarios, which force households to reduce their energy consumption to avoid fuel debts. Hence, by 2035 this group is likely to experience fuel poverty and difficulties paying their energy bills in all the three scenarios. The phase out on sales of ICE vehicles in the NZS and Regulation scenarios hits these households strongly, as a substantial proportion of them rely on the use of private cars for all travel purposes due to disability constraints (i.e.100% of these households are affected by disability constraints). A mild shift to EVs in the Regulation scenario (compared to more affluent households) leads to some savings in fuel expenditure (although not as high as the savings enjoyed by more affluent households). However, the total savings for this archetype mask the fact that only 14% of the households are expected to own an EV, and therefore benefit from reduced fuel expenditure. The remaining 86% of the households are expected to be unable to make the switch to EVs, and will be facing higher fuel expenditure in 2035. In general, a large proportion of these households are at risk of facing higher fuel prices and consequently risk being driven into transport poverty in all three scenarios.
Energy bills in 2035 (difference from Baseline)	NZS 6% Regulation 8% MBI 38%	
Motor fuel expenditure in 2035 (difference from Baseline)	NZS 1% Regulation –13% MBI 28%	

Middle-aged (i.e. age 45–64) households & pensioners with disabilities

Number of households	1.2 million	
Main attributes	• Average income (£40,826) • Predominantly urban • Mostly middle-aged couples • Owner occupied • High energy consumption • Full-time employed or retired • Health issues and disabilities	
Energy bills in 2035 (difference from Baseline)	NZS	6%
	Regulation	10%
	MBI	66%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS	–29%
	Regulation	–47%
	MBI	10%

Commentary

Due to their average income, middle-aged adults are willing to shift to more efficient heating technologies which leads to a relatively high uptake of heat pumps in all the three scenarios. This allows them to benefit from improved energy efficiency, although by 2035 their energy bills increase in all scenarios due to higher energy prices. Moreover, these households are likely to reduce their energy consumption through small changes such as using lighting and appliances less to avoid fuel debts. Due to their average income, these households have some exposure to fuel poverty, that can be exacerbated through large increases in energy prices.

In this archetype, pensioners and 45-64 year old adults rely almost exclusively on private cars for shopping and accessing main services, since around half of these households have long term conditions which impact on their day-to-day activities. The ban on sales of ICE vehicles in the NZS and Regulation scenarios and the higher fuel prices in the MBI scenario leads to large uptakes of EVs, as people with mobility difficulties may find it challenging to shift to public transport or active modes of transport. This results in large savings in fuel expenditure in the NZS and Regulation scenarios, as EVs are more efficient and cheaper to drive. The MBI scenario is characterised by higher fuel prices and a lower uptake of EVs due to the absence of a strict regulation on the sales of ICE vehicles. This leads to an increase in motor fuel expenditure by 2035, which represents a large share of income for this archetype. Although the shift to EVs is particularly beneficial for these households, a disproportionate increase in fuel prices exposes them to some degree of transport poverty, due to difficulties in shifting to other modes of transport.

Low-income young households (i.e. age 25–34)

Number of households	2.4 million
Main attributes	• Low income (£21,756) • Predominantly urban • Ethnic minority backgrounds • Mostly young couples with children • Private renters or social housing • Fuel debt • Part-time workers or unemployed
Energy bills in 2035 (difference from Baseline)	NZS 3% Regulation 4% MBI 38%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS 1% Regulation –16% MBI 28%

Commentary

In the NZS scenario, the relatively small proportion of young households in social housing are supported in the shift to heat pumps by 2035, thanks to the Social Housing Decarbonisation Fund. This leads to wider use of electricity for heating and an increase in energy bills in the medium term due to increased electricity prices. On the other hand, for private renters in this archetype installing heat pumps is difficult, because of the lack of incentives for landlords to take them up. In the NZS scenario, this results in private renters continuing to rely predominantly on gas for heating, hence facing much higher energy bills. Due to the high upfront cost of heat pumps and the lack of financial supports, the uptake of heat pumps in the Regulation and MBI scenarios are much smaller and mainly associated with the replacement of outdated gas boilers. Nevertheless, by 2035 households face higher energy bills in the Regulation and MBI scenarios too, due to increase in energy prices. In all scenarios, these households are likely to reduce their energy consumption to avoid further bills arrears. With a high rate of unemployed households and relatively low-income, this archetype is expected to experience difficulties in paying energy bills and is at greater risk of fuel poverty.

The phase out on ICE sales in the NZS and Regulation scenarios affect this archetype only slightly, as these households live in urban areas, and tend to rely on easily accessible public transport and active travel . Furthermore, upgrades of public transport systems and walking/cycling routes in the NZS scenario leads to intensified use of bus and active travel. This archetype is characterised by low rates of car ownership and therefore relatively low uptake of EVs. However, the latter leads to savings in motor fuel expenditure in the Regulation scenario. On the other hand, those households owning a private car experience increases in fuel bills in the MBI scenario and are therefore likely to reduce the use of private vehicles and fully shift to public transport. In general, this archetype is not vulnerable to transport poverty since they live in urban areas where alternative transport options are easily accessible.

High-income young households (i.e. age 25–34)

Number of households	3.1 million
Main attributes	• High income (£39,886) • Predominantly urban • Mostly young couples • Mostly private renters • Full-time employed
Energy bills in 2035 (difference from Baseline)	NZS 1% Regulation 5% MBI 42%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS −11% Regulation −28% MBI 36%

Commentary

Although on high incomes, private renters in early stages of their career (i.e. predominantly 25 to 34 years old) are unlikely to have heat pumps in their homes due to the lack of incentives for landlords to install them. In all three scenarios, households face increases in energy bills, mainly due to energy price inflation. However, energy bills represent only a small proportion of income for this archetype, therefore they are at relatively low risk of experiencing fuel poverty.

These households are highly reliant on public transport and active travel for commuting given the high accessibility from urban areas, whereas private cars are mostly used for leisure. The phase out of ICE cars creates an incentive for these households to shift to EVs, to reduce their transport expenditure in the long run. By 2035, this leads to moderate savings in motor fuel expenditure in the NZS and Regulation scenarios. Moreover, investment in and the improvement of cycle and walking routes in the NZS scenario leads to more frequent active travel. The soaring fuel prices in the MBI scenario leads to higher spending on petrol and diesel, which does not represent a disproportionate share of their income. However, this may lead to reduced use of private cars for non-essential travelling purposes, given that this archetype is quite flexible with their transport behaviours and can rely on multiple transport modes. In general, these households are not vulnerable to transport poverty, as they have high incomes, predominantly live in urban areas, and are able to rely on different transport modes.

Rural high-income middle-aged couples (i.e. age 45–64)

Number of households	1.9 million	
Main attributes	• High income (£47,541) • Predominantly rural • Mostly middle-aged couples • Owner occupied • Off the gas grid • Full-time employed or retired	
Energy bills in 2035 (difference from Baseline)	NZS	–5%
	Regulation	1%
	MBI	54%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS	–32%
	Regulation	–40%
	MBI	13%

Commentary

This archetype is characterised by middle-aged workers or pensioners on a high income, living in rural areas which are off the gas grid. These households find it convenient and affordable to install heat pumps. The shift away from fossil fuel heating leads to a small reduction in energy bills in the NZS scenario. Although there is a large uptake of heat pumps in the Regulation and MBI scenario, energy bills increase substantially in the MBI due to soaring energy prices. This archetype is not vulnerable to fuel poverty, due to high incomes and large potential to shift to more efficient heating technologies.

Reliance on private cars is high for this archetype due to low accessibility to public transport from rural areas. Therefore, the phase out on sales of ICE cars creates a large incentive for this archetype to shift to EVs in the NZS and Regulation scenarios, which ultimately leads to reduced motor fuel expenditure by 2035. Conversely, the spike in fuel prices together with the relatively lower EVs uptake in the MBI scenario leads to higher motoring costs, which does not represent a large proportion of income. Attitudes towards reduced use of private vehicles is not affected since this archetype finds it difficult to shift to other transport modes. Nevertheless, these households are not exposed to transport poverty, due to high income and the potential to shift to more efficient private vehicles.

Ethnic minorities on average income

Number of households	1.5 million
Main attributes	• Average income (£31,157) • Predominantly urban areas • Mostly young single adults and couples (aged 25-34) • People from ethnic minorities • Mostly private renters • Off the gas grid, predominantly electric heating • High electricity consumption • Full-time employed
Energy bills in 2035 (difference from Baseline)	NZS –3% Regulation 1% MBI 60%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS 2% Regulation –24% MBI 31%

Commentary

Being in the early stages of their careers, these households are typically on average incomes, hence finding it difficult to afford the shift to heat pumps. Therefore, only a small proportion of these households install heat pumps. This leads to a slight decrease in energy bills in the NZS scenario, due to the shift to a more efficient heating system, which requires less energy to operate. In the Regulation and MBI scenarios energy bills raise due to higher energy prices. The latter may lead to attitudes towards reduced energy use, that may affect their quality of life. In general, this household is likely to experience some degree of fuel poverty, due to their average income and high reliance on inefficient heating technologies.

These households are heavily reliant on public transport and active travel and find it difficult to shift to EVs due to high upfront costs. The highest uptake of EVs occurs in the Regulation scenario, mostly for households already owning a private car and resulting from stringent rules on the phase out of ICE vehicles. This leads to a moderate reduction in motor fuel expenditure across the archetype by 2035. Conversely, the increase in fuel prices in the NZS and MBI scenarios results in higher fuel expenditure. As a result, the use of buses and active travel is intensified in the NZS scenario due to upgrades to walking routes and public transport. The large increase in transport costs in the MBI scenario is likely to strongly affect households living in rural areas (29% of the households in this archetype), for which public transport is not as frequent or accessible. Although most of the households in this archetype rely on public transport, the rise in fuel prices exposes some households, particularly those in rural areas, to some degree of transport poverty.

Elderly and very poor single adults off the gas grid

Number of households	0.6 million
Main attributes	• Very low income (£16,116) • Predominantly urban • Elderly single adults • Social housing or owner occupied • Experienced fuel debt • Off the gas grid • Medium electricity consumption • Health issues and disabilities
Energy bills in 2035 (difference from Baseline)	NZS –6% Regulation 3% MBI 66%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS 2% Regulation –18% MBI 30%

Commentary

Elderly single adults with long-term health conditions find it difficult to shift to heat pumps due to high upfront costs. By 2035, in the NZS scenario, a large share of households in this archetype benefit from the Social Housing Decarbonisation Fund for the installation of heat pumps, which allows them to shift away from heating oil and reduce their energy bills. In the Regulation scenario, the uptake of heat pumps is greater than in the NZS scenario, due to stringent regulation on the use of fossil fuel boilers. However, due to the high cost of heat pumps, the use of oil boilers and inefficient electric heaters is still predominant for this archetype by 2030. In the MBI scenarios households continue to rely heavily on inefficient oil boilers and electric heating, hence having to face higher energy prices and increased energy bills. Therefore, without additional financial support, the transition to clean heat pumps exposes this archetype to fuel poverty. Indeed, these households are likely to reduce their energy consumption to avoid fuel dept, with adverse consequences on their quality of life.

The elderly age and low-income profile of these households means they rely on public transport and concessionary travel, and therefore this is one of the least likely archetypes to buy an EV. The purpose of travelling is also reduced to a minimum for this archetype, as health conditions affect day-to-day activities. In the NZS scenario, public transport is assumed to become more accessible and reliable, due to investments that form the National Bus Strategy. This is likely to intensify the use of concessionary travel for elderly households and reduce their vulnerability to transport poverty. In the Regulation scenario, a relatively small shift to EVs leads to savings in motor fuel expenditure, whereas spiking fuel prices in the MBI scenario leads to higher fuel expenditure overall. In general, this archetype is vulnerable to transport poverty, due to their very low income, disability constraints and the fact that households travel only when necessary.

Low-income pensioners with disabilities

Number of households	0.5 million
Main attributes	• Low income (£24,442) • Approx. 50:50 rural:urban split • Mostly pensioner couples over 65 years old • Owner occupied or social renters • Off the gas grid • High electricity consumption • Health issues and disabilities
Energy bills in 2035 (difference from Baseline)	NZS –6% Regulation 6% MBI 69%
Motor fuel expenditure in 2035 (difference from Baseline)	NZS 1% Regulation –6% MBI 29%

Commentary

This archetype is characterised by older, low-income households with disability constraints and long-term health conditions, that struggle to install heat pumps. In the NZS scenario, social renters benefit from the Social Housing Decarbonisation Fund, which allows them to shift away from the use of oil and electric heaters and onto much more efficient heat pumps, therefore reducing expenditure on energy. Due to more stringent rules on the phase out of fossil fuel boilers in the Regulation scenario, many households decide to shift to more efficient heating technologies. However, due to the high cost of heat pumps, households tend to substitute outdated oil boilers with inefficient electric heaters. In the MBI scenarios these households continue to rely predominantly on oil boilers and electric heaters, and are therefore forced to face high energy bills, due to inefficient heating technologies and increasing energy prices. In particular, this archetype is likely to experience difficulties paying their bills due to much higher energy prices in the MBI scenario. As a result, this archetype is likely to reduce their energy consumption, to avoid facing soaring fuel debts. The increase in energy spending represents a relatively high share of their income and exposes them to fuel poverty.

These households are typically constrained to the use of private cars for travelling, partly because many live in rural areas, and partly because many are affected by disabilities and health conditions (Mattioli G., 2017). They are one of the least likely groups to own an electric or hybrid vehicle, given their low income and elderly age, and could find it more difficult to shift to public transport and active modes of transport, due to rural locations and to disability constraints. Indeed, in the NZS and Regulation scenarios the uptake of EVs is very low, resulting in only small savings in motor fuel expenditure in the Regulation scenario. Therefore, these households are likely to rely on old inefficient vehicles as far as possible, before shifting to an EV, while less vulnerable archetypes tend to shift to EVs more easily and benefit from wider savings in fuel expenditure. The soaring fuel prices in the MBI scenario strongly affects this archetype, that is unable to afford to travel by car to access basic services and is therefore highly vulnerable to transport poverty.

4 Implications for policy to support a fair transition to net-zero

4.1 What does this research imply in terms of net-zero policy pathways and the incidence of fuel and transport poverty?

The objectives of this piece of research were to explore how vulnerability to fuel and transport poverty shapes the UK's energy transition by specifically considering whether new inequalities may emerge, or existing inequalities worsen, because of policies designed to transition the UK to a net-zero economy.

Greater understanding of who could be vulnerable to fuel and transport poverty

Through examining the distributional outcomes of hypothetical scenarios of differing policy pathways, this report provides greater understanding of who could be vulnerable to fuel and transport poverty in the UK's transition to net-zero, to what extent, and why. It unveils societal groups and specific household archetypes who may be at particular risk, and in this Chapter, considers the implications for developing effective and supportive policy, which reduces inequalities and promotes a fair and just transition.

Climate policy can generate favourable socio-economic outcomes

Encouragingly, all the policy pathways modelled in this analysis lead to better outcomes for emissions, GDP and employment in the UK compared to the 'business-as-usual' baseline. This finding demonstrates that climate policy has the ability to create a win-win situation in which emissions are reduced, while at the same time the economy grows, and new employment opportunities are created. Furthermore, more ambitious climate action (in terms of emissions reductions) can lead to even greater gains for the environment, economy and society.

There are likely to be 'winners' and 'losers'

However, the findings of the deep-dive into the effects of the policy scenarios on a set of household archetypes show that there can be 'winners' and 'losers' in each of the policy pathways. The three modelled scenarios show that in 2035:

Vulnerable households will be disproportionately affected

- When considering equity-weighted energy bills, the highest household bills are paid by **low-income households**, particularly by people from **ethnic minorities, and living in social housing predominantly in urban areas**.
- Similarly, **pensioners with disabilities and long-term health conditions**,with either average or low-incomes, are also expected to pay high energy bills in all the modelled scenarios.
- Historically, low-income groups spend a greater proportion of their income on household energy, and the findings of this research show that this **inequality is exacerbated** in all three modelled scenarios. As a proportion of income, the archetype spending the most on energy bills is mainly composed of **ethnic minority households on a low income and living in social housing**. By 2035, these households spend between 10% and 13% of their income on energy, which is more than double the proportion spent by families on high incomes (between 3% and 5%). Similarly, by 2035 **young (i.e. age 25-34), low-income renters** spend between 9% and 13% of their income on energy bills, which is double the proportion spent by those with similar socio-economic characterises but earning high incomes. Households comprised of **pensioners, particularly those on disability benefits**, also pay a large proportion of income on energy bills.
- In addition, **young households (i.e. age 25-34) on a low income, people from ethnic minorities and pensioners with disabilities** tend to have the highest relative expenditure on motor fuel in all the three modelled scenarios.
- When considering expenditure as a proportion of income, **vulnerable households tend to spend a greater proportion of their income on motor fuel expenditure**. **The policy pathways explored in this analysis all have regressive impacts** in terms of expenditure on motor fuel. In the medium-term vulnerable groups are likely to be affected negatively by policies aimed at decarbonising the transport sectors, since they are less likely to be able to make the switch to EVs, and therefore benefit from lower fuel costs.

At the same time, less vulnerable groups are not as greatly affected, or even benefit

- **Retired couples and families on average incomes, young (i.e. age 25-34) households and middle-aged households (i.e. age 45-64) on a high income tend to pay substantially lower annual household energy bills (when equity-weighting is taken into account, and as a proportion of income) compared to vulnerable households**.
- **Wealthy and less vulnerable groups are expected to benefit widely from the transition to electric vehicles**.
- In the NZS and Regulation scenarios, regulatory policy leads to sales of new ICE vehicles being phased out by 2030 (NZS) or 2022 (Regulation), which results in a substantial shift to EVs, particularly amongst high-income households who can afford the up-front costs. **While both scenarios lead to savings in motor fuel expenditure for all household archetypes, the results are regressive since the largest savings are achieved by the least vulnerable households**.

The findings of this research are consistent with earlier work in the FAIR project which identified the groups most vulnerable to fuel and transport poverty (see Figure 1.1 in Chapter 1). **Households on a low-income, households with children, ethnic minority households and households with health and/ or mobility difficulties** are all predisposed to experience energy and transport poverty combined, and **our research shows that, without appropriate support, these groups are indeed vulnerable to financial hardship when it comes to paying their energy and transport costs in the UK's energy transition**. When the modelling findings point towards any savings in 2035 (i.e. the NZS and Regulation scenarios lead to savings on motor fuel expenditure), the largest savings are made by the least vulnerable archetypes. **Without appropriate policy that recognises the potential 'winners' and 'losers' of the transition to net-zero, worsening inequalities may emerge**.

4.2 What is driving the worsening inequalities?

According to our scenarios, the transition will lead to higher fossil fuel and therefore energy prices, and therefore moving to a low-carbon heating system and EVs will be essential to keep costs down. The worsening inequalities seen in the findings of this research are **driven by increasing fossil fuel prices, which are expected to have a stronger, disproportionately negative impact on vulnerable groups** as they will be among the **last to adopt clean energy technologies**. High upfront costs present a barrier to adopting these technologies, and in 2035 vulnerable households are still reliant on the use of fossil fuels for heating their homes and running their often old and inefficient cars. Aside from the upfront costs, there are **other barriers preventing vulnerable groups from making the switch** to low-carbon technologies or alternative options.

For example, vulnerable households who live in rural areas and are in forced car ownership due to disability and long-term health issues affecting their day-to-day activity, have no convenient alternative to the use of private cars.

The outcomes of the decarbonisation scenarios lead to increased risk of fuel and transport poverty which could lead to deprivation of other essential goods and services as a knock-on effect.

The **distributional pattern of technology adoption is an important factor** that, if realised, is likely to exacerbate the regressive impacts of high energy prices on vulnerable households identified in this research. These households stand to 'get left behind' in the energy transition if not supported by Government policy sufficiently, as the higher energy prices they face will not be offset by improved efficiency in their use of energy. Meanwhile, **early adopters (who are likely to be the least vulnerable groups in society) can take advantage of cheaper-to-run, more efficient low-carbon technologies, and flexibility services**. Enabling low-income and vulnerable groups to take advantage of these technologies and behaviours through policy measures must be a priority.

4.3 How can the Government support vulnerable households?

Greater and faster deployment of renewables and energy efficiency measures is needed

The 2022 cost-of-living crisis, partly driven by rocketing global gas prices, has made the issues of fuel and transport poverty, and the need to address increasing inequalities, ever more pertinent as higher proportions of the UK population are expected to fall into hardship. The crisis should be a stark reminder for policymakers to speed up the pace at which:

- **The UK decarbonises its energy system (with the dual benefit of reducing the cost of generating electricity and increasing the UK's energy security)** and;
- **The UK prioritises electrification and reduces its demand for energy**.

In practice this means that at the same time as greater deployment of renewable energy sources, the focus should be on the mass retrofit of homes and improving the energy efficiency of the UK's housing stock through installing insulation, double-glazing and low-carbon heating technologies such as heat pumps. While greater deployment of renewable energy sources and moving away from expensive fossil fuel powered sources should reduce the costs of generating electricity, the other aforementioned energy-efficiency and low-carbon measures together reduce the need for energy, allowing for warmer, more comfortable homes at a more affordable running cost.

Targeted retrofitting could help with the cost-of-living crisis in the short-term, as well as provide long-lasting benefits

Furthermore, a mass retrofit programme should be targeted first towards the societal groups most vulnerable to fuel poverty, often living in the most inefficient homes and who are least 'able to pay'. This kind of targeted support could be used in the short-term to partly address the cost-of-living crisis seen in 2022, as households could enjoy lower bills and warmer homes. Fuel poverty could be partly alleviated, while at the same time providing long-lasting benefits for society, the environment and economy in the form of lower bills throughout the transition to net-zero, reduced emissions and new job opportunities.

Support could take the form of subsidies and targeted Government investment

In fact, for both climate and socio-economic reasons it is important to tackle the worst performing buildings first, which in many cases will be the residences of those in the lowest income and other vulnerable groups, often living in fuel poverty. Regulatory policies such as requiring a certain level of energy efficiency below which a property cannot be rented out, or fiscal policy in the form of targeted subsidies for those in the biggest need, would be effective.

Subsidising the upfront costs of low-carbon heating technologies for vulnerable groups identified in this research, including those on a low income, from ethnic minorities and those living with health and/or mobility issues, would be an important means of reducing the risks of fuel poverty.

Low-income and vulnerable households are unlikely to be able to afford the up-front costs of retrofitting their home even with fiscal incentives. These groups need policy programmes tailored to their needs, and advice which recognises the fact that they may also be experiencing transport poverty or are digitally excluded, meaning they will find it difficult to access information and advice.

Investing in a high quality, low-cost, integrated public transport system will not only help to address transport poverty, particularly for vulnerable households such as those in rural areas who have difficulties accessing convenient and affordable public transport, but also increase connectivity and economic growth through increased investment. For example, work being undertaken as part of the Manchester Bee Network[20] and Welsh Government's bus network proposals[21] offer useful lessons to policymakers elsewhere on how to create a lower carbon, more appealing and effective public transport system.

It should be noted that the quantitative aspects of this research relied on motor fuel costs as a proxy for transport poverty risk. Clearly, this is a car-centric perspective on mobility and transport poverty which also does not take account of other costs related to car ownership, or other transport modes which could become more or less costly. Some of these nuances are explored in the qualitative aspect of the household archetypes analysis. However, future work could consider in more detail access to, frequency, suitability and the cost of public and active travel alternatives, with future policy geared towards improving these metrics.

Taking account of intersectional vulnerabilities

Targeted support to address both fuel and transport poverty could also take account of the intersectional vulnerabilities certain groups face, as highlighted by the household archetypes analysis. Policymakers could consider using best available evidence and enhanced data on household composition to better target vulnerable groups. Sophisticated delivery of support could include a spatial analysis to identify pockets of not only deprivation but also higher proportions of people with disabilities and other risk factors to enable better targeting. Indeed, forthcoming work of the FAIR project is investigating the spatial variation of fuel and transport poverty patterns across the UK and is helping to identify specific areas with a high risk of fuel and transport poverty to a high, sub-ward resolution.[22]

Decarbonisation policy can support the levelling up agenda

Ultimately, a strategy based on reducing both the UK's reliance on fossil-fuels through greater renewable energy deployment, and the amount of energy needed to maintain or improve our standards of living, while targeting particular support towards those who may be vulnerable during the energy transition, could support the levelling up agenda and set the UK on track to meet the net-zero target in a socially inclusive and fair way.

20 See The Bee Network | TfGM Bee Active.

21 One network, one timetable, one ticket, Welsh Government sets out plans to change the way we travel | GOV.WALES

22 See Visualising and mapping vulnerabilities | CREDS.

4.4 Specific policy implications associated with the outcomes of a particular policy pathway

The Regulation and MBI scenarios modelled in this research represented extremes, i.e. a decarbonisation pathway based entirely on regulatory policies and a pathway based entirely on carbon pricing. In reality, a likely policy outcome will see elements of each macroeconomic scenario being adopted. However, considering the different 'extreme' scenarios is a useful exercise to explore the specific economic and distributional outcomes of these types of policies. While the research also explored the modelled outcomes of the Government's Net Zero Strategy, the Strategy does not include all details about the type of policy that would be used to reach decarbonisation targets. In Section 4.3, policy implications common to all policy pathways considered in this research are discussed. However, some other considerations which are specific to individual policy pathways should be recognised.

Government Net Zero Strategy scenario

The Net Zero Strategy acknowledges the need to continue supporting those most in need throughout the transition to net-zero, and the Government has already committed to support low-income households with the costs of paying for energy efficiency improvements and low-carbon heating through the Home Upgrade Grant and Social Housing Decarbonisation Fund. However, our findings (supported by other CREDS work) demonstrate that the current ambition of the Net Zero Strategy is not enough to meet net-zero by 2050. Although our modelling suggests a substantial shift to EVs and heat pumps, this occurs mostly within higher income, less vulnerable groups in earlier years.

Some positive effects of the Social Decarbonisation Fund and public transport investment aspects of the Net Zero Strategy can be seen within the findings of our research for specific household archetypes, with a proportion of vulnerable households being helped with the switch to low-carbon heating, and gaining better access to improved public transport. However, the overall outcomes for vulnerable households remain unfavourable. **Extending incentives and support for all households, particularly vulnerable households, would lead to greater emissions reductions and bring the overall outcomes closer to net-zero by 2050**.

Regulation scenario

Similarly to the NZS scenario, the regulation scenario assumes ambitious deployments of both heat pumps and EVs, but take-up of these technologies is still initially skewed towards those who are more 'able-to-pay'. To avoid regressive effects of such policies, vulnerable households should be supported to finance the up-front costs.

MBI scenario and the importance of the way in which tax revenues are recycled

Broader taxation and spending policies associated with the climate transition will have significant distributional impacts. A pathway which relies more heavily on a carbon price, as demonstrated by the MBI scenario in this research, could raise substantial revenue for the Government, which may be used to reduce direct tax rates, or may be spent in some other way, or not at all. A pathway which sees more direct Government investment in clean energy may require tax rises. These fiscal decisions will have important distributional effects on consumption, and therefore on fuel and transport poverty.

Given all of the above, **a pathway which is achieved through a carbon price, without recycling carbon revenues, would be likely to have the worst outcomes for fuel and transport poverty**, as revealed by the findings of the MBI scenario, which had the highest energy prices of all the scenarios. Higher energy prices would impact low-income households the most; and these households would be the least able to adapt to these price changes by switching to clean energy, due to high upfront costs. If a net-zero economy is achieved mainly through carbon prices, then policymakers must provide extra support to low-income households to avoid disastrous outcomes on fuel and transport poverty. Indeed, **if these revenues were used to promote energy efficiency in fuel-poor households, the Government could drive a progressive transition**, while still generating wider economic benefits for the UK, and also ensuring continued reductions in emissions.

The level of carbon tax modelled in the MBI scenario had to reach £500/tonneCO_2 to achieve an outcome approaching net-zero. A carbon tax at this level would prove challenging to implement in reality with carbon leakage and disinvestment a strong possibility. Additionally, the household archetype analysis indicated that the carbon tax-reliant MBI scenario caused substantial increases in energy bills compared to the other scenarios modelled. Crucially, at £250/tonneCO_2 net-zero is not achieved, meaning that a carbon tax with a progressive revenue recycling should be applied alongside other measures to achieve an equitable transition.

4.5 Conclusion

This research points to favourable economic outcomes from a transition to net-zero but also offers warnings of worsening inequalities if issues of equity and redistribution are not taken account of in policymaking. Neither the E3ME modelling exercise, nor the household archetypes analysis should be seen as a prediction of the future but as an indication of possible scenarios, based on a set of assumptions, to prompt further discussion around the best combination of policy actions to boost any positive outcomes, and mitigate possible negative outcomes stemming from the transition. In this final Chapter we have set out our understanding of the implications of the findings for policy, which could form part of future policy debates.

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Appendix A: E3ME modelling methodology

The E3ME model

E3ME is a global, macroeconometric model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used for policy assessment, forecasting and research purposes across different geographical areas.

As a general model of the economy, E3ME is capable of producing projections for GDP and the aggregate components of GDP (household expenditure, investment, Government expenditure and international trade), and other output indicators including employment by sector and GHG emissions.

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2016 and the model projects forward annually to 2050. The main data sources for European countries (including the UK) are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

The current version of the model has the following dimensions:

- 70 regions – all major world economies (i.e. G20), the EU28 and candidate countries plus other countries' economies grouped
- 70 industry sectors, based on standard international classifications
- 43 categories of household expenditure
- 23 different users of 12 different fuel types
- 15 users of 7 raw materials
- 14 types of airborne emissions (where data are available) including the six greenhouse gases monitored under the Kyoto protocol

For more information on the E3ME model, including the model manual, please visit www.e3me.com.

Appendix B: Household archetypes analysis methodology

Assessing the impacts of net-zero policy pathways on different households

Our analysis considered the impacts of the NZS, Regulation and MBI scenarios on different household archetypes in the medium term. To do this we used a set of household archetypes reflecting the population of Great Britain with extensive information on their socio-economic background, characteristics of energy consumption and details on their travel behaviours. The household archetypes are based on energy consumer archetypes developed by Ofgem (Centre for Sustainable Energy, 2020), and were further expanded with quantitative and qualitative data on transport behaviours mainly extracted from the UK National Travel Survey (Department for Transport, 2021) and an extended literature review.

We then constructed a tailored set of archetypes for each scenario. To do this, we made crucial assumptions on the uptake of heat pumps and electric vehicles (EVs) as well as the gas and electricity consumption for each household archetype. This involved making qualitative judgements about how the specific policies being modelled in each scenario would affect the distribution of technologies across different household types (e.g. a purely fuel-tax based policy approach would lead to accelerated take-up of low-carbon technologies by high and middle-income households who could afford the up front costs, while regulation-focussed approaches might lead to a more even distribution of take-up, or even specifically target low-income households).

The set of household archetypes was then further expanded by projecting data ahead in the future, specifically focusing on estimating how the uptake of heat pumps, the level of energy consumption and the ownership of EVs change across archetypes as a result of decarbonisation policies.

Tables B.1 – B.5 provide an overview of the main characteristics of the 2020 baseline archetypes and the household archetypes in each of the scenarios in 2035.

Table B.1 Summary description of household archetypes in the Baseline in 2020

Household archetype	Number of households (£ million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
High-income families	2.8	2.96	15% rural 85% urban	£40,900	Mains gas	9,650	3,250	1.1%	86% (of which 1% EVs)	9,111
Wealthy middle-aged households	2.9	2.96	19% rural 81% urban	£48,200	Mains gas	20,520	4,920	0.7%	86% (of which 1.4% EVs)	9,111
Average income pensioners	3.7	1.80	22% rural 78% urban	£28,000	Mains gas	15,350	3,670	0.2%	82% (of which 1.6% EVs)	4,243
High-income part-time employees	2.3	2.57	20% rural 80% urban	£36,600	Mains gas	15,630	4,090	0.5%	86% (of which 1.4% EVs)	7,644
Elderly and very poor single adults in urban areas	1.9	1.29	17% rural 83% urban	£13,200	Mains gas	11,270	2,570	0.9%	30% (of which 0.2% EVs)	1,777
Low-income ethnic minorities with disabilities in social housing	1.5	2.10	11% rural 89% urban	£13,600	Mains gas	12,340	3,920	8.5%	72% (of which 0% EVs)	3,808
Middle-aged households & pensioners with disabilities	1.2	2.53	18% rural 82% urban	£30,400	Mains gas	15,600	4,140	6.5%	85% (of which 1.4% EVs)	7,525
Low-income young households	2.4	2.52	11% rural 89% urban	£16,200	Mains gas	11,950	3,620	7.7%	72% (of which 0.2% EVs)	4,570

Household archetype	Number of households (£ million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
High-income young households	3.1	2.48	14% rural 86% urban	£29,700	Mains gas	10,440	3,200	2.1%	86% (of which 0.4% EVs)	7,634
Rural high-income middle-aged couples	1.9	2.28	63% rural 37% urban	£35,400	32% Electric heating 68% Oil	–	5,750	0.9%	86% (of which 1.3% EVs)	7,018
Ethnic minorities on average income	1.5	2.11	29% rural 71% urban	£23,200	55% Electric heating 45% Oil	–	5,250	1.2%	82% (of which 0.3% EVs)	4,974
Elderly and very poor single adults off the gas grid	0.6	1.23	35% rural 65% urban	£12,000	45% Electric heating 55% Oil	–	4,030	5.0%	55% (of which 0% EVs)	1,694
Low-income pensioners with disabilities	0.5	1.91	41% rural 59% urban	£18,200	37% Electric heating 63% Oil	–	5,360	5.4%	72% (of which 0% EVs)	3,463

Table B.2 Summary description of household archetypes in the Baseline in 2035

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
High-income families	2.8	2.96	15% rural 85% urban	54,927	91% Mains gas 9% Heat pumps	8,782	3,524	1.1%	86% (of which 30% EVs)	9,111
Wealthy middle-aged households	2.9	2.96	19% rural 81% urban	64,731	88% Mains gas 12% Heat pumps	18,058	5,697	0.7%	86% (of which 36% EVs)	9,111
Average income pensioners	3.7	1.80	22% rural 78% urban	37,603	98% Mains gas 2% Heat pumps	15,043	3,767	0.2%	82% (of which 36% EVs)	4,243
High-income part-time employees	2.3	2.57	20% rural 80% urban	49,152	90% Mains gas 10% Heat pumps	14,067	4,583	0.5%	86% (of which 32% EVs)	7,644
Elderly and very poor single adults in urban areas	1.9	1.29	17% rural 83% urban	17,727	100% Mains gas	11,270	2,570	0.9%	30% (of which 0% EVs)	1,777
Low-income ethnic minorities with disabilities in social housing	1.5	2.10	11% rural 89% urban	18,264	100% Mains gas	12,340	3,920	8.5%	72% (of which 1% EVs)	3,808

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Middle-aged households & pensioners with disabilities	1.2	2.53	18% rural 82% urban	40,826	100% Mains gas	15,600	4,140	6.5%	85% (of which 25% EVs)	7,525
Low-income young households	2.4	2.52	11% rural 89% urban	21,756	100% Mains gas	11,950	3,620	7.7%	72% (of which 1% EVs)	4,570
High-income young households	3.1	2.48	14% rural 86% urban	39,886	100% Mains gas	10,440	3,200	2.1%	86% (of which 22% EVs)	7,634
Rural high-income middle-aged couples	1.9	2.28	63% rural 37% urban	47,541	30% Electric heating 60% Oil 10% Heat pumps	–	5,950	0.9%	86% (of which 35% EVs)	7,018
Ethnic minorities on average income	1.5	2.11	29% rural 71% urban	31,157	55% Electric heating 45% Oil	–	5,250	1.2%	82% (of which 2% EVs)	4,974
Elderly and very poor single adults off the gas grid	0.6	1.23	35% rural 65% urban	16,116	45% Electric heating 55% Oil	–	4,030	5.0%	55% (of which 0% EVs)	1,694
Low-income pensioners with disabilities	0.5	1.91	41% rural 59% urban	24,442	37% Electric heating 63% Oil	–	5,360	5.4%	72% (of which 0% EVs)	3,463

Table B.3 Summary description of household archetypes in the Net Zero Strategy Scenario in 2035

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
High-income families	2.8	2.96	15% rural 85% urban	55,214	35% Mains gas 65% Heat pumps	3,324	5,198	1.1%	86% (of which 75% EVs)	9,111
Wealthy middle-aged households	2.9	2.96	19% rural 81% urban	65,069	30% Mains gas 70% Heat pumps	6,058	9,380	0.7%	86% (of which 80% EVs)	9,111
Average income pensioners	3.7	1.80	22% rural 78% urban	37,799	75% Mains gas 25% Heat pumps	11,329	4,862	0.2%	82% (of which 80% EVs)	4,243
High-income part-time employees	2.3	2.57	20% rural 80% urban	49,409	32% Mains gas 68% Heat pumps	4,922	7,390	0.5%	86% (of which 77% EVs)	7,644
Elderly and very poor single adults in urban areas	1.9	1.29	17% rural 83% urban	17,820	73% Mains gas 27% Heat pumps	8,096	3,515	0.9%	30% (of which 1% EVs)	1,777

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Low-income ethnic minorities with disabilities in social housing	1.5	2.10	11% rural 89% urban	18,360	38% Mains gas 62% Heat pumps	4,615	6,296	8.5%	72% (of which 2% EVs)	3,808
Middle-aged households & pensioners with disabilities	1.2	2.53	18% rural 82% urban	41,039	40% Mains gas 60% Heat pumps	6,141	7,046	6.5%	85% (of which 62% EVs)	7,525
Low-income young households	2.4	2.52	11% rural 89% urban	21,870	60% Mains gas 40% Heat pumps	7,056	5,104	7.7%	72% (of which 2% EVs)	4,570
High-income young households	3.1	2.48	14% rural 86% urban	40,094	82% Mains gas 18% Heat pumps	8,425	3,784	2.1%	86% (of which 40% EVs)	7,634
Rural high-income middle-aged couples	1.9	2.28	63% rural 37% urban	47,789	15% Electric heating 20% Oil 65% Heat pumps	–	6,220	0.9%	86% (of which 75% EVs)	7,018

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Ethnic minorities on average income	1.5	2.11	29% rural 71% urban	31,319	45% Electric heating 15% Oil 40% Heat pumps	–	5,139	1.2%	82% (of which 2% EVs)	4,974
Elderly and very poor single adults off the gas grid	0.6	1.23	35% rural 65% urban	16,200	31% Electric heating 30% Oil 39% Heat pumps	–	3,927	5.0%	55% (of which 1% EVs)	1,694
Low-income pensioners with disabilities	0.5	1.91	41% rural 59% urban	24,570	25% Electric heating 40% Oil 35% Heat pumps	–	5,409	5.4%	72% (of which 2% EVs)	3,463

Table B.4 Summary description of household archetypes in the Regulation Scenario in 2035

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
High-income families	2.8	2.96	15% rural 85% urban	55,743	15% Mains gas 85% Heat pumps	1,354	5,671	1.1%	86% (of which 90% EVs)	9,111
Wealthy middle-aged households	2.9	2.96	19% rural 81% urban	65,692	10% Mains gas 90% Heat pumps	1,920	10,372	0.7%	86% (of which 95% EVs)	9,111
Average income pensioners	3.7	1.80	22% rural 78% urban	38,161	30% Mains gas 70% Heat pumps	4,308	6,842	0.2%	82% (of which 95% EVs)	4,243
High-income part-time employees	2.3	2.57	20% rural 80% urban	49,882	13% Mains gas 87% Heat pumps	1,901	8,104	0.5%	86% (of which 87% EVs)	7,644
Elderly and very poor single adults in urban areas	1.9	1.29	17% rural 83% urban	17,990	68% Mains gas 32% Heat pumps	7,169	3,635	0.9%	30% (of which 10% EVs)	1,777

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Low-income ethnic minorities with disabilities in social housing	1.5	2.10	11% rural 89% urban	18,536	35% Mains gas 65% Heat pumps	4,041	6,288	8.5%	72% (of which 20% EVs)	3,808
Middle-aged households & pensioners with disabilities	1.2	2.53	18% rural 82% urban	41,432	25% Mains gas 75% Heat pumps	3,649	7,594	6.5%	85% (of which 85% EVs)	7,525
Low-income young households	2.4	2.52	11% rural 89% urban	22,079	65% Mains gas 35% Heat pumps	7,267	4,855	7.7%	72% (of which 25% EVs)	4,570
High-income young households	3.1	2.48	14% rural 86% urban	40,478	55% Mains gas 45% Heat pumps	5,372	4,587	2.1%	86% (of which 65% EVs)	7,634
Rural high-income middle-aged couples	1.9	2.28	63% rural 37% urban	48,247	15% Electric heating 85% Heat pumps	–	6,620	0.9%	86% (of which 87% EVs)	7,018
Ethnic minorities on average income	1.5	2.11	29% rural 71% urban	31,619	40% Electric heating 20% Oil 40% Heat pumps	–	5,237	1.2%	82% (of which 40% EVs)	4,974

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Elderly and very poor single adults off the gas grid	0.6	1.23	35% rural 65% urban	16,355	38% Electric heating 24% Oil 38% Heat pumps	–	4,248	5.0%	55% (of which 25% EVs)	1,694
Low-income pensioners with disabilities	0.5	1.91	41% rural 59% urban	24,805	35% Electric heating 33% Oil 32% Heat pumps	–	6,081	5.4%	72% (of which 10% EVs)	3,463

Table B.5 Summary description of household archetypes in the MBI Scenario in 2035

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
High-income families	2.8	2.96	15% rural 85% urban	55,760	25% Mains gas 75% Heat pumps	2,424	5,544	1.1%	86% (of which 60% EVs)	9,111
Wealthy middle-aged households	2.9	2.96	19% rural 81% urban	65,713	17% Mains gas 83% Heat pumps	3,504	10,319	0.7%	86% (of which 65% EVs)	9,111
Average income pensioners	3.7	1.80	22% rural 78% urban	38,173	35% Mains gas 65% Heat pumps	5,397	6,833	0.2%	82% (of which 65% EVs)	4,243
High-income part-time employees	2.3	2.57	20% rural 80% urban	49,898	20% Mains gas 80% Heat pumps	3,140	8,054	0.5%	86% (of which 63% EVs)	7,644
Elderly and very poor single adults in urban areas	1.9	1.29	17% rural 83% urban	17,996	96% Mains gas 4% Heat pumps	10,869	2,713	0.9%	30% (of which 2% EVs)	1,777
Low-income ethnic minorities with disabilities in social housing	1.5	2.10	11% rural 89% urban	18,541	94% Mains gas 6% Heat pumps	11,653	4,155	8.5%	72% (of which 4% EVs)	3,808

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Middle-aged households & pensioners with disabilities	1.2	2.53	18% rural 82% urban	41,445	30% Mains gas 70% Heat pumps	4,701	7,602	6.5%	85% (of which 50% EVs)	7,525
Low-income young households	2.4	2.52	11% rural 89% urban	22,086	93% Mains gas 7% Heat pumps	11,165	3,885	7.7%	72% (of which 5% EVs)	4,570
High-income young households	3.1	2.48	14% rural 86% urban	40,491	85% Mains gas 15% Heat pumps	8,915	3,696	2.1%	86% (of which 20% EVs)	7,634
Rural high-income middle-aged couples	1.9	2.28	63% rural 37% urban	48,262	14% Electric heating 8% Oil 78% Heat pumps	–	6,424	0.9%	86% (of which 60% EVs)	7,018
Ethnic minorities on average income	1.5	2.11	29% rural 71% urban	31,629	52% Electric heating 40% Oil 8% Heat pumps	–	5,247	1.2%	82% (of which 3% EVs)	4,974

Household archetype	Number of households (£million)	Average household size (number of members)	Rural vs urban (%)	Average income after housing costs (£)	Heating fuel (%)	Gas use (kWh)	Electricity use (kWh)	Households that experienced in arrears of energy bills (%)	Car ownership (%)	Average distance travelled by car (miles per year)
Elderly and very poor single adults off the gas grid	0.6	1.23	35% rural 65% urban	16,360	46% Electric heating 50% Oil 4% Heat pumps	–	4,109	5.0%	55% (of which 2% EVs)	1,694
Low-income pensioners with disabilities	0.5	1.91	41% rural 59% urban	24,813	34% Electric heating 60% Oil 6% Heat pumps	–	5,297	5.4%	72% (of which 3% EVs)	3,463

The analysis of distributional impacts comprises two main parts:

- First, we quantified the cost of net-zero pathways in terms of energy bills and motor fuel expenditure for each household archetype. The quantification was carried out for three different scenarios: NZS, Regulation and MBI scenarios. Data on energy consumption were provided by Ofgem (Centre for Sustainable Energy, 2020), whereas information on the distance travelled by car is based on the National Travel Survey (Department for Transport, 2021). Finally, energy and fuel prices are based on historical data (BEIS, 2021a, 2022) and results of the E3ME modelling.

Based on the Green Book guidelines, energy bills were adjusted using equity weighting, so that lower income households are given a higher weight than higher income households (HM Treasury, 2022b). Using equity weighting allows the analysis to account for the fact that the burden of an additional GBP in energy bills is higher for a low-income recipient and lower for a high-income recipient (Box 3.1).

- Second, we carried out a qualitative assessment which provides an in-depth understanding of the impacts of the three modelled scenarios, hence providing additional context to the quantification of energy bills and fuel expenditure. This includes an assessment of the degree of vulnerability to energy and transport poverty for each household archetype.

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The Centre for Research into Energy Demand Solutions (CREDS) was established as part of the UK Research and Innovation's Energy Programme in April 2018, with funding of £19.5M over 5 years. Its mission is to make the UK a leader in understanding the changes in energy demand needed for the transition to a secure and affordable, net-zero society. CREDS has a team of over 140 people based at 24 UK universities.

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