Government
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Net zero society: Potential impacts and co-benefits

Annex 5

March 2023

Foresight

Summary

A summary table of the content of this annex is provided below. It covers the key impacts of the four scenarios in four key areas (health, infrastructure, regional and socioeconomic, and environment and energy security).

	The atomised society	The metropolitan society	The self-preservation society	The slow lane society
Health	• High levels of road vehicle kilometres, air travel and consumption of manufactured goods leads to worse air pollution. • Relatively low levels of physical activity. • Increased meat consumption worsens air pollution and negatively impacts life expectancy from diet.	• Mixed impacts on air pollution; increased active lifestyles and shared travel options improve air quality, but high levels of aviation worsen it. • Higher levels of active travel increase physical activity. • Relatively healthy diets with lower levels of meat consumption.	• Air pollution from travel and industry are relatively high in this scenario, though not the highest. • This scenario also sees high levels of meat consumption, which impacts both air pollution and diet. • Life expectancy increases from diet are joint lowest in this society.	• Reduced industrial emissions and shifts in transport preferences contribute to improved air quality. • Highest levels of physical activity. • Life expectancy increases from diet are the greatest out of all four scenarios in this society
Infrastructure	• Requires significant infrastructure investment in terms of road building and energy infrastructure - particularly investment in the gas grid. • Urban populations are lower than in some scenarios, so there might be fewer challenges in the delivery of urban infrastructure.	• Biggest challenges in terms of infrastructure. • Significant amounts of urban and public transport infrastructure would need to be delivered in dense cities, most likely involving tunnelling. • This scenario also sees relatively high energy demands and requirements for energy infrastructure.	• Moderate infrastructure cost overall, with some need for road building, delivery of infrastructure to serve growing urban populations. • This scenario also has relatively high energy demands and energy infrastructure needs.	• Lowest infrastructure needs, with no significant need for road building, significantly lower energy infrastructure needs, and relatively low urban populations. • This scenario would need to see a significant investment in active travel infrastructure.
Regional and socioeconomic	• This scenario could see growth in jobs across regions from high levels of reshoring, vehicle manufacturing and industrial clusters, although this could be reduced by automation. • Conversely, this scenario could see lower uptake of measures that would benefit lower income households, like insulation and shared mobility.	• Characterised by an urban/rural divide, contributing to regional inequality. • Less obvious regional impacts include the creation of net zero industrial clusters. • Lower income households would benefit somewhat from lower cost transport and energy efficiency solutions in this scenario.	• Some regional benefits from moderate reshoring of manufacturing. • There could also be decreased inequality due to the somewhat increased energy efficiency of homes.	• This scenario could experience decreased inequality due more people living in energy efficient homes and more diverse transport options being available. • This scenario could also see a renaissance in the tourism sector in certain parts of the UK as more people choose to holiday domestically.
Environment and energy security	• Some positive environmental and energy security impacts through reduced burning of fossil fuels. • High levels of meat consumption could increase eutrophication. • High levels of energy use mean energy security concerns could be higher in this scenario.	• Lower meat consumption in this scenario would have wider environmental benefits. • Relatively high levels of energy use, which will worsen both environmental and energy security impacts.	• Mixed impacts on energy and the environment. • Increased energy security through reduced energy use and reliance on imports. • Increased eutrophication from high levels of meat consumption.	• Mainly positive impacts on energy security and the environment from reduced energy demand and its energy mix. • Still requires the manufacture of many new net zero technologies, the environmental impacts of which will need to be managed.

Introduction

1.1 Scope

The four scenarios that form the basis of the net zero society foresight report were developed to test assumptions about what UK society could be like in 2050 and what this might mean for how net zero is met. The scenarios vary across a series of 'levers': variable factors whose future direction is uncertain, which the project team set at different levels to differentiate the four scenarios. These include active lifestyles, circular economy practices, and dietary changes.

The focus of the net zero society report is on the impact of these levers on energy demand and emissions and the scenarios were specifically designed to include societal changes that are most likely to affect these areas. However, changes to levers that affect energy demand and emissions would likely also have broader impacts, such as on health or infrastructure. The scenario narratives avoid setting out detail on potential implications of these societal changes beyond how they relate to energy and emissions, as this was beyond the scope of the core project. However, this annex provides some analysis of the potential wider impacts in different policy areas.

To help provide context and insights on how the scenarios might come about, broader societal changes (such as GDP growth) were also included in the four scenarios. Neither the main net zero society report nor this annex provide analysis on the impacts of these broader societal changes. The purpose of this annex is to support policy makers working in areas directly related to energy and emissions to think about how policy in these areas could have wider impacts.

It would be beyond the scope of our project and very technically challenging to assess all the potential impacts of the different levers used in the scenarios. But this annex considers some important examples that are particularly relevant to policy areas outside of energy and carbon emissions (e.g. population health or biodiversity). Four core policy areas were chosen following deliberation with civil servants to reflect government priorities at the time: health, infrastructure, equity, and environment/energy security. Policy makers may find it useful to apply methods and principles below to assess the potential impacts of the scenarios on other related policy areas.

1.2 Approach

Potential impacts of the scenarios on any given policy area can be assessed quantitatively or qualitatively, depending on the data available. This annex presents a combination of quantitative and qualitative assessments. The examples chosen for assessing quantitative impacts were:

- the impact of dietary changes on life expectancy, and
- the impact on road transport use on air pollution levels (covered in the main report rather than this annex)

For other impacts covered in this annex, the research team undertook a literature review to identify evidence on impact. A qualitative approach was then used to assess the broader impacts of the four net zero society scenarios, focusing on key examples in each case.

Below are the assessments of how different aspects of the net zero society scenarios could impact four areas: health, infrastructure, equity, and environment/energy security. While this annex does not show all possible impacts from the levers considered, it could be used as a template to help assess other areas of interest.

Please note that the research for this report was carried out up until early 2023 and, therefore, the report only considers trends and policy up until this time point.

Health

There are many potential health benefits associated with transitioning to net zero, which are widely reported in research literature. This section outlines our assessment of how levers within the scenarios could affect some aspects of health.

Air pollution, physical activity and diet are risk factors, which affect the chance of a person becoming ill. This section sets out analysis on how the levers within scenarios could affect these risk factors. This analysis omits other important risk factors, such as alcohol consumption or smoking, because no assumptions were made in the scenarios around how societal changes would affect these particular risk factors.[1,2]

Life expectancy is an indicator of health status and the impact of risk factors on life expectancy will be considered in this section. There are other indicators that are not considered in this annex, including years lived without chronic disease, self-assessed health/wellbeing and incidence of mental health conditions.[3] Life expectancy is the most widely used and understood indicator of health status, and was therefore selected for this analysis. This analysis only includes the impact of sector levers on health. Other factors that could play a role but are *not* considered in this analysis include:

- **The impact of cross-cutting levers on health**, such as GDP per capita: These levers are likely to have health impacts that are not fully detailed here. For example, overall GDP is lowest in the **slow lane society**, where public expenditure is also assumed to be lower, which could potentially impact healthcare spending and therefore health.
- **Health system indicators** (such as number of healthcare workers per capita, the number of hospital beds per capita): These play a role in public health but were not included in this analysis because assumptions about changes in the healthcare system were not within scope for the net zero society report.[4]
- **Unquantifiable characteristics of each scenario**: There are characteristics of the future scenarios that are impossible to predict accurately and quantify. For

example, the **metropolitan** and **atomised** societies have high levels of technological growth, which could increase the number of cutting-edge treatments available for those who do become ill. The opposite may be true in the **slow lane** and **self-preservation** societies which have lower technological growth. As it is impossible to be specific about these potential impacts, they were also not included in the analysis below.

2.1 Air pollution

Air pollution is an important determinant in health and has been shown to increase mortality and morbidity.[5] Key air pollutants include particulate matter, carbon monoxide, and sulphur and nitrogen oxides.[6] Many long-term health conditions, including chronic asthma and cardiovascular diseases, are associated with air pollution.[7] Air pollution is affected by many of the sectors considered during the development of the four net zero society scenarios, including work and industry, travel and transport, the built environment and food and land use. Below are the potential impacts of levers by sector.

All four scenarios would see decreases in air pollution due to decarbonising the energy system. Evidence suggests that reducing emissions from burning fossil fuels would reduce the number of premature deaths due to air pollution.[8] This would therefore lead to higher life expectancy in all four scenarios than in a scenario where net zero is not met.

The built environment

In housing, better insulation can reduce exposure to outdoor air pollutants.[9,10] However, there is some evidence that insulation can cause adverse health outcomes in poorly ventilated homes due to increased exposure to indoor pollutants, mould growth and overheating during heatwaves.[11,12] Properly implemented home insulation, alongside ventilation measures, could improve health outcomes and increase life expectancy in the UK.[13] The **slow lane**, **atomised** and **metropolitan** societies all assume home insulation increases, although the scenarios do not describe how successfully these measures are installed, so there is some uncertainty over the net health impacts.

Travel and transport

All vehicles that burn fossil fuels produce some air pollution, and pollution can also be produced through other mechanical processes within vehicles like brake and tyre wear. In this section we touch on aviation and road transport as two key examples.

Aviation causes significant air pollution and is associated with decreases in life expectancy. The **atomised** and **metropolitan** societies assume substantial increases in aviation so would be likely to experience increased air pollution and, therefore, decreased life expectancy. In the **self-preservation society** aviation demand stabilises at approximately pre-pandemic levels, so it would be unlikely to see substantial reductions in pollution from aviation unless aircraft and airport fuel efficiencies improve. The **slow lane society** experiences reduced aviation demand, which would likely decrease air pollution.

For road transport, electric vehicles produce lower levels of nitrogen oxides (NOx) emissions and particulates compared with combustion engines.[14] All four societies have almost completely phased out petrol, diesel vehicles and hybrid road transport vehicles by 2050, which would reduce air pollution. Even with zero tailpipe emissions, high levels of vehicle ownership and total distance travelled by road transport produce air pollution, as brake disc and tyre wear are significant contributors to particulate matter. These include particles less than 10 micrometres in diameter (PM_{10}) and those less than 2.5 micrometres in diameter ($PM_{2.5}$), which can be inhaled and cause adverse health effects.[15] Car ownership and distance travelled is highest in the **atomised society**, and lowest in the **slow lane** society, so these scenarios would be likely to experience the greatest impacts from this. Differences in car travel between the scenarios are due to a range of factors, including levels of income, remote working[16], and attitudes towards active travel[17] and public transport.

See Section 4.3 of the main net zero society report for quantitative analysis on the levels of NO_x and $PM_{2.5}$ emissions from road transport in each of the societies.

Work and industry

Scenario levers relevant to air pollution that vary between our scenarios are mainly demand-side levers that reduce consumption, such as sharing products, decreasing resource consumption and extending product life. Less overall demand for materials reduces industrial emissions and improves air quality, and therefore increases life expectancy.[18] This would be seen across all four societies due the assumed level of ongoing de-industrialisation in the UK, particularly in the chemicals and iron and steel industries. The positive impact on health of assumed changes in industry would be greater in the **metropolitan** and **slow lane** societies which reduce consumption more, and smaller in the **atomised** and **self-preservation** societies. The reshoring of manufacturing in the **atomised** and **self-preservation** societies could worsen air pollution, but this would depend on the combination of sub-industries which are reshored, their location, and the regulations directing them.

Food and land use

Agriculture is a primary contributor to air pollution, largely linked to livestock herd sizes and fertiliser application.[19] Reductions of demand through food waste reduction and meat and dairy substitution would, therefore, have a positive impact on air pollution in both the **slow lane** and **metropolitan** societies. The opposite would be true for the **self-preservation** and **atomised** societies which experience an increase in overall non-cultured meat consumption relative to 2020.

2.2 Physical activity

Physical activity is an important risk factor in health and is key in the primary and secondary prevention of several chronic diseases and premature death.[20] Active lifestyles are associated with significantly lower rates of certain diseases, including cardiovascular disease and certain types of cancer, in addition to improved psychological wellbeing.[20] Levels of physical activity within a society depend on a variety of factors. Out of the drivers considered in the net zero society scenarios, the two found to impact physical activity levels most significantly were home working and active transport.

Increases in home working could have a positive impact on physical activity due to time savings, which are often used for exercise.[21] All four societies see increases in homeworking so would be likely to benefit from this, but particularly the **atomised society** which features the highest levels of homeworking.

Active travel is also associated with significant health benefits due to the increased physical activity.[22,23] The **metropolitan**, **slow lane** and **self-preservation** societies see a substantial shift towards active travel, which would have a significant positive impact on health. The **atomised society** would experience a smaller positive health impact as it has a smaller increase in active travel.

2.3 Diet

Diet is an important risk factor in a variety of diseases, including certain types of cancer.[24] There are many variables which affect the quality of a diet, and its associated health impacts, including sodium intake and levels of consumption of fruit and vegetables. For example, the long-term consumption of red meat is associated with an increased risk of mortality via cardiovascular disease, colorectal cancer, and type two diabetes.[25]

There are a variety of factors which may be associated with or affect diet, including food security, income and knowledge on food and nutrition.[26,27] The health impact that changing diet may have on an individual depends on several factors, including the age at which their diet changes and how long they maintain their new diet for. It was possible to perform quantitative analysis on the impact on life expectancy of the different average diets in each scenario in 2050 because there is a wealth of validated numeric data available in this area. The method and results of this quantitative analysis is detailed below.

Method

The foods consumed in each society in 2050 were categorised by a systematic food group classification, Classification of Individual Consumption by Purpose (COICOP). There is limited literature available containing the final product categories that precisely match those included in the scenario modelling. Therefore, this analysis uses a Health Nutritional Index (HENI) score which quantifies data on the marginal health burden a food has per serving.[28] The HENI score converts specific food choices into the minutes of healthy life gained/lost compared a baseline of the average current diet of adults in the USA. For example, a hypothetical scenario where more red meat was consumed than the baseline would result in lower life expectancy than the current average, whereas one where less red meat was consumed would result in a higher life expectancy than the current average.

The HENI score gives health information for food in terms of grams consumed. Therefore, for each of the four net zero societies developed, the calorific intakes of foods were converted into the average daily weight consumed in 2050. These were set across 70 product groups to represent the average dietary choices in each scenario. The four diets were converted into 'minutes of healthy life'. This gave 'static' per capita values for the scenario diets in 2050.

Results

All four scenarios have a net positive health impact due to dietary changes relative to 2019, according to our modelling (Table 1). In both the **slow lane** and **metropolitan** societies, we assumed large substitutions of meat and dairy consumption compared to the other two scenarios. As a result, they see the biggest health improvements. Life expectancy gains are largest in **slow lane society** (36 additional minutes of healthy life expectancy per day of eating that diet). The **metropolitan society** assumes slightly less significant shifts in diet, mainly due to the higher incomes assumed. As a result, the health benefits are smaller. Between 2019 and 2050, life expectancy increases in the **atomised** and **self-preservation** are less than half that seen in the **metropolitan society** due largely to their levels of meat and dairy consumption. Of course, individual results would vary based on personal dietary composition.[29]

Table 1. Life expectancy implications of average diets in 2050 per scenario (in minutes gained per capita per day of consuming the diet)

	Atomised	Metropolitan	Self-preservation	Slow lane
Additional minutes of healthy life from dietary changes (per capita, per day of consumption)	12	25	12	36

2.4 Summary of health impacts by scenario

The impacts on health on the four scenarios are as follows:

- Positive health impacts in the **atomised society** would be the lowest of the scenarios. Compared to other scenarios, this scenario sees the highest level of demand for travel and production of manufactured goods, both of which could increase air pollution. High levels of meat consumption would also have negative health implications. Life expectancy increases from diet are joint lowest in this society.

Health

- The **metropolitan society** would experience mostly positive but some negative health implications. Impacts from changes to travel would be mixed. While some changes (such as an increase in active lifestyles and shared travel options) would decrease air pollution, high levels of aviation would worsen air pollution. Relatively low levels of meat and dairy consumption in this scenario would support bigger increases in healthy life expectancy from dietary change.
- The **self-preservation society** would experience a mix of health impacts. Air pollution from travel and industry are relatively high in this scenario, though not the highest. This scenario also sees high levels of meat consumption, which impacts both air pollution and diet. Life expectancy increases from diet are joint lowest in this society.
- The **slow lane society** would experience the most positive health impacts due to changes in diet, physical activity, and air pollution. Reduced industrial emissions and shifts in transport preferences contribute to improved air quality. Additionally, changes in diet would lead to the greatest life expectancy improvements out of all four scenarios. However, whilst general health would be good in the **slow lane society**, this analysis does not consider healthcare system indicators, or the treatment someone would be able to receive if they did become unwell.

Infrastructure

Changes in activity linked to societal changes could require new infrastructure to be constructed. Different societal changes are associated with different rates and levels of construction. Construction of new infrastructure could be costly or disruptive and require significant planning. New infrastructure could also bring a range of benefits, including improved reliability, reduced running costs, or increased job opportunities.

This section focuses on the impacts in three core areas: urban infrastructure, transport infrastructure, and energy infrastructure. The analysis considers how levers may affect demand for infrastructure, and the potential impact on cost. This analysis does not compare costs of replacing infrastructure with the costs of maintaining and repairing current infrastructure.

3.1 Urban infrastructure

Urban infrastructure comprises all elements of the built environment in towns and cities that provide necessary services. This includes residential buildings, office blocks, water and sewerage systems, and the infrastructure needed to meet digital requirements. Transport infrastructure is considered separately in the next section.

While all residential areas require infrastructure, there are particular challenges to building in a constrained urban environment, and the overall challenge could increase if the urban population and population density increases. Some scenarios have much larger urban populations than others and, therefore, the costs and challenges of meeting their needs could be greater. More dispersed populations (where there is a greater spread of people living in urban, suburban and rural settings) create different infrastructure challenges, such as ensuring connectivity across a larger area. These issues are most relevant for transport infrastructure and so are covered in the section below.

The **metropolitan society** has the highest urban population, with an increase in population density in large and medium-sized cities likely in this scenario. This means increased requirements for infrastructure associated with accommodating residents and workers in these locations (electricity distribution, digital connectivity, waste, and water). The **self-preservation** society has the second highest urban population, and would be likely to see similar challenges, albeit to a lesser extent than the **metropolitan society**.

There are also benefits to increasing population density in urban areas, such as agglomeration impacts on productivity, and a reduction in floorspace per person required, which could lower construction costs. This would likely be the case in the **metropolitan** and **self-preservation** societies.

Thermal insulation could increase building costs, providing an added challenge to urban infrastructure delivery. The **slow lane**, **metropolitan** and **atomised** societies have significant levels of home insulation so would be likely to experience the highest costs associated with this.

3.2 Transport infrastructure

Transport infrastructure is required to meet demand for travel and haulage. It has many components, including roads, railways, vehicle charging points, airports and stations. Levers that affect transport use, either through changing the demand or preferred mode of transport, could impact transport infrastructure and its associated costs. These all impact the scale and nature of the transport infrastructure a society requires. Key examples include:

- Increased aviation raises the cost of transport infrastructure by requiring new airports to be built or existing ones to be expanded.
- High rates of vehicle ownership and vehicle kilometres travelled by road typically require more roadbuilding and maintenance. Increased infrastructure for cars could also result in increased demand for them, creating a feedback loop between car use and roadbuilding.[30]

- An increase in shared travel options and higher rates of active travel both decrease demand for road infrastructure (although will require some supporting infrastructure).
- Increases in urban populations necessitate investment in public transport infrastructure (e.g. rail, tram, bus), both within and between cities.
- Higher rates of active travel require greater amounts of supporting infrastructure, such as cycle lanes and footpaths, but these are generally lower cost than other forms of transport infrastructure.

In the **atomised society**, extra transport infrastructure would be required due to increased flying, high levels of travel by car and other road vehicles, and the need to serve dispersed populations. The **metropolitan society** would require significant amounts of intra- and inter-urban public transport infrastructure to be built to serve the large and dense urban populations in this scenario. If limited land is available in dense cities, this may require tunnelling, which would increase costs. In the **slow lane society**, transport infrastructure demands would be relatively low, due to reductions in car use and increases in shared travel options, but this scenario would likely need significant active travel infrastructure to meet high demands for cycling and walking. In the **self-preservation society** the need to build new transport infrastructure would be moderate, with relatively high levels of car use, as well as some level of increase in active travel.

High levels of battery-powered electric vehicle (BEV) uptake also raise costs by increasing the demand for electric vehicle charging.[31] All societies see increased battery-powered electric vehicle (BEV) ownership and require significant provision of public charging infrastructure for these.

3.3 Energy infrastructure

Energy infrastructure refers to the infrastructure needed to produce and deliver energy to end users. This covers many components including networks of gas and oil pipelines, electricity transmission lines and power plants which could include renewable energy generation. The amount of energy infrastructure required is impacted by anything that might increase or decrease energy demand, and additionally the cost associated with specific components of the energy system.

The costs associated with energy infrastructure are a critical consideration for net zero, and as such, we included a full analysis of energy system costs by scenario in Section 4.2 of the main net zero society report. Aside from direct costs, other important considerations include the disruption associated with construction and the visual impact of infrastructure, particularly in less built-up areas. In general, the more energy a society demands, the more energy infrastructure will be required, and the greater these impacts will be.

There is a large variation in energy demand between the scenarios, with the **atomised society** seeing the highest demand, followed by the **metropolitan society** and the **self-preservation society**. The **slow lane society** has the lowest overall energy demand and would likely require the lowest level of energy infrastructure across the scenarios. Many levers influence this, including home insulation, which heating technologies are used, consumption of goods, and travel demand.

The **atomised society** would also see the need to convert large parts of the gas grid to carry hydrogen, given its relatively high use of the fuel in home heating and industry. The **metropolitan society** would also need this, albeit to a lesser extent. Other scenarios would need to plan decommissioning of this grid, or possibly reuse it for housing other infrastructure.

3.4 Summary of infrastructure impacts by scenario

The impacts on infrastructure on the four scenarios are as follows:

- The **atomised society** would likely require significant infrastructure investment, in terms of road building and energy infrastructure - particularly investment in the gas grid. But the fact that urban populations are lower than in some scenarios would mean that there might be fewer challenges in the delivery of urban infrastructure.

- The **metropolitan society** would experience the most significant challenges in terms of infrastructure. Significant amounts of urban and public transport infrastructure would need to be delivered in dense cities, most likely involving tunnelling. This scenario also sees relatively high energy demand so would require significant investment in energy infrastructure.
- The **self-preservation society** would see moderate infrastructure costs overall, with some need for road building and delivery of infrastructure to serve growing urban populations. The scenario also has relatively high energy demands and energy infrastructure needs.
- The **slow lane society** would likely see the lowest infrastructure needs, with no significant need for road building, significantly lower energy infrastructure needs, and relatively low urban populations. This scenario would need to see a significant investment in active travel infrastructure.

Regional and socioeconomic impact

The impacts of societal changes and the specific path chosen to meet net zero may be distributed differently throughout society. This section considers the impact of the net zero society scenarios on regional inequality and socioeconomic inequality. While there is potential in any scenario to increase or reduce inequalities whilst transitioning to net zero, these are largely dependent on policy design, which is not considered in this analysis.[32] As such this section discusses the likely dynamics and issues policy makers could face in different scenarios, rather than definitive assessments of how differential impacts will be experienced.

4.1 Regional impacts

The societal changes outlined in the four scenarios would be likely to have differential impacts, especially between urban and rural areas. There are a broad range of potential regional impacts that policy makers would wish to consider in planning for the future.

Regions with a high concentration of carbon-intensive industries, or regions where an industry is one of the main employers, may be disproportionately exposed to the impacts of a net zero transition.[33] However, this may be negated through re-training schemes and the redeployment of jobs towards net zero industries, particularly if these are located in areas that lose carbon-intensive industries. Additionally, reshoring may bring new jobs to different parts of the UK.[34]

Vehicle manufacturing is one industry with potential to provide jobs across the regions of the UK in any of the scenarios, as large numbers of electric vehicles need to be manufactured in all scenarios. The potential is likely to be strongest in scenarios with high levels of vehicle ownership and the highest levels of re-shoring of manufacturing to the UK (although this may be minimised if such manufacturing uses high levels of automation). The scenario with the highest potential for this is the **atomised society** but the **self-preservation society** also has some potential.

An increase in domestic travel within the UK, as opposed to overseas, has the potential to benefit areas with a strong tourism economy across the regions of the UK. The **slow lane society** is the scenario where this trend is most significant.

Energy system changes also have regional impacts, including jobs and investment in places where new energy infrastructure is located. This is particularly true for places involving clusters of industrial sites, hydrogen production, and Carbon Capture and Storage (CCS). These technologies are present in all scenarios but are most significant in the **atomised** and **metropolitan** societies.

4.2 Socioeconomic impacts

There are a range of potential socioeconomic impacts associated with net zero. Here we focus on the different energy and technology costs that households might face.

The level of energy efficiency investment in the home has the potential to affect inequality. Lower income households spend a higher proportion of their income on heating and powering their homes compared with higher income households.[35] Low-income groups would benefit the most from the widespread rollout of energy-efficiency measures and technologies, such as insulation and heat pumps. However, the affordability of these technologies could affect their impact on inequality. The **metropolitan**, **slow lane** and **self-preservation** societies assume increased insulation and energy efficiency in homes, so could experience changes in equality as a result.

There are further potential impacts that different pathways to net zero could have on inequality. For example, high car ownership could lock consumers into expensive patterns of mobility, particularly affecting low-income households. The switch away from cars is most limited in the **atomised** and **self-preservation** societies. Conversely, high levels of active travel and shared travel options could benefit lower-income consumers most. These feature most strongly in the **slow lane** and **metropolitan** societies.

4.3 Summary of differential impacts by scenario

The impacts on equity in the four scenarios are as follows:

- The **atomised society** could experience growth in jobs across the regions resulting from high levels of reshoring, vehicle manufacturing and industrial clusters, although this could be reduced by automation. Conversely, this scenario could see lower levels of technologies and services that would benefit lower income households, like insulation and shared mobility.
- The **metropolitan society** is characterised by an urban/rural divide, so regional differences are baked into this scenario. Less obvious regional impacts include the creation of net zero industrial clusters due to the relatively high levels of energy use, CCS and hydrogen. Lower income households would benefit somewhat from lower cost transport and energy efficiency solutions in this scenario.
- The **self-preservation society** experiences some regional benefits from moderate reshoring of manufacturing. There could also be decreased inequality due to the somewhat increased energy efficiency of homes.
- The **slow lane society** could experience decreased inequality due to more people living in energy efficient homes and more diverse transport options being available. This scenario could also see a renaissance in the tourism sector in certain parts of the UK as more people choose to holiday domestically.

Environment and energy security

This section considers the impacts of the net zero society scenarios on two key areas likely to be affected in the transition to net zero: the environment and energy security.

5.1 Environmental impacts

This section considers environmental impacts not related to carbon dioxide emissions or air pollution (which was considered in the Section 2.1 of this annex). These impacts include eutrophication, water pollution and biodiversity. Such impacts can be managed to an extent, but this usually has a cost that would need to be considered in choosing between different approaches to meeting net zero.

Changes to the energy system could have a range of environmental impacts. The expansion of renewable energy is likely to lead to many positive environmental impacts at the national or global scale but could have negative environmental consequences at the local scale.[36] For example, biofuels from crops could have negative impacts on biodiversity, water quality and landscape, while some forms of renewable energy (such as hydropower) could negatively impact the local ecosystem through changes to habitats.[37,38]

Another impact is eutrophication, where a large body of water experiences significant increases in nutrients and minerals, leading to excessive plant and algae growth. Animal agriculture has been shown to have a large impact on water eutrophication.[39] The **atomised** and **self-preservation** societies have higher levels of meat consumption and could experience higher levels eutrophication associated with this lever. Burning fossil fuels can also cause eutrophication[40], but as all four societies reduce the burning of fossil fuels, they would all be expected to experience reduced eutrophication associated with this.

The manufacture and use of other net zero fuels and technologies (e.g. for heating and transport) will also have different environmental impacts. The environmental impact of such processes is determined by the intrinsic nature of the process itself, and how well it is managed in practice. For example, manufacturing processes generally rely on resource extraction, which has the potential to cause environmental damage if not properly managed. Proper management of these processes has the potential to minimise such environmental impacts, but the associated costs and any residual impacts that are hard to manage will need to be considered when comparing technologies. Here we focus on heating technologies, but such issues will need to be considered for other net zero technologies, including zero emission vehicles.

As an example, use of hydrogen boilers requires hydrogen gas to be extracted. Electrolysis is one method of hydrogen extraction which requires high amounts of electricity. Electrolysis can produce toxic byproducts that need to be managed, and requires high levels of land use, as compared with other heating technologies and methods of hydrogen extraction.[41] Steam methane reforming is another method of hydrogen extraction which has a risk of climate impacts from methane leaks, but has lower levels of toxic byproduct and land use than electrolysis.[41] Hydrogen boilers feature significantly in the **atomised society**, and to a lesser extent in the **metropolitan society**, so these societies could experience such negative impacts to varying extents, depending on the method of hydrogen extraction used and how well managed the potential impacts are.

Heat pumps are another heating technology used in the scenarios. As with hydrogen production, the extraction of copper to manufacture heat pumps (and other technologies) could cause release of toxic byproducts into the environment if not properly managed.[41] However, across the majority of categories of environmental impact, heat pumps are found to have lower negative effects than production of hydrogen by electrolysis.[41] The **slow lane** and **metropolitan** societies assume high levels of electric heat pumps in 2050 so could experience such environmental impacts from manufacture and use of the technology. Other forms of heating, such as district heating which is featured in the **slow lane** and **metropolitan** societies, are not considered in this analysis of impacts.

5.2 Energy security

Energy security is defined as the uninterrupted availability of enough energy to sustain people's daily lives, at an affordable price.[42] The relationship between decarbonisation and energy security is not straightforward. It is largely dependent on flexibility, sources of imports and supply chain risk, as well as public attitudes to electricity sources.[43]

Increased renewable energy can impact energy security, depending on how it is implemented. Generally, renewables increase the share of domestic energy supply and reduce energy import dependency. Additionally, having a diverse range of renewable sources that is interspersed throughout areas of the UK could increase the flexibility of the energy system and resilience against faults with the centralised system, improving energy security. However, many sources of renewables, such as wind turbines, solar photovoltaics and bioenergy, depend on weather cycles with varying timescales.[44] There are further considerations for energy security and renewables, such as reliance on certain materials (including lithium, cobalt, and rare earth elements).[45] For example, rare earth elements neodymium, praseodymium and dysprosium are crucial for the operation of wind turbines.[46]

Less reliance on fossil fuels such as natural gas (as found in all four scenarios) would reduce import dependency and mean consumers are less vulnerable to price spikes based on international markets. Oil markets are also vulnerable to many risk factors including major technical failures, geo-political tensions and natural disasters.[47] In future, hydrogen supply could also suffer from energy security issues similar to fossil fuels if reliant on methane imports for steam methane reforming.[48]

Overall, it is difficult to assess the net impact on energy security associated with the different technology mixes in each scenario. But more generally, energy efficiency has been found to improve energy security across all forms of generation by reducing the need for both imports and domestic supply. It is therefore likely that scenarios that use lower levels of energy overall - the **slow lane society** and to a lesser extent the **self-preservation society** - will have higher levels of energy security.[49]

5.3 Summary of environmental and energy security impacts by scenario

The impacts on environment and energy security in the four scenarios are as follows:

- All societies would experience positive impacts associated with burning fewer fossil fuels. These include reduced eutrophication and reduced import dependency, which would contribute to energy security.
- The **atomised society** would experience some positive environmental and energy security impacts through reduced burning of fossil fuels. However, its high levels of meat consumption could increase eutrophication. It also has the highest levels of energy use, which mean energy security concerns could be higher in this scenario.
- In the **metropolitan society**, the impacts on energy security and the environment would be more positive. In particular, lower meat consumption in this scenario would have wider environmental benefits. But this scenario has relatively high levels of energy use, which will worsen both environmental and energy security impacts.
- The **self-preservation society** would experience mixed impacts on energy and the environment. It would have increased energy security through reduced energy use and reliance on imports. However, it would experience increased eutrophication from high levels of meat consumption.
- The **slow lane society** would experience mainly positive impacts on energy security and the environment from its reduced energy demand and its energy mix.

However, this scenario still requires the manufacture of many new net zero technologies, the environmental impacts of which will need to be managed.

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