Development & provision of UK socioeconomic scenarios for climate vulnerability, impact, adaptation & services research & policy

A report by the UK-SSP consortium for the Met Office

UK-SSPs

Activity 1: Evidence review

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UK-SSP consortium

Contact:
jd@camecon.com

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1.0	20/03/20	Jon Stenning	Draft evidence review, for client comment
2.0	21/04/20	Jon Stenning	Final version of evidence review, with client comments addressed and the addition of an executive summary

The UK-SSP Consortium is led by Cambridge Econometrics, and includes the Centre for Ecology & Hydrology, the University of Edinburgh and the University of Exeter.

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Executive Summary

Wider context of the project

At the international level, several global socioeconomic scenario exercises have emerged from the climate change and biodiversity/ecosystem service communities, including the IPCC SRES scenarios and the IPCC RCP-SSP framework. Many of these global scale scenarios have been interpreted and downscaled to regions, including Europe and the UK. However, these tend not to be comprehensive in treating the full range of possible socioeconomic change drivers or are not easy to map to international scenarios.

While the UK Climate Projections 2018 produced by the Met Office provide a set of downscaled climate projections for the UK, no regionally enriched versions of the global SSPs are publicly available for the UK to combine with these RCP-based climate projections. The wider context of the 'Development & provision of UK socioeconomic scenarios' project is to fill this gap by developing a set of internally consistent future socioeconomic scenarios for the UK, as the basis for further climate resilience research, including research and analysis for the fourth Climate Change Risk Assessment.

The purpose of Activity 1

The purpose of Activity 1 was to first understand the key questions relating to the climate resilience of the UK that need to be addressed by the research community, and which the dataset developed in the project will be used to assess. Understanding these questions is an important first step in establishing precisely which variables should be included within the socioeconomic scenarios. Once these key questions were fully understood, Activity 1 established precisely which variables should be included in the consistent set of socioeconomic scenarios to be constructed within the rest of the project, plus how these variables link together.

Evidence was collected via a literature review and stakeholder engagement with a User Panel, which consisted of members of the climate resilience research community, representing expertise across a wide variety of disciplines. The User Panel were invited to share their views at a half-day workshop which took place in February 2020. This report details the evidence collected through the literature review and the feedback received at the workshop.

Key climate resilience questions

The User Panel workshop, and a review of climate resilience literature, has enabled us to develop a clear understanding of the key questions relating to the climate resilience of the UK that are currently being assessed by the research community. The suggestions and inputs gathered at the User Panel workshop echo the general climate resilience risks and research topics found within the literature. Understanding these research topics was an important first step in establishing precisely which variables should be included within the socioeconomic scenarios developed within this project. Table 2.1 summarises the main research questions relating to climate change resilience of the UK that were identified in this Chapter.

Table 0.1 Key climate resilience questions

Topic area	Main research questions relating to climate change resilience of the UK that currently need addressing

Adaptive capacity & ability to respond	• Understanding the extent of adaptive capacity in the UK.
	• The social, biophysical and economic limitations and barriers to adaption.
	• The links between behaviours/ behavioural responses and adaptive capacity.
	• The ability of systems, institutions and society to act, including;
	  ◦ the speed at which they can react
	  ◦ the effectiveness of any reactions
	  ◦ interconnections between the capacity of each to adapt
	  ◦ factors which could improve adaptive capacity and resilience
	• The role of central and local government and decision-makers, and the policy response required, to improve adaptive capacity.

Infrastructure (including transport)	• Many of the individual elements of existing UK infrastructure are not currently sufficiently prepared for extreme weather events or for long-term changes in average climate, more research and policy action is needed to manage some risks to infrastructure. • There is need to understand further the interdependencies between the various elements of infrastructure, the links between infrastructure and society, and the links between infrastructure and demographic change.
Land use	• Further research to assess the feasibility of land use change, the potential for changes in land use to reduce emissions, and the subsequent impacts of land use change. • Consideration of the economic, environmental and spatial trade-offs that will exist if the way an area of land is used is changed. • Research around methods which increase the carbon sequestration potential of the land (natural climate solutions). • Research on low-carbon farming practices aimed at reducing the environmental impact of the activity being carried out on the land. • Research into the behavioural changes related to the food we eat are also required, in order to reduce food waste and consumption of the most carbon-intensive foods.

	• Research questions about land use planning and what proportions of land will be available or used for buildings and infrastructure, agriculture, forestry, bioenergy and water resources in future.
Health	• The impact of climate change on human health (in particular, the risks to health and wellbeing from high temperatures, potential benefits to health and wellbeing from reduced cold, risks to health and social care delivery from extreme weather and risks to health from vector-borne pathogens. • The links between, and implications of, the health impacts of climate change and vulnerable groups in society.
Demographics and society	• How climate change will affect the movement of people within the UK, how development plans for infrastructure and resources is influenced by changes in population and the links between population, housing, technology and behaviours. • How demographic change affects infrastructure requirements, land use, availability of natural resources, energy requirements and the provision of public services such as health services. • Greater understanding of the risks to certain communities given their geography or livelihood, the spatial distribution of climate change risks and impacts, who in society is particularly vulnerable to the risks of climate change. • Greater understanding about the behavioural responses of households and businesses to climate change adaptation and mitigation policy (such as better understanding of diets and personal preferences).
Energy	• The assessment of new and existing energy infrastructure in terms of its resilience to current and future climate risks and interactions with other aspects of climate change resilience is a major climate resilience concern.

Socioeconomic scenario variables

A key step in designing credible socioeconomic scenarios is to identify relevant drivers that help describe the global socioeconomic. To frame the later quantification of such frameworks, it is also necessary to identify variables used to measure performance across themes and drivers. For this purpose, desk-based research was carried out to review available materials and investigate the key trends analysed in previous scenario analysis.

In addition to drawing on existing literature, the User Panel provided input to inform the understanding of how socioeconomic scenarios can respond to the diverse needs of research and policy.

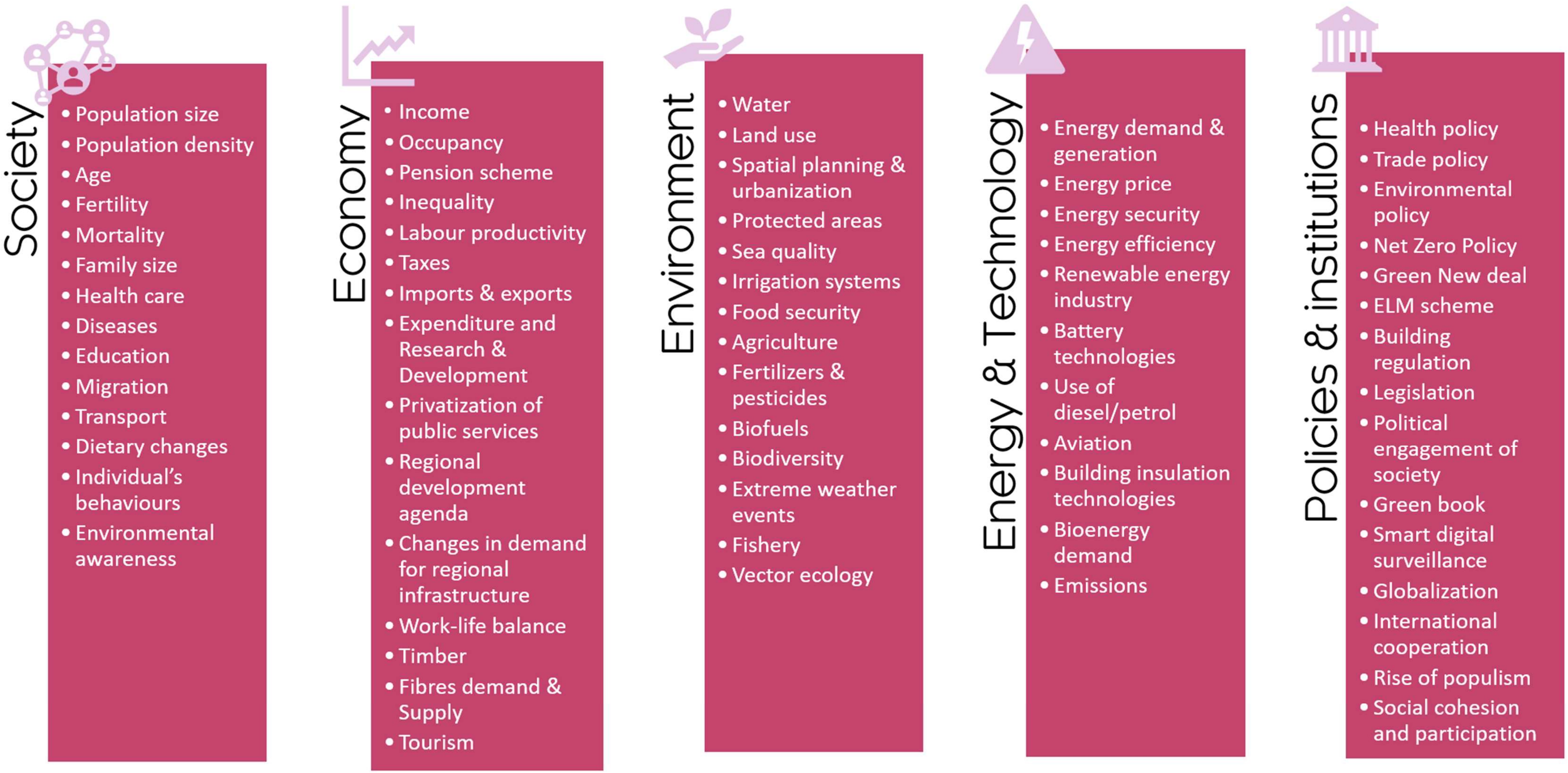
The outcome of this part of Activity 1 was twofold. First, a comprehensive longlist of variables, both quantitative and qualitative, was defined. Second, for each variable we considered the appropriate level of spatial resolution.

Key socioeconomic variables

Studies that have developed SSPs, either globally or nationally, focus on trends in society, economy, energy and technology, environment, policies and institutions. These themes or pillars can be defined as the over-arching drivers of change, as they are expected to influence future socioeconomic outcomes. Key variables exist within each of the pillars, and this part of Activity 1 aimed to compile a longlist of these variables, from which a shortlist could later be selected by the User Panel and Advisory Group.

A comprehensive longlist of variables is presented in Figure 0.1 below. This longlist was created by assembling the collected evidence from the literature and the insights provided during the stakeholders User Panel workshop.

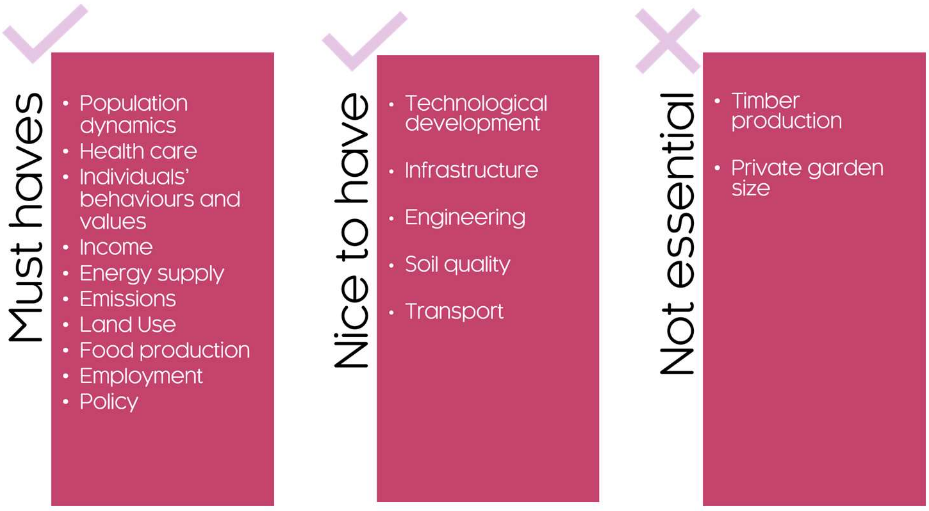
Figure 0.1 Longlist of variables



The variables in Figure 0.1 above were then grouped by the User Panel according to their relevance to the socioeconomic scenarios to be developed by the project. Figure 0.2 provides a representation of the suggested variables. The grouping of variables can be defined as follow:

- *Must have:* variables that were requested more than two of the user panel and that were considered as essential in previous SSP studies.
- *Nice to have*: variables that were requested by two or fewer of the User Panel and that were regarded as useful in previous SSP studies.
- *Not essential*: variables of little interest to the User Panel and therefore outside the scope of this project

Figure 0.2 Shortlisted variables



The main outcome of this task is a list of prioritised variables related to climate resilience. For the purpose of the analysis, the variables were clustered into five main themes: society, economy, energy and technology, environment, policies and institutions.

Figure 0.3 Additional lessons learnt

Some additional lessons were learned from this part of the analysis, summarised as follows:

- Both the review of the more recent literature and the user panel suggestions conclude that attention should be paid to patterns in health care and social care. These topics have previously been rarely explored in scenario building.
- Changes in societal behaviours and values, focussed on reducing consumption and waste (e.g. diets, energy, water) and their follow-on effects on supply chains has been scarcely explored in previous studies. However, these topics are gaining increasing interest from the research community, as individuals' environmental awareness is rapidly growing, leading to changes to consumer demand.
- Within the climate resilience community there is consensus on the necessity of increasing spatial and other resolutions. Regional and sectoral analysis provides useful additional insight into scenarios beyond the national-level outcomes.

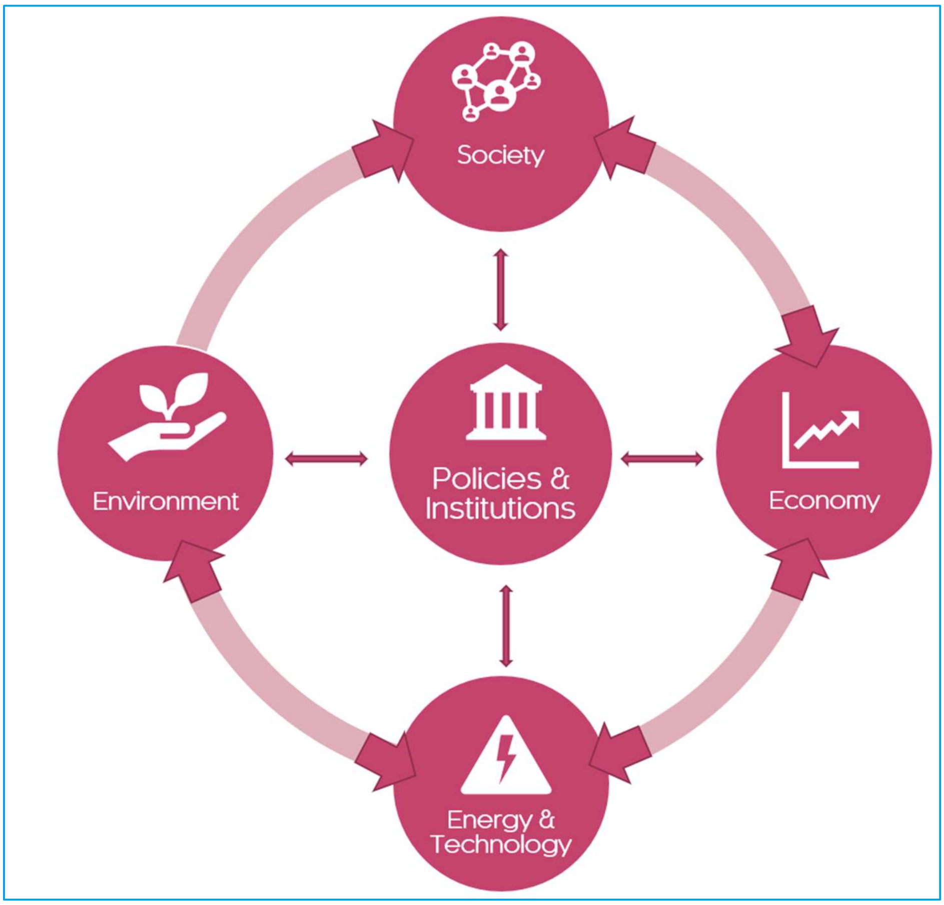
Socioeconomic systems

A further step in the design of scenarios is understanding interrelations between key topics and variables. This topic is not widely covered in the literature. with the primary source of input was therefore the User Panel. Panel members were asked to discuss the main linkages between the key variables they had identified and prioritised. In this part of the analysis we defined the socioeconomic system and described how it functions. This was an important step to explore how key variables are connected and how consistent scenarios should account for these linkages.

How socioeconomic systems function

Scenario exercises attempt to describe highly integrated systems, where marginal changes in one component can substantially affect the others. Demographic trends and population dynamics have effects on the economic activity undertaken by individuals, firms and other agents in society. The effects are transmitted through the environment, the energy sector, the use of land and persist over time. These interdependencies suggest that socioeconomic scenarios should account for an extensive set of linkages, in order to obtain consistent projections. Figure 0.4 provides a representation of the socioeconomic system that enables us to capture linkages between the main themes.

Figure 0.4 Socioeconomic system



The primary interaction between society and economy is through the changing dynamics in population, and the demands of that population. Meanwhile, economic activity determines to some extent the level of education in, and health of, society. Economic activity also determines demand for energy, subject to changes in technological development. The resulting developments in the energy sector are reflected in the economy through the price of energy. Furthermore, the generation of energy from fossil fuels contribute to GHG emissions, therefore impacting the environment and biodiversity. At the same time, the transition to renewables sources of energy relies closely on the environment and on the stability of climate. The degradation of the environment causes discontent in the society, that attributes substantial value to this (e.g. for cultural heritage and recreational reasons). Finally, increased frequency of extreme climate events alters the environment and can make locales less suitable for habitation, hence affecting dynamics in population density.

The framework described in this part of the analysis represents a highly integrated system, where factors are closely connected to each other. Variations in one of the components are conveyed to the others in a trickledown effect. The result is a combination of changes in each component and of the persistence of the effect over time.

Key conclusions

This report provides evidence on the socioeconomic variables required within the UK-SSPs to be developed within the *Development & provision of UK socioeconomic scenarios for climate vulnerability, impact, adaptation &*

services research & policy project, and illustrates the possible interrelations among them. In order to develop the relevant evidence base on constructing UK socioeconomic scenarios, we brought together evidence from an extensive body of literature, as well as the insights provided by a User Panel which represented the climate resilience research community.

A mixture of qualitative and quantitative variables has been established

The evidence presented in this report covers both qualitative and quantitative socioeconomic variables. Qualitative variables are useful when developing scenario narratives as they illustrate aspects that cannot be explained by quantitative exercises. On the other hand, quantitative variables provide more precise projections of future outcomes.

Constructing a longlist of variables

Based on the literature review and inputs obtained at the User Panel workshop, we constructed a comprehensive longlist of variables relevant for climate resilience assessments, which could be categorised into five broad pillars – society, economy, environment, energy and technology, and policies and institutions. With the support of the stakeholders from the climate research community, we then identified a list of prioritised socioeconomic variables, which we are proposing be taken forward and used to develop UK specific socioeconomic scenarios.

The short-listed variables presented here are the result of the prioritization exercise carried out in the User Panel workshop.

Inter-dependencies between variables

As a final step, we explored the interdependencies between the five pillars into which identified socioeconomic variables fall. The resulting socioeconomic framework is an extremely integrated system, where changes in one component affects the others through a number of direct and indirect linkages.

Report outcomes

This report presented the relevant evidence collected about key socioeconomic variables and the related interconnections between drivers. In the project Activities that follow, this framework will be evaluated and further developed to meet the needs of the qualitative narratives and quantitative scenarios to be developed, specifically informing UK SSP narratives developed in Activity 2, and the quantification framework based on causal loop diagrams developed in Activity 3.

1 Introduction

1.1 Background

Previous socioeconomic scenarios work

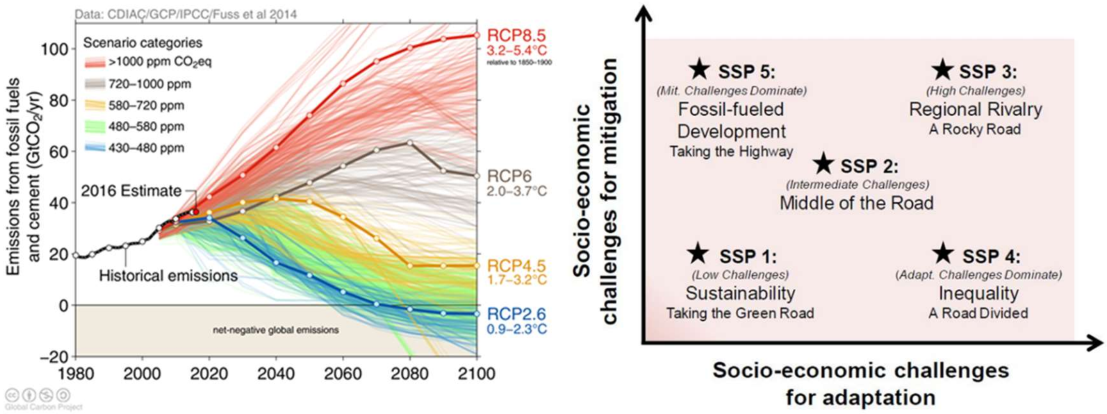
At the international level, several scenario exercises have emerged from the climate change and biodiversity/ecosystem service communities. These include the IPCC SRES scenarios (Nakićenović 2000), the IPCC community RCP-SSP framework (van Vuuren 2011) (B. C.-B. O'Neill 2017) and the Millennium Ecosystem Assessment (MA 2005). Many of these global scale scenarios have been interpreted and downscaled to regions, including Europe ((Rounsevell 2006) (Lebel 2006) (Kok K 2019)), and to a lesser extent the UK (UKCIP 2001) and (Kok 2016). At the UK national level, previous scenario studies have come out of the Foresight Programme (FLUF 2010), the UK National Ecosystem Assessment (UK NEA 2011), Natural England (Creedy 2009), UKCIP ((UKCIP 2001), (Hulme 2002)) and the Environment Agency's Scenarios 2030 (Environment Agency 2009). Because these national scenarios were derived for specific purposes by specific research and/or stakeholder communities, they tend not to be comprehensive in treating the full range of possible socio-economic change drivers or not easy to map onto international scenario exercises. Other international studies (IPBES 2018) utilised the concept of scenario archetypes to address this challenge by classifying existing scenario studies into four to seven categories based on their underlying assumptions, characteristics and narratives (Harrison et al. 2018), to make comparison between studies easier. This has informed the approach taken in this evidence review.

To inform the upcoming third Climate Change Risk Assessment (CCRA3), the Committee on Climate Change (CCC) is in the process of producing an Evidence Report, which is due to be finalised by the summer 2021. Five research projects, commissioned by the CCC, will feed into the Evidence Report and address evidence gaps that existed in the CCRA2. A key gap identified in previous CCRAs was the lack of consistency regarding the socioeconomic dimensions used throughout the assessment. For the CCRA3, it was decided that a consistent set of dimensions should be used, to improve the analysis. For the Evidence Report, the CCC therefore commissioned a sixth research project, to develop a consistent set of socioeconomic projections to be used across all the research projects, as well as other chapters and analysis of the CCRA3, to ensure that the analysis presented throughout the CCRA3 is also consistent (Cambridge Econometrics 2018). The project was carried out by Cambridge Econometrics, and involved a series of scoping, shortlisting and data collection and manipulation tasks, to produce a consistent set of social and economic data projections as required by the five Evidence Report research projects, such as projections of population, GDP, employment and land use. All projections were based upon existing socioeconomic projections, but in many cases these were downscaled to more detailed spatial and sectoral detail than was originally available. A recognised limitation of the project was that the scenario narratives developed were limited, and linkages between variables was not defined in detail. The project focused on building a consistent socioeconomic dataset, and while narratives for high, low and central scenarios for each indicator were provided, detailed interrelationships between different socioeconomic indicators was not described in the scenario narratives. The current 'Development & provision of UK socioeconomic scenarios' project will build upon the work of the CCC research project to produce narratives for all five SSPs for the UK and its countries that have been regionally, sectorally and temporally extended from the global SSPs.

The IPCC RCP-SSP framework

The most recent and commonly used scenario framework in climate change studies is the IPCC community RCP-SSP framework of Representative Concentration Pathways (RCPs) and the Shared Socio-economic Pathways (SSPs) (see Figure 1.1). Like previous scenarios, the SSPs and RCPs contain internally consistent quantifications of key indirect drivers of climate change developed from narratives describing alternative futures of socioeconomic development. The RCPs prescribe levels of radiative forcing (Wm-2) arising from different atmospheric concentrations of greenhouse gases that lead to different levels of climate change. For example, RCP2.6 (2.6 Wm-2) is projected to lead to global mean temperature changes of ca. 0.9-2.3°C, and RCP8.5 (8.5 Wm-2) to global mean temperature changes of ca. 3.2-5.4°C (van Ruijven 2014).

Figure 1.1 The IPCC community RCP-SSP scenario framework: RCPs (left hand side); and SSPs (right hand side)

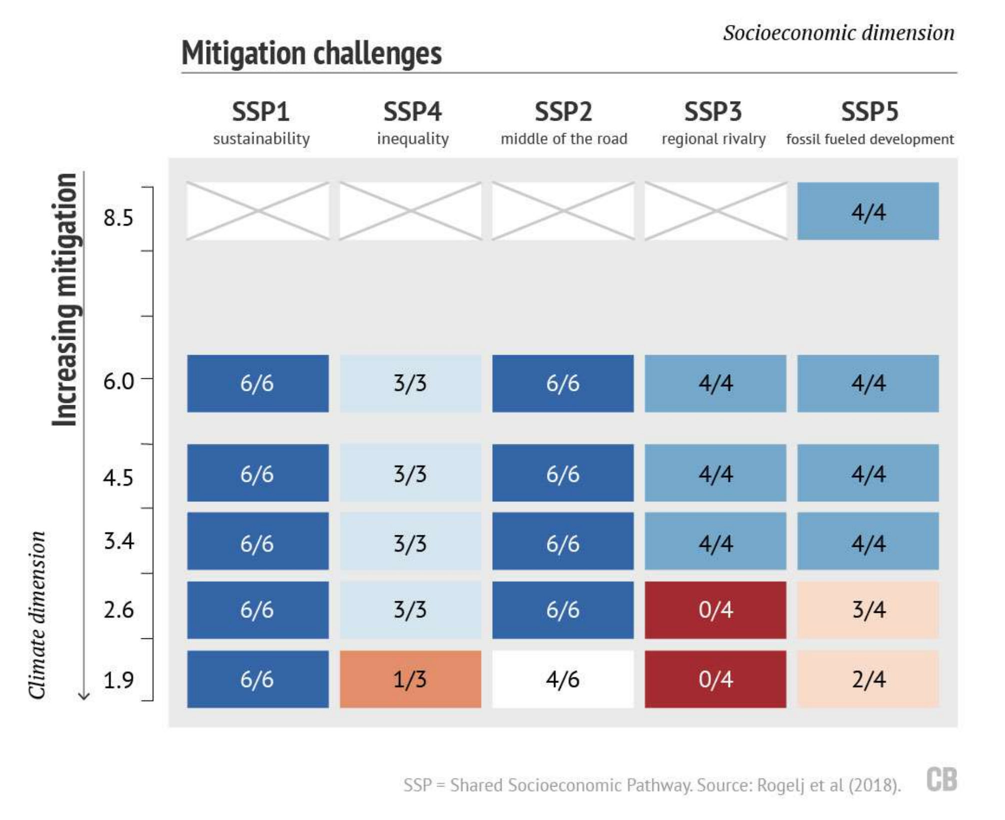


The SSPs describe alternative trajectories of future socioeconomic development with a focus on challenges to climate mitigation and challenges to climate adaptation (B. C.-B. O'Neill 2017). SSP1 represents a sustainable and co-operative society with a low carbon economy and high capacity to adapt to climate change. SSP3 has social inequality that entrenches reliance on fossil fuels and limits adaptive capacity. SSP4 has large differences in income within and across world regions that facilitates low carbon economies in places but limits adaptive capacity everywhere. SSP5 is a technologically advanced world with a strong economy that is heavily dependent on fossil fuels, but with high adaptive capacity. SSP2 is an intermediate case between SSP1 and SSP3 (B. C.-B. O'Neill 2017). The SSPs and RCPs were developed in a parallel process and are designed to be scalable (van Ruijven 2014). This means that different socioeconomic assumptions captured in the SSPs can be associated with different emission pathways (RCPs) (K. S. Ebi 2014).

There are however limitations to the scalability of the SSPs and RCPs. Model runs that combine SSP and RCP pathways do not always successfully reach the RCP target for a given SSP. Figure 1.2 below summarises the outcome of an exercise that used integrated assessment models to combine the five

SSPs with six RCPs. Each box describes how many of the models used were able to find a solution where an RCP is achieved within a particular SSP. In some cases, an RCP pathway cannot be achieved within a particular SSP, for example RCP1.9 and RCP2.6 cannot be achieved in SSP3, while only SSP5 could generate a solution that reached RCP8.5 levels of radiative forcing, because emissions were too low in other SSP pathways.

Figure 1.2 Modelling combination of SSPs and RCPs



Source: (Carbon Brief 2018), adapted from (Rogelj 2018).

Despite some limitations, the scalability of the SSPs enables the development of national and multiscale versions of the global SSPs that are both internally consistent and compatible across the IPCC research community, facilitating the synthesis of research on climate impacts and risks in the IPCC Sixth Assessment Report.

There is a lack of downscaled SSPs for the UK

A set of downscaled climate projections for the UK has recently been released based on the RCPs, the UK Climate Projections 2018 (Met Office, 2019), which includes future climate projections for the globe at 60km scale and for the UK at 12 km scale. The 12km climate model has been further downscaled to 2.2km scale local UK climate projections at 2.2km scale (UKCP Local). However, no regionally enriched versions of the global SSPs are publicly available for the UK to combine with the new RCP-based climate projections. This severely restricts analysis of the impacts and risks associated with multiple drivers relevant to climate change, as well as assessment of the effectiveness or robustness of climate change policy for both adaptation and mitigation. To address this major gap, the CEH National Capability project UK-SCAPE has been developing downscaled versions of the SSPs for the UK as a whole (https://www.ceh.ac.uk/uk-scape/speed-spatially-explicit-projections-environmental-drivers-and-impacts). These UK-SSPs were co-produced with a wide range of stakeholders through a facilitated two-day stakeholder workshop in October 2018, followed by analysis by the research team and cross-checking of this analysis using two questionnaires. The participatory process engaged with stakeholders involved in research, policy, NGOs and the private sector, and with a diversity of sectoral/disciplinary expertise. The process involved the identification of driving forces of change and their uncertainties specific to the UK context and mapping them to the global and European SSPs (the latter from the EU-funded IMPRESSIONS project, (Kok K 2019)). Workshop participants then elaborated a narrative of each UK-SSP and agreed semi-quantitative trends over the 21st century in nine specific socio-economic variables. Based on discussions at the workshop and other data sources, the research team then further elaborated the narratives and developed tables of trends for a wider list of socio-economic variables. Work is continuing to quantify a few of these variables at the national scale. The scenario work package of the UK-SCAPE project focuses on developing spatially explicit drivers of climate, land use and pollution, and analysing their impacts on functional biodiversity. Hence, within UK-SCAPE the UK-SSPs are only being developed at a national scale and have a focus on those socio-economic variables of most relevance to modelling land use, heavy metals pollution and biodiversity. Nevertheless, they form an important foundation upon which this project, and others in the research community, can build. This new project will extend beyond the focus of the UK-SSPs produced by the UK-SCAPE project, by producing socioeconomic scenarios that can be used across a broader variety of disciplines related to climate change resilience, by extending the scenarios regionally, temporally and sectorally, and by quantifying projections for the key socioeconomic indicators.

The purpose of this project

There are key questions relating to the climate resilience of the UK that need future research, which require robust exposure and vulnerability data to be able to properly address. The wider context of the ‘Development & provision of UK socioeconomic scenarios’ project is to produce internally consistent future socioeconomic scenarios for the UK, as the basis for further climate resilience research.

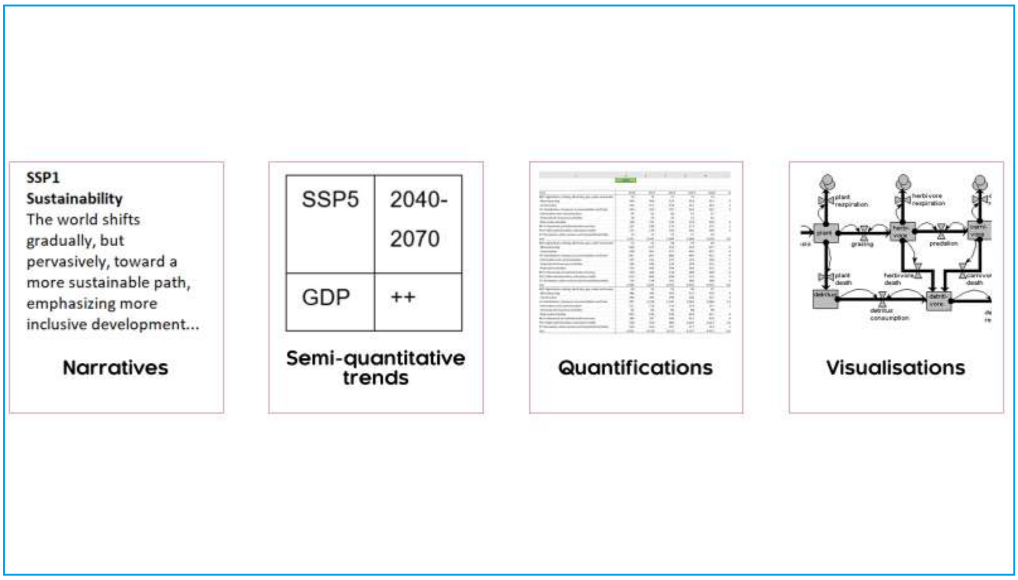
The overall approach to the project involves downscaling and extending the SSPs for the UK, to support more detailed analyses of climate risk and resilience. The research will build upon existing work that has been led by the project team on extending the global SSPs (including the EU-funded

IMPRESSIONS project led by the UK Centre for Ecology & Hydrology, developing a set of socioeconomic projections for the UK led by Cambridge Econometrics and the UK-SCAPE project led by UKCEH.

When downscaling SSPs to the national and subnational level, the limits on related RCP outcomes are much less strong, since the RCPs are a function of *global*, rather than local, emissions, as well as other factors (tipping points, radiative forcing levels). In other words, the challenge of aligning SSPs and RCPs is reduced at the national (and below) level, since the realisation of a specific RCP is much more influenced by actions/emissions in other countries than in the UK. However, a key output of this work will be an assessment of the level of greenhouse gas emissions associated with each SSP; in this way, it will be possible to assess how closely each SSP aligns with stated UK policy (e.g. delivering a net zero economy by 2050).

The final project outputs will consist of a set of narratives, semi-quantitative trends, quantifications for specific variables and visualisations of the interrelationships between those variables for a nested set of UK and country-specific SSPs that are consistent with the global/European context (depicted as examples in Figure 1.3 Final project outputsFigure 1.3 below.

Figure 1.3 Final project outputs



This will allow UK-specific research by the climate resilience community that is consistent with the IPCC process, including research and analysis for the fourth Climate Change Risk Assessment.

Specific aims of the project

The project has various overall objectives:

- to identify key socioeconomic variables needed to address climate resilience issues
- to downscale the existing global and European SSPs for the UK by extending them spatially, temporally and sectorally
- to develop a modelling framework that captures the interrelationships between different socioeconomic variables in the scenario narratives
- to create internally consistent quantitative projections for the key socioeconomic variables

- to publicise the new scenarios to the UK climate resilience community

1.2 Overview of Activity 1: Scoping of variables and linkages between them

The purpose of Activity 1

The purpose of Activity 1 was to first understand the key questions relating to the climate resilience of the UK that need to be addressed by the climate resilience research community, and which the dataset developed in the project will be used to assess. Understanding these questions is an important first step in establishing precisely which variables should be included within the socioeconomic scenarios. Once these key questions were fully understood, Activity 1 established precisely which variables should be included in the consistent set of socioeconomic scenarios to be constructed within the rest of the project, plus how these variables link together.

Approach

A two-stage approach was used to carry out Activity 1, beginning with a literature review, followed by stakeholder engagement.

Literature review

The purpose of the extensive literature review was to build a detailed picture about the key climate resilience questions to be addressed, and what variables, linkages between variables and scenario narratives are required to facilitate future research.

User Panel

The literature review was followed by stakeholder engagement, where a User Panel, comprised of potential users of the scenarios, provided feedback and suggestions (mainly via a face-to-face workshop) on the list of priority variables to include in the qualitative and quantitative components of the scenarios. Table 1.1 details the organisation each member of the User Panel represents and the specific expertise of each member of the Panel.

Table 1.1 User Panel members

Organisation	Expertise (theme/ discipline)
Natural England	Natural resources
Paul Sayers Associates	Flooding
HR Wallingford	Water availability
Forestry Commission	Forestry
Defra	Agriculture
James Hutton Institute	Land Use
Public Health England	Health
University of Manchester	People & built environment Energy
John Dora Consulting	Infrastructure
Watkiss Associates	Economics
University of Cranfield	Cross-sectional impacts
London School Hygiene & Tropical Medicine	Health

Environment Agency	Climate Change and Resource Efficiency
University of Bristol	Flooding

Together, the User Panel demonstrated expertise across a diverse range of disciplines/ themes, as detailed in the table above. When constructing the User Panel, the aim was to include at least one panel member with expertise of a particular theme/ discipline, whilst also being mindful to keep the group to an optimal size, within which constructive discussion could take place. For most of the themes/ disciplines that the project team and client deemed important in relation to the scenarios to be constructed in the project, there was at least one Panel member, who actively participated in Activity 1 of the project. However, it should be noted that (at the time of writing), the User Panel does not include any members with particular expertise in biodiversity, soil, businesses and equality or justice. However, various contacts have been approached, some of which indicated willingness to participate in the project in future, but were unable to provide input to Activity 1 due to time limitations.

Advisory Panel

An Advisory Panel was also established during Activity 1, comprising of individuals linked to the Strategic Priorities Fund (SPF) UK Climate Resilience Programme (UKCR) and to the UK Climate Change Risk Assessment process. The role of the separate Advisory Panel was to support the project team in ensuring the outputs of the project (including the outputs of Activity 1) are directly usable within the UKCR programme in general and meet the requirements of future CCRAs (for example CCRA4).

1.3 Report structure

The rest of this report is structured as follows:

- Chapter 2 contemplates the key questions relating to the climate resilience of the UK that need to be addressed by the climate resilience research community (i.e. the questions that the socioeconomic scenarios will be used to assess once finalised).
- Chapter 3 presents the findings from both the literature review and stakeholder engagement about which socioeconomic scenario variables are frequently used in analyses addressing the key climate resilience questions identified in Chapter 2, and which are deemed most important to the climate resilience research community.
- Chapter 4 also draws on findings from both the literature review and stakeholder engagement, to present the linkages and relationships between key socioeconomic variables.
- Finally, in Chapter 5, all evidence collected in Activity 1 is brought together to form conclusions about the socioeconomic variables that should be included within the socioeconomic scenarios developed in this study, and how these variables could link together.

2 Key climate resilience questions

2.1 Introduction

When considering what socioeconomic factors are relevant for climate resilience research, and those that are most frequently required within climate resilience analyses, it is important to first consider the key climate resilience questions the UK is presently facing. Having a clear understanding of these key questions is an important first step in establishing precisely which variables should be included within the socioeconomic scenarios developed within this project.

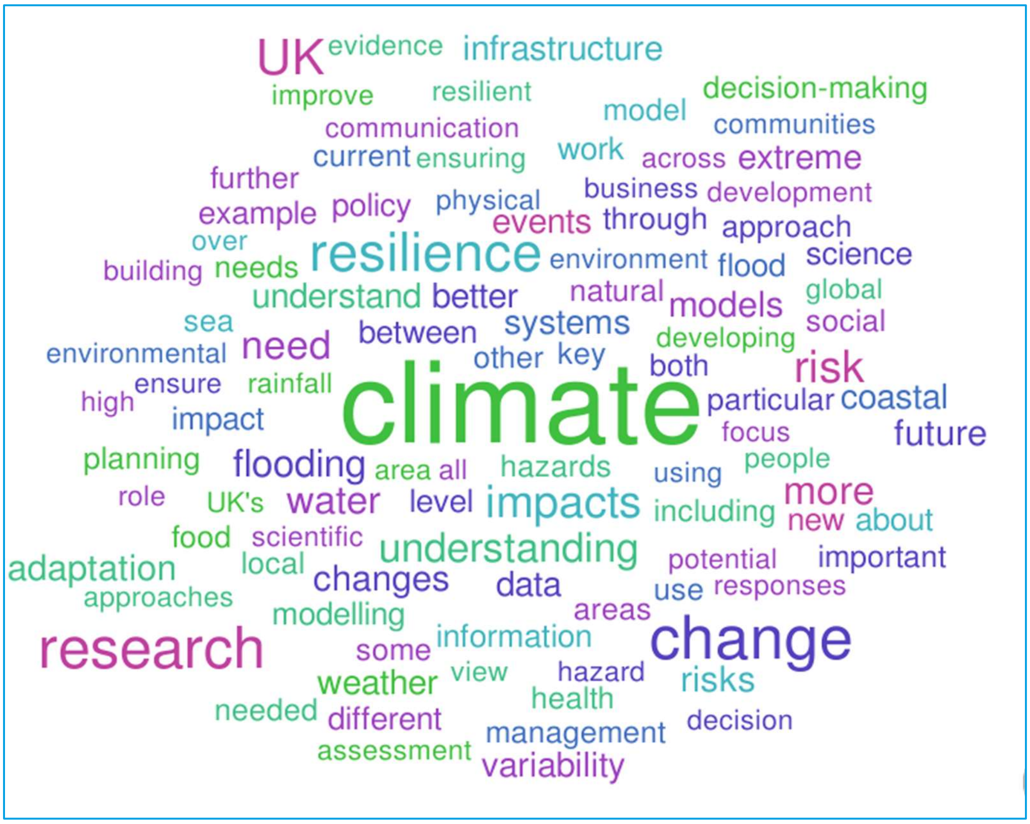
Figure 2.1 below presents the outcome of a workshop session, held in February 2020, in which members of the project User Panel were asked to evaluate what they considered to be the key research questions relating to the climate resilience of the UK. The figure depicts in larger font the topics or aspects related to UK climate resilience which were mentioned most frequently.

Figure 2.1 Frequent words when considering 'what are the key research questions relating to the climate resilience of the UK?'

Some clear considerations appear to be links between climate risk and resilience and infrastructure, land use, agriculture and food, health, various natural resources, adaptive capacity, transport, demographics, behaviours, energy, interactions between different aspects, biodiversity and social and local considerations.

In addition, a UK Climate Resilience Workshop facilitated by UK Research and Innovation (UKRI) and the Met Office in September 2018 (UK Research and Innovation 2018) posed a similar question to its workshop participants (comprised of 75 members of the UK climate resilience research community); *'…outline what research you consider is needed to ensure that the UK is resilient to climate variability and change?'.* Figure 2.2 below is a similar word cloud presented in the UK Climate Resilience Workshop report, presenting the high frequency words in the participants' responses. Similar topics to those frequently mentioned in our User Panel workshop, were also frequently mentioned in the UK Climate Resilience Workshop, such as resilience (which could also be interpreted as adaptive capacity), infrastructure, water and flooding and other natural resources. The representatives of the climate resilience community present at both our project workshop in February 2020 and the UKRI climate resilience workshop held in September 2018 deem many of the same themes or topics to be important to current climate resilience research, suggesting robust findings from our workshop. What seems to be apparent from the more recent workshop is that some new areas are deemed important to further research, such as behaviours and behavioural responses, diets and health; aspects which were not as prominent when a similar group of experts were asked the same kinds of questions at the 2018 UKRI workshop.

Figure 2.2 UK Climate Resilience Workshop responses to: 'Please outline what research you consider is needed to ensure that the UK is resilient to climate variability and change?'



Source: UKRI & Met Office (2018)

Furthermore, the UK's five-yearly Climate Change Risk Assessment (CCRA) Evidence Report, published by the Committee on Climate Change, identifies most potential risks to the UK associated with climate change, based on the latest understanding of current and future climate risks and opportunities.

These risks are grouped within various themes, which in many cases are similar to the high-level topics identified from our workshop responses:

- natural environment
- infrastructure
- people and the built environment
- business and industry
- international dimensions

In the following sub-sections, we consider more closely some of the main research questions relating to climate change resilience of the UK that currently need addressing within each broad topic (according to the information received at the User Panel workshop and the findings of a literature review). In many cases, interactions and crossovers between different topics exist and these interactions were often cited as key research concerns by the members of our User Panel.

2.2 Adaptive capacity & ability to respond

Cutting across all other research topics identified below is further research into the UK's adaptive capacity and ability to respond to a changing climate. Adaptive capacity relates to the capacity of systems (e.g. infrastructure, technology, public services etc.), institutions (e.g. central and local government, businesses etc.) and society (e.g. households, human behaviour etc.) to adjust and respond to the impacts of climate change. When considering whether the UK has the right resources available to increase its adaptive capacity, adaptive capacity can be considered a 'function of available financial recourses, human resources and adaptation options, and will differ between risks and sectors'. Variables which can be therefore used to assess adaptive capacity include income variables (including GDP), education statistics, availability of impact data, quality of emergency responses, business continuity schemes or the quality of overall adaptation strategies.

The User Panel workshop highlighted that understanding the extent of adaptive capacity in the UK is currently a key research concern, naturally linking together all the individual topics below. In particular, further research is required to address:

- the social, biophysical and economic limitations and barriers to adaption,
- the links between behaviours/ behavioural responses and adaptive capacity
- the ability of systems, institutions and society to act, including;
    - the speed at which they can react
    - the effectiveness of any reactions
    - interconnections between the capacity of each to adapt
    - factors which could improve adaptive capacity and resilience

Policy and decision-making

Across all topics, a key research consideration is the role of central and local government and decision-makers, and the policy response required, to improve the adaptive capacity and climate resilience of the UK.

2.3 Infrastructure (including transport)

Infrastructure has many elements including transport infrastructure (roads, railways, airports and ports), energy infrastructure (generation, transmission and distribution), water supply infrastructure and communications infrastructure (telecoms, digital and ICT). In a changing climate in which more extreme weather events are likely to occur, it is increasingly important to have sufficient infrastructure in place to limit the negative impacts of extreme events and long-term changes in the average climate. Furthermore, having the right infrastructure in place is linked to the key climate resilience question outlined above, about the UK's ability to adapt to a changing climate and its ability to cope.

A report from the CCC considers the progress the UK has made regarding preparations for climate change (Committee on Climate Change, 2019). Part of the report focuses on infrastructure, and highlights that while the design and location of new infrastructure adequately takes climate change into account, many of the individual elements of existing UK infrastructure are not currently sufficiently prepared for extreme weather events or for long-term changes in average climate. While flood defence and water resource management plans are well-established, other aspects of infrastructure could be better prepared, such as the transport network, and it is noted that plans related to telecoms, digital and ICT infrastructure are of low quality.

Furthermore, the most recent CCRA (CCRA2) Evidence Report identifies specific risks to UK infrastructure associated with climate change. The report highlights that more action is needed (in terms of policy action and research) to manage some risks such as; risks to transport networks from heavy rainfall, risks to water supplies from drought, risks to energy, transport and digital infrastructure from high winds and extreme heat, and risks to offshore infrastructure from storms and high waves.

Insights from the User Panel workshop also highlighted the need to understand further the interdependencies between the various elements of infrastructure, the links between infrastructure and society (for example quality of and access to healthcare facilities), and the links between infrastructure and demographic change (e.g. migration and population changes and the impact these have on the demand for infrastructure services).

2.4 Land use

There is a great deal of research being carried out to assess the feasibility of land use change, the potential for changes in land use to reduce emissions, and the subsequent impacts of land use change.

A report published by the CCC in 2020 (Committee on Climate Change, 2020) assesses the way land is currently used in the UK and highlights the changes required in terms of land use and the agricultural sector to achieve the Net Zero target by 2050. Various recommendations for action are set out, as presented in Figure 2.3**Error! Reference source not found.** below.

Figure 2.3 CCC recommendations on land use actions to be taken now

Source: CCC (2020)

Key actions for reducing emissions through changes to way land is used in the UK include:

- methods which increase the carbon sequestration potential of the land (natural climate solutions including increased tree-planting and restored peatlands)
- low-carbon farming practices aimed at reducing the environmental impact of the activity being carried out on the land
- the growing of bioenergy crops to support a higher share of renewable energy in the energy mix
- behavioural changes related to the food we eat are also required, in order to reduce food waste and consumption of the most carbon-intensive foods

All these recommendations pose ongoing questions for the climate resilience research community about how the land in the UK should be used most effectively, especially considering that in most cases important economic, environmental and spatial trade-offs will exist if the way an area of land is used is changed. For example, whereas a particular measure may lead to reductions in emissions, the same measure may have negative economic consequences for some sectors, or adverse effects on species currently inhabiting the land. The interactions between different agents gaining utility from an area of land is a key research issue, particularly the question of how we can best manage land in the UK to deliver multiple benefits for people and nature in a changing climate. Conversely, it is important to acknowledge that land use is expected to play a critical role in climate adaptation. The UK must make decisions about the management of landscapes, cities, buildings and species. These decisions could highlight opportunities for the use of land and help improve climate resilience. For instance, the adoption of new crops and the development of new species determine changes in the use of land, while improving the adaptation of the ecosystem to the changing climate. Similarly, climate adaption measures in the UK must focus on reducing costal and fluvial hazards, reinforcing barriers to protect properties and restoring vegetation. Such measures are expected to improve climate resilience, while also affecting economic activity.

User Panel members emphasised further research questions about land use planning and what proportions of land will be available or used for buildings and infrastructure, agriculture, forestry, bioenergy and water resources in future.

Agriculture and food production

In 2017, emissions from agriculture accounted for 9% of total UK GHG emissions. The agricultural sector thus has a substantial role to play in the context of reaching the Net Zero emissions target, both through reducing the emissions from the sector (through production techniques) and through maintaining or increasing carbon sequestration in soil. A further key issue facing both the agricultural sector is the food production sector, is the need for individuals to reduce the carbon footprint of their typical diets, reducing their intake of carbon-intensive foods such as beef, lamb and dairy, and instead consuming more plant-based foods, while simultaneously reducing food waste.

Further research is therefore expected to first understand the behavioural challenges related to changes to agricultural production methods and changes in diets. Second, questions remain regarding the impacts and risks of both land use change and changes in household attitudes to food waste and diets on the agricultural and food production sectors.

When considering the agricultural sector, it is important to highlight its vulnerability to changes in climate. Agricultural techniques need to adapt to future pathways in climate and ecosystem. Specifically, changes in technology and the adoption of new crops could minimize agricultural damage from climate transformation, while improving the adaptive capacity of agriculture. Similarly, agricultural policies have a role in enhancing food production and reducing vulnerability in the sector. The UK's decision to leave the European Union presents a major opportunity for UK agricultural policy. New UK policy setting is expected to replace the Common Agricultural Policy (CAP), therefore influencing future agricultural practice and food production.

Natural capital

Inherently linked to climate resilience questions related to land use, are questions related to natural capital which is affected by changes to land use. Natural capital can be defined as 'the naturally occurring living (biotic) and non-living (abiotic) components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity'. The resilience of natural capital to extreme weather events and long-term changes in climate therefore has an impact on the benefits received from it by society.

Various risks to the natural environment and natural capital are set out within CCRA2, many of which are not currently well prepared for. Therefore, more research and action is recommended to better understand (and plan responses to) the risks to species and habitats due to inability to respond to changing climatic conditions, the risks to agriculture and wildlife from water scarcity and flooding, risks to freshwater species from higher water temperatures, risks to habitats and heritage in the coastal zone from sea-level rise and risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidification and higher water temperatures. Similar variations of these potential research questions were quoted by members of the User Panel at the workshop.

2.5 Health

Climate change has direct impacts on human health. It affects the air we breathe, the water we drink, the food we eat, and has implications for the suitability of our housing. Extreme weather events such as heatwaves can cause serious health problems and even death for some, while other extreme events such as heavy rainfall and subsequent flooding poses health risks and hazards. The impact of climate change on human health is therefore an ongoing concern for the UK climate resilience community. As well as more general questions about the impact of climate change on human health, our User Panel members noted particular questions surrounding the links between, and implications of, the health impacts of climate change and vulnerable groups in society.

Various risks to people are set out within CCRA2, for which further action or research is needed for some, including; the risks to health and wellbeing from high temperatures, potential benefits to health and wellbeing from reduced cold, risks to health and social care delivery from extreme weather and risks to health from vector-borne pathogens.

2.6 Demographics

Developed countries such as the UK are set to experience substantial demographic change in the next thirty years up to 2050, primarily driven by higher life expectancies and falling birth rates, but also changes in migration and changes in labour force participation rates (which may have implications for urban areas). Demographic change must be considered when making decisions about infrastructure requirements, land use, availability of natural resources, energy requirements and the provision of public services such as health services. Questions related to demographics are therefore high on the research agenda of the climate resilience community. Questions posed by members of our User Panel included how climate change will affect the movement of people within the UK, how development plans for infrastructure and resources is influenced by changes in population and the links between population, housing, technology and behaviours.

Risks to society

Further societal questions were put forth by our User Panel, including the risks to certain communities given their geography or livelihood, the spatial distribution of climate change risks and impacts, who in society is particularly vulnerable to the risks of climate change and questions about social cohesion and inclusion.

Various risks to communities are set out within CCRA2, for which further action or research is needed for some, including; risks to people, communities and buildings from flooding, risks to the viability of coastal communities from sea level rise and risks to culturally valued structures and the wider historic environment.

Behaviours

A frequently mentioned topic was the need for greater understanding about the behavioural responses of households and businesses to climate change adaptation and mitigation policy, including a greater understanding of the incentives required to ‘do the right thing’ in ‘the right place’, a greater understanding of diets and personal preferences and the interactions between behaviour and the environment and agriculture.

2.7 Energy

A final topic within which key UK climate resilience questions to be addressed fall, is energy. Climate change has implications for the energy sector both in terms of the demand on the energy system (as a result of changes in heating and cooling demands), and in terms of the risks associated with reduced power plant efficiency (caused by higher atmospheric temperatures) and the risk of damage to energy infrastructure caused by extreme weather events. The assessment of new and existing energy infrastructure in terms of its resilience to current and future climate risks and interactions with other aspects of climate change resilience is a major climate resilience concern.

2.8 Summary

The User Panel workshop held in February 2020, and a review of climate resilience literature, has enabled us to have a clearer understanding of the key questions relating to the climate resilience of the UK that are currently being assessed by the research community. The suggestions and inputs gathered at the User Panel workshop echo the general climate resilience risks and research topics found within the literature. Understanding these research topics was an important first step in establishing precisely which variables should be included within the socioeconomic scenarios developed within this project. Table 2.1 summarises the main research questions relating to climate change resilience of the UK that were identified in this Chapter.

Table 2.1 Key climate resilience questions – a summary

Topic area	Main research questions relating to climate change resilience of the UK that currently need addressing

Adaptive capacity & ability to respond	• Understanding the extent of adaptive capacity in the UK.
	• The social, biophysical and economic limitations and barriers to adaption.
	• The links between behaviours/ behavioural responses and adaptive capacity.
	• The ability of systems, institutions and society to act, including;
	  ◦ the speed at which they can react
	  ◦ the effectiveness of any reactions
	  ◦ interconnections between the capacity of each to adapt
	  ◦ factors which could improve adaptive capacity and resilience
	• The role of central and local government and decision-makers, and the policy response required, to improve adaptive capacity.

Infrastructure (including transport)	• Many of the individual elements of existing UK infrastructure are not currently sufficiently prepared for extreme weather events or for long-term changes in average climate, more research

	and policy action is needed to manage some risks to infrastructure. • There is need to understand further the interdependencies between the various elements of infrastructure, the links between infrastructure and society, and the links between infrastructure and demographic change.
Land use	• Further research to assess the feasibility of land use change, the potential for changes in land use to reduce emissions, and the subsequent impacts of land use change. • Consideration of the economic, environmental and spatial trade-offs that will exist if the way an area of land is used is changed. • Research around methods which increase the carbon sequestration potential of the land (natural climate solutions). • Research on low-carbon farming practices aimed at reducing the environmental impact of the activity being carried out on the land. • Research into the behavioural changes related to the food we eat are also required, in order to reduce food waste and consumption of the most carbon-intensive foods. • Research questions about land use planning and what proportions of land will be available or used for buildings and infrastructure, agriculture, forestry, bioenergy and water resources in future.
Health	• The impact of climate change on human health (in particular, the risks to health and wellbeing from high temperatures, potential benefits to health and wellbeing from reduced cold, risks to health and social care delivery from extreme weather and risks to health from vector-borne pathogens. • The links between, and implications of, the health impacts of climate change and vulnerable groups in society.
Demographics and society	• How climate change will affect the movement of people within the UK, how development plans for infrastructure and resources is influenced by changes in population and the links between population, housing, technology and behaviours. • How demographic change affects infrastructure requirements, land use, availability of natural resources, energy requirements and the provision of public services such as health services. • Greater understanding of the risks to certain communities given their geography or livelihood, the spatial distribution of climate change risks

	and impacts, who in society is particularly vulnerable to the risks of climate change. • Greater understanding about the behavioural responses of households and businesses to climate change adaptation and mitigation policy (such as better understanding of diets and personal preferences).
Energy	• The assessment of new and existing energy infrastructure in terms of its resilience to current and future climate risks and interactions with other aspects of climate change resilience is a major climate resilience concern.

In subsequent chapters we explore the socioeconomic variables that are of interest to climate resilience researchers, which of these socioeconomic variables are of most interest, and how variables fit together.

3 Socioeconomic scenario variables

3.1 Introduction

A key step in designing credible socioeconomic scenarios is to identify relevant drivers that help describing the global socioeconomic framework in the future. To frame the later quantification of such frameworks, it is also necessary to identify indicators used to measure performance across themes and drivers. For this purpose, desk-based research has been carried out to review available materials and investigate the key trends analysed in previous scenario analysis. The starting point for the review referred to two previous studies: one conducted by Cambridge Econometrics to inform the third Climate Change Risk Assessment (CCRA3) and another conducted by UK CEH as background to the UK-SSP in the UK-SCAPE project. Building on these studies, our work identified further aspects which are expected to affect the UK socioeconomic framework in the next 80 years.

In addition to drawing on existing literature, stakeholders from the climate resilience community were engaged in a participatory User Panel with the aim of understanding how socioeconomic scenarios can respond to the diverse needs of research and policy. Stakeholders were invited to contribute their insights on key variables and the interdependencies between them.

The outcome of this activity was twofold. First, a comprehensive longlist of variables, both quantitative and qualitative, has been defined. Second, for each variable we considered the appropriate level of spatial resolution.

3.2 Evaluation of variables

Overview

Studies that developed SSPs, either globally or nationally, focus on trends in demography, economy, technology, socio-political context, the energy sector and the environment. These variables can be defined as the over-arching drivers of change, as they are expected to influence future socioeconomic outcomes.

In many scenario analyses, measurable variables are identified and estimated (i.e. GDP, population, level of emissions). However, a complementary branch of the literature focuses on developing qualitative scenario narratives that underpin related methods of quantifications. Not all SSPs consider the same set of variables. The scope of this section is to provide an overview of the themes covered by the existing literature and the insights collected during the User Panel workshop. The key variables have been classified into five main themes: society, economy, energy and technology, environment, policies and institutions. In each theme, we identify relevant key variables from the collated evidence.

Society

Climate change impacts depend on the interactions between the ecosystem and the socioeconomic framework. Societal changes determine the demand for natural resources, therefore affecting the resilience of the ecosystem. Demographic trends, including changes in the level and structure of the UK's population, for instance, both affect and reflect how society will adjust to changes in climate. Therefore population, health and individual behaviour are important inputs in understanding the challenges for mitigation and adaption.

Variables related to society include demographic trends, health care systems, behavioural tendencies and values.

Population

The size of future population has been extensively addressed in previous scenario exercises, especially in the SRES framework. The new generation of scenarios adopts multi-dimensional population dynamics to account for heterogeneity in age, sex, education, fertility and mortality rate. Such heterogeneity in population dynamics is of great concern for population-environment interactions, where the impacts on the environment vulnerability differ by age and sex (S. KC 2014). Further studies integrated population projections with educational attainment (Kc 2010). The latter highlights the impact of educational attainment on population growth. Higher levels of female education, for instance, are commonly associated with lower birth rates and lower population growth. Higher educational levels may be associated with good population health and low mortality rates, therefore being a signal of an improved quality of life. Although not directly quantifiable, quality of institutions and democratic participation are also partly driven by the level of education of the populace.

In socioeconomic scenarios, population dynamics are used as inputs to determine the level of urbanization, the amount of emissions and the demand for energy. (Terama 2019) uses population projections to determine the effects on land use in Europe. The author develops a growth model to investigate changes in urbanization concentration at the national and regional level. Further extensions examine how the population growth could exacerbate regional exposure to heat extremes ((B. T. Jones 2018), (Harrington 2018)). Although population projections are usually produced at the country level (Wear 2019), the literature points out the need of increasing geographical resolutions to the regional level in order to obtain meaningful analysis (Reimann, Merkens and Vafeidis 2018). Higher resolution scenarios, that adopt city level analysis and gridded population projections ((Murakami 2019), (McManamay 2019)), are useful to identify challenges for adaption and mitigation. Moreover, higher resolution models allow to control for spatial spillovers and interrelations between geographical units.

The appropriate level of spatial disaggregation for population was the subject of a variety of views during the User Panel workshop. Two participants highlighted the need to attribute to population at lower super output area (LSOA) level, while other participants opted for 1 to 5 km grid resolution. A useful suggestion at the workshop was to consider population (and indeed all variables) at the level at which they can still be removed from climate impacts – i.e. at the local authority level population demand is likely to be (relatively) unaffected by climate change impacts; but at the street level, climate change and adaptation are key determinants of population. Furthermore, the User Panel made relevant suggestions on other relevant dimensions of population, namely age and sex. Participants were split on whether population should be split by single year of age or five year age bands. The importance of further disaggregating population in this way is supported by models of population heterogeneity described in the literature (Kc 2010), (W. L. Samir KC 2014). The literature and User Panel were both clear that, as far as possible, population should be presented on an annual basis.

Health care

Though not widely investigated in the SRES framework, health care trajectories are described in the SSPs as they are determined by socioeconomic trends. The health research community requires an improved understanding of risk diseases development in order to drive decisions in health care policy. Although strongly related to climate, the transmission of diseases is associated with a much broader range of socioeconomic variables (Li 2019). Socioeconomic scenarios exercises prove useful to inform possible trajectories for population health and its consequences on other sectors.

(Sellers 2018) argues that very different health care systems are associated with each scenario, with substantial implications for population health and mortality rates. Similarly, (K. L. Ebi 2014) extends the SSPs framework to explore future uncertainties associated with public health and health care. The toolkit provided is useful to illustrate the risks human will face and how they could be minimized by the health system. Overall, health considerations and risk of disease projections are difficult to separate from temperature predictions, even though the SSPs are designed to be fully detached from climate change. Although climate is explicitly separate from the SSPs, and therefore not directly considered in our framework, it is important to acknowledge that increasing temperature and heatwave frequency contribute to heat-related health impacts such as exhaustion and heatstroke ((Dong 2015), (G. F. Rohat 2019)). The health research community strongly relies on integrated scenario modelling, where SSPs are combined with RCP-based climate projections. Some literature adopts fine scales of resolution (e.g. grid level or patient level) to quantify dynamics in population health, while there is a widespread consensus in the literature that such data should be presented on an annual basis. However, due to data availability constraints our analysis may characterise these outcomes at a more coarse spatial resolution (e.g. national or regional level).

Individuals' behaviours

Increasing environmental awareness and other changes in individuals' behaviours alter consumption patterns. Individual behaviours across many areas of life change over time (e.g. energy consumption trends, diets, water use, transport use, etc.). There is broad consensus that dietary changes in particular are expected to become more radical in the future. This is particularly relevant in terms of the consequences on food production and the resulting demand for land. Only a few studies include dietary changes in the socioeconomic scenario analysis (Maury 2017, Hasegawa 2015), even though there seems to be consensus on the importance of consumerism and individuals' behaviours (Natural England 2009), (Environment Agency 2009). Existing evaluations tend to assess behaviour changes as a sudden change in lifestyles and consumption patterns, with a supporting qualitative narrative. Although it might be difficult to quantify these patterns, they are important to acknowledge in qualitative terms. As such, scenario exercises that account for individuals' behaviours and dietary patterns are based on qualitative analysis of trends in lifestyle and wellbeing. Quantification of these variables would require collection of self-reported information and questionnaires, which is beyond the scope of this work.

Economy

The economy is a major determinant of both the extent of climate change (at a global level) and localised climate vulnerability. Including economic determinants in the socioeconomic system helps to illustrate the role of income effects and consumption trends in the creation of the global demand for food and commodities, and the consequences for land use. Economic growth and changing global economic conditions are expected to influence the UK economy in terms of employment level, prices of commodities (and therefore the overall price level) and financial stability.

Although GDP and income inequality measures are useful for global scenario analysis, the scope of this project is to develop scenarios at the UK and subnational level. For this purpose, downscaling national economic measure to a finer spatial scale is particularly informative (Wear 2019). The downscaling of global scenarios to the national resolution increases their relevance and suitability for regional applications; likewise, assessing UK macroeconomic performance at the regional level allows the analysis to expand the coverage of more detailed variables like household income, demography, housing situation and income distribution to the subnational level.

GDP

Measures of income are regarded to be key components for the development of socioeconomic projections, as highlighted by (B. K. O'Neill 2014). Models of long-term GDP projections have been developed to be used for climate research applications ((Leimbach 2017), (Cuaresma 2017). These models are usually combined with projections of population by age, sex and educational attainment ((S. KC 2014), (B. B. Samir KC 2010)). Applications of these combined models have been applied to predict population exposure to heat waves (G. T. Rohat 2017), to determine future demand for land ((Riahi 2017), (McManamay 2019)) and to estimate income distributions.

Income distribution

(Van der Mensbrugghe 2015) points out that regional differences should be accounted for in scenario analysis, since in even the most optimistic pathways, the distribution of income within countries is expected to be unequal. Assessing income inequality is useful to determine differences in energy demand, emissions and population exposure to heat waves. Likewise, further studies applied SSPs to assess climate change impacts through a poverty lens (Hallegatte 2010).

There is a broad consensus in the literature on the use of annual measures of economic output. This is the case for GDP and further income variables. For UK-based studies, however, a finer scale of economic data could be more informative. In particular, data at the regional and local authority level should be considered in order to highlight different distributions of economic activity and development across the country.

Energy

Energy production (at least that which is fossil fuel-based) leads directly to environmental impacts, in terms of carbon emissions and air pollutants. The increasing deployment of low- and zero-carbon generation technologies can, however, mitigate the impacts of increased energy demand. The future use of generation technologies, however, is uncertain as it depends on a wide range of factors including economic activity, demography, technological development and policy. Socioeconomic scenarios have proven useful for describing different pathways for the energy system and identifying the associated challenges for adaption and mitigation ((Riahi 2017), (Bauer 2017)

Access to energy

Global SSPs highlight the need to study future access to energy, especially in terms of electrification of rural areas. Energy pathways in developing countries may undeniably influence levels of air pollutions, with consequent negative impact on health and wealth (Pachauri 2013). However, when focusing on downscaled scenario analysis - which is the scope of our work - it is useful to explore the pathways in energy supply, and electricity sector (Bauer 2017). In addition, in the scope of subnational UK analysis, access to energy is likely to focus on the resilience of the electricity grid in different regions (and the extent to which it can support economy-wide electrification and potentially two-way generation flows) and connections to the current UK natural gas network (whether for the future deployment of natural gas, hydrogen or other synthetic fuels).

Energy demand

It is clear that there is the potential for substantially different links between economic activity and energy demand (i.e. for continued relative, and even absolute, decoupling of energy demand from economic activity). (Hasegawa T 2016) uses scenario analysis to explore developments in the building sector, where energy is used for space heating and cooling, cooking and lighting (Park 2018). Similarly, other contributions investigate energy-saving technologies in the building sector. Energy pathways are linked to the changing nature of energy generation ((Serrano S 2017) (Waite M 2017) (Hanaoka T 2014)), which is observed through consumer choices and lifestyles as well as in the development of the transportation sector.

The energy scenarios in the literature are generally derived at the national level. However, in some of the literature there is a specific consideration of the impacts of the transition to renewables. In these cases, it is useful to adopt finer scale resolution; in particular, the geographical characteristics of region and subregions can affect the security of the energy supply.

Emissions

The energy sector is one of the main contributors of GHGs emissions and air pollution.GHG emissions are also associated with changes in land use (Riahi 2017) and agricultural production systems. The increase in population and the expansion of national and international food demand affect the development of agricultural activities. The latter increases emission directly, through livestock practices for instance, or indirectly by reducing the ability of land to absorb carbon (Popp 2017). Most studies of socioeconomic scenarios consider emission pathways as an essential input to the framework, as it represents a major risk to mitigation and adaption strategies (Bauer 2017). Carbon emissions can cause damage to the environment, including but not limited to climate change impacts, but they also endanger the health of the entire population. Substantial health damages, caused by poor air quality, require institutional engagement (e.g. carbon reduction measures or public health support) and affect socioeconomic trajectories (S. K. Rao 2017). Weak institutions respond with lower investments in public health and health care research, thereby imposing a significant health burden on society (K. L. Ebi 2014). The repercussions of health damages are high mortality rates and lower life expectancy levels, especially among lower-income households.

The analysis of overall emissions pathways is typically carried out at the aggregate level, hence requiring a country-level spatial resolution. However, when considering emissions from land use change, information at much finer spatial resolution could be relevant. For instance, the impact of land use change of biodiversity is not fully visible at the regional scale.

Infrastructure & transport

Developments in the energy sector also affects the provision of national infrastructure and transport system. The latter is expected to face serious challenges in the medium-term, as a result of the growing population, energy supply, land cover and the need to meet environmental standards (Hickford 2015). Socioeconomic scenarios are useful for determining future configurations of the infrastructure and transport sector and the possible interactions with energy supply. Scenarios that provide decarbonisation trajectories of the economy are typically associated with efficient low-carbon infrastructure for transport, with implications for climate mitigation and adaption. However, the sustainability of the transport sector relies on the efficiency and cleanliness of the energy production. Changing demand for transport and mobility, resulting from population growth and behavioural changes, determines changes in the road infrastructure, vehicles and aviation technology (Environment Agency 2009) (Natural England 2009). The electrification of the transport sector is expected to reduce CO_2 emissions, while exploiting renewable sources of energy. The deployment of zero emission vehicles also requires transformation of the supporting infrastructure. Similarly, the electrification of the transport sector has the potential to increase efficiency in the railway sector (Ghaviha 2017) (Mathiesen 2015), with implications in terms of decreased road congestion (IRENA 2019). Moreover, the expansion of the road network could reduce the availability of land, therefore increasing deforestation. Overall, the future of infrastructure depends on investments and government expenditure as well as the orientation of policy towards the development of greener infrastructure.

Environment

Economic activity, population growth and land management have placed enormous pressure on the environment. The preservation of the ecosystem represents a crucial challenge for mitigation and adaption. Environment degradation is one of the major impacts of changes in climate. Socioeconomic scenario usually depicts environmental alterations under different aspects such as agriculture, food production, forest management, flood risks, and water supply. The trajectories identified by the SSPs, however, are meant to be independent from climate predictions. The reasoning behind this is to provide a toolkit that can be combined with separate models of climate pathways, to explore complementarities between the two. This scenario design remains controversial, and in practice, particularly at the detailed spatial level, it is very difficult to completely separate out socioeconomic developments from the impacts of climate change.

Forests

Integrated scenario extensions highlight that land dynamics have consequences for sustainable development, for instance endangering biodiversity (Popp 2017). There are undeniably uncertainties as to how demand for forest will evolve in the future. This is particularly relevant since forests work as sinks for carbon sequestration, as well as providing many other ecosystem services, including recreation. On the one hand, future increases in income and population can drive the demand for forest products to rise and the investments in forests to increase, with beneficial effects in terms of carbon storage (Tian 2018). On the other hand, the expansion of both economic activity and population can put extreme pressure on land management (Popp 2017). Several stakeholders suggest that future competition for agricultural land may reduce the potential benefits related to the carbon sequestration of forests. SSP exercises have been used to develop forest-specific narratives, since aggregated results across country and forest types lack the required detail ((Kemp-Benedict 2014), (Daigneault 2019)). A similar approach has been adopted to draw oceanic system pathways, hence focusing on oceanic resources and fisheries (Maury 2017).

The User Panel workshop highlighted the need to use fine scale resolution to create scenarios for land use and deforestation. Generally, regional analysis should be preferred to national level. Likewise, to account for agricultural intensity and land management, a finer scale of 5km resolution is desirable. The requested temporal resolution associated with this variable is annual.

Water availability

Initially under-served by socioeconomic scenario analyses, water sector pathways have recently gained in importance in the literature. Models accounting for water implications sometimes adopt weak assumptions about its future availability (Kim 2016). SSPs have been also used to assess global water scarcity, considering irrigation activity, crop intensity, industrial and municipal demands. (Hanasaki 2013) highlights that, regardless of the scenario considered, water availability is expected to decrease by the end of the century. Similar results are provided by (Hejazi 2014). This scarcity could be driven by rising in income, population and by the increased pressure coming from economic activity (Alcamo 2007). Stakeholders emphasised the need to consider water resources pathways in the UK socioeconomic framework, as it is expected to affect social and economic activity. A similar approach should be adopted for developing food security and agriculture scenarios.

The User Panel participants representing the water sector provided detailed insights about the desirable spatial resolution. Ideally, data would be presented at a detailed spatial level, such as river or basin catchment, water resources zones and water companies' regional groups. The literature adopts similar approaches; numerous studies prioritize – where possible – gridded resolution to derive consistent pathways for water availability and quality. Moreover, the literature is clear that the most informative projections would preferably go beyond the 2100 threshold, although such a longer timespan is outside the remit of this project.

Flooding

There is a need to understand how the environment will be affected by increased risk in flooding, although it is very difficult to separate this from climate change effects (i.e. even though flooding affects the socioeconomic system, particularly the spatial allocation of activity, the severity and frequency of such events is primarily a function of the climate). This is particularly relevant for the UK, that has experienced recurrent flooding since 1945. The occurrence of flooding can drastically affect the economy. In order to develop successful flood control measures, it is essential to draw patterns in flooding occurrence under various socioeconomic assumptions. (Mokrech 2008) provides a regional flood assessment for East Anglia and North West England, which are regarded to be more vulnerable regions to climate change. This scenario exercise concludes that socioeconomic factors will significantly influence the risk of flooding. In the literature, socioeconomic scenarios are used to identify the number of people exposed to increased water resources stress and increased flood frequency. In (Arnell 2014), the authors conclude that flooding events have direct negative effects on the exposed population. These effects are then reflected in the economic activity of the affected area. Similarly, (Alfieri 2015) performs a European wide flood risk assessment, and estimates large impacts on the European economy and society as a result of increased future extreme flood events. The impact assessment of flooding also shed a light on the importance of considering high spatial resolution models to insure consistent projection. We consider this as a potential option for inclusion in our socioeconomic scenarios, although recognise the difficulty in separating out flooding impacts on socioeconomic scenarios from changes in climate.

For climate risk analysis linked to flooding events a high spatial resolution is needed. The User Panel suggested the adoption of up to 30m and/or 1km grids. Finer data allows detailed assessments of the exposure and vulnerability of a particular area to climate extreme events. Similarly, where possible, monthly level should be used for flooding risk analysis. Existing studies on flooding risks and water stress use 1-5km scale or gridded resolution, while looking at annual data.

Policies and Institutions

Few SSP models directly consider the role of policy and institutions in the socioeconomic framework. However, extensive narratives account for policy as an essential factor influencing future outcomes (Natural England 2009), (Van Vuuren 2014), (B. C.-B. O'Neill 2017). The major justification for this approach is that it would be extremely complicated (and require a spurious degree of accuracy) to quantify the impact of policy or the quality of institutions. Several stakeholders attributed increasing importance to green policy measures that are currently being implemented. The outcome of the Paris Agreement internationally, as well as the commitment to a net-zero economy in 2050 in the UK, will determine how economic activity will develop, how the carbon emission targets will be met, and the impacts that it will have on the environment. At the same time, the nature and strength of institutions has a profound influence on how effectively policy measures are implemented. On the one hand, strong centralized institutions have the potential to deliver larger impacts on the economy and in the environment. On the other hand, autonomous regional governance plays a fundamental role in balancing local needs and policy requirements. When developing socioeconomic scenarios, it is also important to consider global agreements and international cooperation among institutions. The environment, as described previously, delivers numerous public goods (etc. wildlife and biodiversity), which can be better served by effective international standards. For instance, national targets for reduction of emissions are effective at improving air quality. However, a much greater impact in mitigating climate change could be achieved with a global agreement on emissions reduction. It is clear that policies and institutions play a fundamental role in determining future outcomes, not only influencing economic activity, but also the way in which environmental challenges are addressed.

3.3 Identifying relevant variables to be constructed

A comprehensive longlist of variables is presented in Figure 3.1. The listing has been created by assembling the collected evidence from the literature and the insights provided during the stakeholders User Panel meeting.

The variables above were then grouped according to their relevance to the research project. Figure 3.2 provides a representation of the suggested variables. The grouping of variables can be defined as follow:

- *Must have:* variables that were requested more than two of the user panel and that were regarded essential in previous SSPs studies.
- *Nice to have*: variables that were requested by two or less of the User Panel and that were regarded useful in previous SSPs studies.
- *Not essential*: variables scarcely requested by the User Panel and considered beyond the scope of this project.

Figure 3.1 Longlist of variables

Society

- Population size
- Population density
- Age
- Fertility
- Mortality
- Family size
- Health care
- Diseases
- Education
- Migration
- Transport
- Dietary changes
- Individual's behaviours
- Environmental awareness

Economy

- Income
- Occupancy
- Pension scheme
- Inequality
- Labour productivity
- Taxes
- Imports & exports
- Expenditure and Research & Development
- Privatization of public services
- Regional development agenda
- Changes in demand for regional infrastructure
- Work-life balance
- Timber
- Fibres demand & Supply
- Tourism

Environment

- Water
- Land use
- Spatial planning & urbanization
- Protected areas
- Sea quality
- Irrigation systems
- Food security
- Agriculture
- Fertilizers & pesticides
- Biofuels
- Biodiversity
- Extreme weather events
- Fishery
- Vector ecology

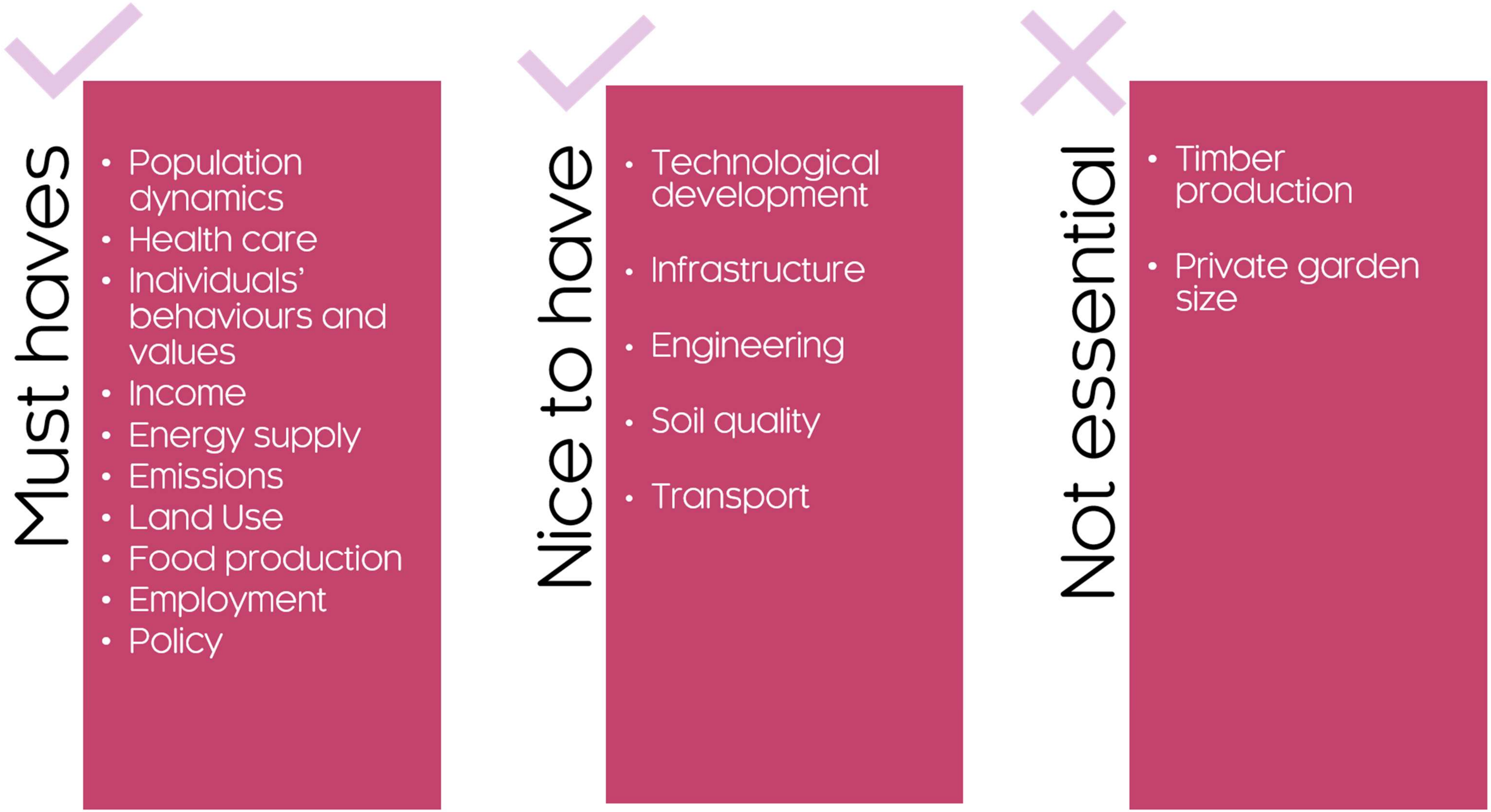
Energy & Technology

- Energy demand & generation
- Energy price
- Energy security
- Energy efficiency
- Renewable energy industry
- Battery technologies
- Use of diesel/petrol
- Aviation
- Building insulation technologies
- Bioenergy demand
- Emissions

Policies & institutions

- Health policy
- Trade policy
- Environmental policy
- Net Zero Policy
- Green New deal
- ELM scheme
- Building regulation
- Legislation
- Political engagement of society
- Green book
- Smart digital surveillance
- Globalization
- International cooperation
- Rise of populism
- Social cohesion and participation

Figure 3.2 Prioritisation of variables



The outcomes of Activity 1 summarised in this report will form the basis for Activity 2. In particular, the variables and linkages identified will be used to develop SSP narratives for the UK and four nations, with sectoral and regional considerations. Semi-quantitative trends of the key variables will be provided and compared with the global SSP results.

3.4 Conclusions

The aim of this section is to provide an overview of the literature on socioeconomic scenarios and depict the insights of stakeholders from different backgrounds. Previous studies on socioeconomic scenarios adopted different sets of variables, either quantitative or qualitative. In this chapter, we provided a comprehensive outline of the subjects explored in the literature. Similarly, the review of the literature has been complemented with the vision of stakeholders on the needs of research and policy. The main outcome of this task is a listing of prioritized variables related to climate resilience. For the purpose of the analysis, the variables were clustered into five main themes: society, economy, energy and technology, environment, policies and institutions.

The lessons learned from this section can be summarized as follow:

- Both the review of the more recent literature and the user panel suggestions conclude that increasing attention should be attributed to patterns in health care and social care. These topics have previously been rarely explored in scenario building.
- Changes in societal behaviour and values, focussed on reducing consumption and waste (e.g. diets, energy, water) and their follow-on effects on supply chains has been scarcely explored in previous studies. However, it is gaining increasing consideration in the research community, as individuals' environmental awareness is rapidly growing, leading to changes to consumer preferences.
- Within the climate resilience community there is consensus on the necessity of increasing spatial resolutions. Regional and sectoral analysis prove useful to depict consistent scenario analysis and to draw their applications.

4 Socioeconomic systems

4.1 Introduction

A further step to the design of scenarios is understanding interrelations between key topics and variables. This topic is not widely covered in the literature. Therefore, to assist us in this task, we consulted with the User Panel. Panel members were asked to discuss the main linkages between the key variables they had identified and prioritised. In this section we provide an overview of the interrelations identified. This section aims to define the socioeconomic system and describe how it functions. This is an important step to explore how key variables are connected and how consistent scenarios should account for these linkages.

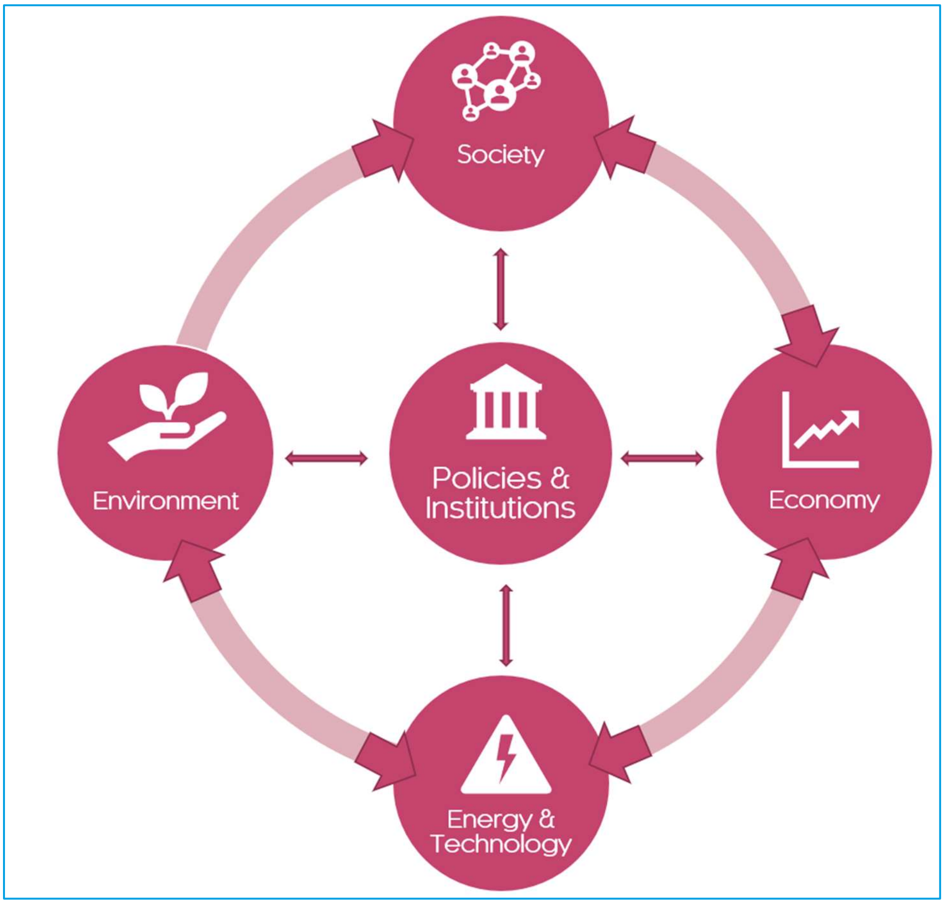
The following section starts with a brief discussion of the socioeconomic scenario system and the basic linkages between variables. We then move to describing in more details the main themes (society, economy, energy and technology, environment, policies and institutions) and their interdependencies.

The socioeconomic scenario literature does not often consider explicitly the linkages between different parts of the system; instead, in our narrative for the system set out below, we rely primarily on our own understanding of the ecosystem, and draw as far as possible from existing studies which have attempted to link individual parts of the system together.

4.2 Evidence on how socioeconomic systems function

Scenario exercises attempt to describe highly integrated systems, where marginal changes in one component significantly affect the others. Demographic trends and population dynamics have effects on the economic activity undertaken by persons, firms and other agents in society. The effects are transmitted through the environment, the energy sector, the use of land and persist over time. These interdependencies suggest that socioeconomic scenarios should account for a comprehensive setting of linkages, in order to obtain consistent projections. Figure 4.1 provide a representation of the socioeconomic system that enables us to capture linkages between the main themes. Based on this representations, further description of the linkages is provided in the following sub-sections.

Figure 4.1 Socioeconomic system



Society and economy

Existing studies highlight a direct connection between society and economic activity ((Wear 2019), (Murakami 2019)) . Societal dynamics influence the economy through demographic changes. For instance, a significant increase in the population during the current decade would determine a rise in consumption patterns, global demand and production, with systemic changes (e.g. reduced individual consumption) only likely to affect this dynamic over the longer term. Domestic production could be insufficient, and the national economy would rely on trade and imports from other countries. The rise in population also affects the employment level within the country (in a demand-driven system), therefore influencing households' income and wealth. However, population is not the only factor driving changes in the economy. Societal behaviours determine changes in food production and goods demanded. The attitudes of individuals towards consumerism have consequences for economy activity and for its sustainable development.

The connection between society and economy is not unilateral. The way economic activity is conducted evidently shapes societal trends. On the one hand, higher income levels can boost fertility rates and educational attainment. On the other hand, higher occupancy rates, especially among the females, may instead discourage an increase in the size of population ((Lutz 2010), (W. L. Samir KC 2014)). Society and economy are closely related, hence determining an infinite loop of causational effects.

Policy and institutions in the system

The socioeconomic system as a whole is endogenous to the institutional framework. The orientation of policy and its enforcement contribute to shape each of the themes discussed above (i.e. society, economy, energy, environment).

Economy and energy

Economy is directly related to the energy sector and its development ((Cambridge Econometrics 2019), (Barker 1998)). Exploring this interrelation is essential to determine challenges to mitigation and adaption. An expansion in economic activity implies an increase in the supply of goods and an expanded demand for services. The economic growth, however, requires higher demand for energy. Increased use of energy is meant to sustain higher economic rhythms as well as more elevated households' standards. The increased demand for energy puts the availability of energy at risk, as its generation loosely depends on the accessibility of natural resources. In addition, energy generated from renewable sources encourage competition within the sector and allows the price of energy to fluctuate. With the surge of new sources of energy, the price of carbon would need to rise encouraging the transition to new energy infrastructure. An economic expansion also affects the energy sector through technological development (Mercure 2014). The latter incentivises the development of energy efficiency and promotes competition in the sector.

The energy market dynamics reversely affect the economy. For instance, a lower price in renewable energy sources could determine the phasing out of traditional forms of energy. The consequent transformation in the energy sector also causes structural economic changes. The rise of renewable sources of energy would create job opportunities in the new energy technology market, until a complete shift across sectors would take place. This mechanism could represent an opportunity for central government to collect revenues from taxing energy generated from fossil fuels, in order to accommodate the transition towards renewable forms. It is evident that energy dynamics could also incentivise economic growth. However, such trajectories are subject to substantial uncertainties. Socioeconomic scenarios are meant to explore and illustrate the possible interactions between the economy and the energy sector.

Energy and environment

Energy also interacts with the environment in a circular form ((Riahi 2017) (Fouré 2016)). Energy production and consumption are responsible for increasing carbon emissions, hence deteriorating air quality and environment conditions. At present times, the energy sector causes a substantial share of global emissions. Further developments in the energy sector determine various emission pathways, therefore endangering the environment on different levels. For instance, a complete shift towards renewable energy would reduce the carbon footprint to the minimum level. The coexistence of fossil fuels and renewable source of energy could instead comprise higher level of carbon emissions, with negative repercussion on climate. Increased global temperatures determine the surge of extreme weather events like flooding and severe droughts, with negative effects on agriculture and food production. Similarly, the sea level, water availability, and protected habitats would suffer severe consequences from a changing climate.

Conversely, environment degradation caused by GHGs emissions jeopardizes the potential of renewable sources of energy. Instability in climate would then be reflected in an unsteady generation of energy from wind, solar and hydrogen. This framework would slowdown the transition towards green energy generation, therefore enhancing traditional fossil fuels sources.

Economy and environment

Energy consumption is not the only cause of environment degradation. An expansion in economic activity puts enormous pressure on the use of land (Daigneault 2019). An increase in food production, for instance, would require higher shares of land dedicated to agriculture. For this purpose, forests would be reverted to alternative uses of land, with controversial implications for carbon sequestration. Similarly, increased rates of urbanization could encourage the practice of deforestation, with negative repercussions on biodiversity.

Environment and society

The constant transformation of the environment imposes relevant costs on society. Increased occurrence of climatic extreme events threatens urban spatial planning and the resulting population density (FLUF 2010). For instance, higher risk of coastal and fluvial flooding events in the UK, amplified by high intensity precipitation and sea level rise, forces households living in coastal and fluvial areas to move to risk-free regions instead. Therefore, future flood risk will affect the way urban areas are organized and how the population will adapt to new habitation patterns.

The interactions between the environment and society are not exclusively related to climate events. In fact, environment degradation and biodiversity loss develop holistic sentiments for individuals feeling closely attached to nature. This results in the spread of environmental awareness across society.

Policy and society

Institutions play a significant role in determining societal norms and thereby influencing socioeconomic trajectories. They decide how to allocate financial resources to respond to diverse needs. Depending on political will, institutions may attribute different priorities to societal concerns. These political actions may generate either approval or discontent across individuals. However, political decisions have concrete effects on the characteristics of society. Higher investments in public health might reduce inequality and be beneficial for population health. Similarly, policies that favour educational attainment generate positive spillovers for the economy, in terms of employment and labour productivity. In fact, education affects every aspect of societal development. A better educated society is also expected to perform better in systems of governance and democracy. Moreover, policy orientation towards education and public health influence demographic trends. Higher levels of education among women, for instance, may be associated with lower birth rates and consequent reduction in population size. Meanwhile, more educated population could increase life expectancy rates, as education is a major driver of health, mortality and earnings.

Policy and economy

As well as society, economic dimensions are affected by institutions. Policies can be oriented towards international trade or strictly focused on the internal economic activity. Decisions to facilitate international trade have relevant effects on the economic activity and labour productivity. The UK decision of leaving the European Union, for instance, is expected to have significant implications for its economy, with trickle down effects on the whole socioeconomic system. One of the major feared implications, for instance, is that leaving the European Union would shrink the employment opportunities as well as the households' income. Likewise, the occurrence of Brexit is expected to influence the dynamics in the energy sector and in the environmental regulation, as the UK will no longer implement agreed European policies and directives.

Policy and energy

The future of the energy sector is not only strictly related to the development of new technologies, but it will be determined by policy decisions. Governments will decide whether to support the decarbonization of the energy sector or not. Even when the market signals indicate the competitiveness of renewable sources of energy, the actual transition towards them could never occur without the support of policy. The surge of environmental policies, seeking to reduce carbon emissions, causes the price of carbon to increase, therefore encouraging the shift to low-carbon sources of energy. In the absence of government incentives, an increase in the price of carbon could instead determine a reduction in energy consumption.

Policy and environment

The measures provided by the government to reduce carbon emission also aim to preserve the natural environment and its biodiversity. The economic activity poses pressures on the use of land, the quality of air and the maintenance of biodiversity. The European Union have made significant progress in environmental regulation. The Net Zero emission targets in the UK, seeking to sharply reduce carbon emissions, are expected to be beneficial for the quality of air and for reducing climate extreme events. Likewise, policy plays a fundamental role in safeguarding natural habitats. Agricultural quotas as well as afforestation incentives contribute to protecting forests and biodiversity. While there are extensive UK environmental policies in place, such as the 25 year Environment Plan and the Agriculture Bill, there is considerable uncertainty around how these will be implemented in practice.

4.3 Conclusions

The engagement of stakeholders with diverse expertise has proven useful to identify interrelations between society, economy, environment, energy and technology, policies and institutions. The insights provided by the User Panel have contributed to define a socioeconomic framework that will be built upon in Activity 2 and Activity 3.

The framework described in this section represents a highly integrated system, where factors are closely connected to each other. Variations in one of the components are conveyed to the others in a trickledown effect. The result is a combination of changes in each component and of the persistence of the effect over time.

5 Conclusions

The purpose of this report

This report provides evidence on the socioeconomic variables required within the UK-SSPs to be developed within the *Development & provision of UK socioeconomic scenarios for climate vulnerability, impact, adaptation & services research & policy* project, and illustrates the possible interrelations among them. In order to develop the relevant evidence base on constructing UK socioeconomic scenarios, we brought together evidence from an extensive body of literature, as well as the insights provided by a User Panel which represented the climate resilience research community.

A mixture of qualitative and quantitative variables has been established

The evidence presented in this report covers both qualitative and quantitative socioeconomic variables. Qualitative variables are useful when developing scenario narratives as they illustrate aspects that cannot be explained by quantitative exercises. On the other hand, quantitative variables provide more precise projections of future outcomes.

Constructing a longlist of variables

Based on the literature review and inputs obtained at the User Panel workshop, we constructed a comprehensive longlist of variables relevant for climate resilience assessments, which could be categorised into five broad pillars – society, economy, environment, energy and technology, and policies and institutions. With the support of the stakeholders from the climate research community, we then identified a list of prioritised socioeconomic variables, which we are proposing be taken forward and used to develop UK specific socioeconomic scenarios.

The prioritised variables, deemed to be most important to include within socioeconomic scenarios used within climate resilience assessments, include:

- Demographics
- Health care
- Individuals' behaviours
- Income
- Energy supply
- Emissions
- Land use
- Food production
- Policy measures

The short-listed variables here presented is the result of the prioritization exercise carried out in the User Panel workshop. The final list of variables was also synthesised by prioritizing broader variables instead of specific indicators. The final list includes some of the 'nice to have' variables identified in Figure 3.2. This is because some are considered under a broader variable (e.g. the quality of soil is strictly related with land use and food production).

Inter-dependencies between variables

As a final step, we explored the interdependencies occurring between the five pillars into which identified socioeconomic variables fall. The resulting socioeconomic framework is an extremely integrated system, where changes in one component affects the others through a number of direct and indirect linkages.

Report outcomes

This report presented the relevant evidence collected about key socioeconomic variables and the related interconnections between drivers. In the Activities that follow, this framework will be evaluated and further developed to meet the needs of the qualitative narratives and quantitative scenarios to be developed, specifically informing UK SSP narratives developed in Activity 2, and the quantification framework based on causal loop diagrams developed in Activity 3.

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