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Abstract
Climate impact assessment requires a clear picture of two intimately interrelated processes: socio-economic change and climate change. To date, future change in socio-economic systems has been mostly ignored in the analysis of climate change impacts. More inclusive and systematic scenario approaches offer a means of dealing with critical issues of complexity, innovation, reflexivity and framing in analysing change in socio-economic systems, paving the way for a more sensitive and systematic handling of socio-economic futures in impact assessment. We argue that scenarios represent a heuristic tool encouraging policy and organisational learning in climate impact assessment. The advantages and disadvantages of a scenario-based approach are explored via a detailed study of a regional climate impact assessment in the UK.

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Introduction

Climate impact assessment requires a clear picture of two intimately interrelated processes: socio-economic change and climate change. By combining the two it is possible to evaluate the exposure to harm from climate change, and how future societies may cope and adapt to these impacts. This is reflected in the IPCC definition of climate impacts as being '…differences…between socio-economic conditions projected to exist without climate change and those projected with climate change' (Carter et al., 1994, p. 16). Most impacts and adaptations to them are assumed to take place up to a century into the future from today. Parry and Carter (1998, p.72) argue that the development of baselines representing current and projected socio-economic conditions in the absence of climate change "is a key and fundamental step in assessment." This means that an adequate understanding of time, change and the dynamics in both climatic and in socio-economic systems should become *a sine qua non* of all climate impact assessment.

Nevertheless, Parry and Carter (1998, p.79) also conjecture that many future socio-economic trends are "…almost impossible to anticipate." This implies that understanding the future development of socio-economic systems is not only different from, but may be more difficult than in natural systems. Why might this be so? Humans are endowed with a capacity to alter their surroundings (the notion of human agency). In making these changes they are capable of reflecting critically on the implications of their behaviour (the notion of reflexivity) and making adjustments in the light of experience. In sum, humans can "transcend established 'laws' and create new 'reality' in ways that no other species – let alone 'dead matter' – can do" (Underdal, 1999, p.2-3). They *can* learn from the past and apply these lessons in ways that shape their future (Clark 2001).

Questions of human agency and reflexivity place a special burden on those seeking to understand processes of change in the social and economic sciences. These problems

cannot and should not be avoided by those undertaking climate change impact assessments (CIA) and other forms of integrated assessment. Indeed, they may be rendered more, not less, acute by virtue of the intimate coupling (or "co-evolution") of natural and social systems (Norgaard, 1994).

In this paper we: present a critique of existing approaches to social and economic change in CIA; summarise the key differences between projecting socio-economic and environmental futures; explore the history of scenario-based planning; and describe an exercise that produced national level socio-economic futures scenarios for CIA in the UK. We conclude that scenarios are potentially important 'learning machines' that overcome the dichotomy between analysis and 'participation' in making sense of the future, that has to date permeated the CIA literature.[1]

Future change in social and economic systems

A set of 'framing' assumptions about socio-economic futures underpins much work on CIA (Carter *et al*., 1994). First, there is a general supposition that the future of socio-economic systems is knowable and can be portrayed using simplified quantitative characterisations of these systems (i.e. a baseline). Second, there is an assumption that the influence of climate change can be analysed and predicted by mapping it on to a future social world experiencing climate change. This step requires an understanding of the vulnerability and 'adaptive capacity' of future socio-economic systems to climate impacts. Third, it is assumed that a 'baseline' non-climate future state can be segregated from a 'climate influenced' future state, and that the difference between them can be calibrated and measured, typically in scientific and economic terms. The difference will represent the climate impact (Parry and Carter, 1998, p.72).

Implicit in these framing assumptions is a rather mechanistic view of social systems, and of social and economic change. Several features of social systems mark them out as being manifestly different from natural systems, with the result that processes of change in social systems are inherently more uncertain and indeterminate. One of the reasons for this is the complexity and mutability of relationships within and between different social systems. For example, whereas the evaporation rate for water can be estimated in a relatively predictable way using a fixed number of factors which can be assumed to hold under most situations now and in the future (the principle of uniformitarianism), the rate of almost any social and economic process (e.g. the rate of innovation) will be influenced by a changing set of factors such as human ingenuity, prevailing institutional conditions and the state of the economy. The drivers of change in social systems are therefore not only multiple, they are mutable, and as a result imperfectly understood. So, although change in social and economic systems is often 'directional', path dependent or 'locked in', novelty and surprise are inescapable features (Dosi, 1984; Nelson and Winter, 1982; North, 1990). Consequently, the notion that the future is *a priori* knowable in a concrete or predictable way seems extremely doubtful. In fact, some social scientists would

[1] We contrast this with the use of climate models as 'truth machines' producing definitive and verifiable predictions about the future (Jasanoff and Wynne, 1998).

strenuously resist such claims as being overly deterministic. The notion that it is possible to segregate 'climate-affected' from 'non climate' socio-economic futures has also come in for sustained criticism (Lorenzoni *et al*., 2000).

Finally, there is the paradox that we are simultaneously ignorant about crucial aspects of the future dynamics of socio-economic systems, while being aware that humans are uniquely capable of shaping their destinies. Actors make choices informed by their interests, knowledge, capabilities and values, in order to manage their environments. Crucially, one important element of reflexivity is foresight itself, so that social and economic futures are always the outcome of efforts to bring into reality projections of preferred or idealised futures. Social actors participate in processes of change, trying to anticipate future states, and so tend to orient social systems towards more desired outcomes and away from less desirable ones. We may even speculate that the very act of making a prediction about the future may make it more or less likely to occur depending on the perceived advantage that may be gained in pursuing it.

All this means that 'the future' cannot be treated as an objective fact, but needs to be thought of as being emergent and only partially knowable; it is something about which legitimately diverse opinions exist; and a phenomenon with which organisations and societies are in a constant dialogue. The future in this sense is not a given and should not be treated as 'empirical' reality (it does not exist until it exists), but rather as a 'possibility space' that may be explored. Scenario planning tools provide one way of handling the complexity and uncertainty of social and economic change in climate impact assessment (Berkhout and Hertin, 2000).

Social and economic change in climate change impact assessment

Climate impact assessment is concerned with understanding changes in natural and socio-economic systems that may be attributed to anthropogenically -caused changes in the climate. Two strategies are used in mainstream CIA to cope with the complexity of the relationship between climate and society. First, assessment studies have sought to reduce complexity by looking at limited aspects of a subset of potential future conditions. Early studies focused entirely on physical impacts of climatic conditions on natural processes (Arnell, 1998; Stakhiv, 1998; CCIRG, 1996; Harrison *et al*., 1995; Glantz, 1992; Bentham and Langford, 1995). In general, these studies examined a few exposure units and climate change scenarios (typically based on doubling of atmospheric carbon dioxide). Those studies which did include socio-economic conditions considered them either as 'static' (in the sense of being a continuation of the present), or analogies in space (i.e. a comparison between comparable cases in the present) and/or time (comparison with cases in history). The recent Working Group II Report of the IPCC draws all of its conclusions on the basis of the situation in different regions in the present-day, making no explicit attempt to deal with socio-economic change at all (Intergovernmental Panel on Climate Change, 2001). Feedback mechanisms between the socio-economic and the climatic system (e.g. adaptation strategies) tend to be disregarded, although there is recognition that the scale of an impact will be dependent on the level of social response –

vulnerability and adaptation are linked to each other. To summarise, the prevailing literature assumes that socio-economic and climate systems are separable for the purposes of CIA, and assumes that socio-economic conditions can be held constant.

In this paper, we argue that CIA must take account of change in socio-economic systems. Without this, assessment will remain one-dimensional (i.e. relating only to climate variables). The commensurate change in social and economic systems, which will to a large extent condition their sensitivity and vulnerability, could be overlooked. Unless the CIA community grapples with the problem of future social and economic change, the authority of its conclusions will be open to question, not least by social scientists.

The CIA community must confront and overcome three critical epistemological problems. First, impact assessment must come to terms with agency and reflexivity in social systems. We have argued that social systems are unpredictable because humans are uniquely capable of altering their environment, and because in acting on their environment, they are being reflexive. Some aspects of change – population, mortality etc. – are relatively easy to model, providing the basis for long-term predictions. Some social scientists (i.e. rational choice political scientists and economists) seek to model other aspects of human behaviour (e.g. the choice between certain courses of action) albeit in simplified social settings. But many other facets of social reality (and the future) – e.g. the development of cultural norms, values and beliefs – stubbornly defy this type of analytical treatment. Efforts to make predictions in economics, political science and sociology tend to reduce complexity, but in doing so lose vital qualitative aspects of the worlds they seek to portray – political interaction, norm formation, debate, advocacy – which shape socio-economic futures. The ability to quantify future impacts is therefore fundamentally constrained.

The second problem may be called the 'mismatch of futures'. In general, the natural sciences make well-founded assumptions of *continuity* and *universality*. Natural phenomena are assumed to behave in the same way, *ceteris paribus*, whenever and wherever they occur. Most scientists also hold to the positivist claim that as knowledge accumulates, more will be known and the models used to explain natural phenomena will be improved. This expectation extends also to natural processes that represent a departure from long-term average conditions, and to events like threshold flips and other non-linear events, such as a collapse of the thermohaline circulation (Rahmstorf, 2000). As knowledge accumulates, there is a general expectation that better predictions of the evolution of a broader set of climate variables will be possible at progressively finer resolutions.[2] This confidence does not extend to the social sciences, mainly because the assumptions of continuity and universality do not hold in many (and under conditions of modernity progressively fewer) social, political and economic systems. Although over

[2] In making this characterisation, we are avoiding a discussion of 'contructivist' approaches to science studies which argue that all knowledge of natural phenomena needs to be placed in the social and political milieu in which it was produced, since all knowledge is underwritten by the interests and assumptions of scientists and the institutions in which they operate. This discussion portrays the 'working assumption' of many scientists working in the climate impacts field.

short periods of time many important structures, processes and attitudes are stable, over longer periods of time we are aware that social and economic relationships change, and that institutional and technological innovations modify prevailing systems. Usually these processes of change are unexpected and poorly understood by participants, even as they are occurring.

Finally, the framing of impact assessments must themselves be placed into some social and political context. Social studies of science have long emphasised that scientific knowledge cannot be understood independently of the social context in which it is produced (Jasanoff and Wynne, 1998). The post-modern turn in social inquiry "…rejects all truth claims, accepting that there are multiple realities and no foundations for asserting the superiority of one interpretation over another" (Rhodes, 1997, p.184). 'Scientific facts' are *constructed* through social processes and rituals. What is accepted as knowledge and what constitutes good scientific practice is the outcome of social processes of negotiation within frameworks of power and authority. All research is framed by assumptions, discourses and interests, including those of the scientists involved. What has been shown for a wide range of academic fields is particularly relevant in CIA. Partly as a result of complexity and uncertainty, results are shaped by necessary choices regarding spatial and regional scales, exposure units, types of impacts to be examined, ways in which they are expressed and so on. Specific interests (political, economic, cultural) colour pictures of the future because they imply winners and losers. The way in which these affect study results remains largely concealed from policy and other audiences. How these practices unfold has been shown in detail for Global Circulation Models (Shackley and Wynne, 1995).

The discussion about methodologies for the assessment of climate impacts therefore does not stop at the issue of scientific quality. Explicitly or implicitly, it also concerns social and ethical questions on which a legitimate diversity of positions exists. Parallels can be drawn with recent debates in the social sciences concerning the economic valuation of nature (Foster, 1997) and of human life in the context of climate change.

These inter-related problems of agency, discontinuity and framing pose immense challenges for the analysis of future social time in climate impact assessment. Do we accept that the future of society and the economy cannot be explored? Or are there ways to make studies more robust, even if the issue is inherently uncertain, complex and value-laden? How can CIA research be made more useful to a wider range of stakeholders? Three main conclusions can be drawn:

First, studies which seek to assess future climate impacts (rather than examining physical sensitivities) need to look at a range of different future socio-economic conditions. Imposing future climate on only one (current or future) set of economic, technological and social conditions does not give a full representation of possible outcomes. This approach downplays rather than explores the various sources of uncertainty, and compresses rather than reveals different interpretations of reality.

Second, qualitative analysis and participatory approaches should be given a more prominent role. CIA research should partly be understood as a joint learning process between researchers and stakeholders, aiming to better understand the mechanisms of climatic effects and how they may be avoided or adapted to. However, this claim begs a number of questions. Which elements of the ecological system, which social groups, and which economic sectors are particularly vulnerable? Which adaptation options exist and what are their intended and unintended effects? How will continuing socio-economic change affect vulnerabilities and the capacity to adapt to climatic changes? Using these as a basis for analysis would imply taking social and economic conditions as a starting point and then adding in the climate effect. This process inverts the logic of much current CIA which foregrounds climate variability and change in a series of climate forcing effects.

Third, CIA studies need to make underlying assumptions more transparent. New tools and wider participation in studies could lead to a broader and more open comparison of potential impacts and policy options. Researchers should represent uncertainties and acknowledge the limits of knowledge more explicitly, while not being overwhelmed by uncertainty and ignorance about the future. Assessments should be used and presented as heuristic tools, drawing on the knowledge and experience of diverse stakeholder groups and encouraging learning.

These three responses: foregrounding the socio-economic; encouraging participation; and increasing transparency are increasingly recognised in current scholarship (e.g. Morgan *et al.*, 1999). Recent CIA studies have begun to address the problem of how to integrate socio-economic change into their analysis by seeking to create a link between more formal modelling of natural systems and qualitative socio-economic futures scenarios (Parry, 2000; US Global Change Research Program, 2000). Next we present a scenario-based approach.

The role of futures scenarios

Socio-economic scenarios can be used to respond to the challenges discussed above. According to the IPCC, a scenario is a coherent, internally consistent and plausible description of a possible future state of the world (Parry and Carter, 1998). Scenarios are planning and communication tools used to explore uncertain futures. They do not aim to predict, but are designed to give representations of possible futures. Typically, futures scenarios include a narrative component as well as quantitative illustrative indicators. Rotmans and van Asselt (1998, cited in Greeuw *et al.*, 2000) define scenarios as:

> '…archetypal descriptions of alternative images of the future, created from mental maps or models that reflect different perspectives on past, present and future developments.'

Complexity and reflexivity

The challenge of bringing together both climate and socio-economic changes in a coherent and useful manner can be met through the use of scenarios in two main ways. First, those who have a legitimate stake in the uses and outcomes of a CIA are brought into the process of assessment, and thereby encouraged to participate in a discursive process of scenario elaboration. Users bring with them their expert knowledge of the social processes which affect and will be affected by climate change. The stakeholders define the appropriate level of complexity required in the analysis of future states. The process of visioning futures can therefore be defined by the interests of users, rather than by the interests of the analyst. In this way complexity can be contained without falling into the trap of reductionism. An important attribute of some futures scenario approaches is *scalability* – that the approach can be applied to problems at whatever scale is appropriate to the interests of diverse user communities. Not all scenario frameworks meet this criterion (see Hertin *et al*., 1999 and Greeuw *et al*., 2000 for useful reviews).

Second, reflexivity is intrinsic to the choices that are made in defining the scenarios. The process of scenario construction can be seen as a sequence of 'what if?' conjectures in which a set of hypothetical prior conditions are assumed from which a number of consequences follow. Kahn and Wiener (1967) describe scenarios as '…hypothetical sequences of events constructed for the purpose of focussing attention on causal processes.' The participants are thus encouraged to reflect on the cascading consequences of a range of possible future worlds. The strength of a participatory process of scenario elaboration is that the attitudes and knowledge of many actors can be synthesised into this analysis of causal processes. Complexity is handled by having multiple, alternative scenarios that are elaborated within a single framework. This process generates scenarios that are self-consistent and comparable. Uncertainty about future outcomes is revealed not by comparing them with conditions in the present day as in many CIA, but by comparing between future states.

Discontinuity and innovation

Scenarios also provide a response to the problems of discontinuity and innovation in socio-economic systems, especially over longer time frames. They begin by explicitly acknowledging the indeterminacy of future change. The assumption of continuity is suspended. Scenarios thus provide an alternative to the handling of uncertainty using stochastic (Bayesian statistics) or deterministic (the application of learning and diffusion curves used in modelling future technological change) methods (Grubler *et al.*, 1999). The main advantage is that the focus remains on causality. 'What if?' questions encourage participants to evaluate possible causal chains and investigate the scope for modifying them. This process puts the question of how to deal with uncertainty into the hands of the user, rather than retaining it in expert circles. Within a consistent framework for elaborating scenarios, qualitative changes can be handled explicitly – technology can be considered as endogenous, rather than imposed exogenously; surprises and discontinuities can be postulated and their plausibility and impacts tested.

Framing and relevance

Scenarios also accept that there are multiple social and political realities, that many of these have a claim to legitimacy, and that the interests represented by these alternative realities may often conflict in the portrayal of 'the future'. The involvement of stakeholders in the process makes explicit diverse opinions about the future, as well as the interests behind them. Framing assumptions are not embedded within the mechanics of modelling approaches, but become transparent through debate, controversy and learning in the process of scenario elaboration. Scenario elaboration provides a forum in which multiple, tacitly-held assumptions about the future can be brought out and critically evaluated.

In the scenario elaboration process, analysis and participation are convergent. Analysis is strengthened and made more relevant through the inclusion of multiple perspectives through participation (because no single perspective is authoritative in its own right, and because there is no substitute for stakeholder judgement in addressing ignorance about the future). But participation also encourages reflection and engagement with questions of change over longer periods of time, so creating the conditions for processes of learning (and adaptation).

The participatory element not only brings together different types of expertise, but also encourages stakeholders to reveal the pictures of the future they already hold. Assumptions about the future are universal because they are inherent in the actions and beliefs of individuals and organisations. Participatory scenario analysis sees these 'futures routines' as a body of practice that can be revealed. They are a resource of assumptions and knowledge that can be drawn upon in a structured analysis of futures. The aim is to engage a variety of opinions about the future and to synthesise them through a process of scenario elaboration. Participation is important because in a more active role, futures exercises seek to challenge tacit assumptions about future change, enabling their *reconstruction* by the actors involved in the process. This process of reconstruction may be characterised as a learning process because it encourages collective self-reflection about assumptions that were previously tacit and may help orient actors and decision makers towards a set of commonly-agreed outlooks on the future (Senge, 1990; Schön and Argyris, 1978). There is therefore a dual benefit to participatory approaches – they provide the narrative resources for scenario elaboration (policy learning); while also generating critical self-reflection and preparing the conditions for change (organisational learning). It is in this joint sense that scenario tools can be regarded as 'learning machines'. Futures research, including all elements of climate impact assessment, is most likely to achieve its intended impacts of learning if the framing, scaling and interpretation of futures are carried out by the actors whose futures are being portrayed.

Mapping the future

The history of futures research

Futures research has heterogeneous traditions and strands, including scenario planning ('La prospective') and strategic management. It has been influenced by a number of schools, including the RAND corporation, Stanford Research Institute, Shell, SEMA Metra Consulting Group, and many others (cf. Ringland, 1998; van der Heijden, 1996). Futures research has its foundations in early systems thinking in the 1940s, where it was mainly linked to national defence strategy. The 1950s and 1960s saw the emergence of rationalistic and control-oriented planning approaches. Early futures studies, for example Herman Kahn's famous book 'The Year 2000' (Kahn and Weiner, 1967), tended to over-estimate the potential of modern technology, as well as the reliability of forecasting. More often than not, predictions proved to be wildly incorrect. In the 1960s, policy makers and industry realised the need for better long-range forecasting (de Jouvenel, 1967).

The 1970s saw a new wave of interest in scenario planning, especially as a part of corporate strategic planning, following the example of Royal Dutch Shell (Schwartz, 1991) stemmed from the traumatic effect of the 1973 'oil crisis', which emphasised the possibility of major unexpected changes in the international economic system (Godet, 1987). During this period a number of influential studies supported by transnational industrial bodies – Limits to Growth sponsored by the Club of Rome, and the World Energy Council studies of the future of energy technologies – were published that made predictions about long-term resource needs (Meadows, 1972). These accounts were criticised for being overly pessimistic, for adopting a naïve view of technological change and for excluding important stakeholders (Cole *et al*. 1973). But they did precipitate research into alternatives, including the influential debate about 'soft energy paths' which rumbles on today (Lovins, 1976).

The popularity of scenarios as a focus for public debate and corporate planning declined during the 1980s with the onset of economic recession and more market-led management. The more recent revival of interest in scenario and 'visioning' approaches (Hertin *et al*., 1999; European Environment Agency, 2000) in both private sector and public sector decision-making has several explanations. Major transformations in technology and the arrangements of markets (globalisation, liberalisation) have made companies more vulnerable to sudden, exogenous shocks in their operating environments. In policy making arenas, the need to respond to long-term 'global' concerns about environment (climate change) and a growing recognition of the need for less deterministic approaches to 'technology steering' (for example, Martin and Irvine, 1989) also produced a need for tools for apprehending the future, and bringing it to bear on current decisions. These demands reinforced a shift from forecasting approaches – explaining the future by extrapolating trends and relationships of the past – towards more exploratory approaches to considering uncertainty and searching for potential discontinuities. Among this new generation of futures studies are the Special Report on Emissions Scenarios (SRES) emissions scenarios developed by the IPCC, in which qualitative scenarios are used as a basis for making quantitative projections about greenhouse gas emissions up to 2100

(Nakicenovic *et al*. 2000). Other examples include World 3 (Meadows and Meadows, 1991), TARGETS (Rotmans and de Vries, 1997) and IMAGE (Rotmans, 1990).

The scenario approach

No unique approach to scenario construction exists, and the literature distinguishes between two major categories of scenario exercise:

Normative scenario approaches (backcasting) are built on positive or negative visions of the future and explore pathways of change and decision points that might lead to them (cf. Dreborg, 1996). Here 'the future' is pictured as a single state and capacity of social agents to make the changes necessary to move towards this state is highlighted. This approach approximates closely to traditional objective-based planning in which milestones are set and actions enumerated.

Exploratory scenario approaches posit alternative socio-economic conditions and attempt to construct plausible representations of the future. These representations are seen as alternatives against which current strategies may need to be robust (the notion of 'robust strategies'). Here 'the future' is pictured through the elaboration of multiple alternative states over which social agents may have limited control, but against which they can respond more or less gainfully. This approach sets itself apart from traditional planning by stressing the importance of adaptation to new circumstances.

Current approaches tend to stress the exploratory, heuristic and creative elements of scenario development, and the role of participation by diverse stakeholders. These exploratory approaches are based on four key assumptions:

1. The future cannot be described as a persistence of past trends. It can be shaped by human choice and action.
2. The future cannot be foreseen, but exploring the future can inform the decisions of the present.
3. There is not only one possible future. Uncertainty and ignorance calls for a diverse set of futures (scenarios) mapping a 'possibility space'.
4. Developing scenarios involves both rational analysis and subjective judgement. It therefore requires interactive and participatory methods. Users of scenarios must participate in their generation and evaluation.

The French school 'La Prospective' developed a structured process for scenario elaboration with three main elements: identification of the key independent and dependent variables; analysis of actor roles and strategies; and construction of plausible scenarios on the basis of assumptions about key variables and consistency between them (Godet *et al*., 1996).

Explicitly or implicitly, these three steps build the core of most scenario exercises. However, large differences exist with respect to the methods used to build, test and refine them. More formal techniques based on expert knowledge include numerical modelling,

Delphi and SMIC (an expert consensus method); creative exercises such as brainstorming and scenario writing; and interactive methods such as futures workshops.

The link between participatory and expert-based scenario techniques remains problematic, mainly because they are represented by distinct methods. Expert-based scenarios are typically articulated through models, while participatory methods are far more methodologically heterogeneous. Greeuw *et al.* (2000) argue that these approaches can be regarded as being distinct, while accepting that a balance of methods enabling their interaction is a desired goal. In general, the narrower and more technical the issue, the better defined the options, and the shorter the time interval, the more useful are quantitative techniques. Under conditions of higher uncertainty the authority of formal methods and experts tends to decline. The virtue of quantitative techniques remains, however, a matter of controversy amongst practitioners of futures research (Fontela, 2000).

Developing scenarios for climate change impact assessment

The approach

In the following two sections we describe one scenario approach and its application to climate impact assessment. The Non-Climate Futures study developed an exploratory socio-economic scenarios approach relevant to climate change impact assessment in the UK (UKCIP, 2001). It was funded by the UK Climate Impacts Programme (UKCIP) to complement the UK climate change scenarios (Hulme and Jenkins, 1998) it had previously supported. The objective was to combine the two scenario approaches – one dealing with changes in climate variables, the other dealing with change in socio-economic variables – in a more integrated approach to UK regional impacts assessment studies (Hedger *et al*., 2000). The time horizon for the scenarios were intended to match those of the UK climate scenarios (2020, 2050 and 2080). Most attention was given to the period to 2020 and 2050, since few stakeholders would find value in exploring developments beyond 50 years.

On the basis of a review of futures literature, the study generated a generic, open and scalable framework for elaborating a scenario set using differing assumptions about the influence of particular drivers, trends and actors. This framework included dimensions, storylines and indicators, drawing on an earlier futures exercise for the Natural Resources and Environment Panel of the UK Foresight Programme (Office for Science and Technology, 1998) and upon the IPCC emissions scenarios (Nakicenovic *et al*., 2000). Consistency with the IPCC approach was sought to avoid a proliferation of mutually exclusive frameworks. The scenarios aimed to describe social and economic conditions in a range of possible futures that could be used to assess regional and sectoral vulnerability and policy responses to climate impacts in the UK.

The UK Socio-Economic Scenarios (UKSES)[3] were developed through an iterative process of consultation and research, involving interviews, workshops and intensive bilateral and group contacts with climate impact researchers, policymakers at the national and regional level, and stakeholders in the business and NGO communities.[4] All aspects of the scenario framework were subject to stakeholder and peer review. The UKSES have been applied in planning by government agencies and in research-based exercises, and found to be a robust and useful basis for considering futures in a wide variety of different contexts (a summary of scenario applications is presented in Table 1).

As the scenario literature emphasises, it is crucial to identify relevant drivers, trends and actor strategies (Godet, 1987). Compared to other issues studied in scenario exercises, CIA covers a very broad range of problems. The vulnerability of individuals, groups and organisations to climatic changes and events is affected by a variety of non-climatic factors (political, technological, economic, cultural changes, for instance). The dimensions of the 'possibility space' generated in the socio-economic scenarios had to correspond with this breadth. A review of the global futures literature and continuing discussions with stakeholders identified five main dimensions of change (Hertin *et al.*, 1999): demography and settlement patterns; the composition and rate of economic growth; the rate and direction of technological change; the nature of governance; and social and political values.

The UKSES framework highlights the latter two dimensions of change. First, human demography in developed societies is relatively well-characterised in current population models. Deep trends such as the ageing of populations can be taken as givens; 'facts' about the future that do not need to be contested and debated within the scenario elaboration process. Second, economic growth can be regarded as the outcome of a set of institutional factors (economic and monetary policy, trade, the liberalisation and regulation of markets, relationships between capital and labour and so on), not as an autonomous factor of change. The UKSES approach argues that the same conditions determining the rate of economic growth will also influence the vulnerability and adaptive capacity of actors and organisations. Likewise, technology is regarded as being shaped by market, regulatory, political and cultural factors, and should not be seen as an autonomous factor of change. This corresponds with theories in evolutionary economics, which see the rate and direction of innovation as the product of economic and institutional contexts within which innovation occurs (Nelson and Winter, 1982). We therefore sought to include technology as endogenous to processes of social and technological change – an outcome, rather than an exogenous input.

To create a frame for more institutionally-based futures scenarios, we chose first social and political *values*, and second the nature of *governance* to be foundational determinants

[3] The scenarios are referred to as the UKCIP 'Non-Climate Scenarios' in the IPCC Working Group II report (IPCC, 2001) and are referred to as the UKCIP SES scenarios in UKCIP's literature (UKCIP, 2001).
[4] In total some 65 UK stakeholders, including national and regional level policy makers, participants from vulnerable sectors (water, insurance, built environment, agriculture), climate impacts modellers, and civil society organisations, were involved in elaborating the national socio-economic scenarios.

of future change. Economic growth, demographic change and technological change are therefore viewed as an outcome of social and political processes, as well as being generative of them. This framing of socio-economic futures means that the scenarios were generated from a set of conceptual associations, rather than from an empirical model of the real world. The strength of this approach is that it facilitates an open exchange of ideas in the process of scenario elaboration, making them transparent and contestable. It also keys into many contemporary political and social debates in the UK about the nature of government, the role of the market, political relationships within the European Union, and the social control of new technologies (information and communication technologies and biotechnology in particular).

However, 'values' and 'governance' are not simple, independent or easily definable concepts. In using them to construct a scenario framework we have made a number of simplifying assumptions about what they mean, and about the range of different values and models of governance that are considered. We take *values* to mean contemporary tastes, beliefs and norms, and *governance* to mean the way in which authority and control is exercised in societies – whether local, national or global.[5]

While there are obvious connections between values and structures of governance (a democratic society can only function if democratic values prevail) we take these two dimensions to be independent in this scenarios framework, for three primary reasons. First, many of the key social science debates centre on the role of values and ideas on the one hand, and interests embedded in institutional structures on the other (Giddens, 1982). Values are often held to play a role in supporting or legitimating structures of power, but they can also have a role in disrupting and changing them. Likewise, structures of power can be seen as creating the essential conditions within which values, ideas and knowledge and generated and sustained (Barnes *et al*., 1996; Latour and Woolgar, 1986). Crucially, ideas/values and structures of governance are regarded as analytically separate in other domains of scholarship.

Second, socio-economic scenarios confront the central paradox of 'future social time' between the opportunity to reflect upon and remake the future, and the cultural, institutional and other constraints that limit the scope for change in social systems (the 'stickiness' of institutional routines, March and Olsen, 1989). The values-governance frame of the scenarios can be seen as representing these institutional constraints, allowing the scenario elaboration process to focus more on the reflexive and creative opportunities in the possibility space. Third, experience showed that the two axes were well understood and tractable for participants in scenario exercises, being neither too narrow and prescriptive, nor too obtuse.

[5] By *governance* it is meant something wider than *government* (see Rhodes, 1997). Government refers to governmental institutions. Governance also includes non-governmental (private sector, civil society, regional and international organisations) institutions with a role in exercising and shaping the exercise of power in society.

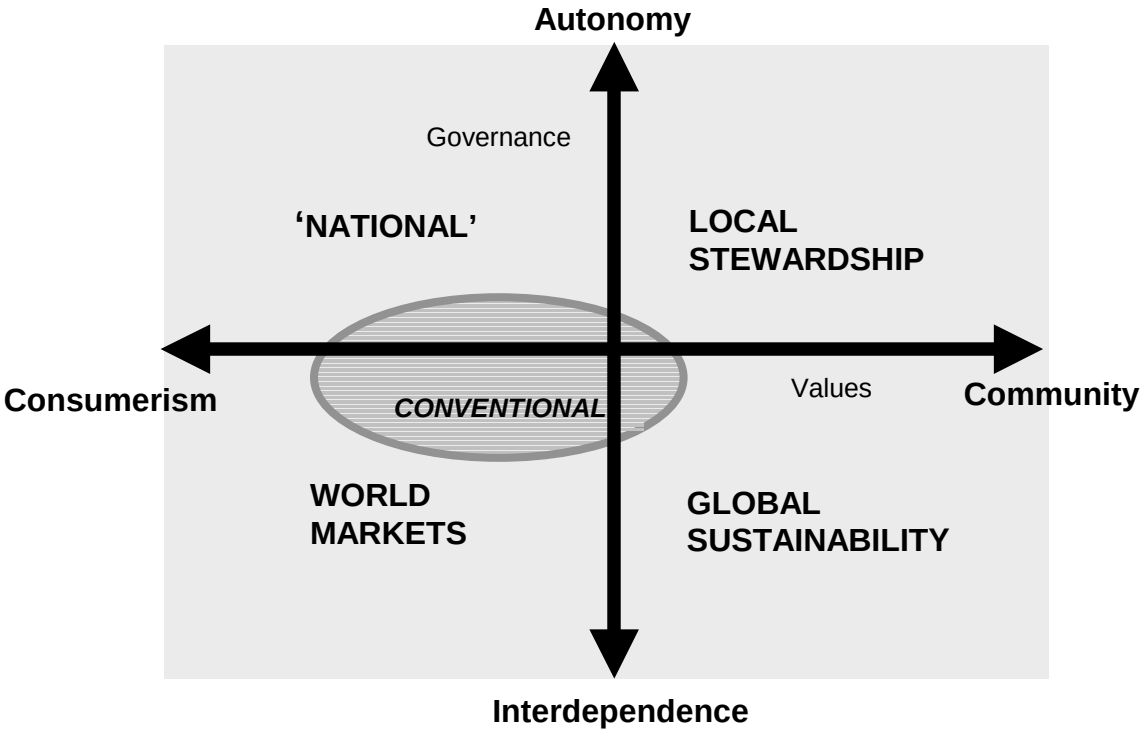


Figure 1: Four socio-economic scenarios for climate change impact assessment

The scenarios framework is illustrated in Figure 1. The framework represents future states within a two-dimensional matrix defined by axes describing two qualitative drivers of change. This matrix approach – not uncommon in scenario building (see Ringland, 1998) – was chosen because it supports systematic thinking, as well as for its simplicity. The two dimensions describe four quadrants in the 'possibility space' that is populated with scenarios.[6] The horizontal 'values' dimension captures alternative developments in core values represented in choices made by consumers and policymakers. At one end of the spectrum ('Consumerism'), values are dominated by the drive to private consumption and personal freedom. The rights of the individual and the present are privileged over those of the collective and the future. Resources are distributed through free and competitive markets, with the function of governance limited to guaranteeing trade and capitalist accumulation. At the other end ('Community'), values are shaped by concern for the common good. The individual is seen as part of a collective, with rights and responsibilities determined by social goals. There is greater concern about the future, equity and participation. Civil society is strong and highly valued, and resources are allocated through more heavily regulated markets.

The vertical governance dimension aims to show alternative structures of political and economic power and decision-making. The future of governance at the UK and regional levels will be influenced to a great extent by developments in the European Union, and at the global level. At one end of the spectrum ('Interdependence'), the power to govern is

[6] Global and regional scenario studies revealed a range of approaches on the question of how many scenarios should be developed (3 to 17 scenarios) (Hertin *et al*., 1999).

distributed upwards, downwards and outwards away from the national state level. International economic, political and cultural relationships strengthen, and regional and national boundaries become more permeable. At the other end of the spectrum ('Autonomy'), economic and political power is retained at national (National Enterprise) and regional (Local Stewardship) levels. Sovereignty is retained over key areas of policy, and the processes characterised as 'globalisation' are weakened. Governments have greater autonomy in decision-making, and economic, political and cultural boundaries are maintained or strengthened. National and regional development is based on more closely linked to local capabilities and resources.

Four Futures Scenarios

These two framework dimensions generate a set of associations which can be applied to understanding socio-economic changes at a national, regional and sectoral level. In this study, the scenarios refer to the UK set in a global context in the 2020s. Broad socio-economic trends are presented in a number of 'driver domains': governance, role of the state, economic policy and structure, international trade, sectoral development, planning, energy and transport. Storylines were also elaborated for 'impact domains' judged to be most sensitive to a changing climate: agriculture, water, biodiversity, and coastal zone management. The scenarios were designed to provide a socio-economic baseline against which climate change can be assessed. Therefore, they do not at this stage assume any adaptation to climatic effects. This analytical distinction corresponds with the IPCC guidelines (Carter *et al*., 1994), but has been criticised for ignoring the 'co-evolution' of climatic and socio-economic systems (Lorenzoni et al., 2000).

Each of the scenarios was developed with two elements: a qualitative storyline and illustrative quantitative indicators. The storylines were designed to be self-consistent and clearly distinctive from each other. This means that the storylines should be considered in relation to each other. A principle of *symmetry* was applied during elaboration. That is, no a priori assumption was made about the plausibility of any one scenario, a common template was used for elaborating each storyline, and equivalent effort was expended on elaborating storylines across each quadrant. Furthermore, a process of *triangulation* was developed whereby narratives for each scenario were systematically compared with each other to ensure their deductive coherence and distinctiveness. Scenario indicators were developed on the basis of official statistics and through close collaboration with sector specialists.

Given a particular objective, the elaboration of scenario storylines will be dependent on the skills of the co-ordinator of a study, the range of participants in the process and the quality of the interaction that takes place between them. All scenario elaborations are therefore the product of unique and contingent processes. This is both a strength (they are fit for purpose) and a weakness (they are perceived as unvalidated). To the extent that the UKSES build on the earlier SPRU/OST scenarios and were subject to wide stakeholder consultation, they may be seen as widely recognised as appropriate, if not validated in any formal sense. In this section we illustrate the scenarios with abbreviated

contextual information about the driver domains (Table 2) and examples of futures across different impact domains. The aim is to demonstrate the range of results derived and the flexibility and scalability of the scenario approach.

Through a process of deduction from these assumed institutional contexts, implications for driver and impact domains can be elaborated. Some examples of this process are presented below: the agriculture domain under National Enterprise (Box 1); and the biodiversity domain under Local Stewardship (Box 2). In each case impacts are described at the UK-national level.

Box 1: UK agriculture under National Enterprise
Agricultural policy aims to protect the British agricultural and food industry and to ensure the availability of high-quality food at modest prices. There is little concern about the rural environment. Public support for agricultural production continues through a modified Common Agricultural Policy and national subsidies. As a result, consumer prices remain relatively low. There is almost no link between public support and environmental objectives. Self-sufficiency in food supply increases slightly because of trade barriers and subsidies. Diets do not change radically, meat consumption remains high. Trade in food commodities continues but there is less development of global markets for seasonal and high-quality food inputs. Retailers have a strong influence over farmers, but this is manifested in requirements for uniform, high quality products, rather than for sustainable farming practices. Current agricultural practices intensify with high inputs of pesticides and fertilisers. The uptake of genetically modified organisms is patchy, drawing on the UK science and industrial supply base. There is a moderate trend towards large farms. Agricultural productivity increases within the limits of conventional technologies. This leads to a further decrease in the area devoted to UK agriculture. Productivity growth slows gradually.

Box 2: UK biodiversity under Local Stewardship
The vulnerability of species and habitats varies, but is generally lower due to lower growth and tougher planning controls. However, the extension of agricultural areas may have negative effects on biodiversity. To balance this, strenuous efforts are made to preserve wildlife at the local level, both in rural and urban areas. The shift away from high input and large-scale livestock agriculture to more diverse and organically-based farming may also ameliorate this impact. Planning controls ensure that land is set aside for nature conservation and that habitats are protected from housing and industrial development. Tensions arise because demands for public access to conservation areas puts pressure on ecologically vulnerable areas.

Scenario indicators

The role of quantification in scenario-based futures studies is a matter for debate. It can be argued that scenarios try to capture precisely those trends and aspects that do not lend themselves to quantification. Also, quantitative analysis might create the false impression of neutrality and accuracy where in practice uncertainty and judgement prevail. However, a comprehensive set of quantitative indicators were developed because they served a number of valuable functions by: providing an additional ‘reality check’ and a means to improve consistency of trends; illustrating the magnitude of trends described in the storylines; allowing a quick and systematic comparison between scenarios; making the scenarios more accessible, therefore facilitating a participatory process of scenario

development; and providing parameter values for impact assessment and integrated assessment modelling in other UKCIP-funded studies.

Definition of the indicator set was done in consultation with sector experts and with modellers in on-going UK regional climate impact assessments. All indicators are based on existing statistics or indicators for which UK national data was available. Indicator values are informed 'best guesses' based on expert judgement, in the context of the narrative storylines that had been generated. They should be seen as indicative and illustrative, rather than definitive. In practice, many values were derived by postulating variations about historical trends (where these were available). They are not the result of a comprehensive assessment involving modelling, although consistency checks were made between indicator values.[7] The derivation of indicator values was broadly regarded as an area for more productive interaction with more formal modelling methods. A number of example indicators are presented in Table 3.

Using scenarios in climate impact assessment

Scenario storylines and indicators can be used in different ways. They can generate inputs for model-based assessment studies at the regional, national, or even international level. They may be used to structure qualitative impact studies. They also have a value when used directly by policymakers and stakeholders as a means of assessing the vulnerability and adaptive capacity of different sectors to climate change. Finally, they have a role in communication and awareness-raising, by allowing stakeholders to explore possible futures. Indeed, one of the findings of the UKSES exercise was that user-driven futures scenarios are themselves impact assessment techniques, complementing the results of formal models and economic analysis. This coincides with the conclusions of the US National Assessment (US Global Change Research Program, 2000).

The use of scenarios will be specific to the context. They may be used to set the parameters of a one-off workshop, or they may be employed in concert with longer-running scientific assessment studies. As a problem-solving framework in this context, the scenario storylines and indicator sets can be developed in more detail for the sector under investigation and tailored to specific time scales. Each particular study has different needs for data and input assumptions. A sectoral or regional study might want to examine specific trends that have not been considered in developing the framework scenarios (an example of more detailed elaboration is given in Box 3). The research team carrying out a sectoral or regional study, by virtue of its expertise, will be best placed to develop more detailed scenarios.

One example of a regionally-specific application of the scenario framework, demonstrating both the scalability and flexibility of the scenario framework, comes from a project on regional climate change impacts and response studies in East Anglia and North West England (REGIS) (Shackley and Wood, 2000). Box 3 describes the impacts

[7] For instance, in projecting water demand changes for each of the scenarios, consistency checks were made with population, household size, GDP and economic activity.

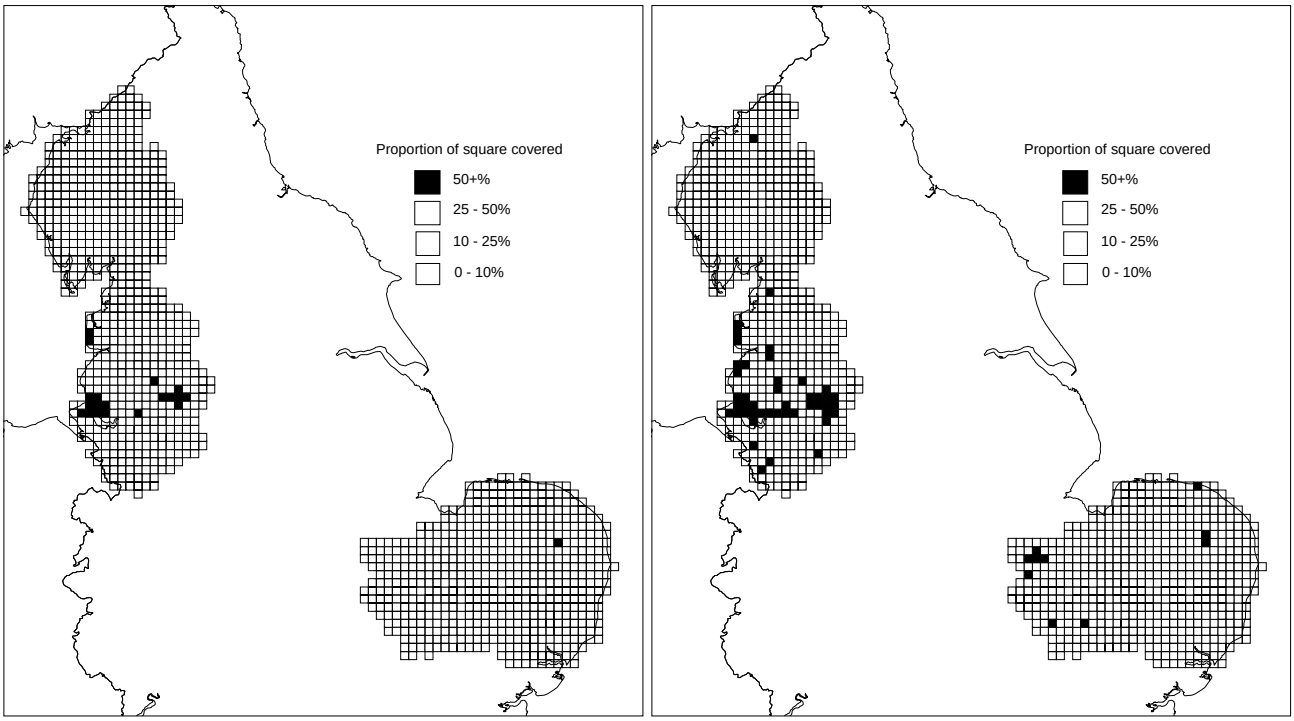
on environmental resource management in East Anglia under the Global Sustainability scenario.

Box 3: Environmental resource management in East Anglia under Global Sustainability
Water resources are regarded as a strategic national resource. Some water transfers to Essex are permitted due to greater demand there, but only if effective demand management in the South East has been undertaken, and only if strategically important wetland habitats (at the national level) are not threatened. Coastal zone protection is seen from a national strategic perspective. East Anglia receives considerable attention because it has so much vulnerable coastline. Managed realignment is the policy adopted in many regions. Resources are devoted to establishing procedures for achieving consensus on the future of the coastline. However, local objections do not stand in the way of national policy objectives. The consideration of biodiversity assets as global and EU-wide resources could bring a reassessment of protection priorities. Where EU-wide important habitats are forfeited to the sea, new areas of land will be identified for creation of replacement habitats. Coastal and inland habitats which support migratory bird populations (protected under SPA, SAC and RAMSAR designations) are an example. There could also be pressure for an increase in the overall area of EU-wide important habitats. Funding for such enhancement will come from a central EU fund for such projects. Collectively, the pressures suggest that, using natural hydrological dynamics, significant parts of the coastal plains of north west and north east Norfolk might be allowed to revert to Fenland habitat, also enhancing sustainable flood control.
Source: (Shackley and Wood, 2000).

In the REGIS study the scenario framework was adjusted to take account of the particular interests and perspectives of planners and policy makers at regional levels of government in the UK. The National Enterprise scenario was reframed as a more regionally-based and entrepreneurial future called Regional Enterprise. Scenario elaborations were used to produce key parameter values for model runs for a number of spatial and non-spatial variables: patterns of urbanisation; crop and produce prices and so on (Hedger *et al*., 2000). One example is the production of modelled scenarios for urbanisation in the two regions (see Figure 2). Key parameter values derived using the scenario framework were regional population, household numbers and dwelling densities, together with expert judgements about how urban development would evolve under the different scenarios.

The use of the scenarios for local stakeholders poses different challenges. In particular, interviews carried out in the context of this UKSES study showed that the analytical distinction between 'climate' and 'non-climate' socio-economic futures does not resonate with many practitioners. For instance, climate change is already an integral element of strategic planning in the electricity supply and insurance sectors. For these sectors there is no socio-economic baseline of the world 'without climate change' because they have already taken steps to reduce their emissions and enhance their adaptive capacity.

Figure 2: Urbanisation patterns in NW England and East Anglia: present day and 2020 under Regional Enterprise scenario (Source: Shackley and Wood, 2000)



Conclusion

We have argued that climate impact assessment must develop tools to handle change in socio-economic systems. Impact assessment requires an account both of future climatic conditions, as well as future social and economic conditions. However, the paper also argues that the question of how to deal with the temporal (particularly the future) dimension in social systems is manifestly different and arguably more complex than in natural systems because of the differences between the two systems. In particular we emphasise the importance of complexity (imperfectly understood structures and processes), innovation (the expectation of novelty and surprise in technological and social systems), reflexivity (the ability of people and organisations to reflect about and adapt their behaviour) and framing (the legitimacy of diverse and conflicting attitudes to the future). Current scholarship relies on a rather simplistic, deterministic view of social time in climate impact assessment that does not do justice to these difficulties. In particular, it rests on the idea that a 'non climate' baseline of social and economic future can be segregated from a climate-influenced state.

Innovative new techniques that combine participation, transparency and flexibility with a systematic approach to elaboration and analysis are needed to integrate conceptions of future social time in climate impact assessment. We have argued that futures scenarios represent one such technique. An example of a socio-economic futures scenario framework developed for the UK is presented, and its conceptual foundations are

explained. The basic framework has been applied across a range of different policy and technology domains over the past three years. It emphasises the importance of ideological and institutional factors as drivers of social and economic change, in place of more conventional technological and economic drivers. Some examples are given of applications in UK regional climate impact assessments, demonstrating the flexibility and scalability of scenario framework. These show how qualitative scenario approaches can be linked to more formal modelling approaches. In this role, scenarios operate as antecedents to impact assessment or integrated assessment modelling.

Finally, we believe that the problem of how to handle future social time puts into question the function of climate impact assessment, and more broadly integrated assessment. Implicit in the arguments of this paper is the perception that the purpose of climate impact assessment should be not only analysis, but the broader goal of social learning. Even if it is possible to predict with increasing confidence a changing climate, the prediction of social responses to this changing climate will always remain out of reach. In this context, a robust approach is to put in place tools that can enable processes of institutional learning – by setting the frame for iterative processes of self-reflection, change and adaptation within organisations.

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Table 1: Overview of uses of OST/SPRU scenarios

Organisation/User	Sector	Aim	Type	Process	Output / Key Audience
ACACIA research project	climate change	assess climate change impacts (EU, 2050)	detailed, qualitative and quantitative	based on data and expert knowledge, small team	report / EU policy
REGIS research project	climate change	assess climate change impacts (NW England and East Anglia, 2020, 2050)	detailed, qualitative and quantitative	based on data and expert knowledge, small team	report / UK policy
Climate Change and the Demand for Water research project	climate change and water demand	assess impacts of climate change on water demand	detailed, qualitative and quantitative	based on data and expert knowledge, small team	*underway* / UK policy
CSERGE, University of East Anglia	climate change	explore climate change impacts (East Anglia, 2020/2050)	detailed, mainly qualitative	structured stakeholder interviews	report / regional stakeholders
Environment Agency, National Water Demand Management Centre (NWDMC)	water demand	assess levels and structure of water demand (2025)	detailed, mainly quantitative	based on data and expert knowledge, small team and consultation	National Water Strategy/ UK policy and business
Digital Futures research project	ICTs and e-commerce	explore the digital economy (2010, 2020)	detailed, qualitative and quantitative	based on data and expert knowledge, small team and consultation	report / UK policy and business
Foresight – Crime Prevention Panel	crime	explore issues of crime and crime prevention (2020)	sketchy, qualitative	participatory workshop	consultation document / UK policy and business
Foresight – Integrated Transport Chain Task Force	transport	assess priorities for sustainable transport strategy	detailed, quantitative and qualitative	workshop, detailed elaboration by project manager	report/UK Government
Foresight – Energy Futures Task Force	energy	assess sustainable energy technologies	sketchy, qualitative	based on data and expert knowledge	report/UK Government
Foresight – Minerals Panel	minerals	assess sustainability of minerals extraction and use	detailed, qualitative and quantitative	workshop	report/UK Government
Natural Environment Research Council	environment	identify environmental research priorities	sketchy, qualitative	participatory workshop	report / ENE Panel, NERC science policy
UK Cabinet Office Performance and Innovation Unit	trade	assess social and ethical issues in international trade	detailed, qualitative	workshop	Report/UK policy
ESRC Financial Services Environmental Network	Financial services	explore ethical and environmental impacts on financial products	sketchy, qualitative	workshop	report/financial services industry
Housing / Future Skills	Built environment	offered as strategic planning tool	n.a.	n.a.	construction and engineering industries
Environment Agency	Environmental protection	element of corporate 'visions' exercise	illustrative scenarios developed for nine environmental themes	workshop	input to early framing of 'Visions' report

Table 2: UKSES synopses

Scenario	*Synopsis*
National Enterprise	Private consumption and personal freedom are overarching social and political objectives. Policy aims to balance these with the preservation of a strong national identity, and national sovereignty over key areas of economic, social and security policy.
Local Stewardship	Equity, social inclusion and environmental sustainability are social and political priorities. Policy seeks to achieve these while enhancing local and regional-level autonomy. A more federal UK political system leads to greater focus on regional resources and capabilities within a more participatory political culture. Regional distinctiveness grows.
World Markets	Private consumption and individualisation within a global culture are fundamental aims in society. Policy aims to achieve these by assuming a position of a 'minimal state', promoting liberalised global markets and through international political and monetary integration.
Global Sustainability	Political and social values are shaped by the desire to preserve and improve collective goods and social capital. Policy aims to achieve these goals by balancing private and market-based rights with communitarian obligations. This is achieved through international co-operation and the active promotion of technological and social change.

Table 3: Indicators for the UK in the 2020s

	Today	Linear trend	'National' Enterprise	Local Stewardship	World Markets	Global Sustainability
Economy						
GDP growth (p.a., 1995-2025)	+2 %	+ 2 %	+ 1.75 %	+ 1.25 %	+ 3 %	+ 2.25 %
GDP / capita (p.a.)	£ 10,500	£ 18,500	£ 17,000	£ 15,000	£ 24,000	£ 20,000
...						
Planning						
Household numbers	24.5 million	28 million	25.5 million	23 million	31 million	27.5 million
Passenger kilometres (p.a.)	690 billion km	1100 billion km	900 billion km	700 billion km	1200 billion km	900 billion km
...						
Agriculture						
Agricultural area under production	18 million ha	17 million ha	17.5 million ha	18.75 million ha	16 million ha	17 million ha
Pesticide usage (average)	3.8 kg / ha	*no stable trend*	4.0 kg / ha	1.5 kg / ha	3.0 kg / ha	2.0 kg / ha
...						
Coastal Zones						
Protected coastal zone	240,000 ha	*no data*	235,000 ha	220,000 ha	240,000 ha	225,000 ha
Investment in coastal defence	£ 200 million	£ 225 million	£ 230 million	£ 150 million	£ 350 million	£ 200 million

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The inter-disciplinary Tyndall Centre for Climate Change Research undertakes integrated research into the long-term consequences of climate change for society and into the development of sustainable responses that governments, business-leaders and decision-makers can evaluate and implement. Achieving these objectives brings together UK climate scientists, social scientists, engineers and economists in a unique collaborative research effort.

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