Socio-economic scenarios in climate change research: a review

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1. Introduction

The *Socio-Economic Scenarios for Climate Change Assessments* project will provide socio-economic scenario resources for climate impacts and adaptation research and policy in The Netherlands. The scenarios and scenario resources (storylines, parameter values, numerical and simulation models and process guidance) will be designed with and for stakeholders in two BSIK Programmes Klimaat voor Ruimte (KvR) and Leven met Water (LmW). These stakeholders include researchers, as well as principal users of KvR and LmW research in Government agencies, the private sector and NGOs. The project is stakeholder-driven and synthetic, drawing on existing scenarios, including the Welvaart en Leefomgeving (WLO, 2006) scenarios developed by MNP, CPB and RPB.

The definition of a scenario used in the Millennium Ecosystem Assessment (2005: xvii) is:

> 'Scenarios are plausible, challenging and relevant sets of stories about how the future might unfold. They are generally developed to help decision-makers understand the wide range of possible futures, confront uncertainties and understand how decisions made now may play out in the future.'

Climatic change is both anthropogenically-forced and has impacts on biophysical and socio-economic systems. A defining characteristic of changes in climate is that they are likely to occur over the long-term – periods measured in decades and centuries. Understanding the likely possible course of climatic change therefore requires, on the one hand, long-term projections of anthropogenic forcing in terms of global emissions of greenhouse gases (GHG). For this purpose the IPCC and many others have developed emissions scenarios based on assumptions about energy supply and demand, and the structure of energy supply systems.

On the other hand, in order to assess the possible vulnerability of eco- and social systems to future climatic change and to calculate damage costs, it is also necessary to build up a picture of the future societies and economies that may be impacted by climatic change. It is evident that economic growth, demographic change, technological change, changes in governance, changes in lifestyle and so on will influence the vulnerability to climatic change impacts of different groups in The Netherlands and internationally. We would also expect he capacity of these groups to adapt to reduce their exposure to new risks, to be able to respond to negative impacts and to take advantage of new opportunities emerging from climatic change to evolve through time. On these grounds, it is not sufficient to assume, as many early climate impact studies did, that the future resembles the present.

For this reason there is a need for socio-economic scenarios to inform research and policy related to climatic impacts and adaptation. These scenarios can build on the foundations of earlier scenario exercises, but need to be tailored to the specific needs of climate assessments.

The objectives of this report are:

- To review social and economic scenarios relevant to integrated climate change assessments;
- To make recommendations for good practice; and
- To reflect on key issues in the use of scenarios in climate assessment.

2. A brief history of scenarios

The 'futures' literature related to climate change is not well organised.[1] Broadly we can identify 'global' scenarios and more specific, 'domain' scenarios. The boundary between what to leave in and what to leave out is also not always clear. Government departments in all countries and many industrial companies use projections and scenarios for planning purposes. Environmental research also increasingly uses scenario approaches. We have chosen to include only studies that appear to have a significance in relation to climate impacts and adaptation research.

2.1 Scenarios studies relevant to the environment

Scenarios have been used since the 1970s to bring the issue of environmental damage and resource use to the attention of policy makers and the general public.[2] In general, the aim of these studies was to illustrate the negative consequences of continuing to develop economically with a 'business as usual' scenario. *Limits to Growth* came at a time of great fear about scarcity of mineral and key renewable resources and was an important influence on the first wave of environmentalism and environmental policy. These early studies also made the argument that the *rate* of economic, technological and social changes was accelerating, that socio-economic systems were becoming increasingly *embedded* in ecological systems, and that this meant increasing *uncertainty* about what the future held. These features are all shared with contemporary studies.

By the early 1980s it was clear that many of the predictions contained in these studies would not be fulfilled. In addition, government policy and ideology became less sympathetic to the idea of long-range planning and intervention. Interest in scenario exercise waned at a time of more rapid economic growth in the OECD, falling raw materials and energy prices, and declining interest in environmental issues, with one exception. The oil and gas industry, having created scenarios and long-range planning capabilities during the 1970s continued to develop and apply them to strategic decision-making. Much current interest in environmentally-relevant scenarios is related to expertise accumulated during this period in the oil industry.

The second environmentalist wave beginning in the late 1980s did not immediately lead to renewed interest in long-range scenarios.

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[1] One recent review of scenario studies relevant to climate assessment in The Netherlands is: Eerste Kamer der Staten-Generaal, Brief van de minister van volkshuisvesting, ruimtelijke ordening en milieubeheer, XXI-G, Den Haag, 8 november 2005.

[2] Early studies include: Meadows, D.H., Meadows, D.L., Randers, J. and Behrens W.W. (1972), *Limits to Growth*, Basic Books, New York; M.D. Mesarovic and E. Pestel (1974) *Mankind at the Turning Point*, Dutton, New York; H. Kahn and A. Wiener (1967) *The Year 2000*, Macmillan, New York; G.O. Barney (1980) *The Global 2000 Report to the President of the US, Entering the 21st Century*, USGPO, Washington DC.

However, as the global and long-term nature of the new environmental agenda became clearer, and the need for long-range projections to make policy on problems such as acidification, ozone depletion and climate change became more obvious, there has been a greater interest in scenarios since the early-1990s. With the progressive development and implementation of policies for sustainable development, with its stress on integrated and long-term approaches to environmental, social and economic policy, the use of scenarios has become all-but universal in environmental policy and sustainability assessments.[3]

Classes of Scenario

A wide range of different scenario exercises have been identified in the literature, each with different aims, approaches and outputs.[4] For simplicity, we have classified these into two classes: global and domain. We have also surveyed studies with projections which do not constitute scenarios, but which were relevant to the construction of contextual scenarios.

Global scenarios are exercises that provide an integrated picture of future developments and they are frequently used to frame global assessments of environmental problems (for example, climate change (IPCC) and biodiversity (MA)). By implication, they are concerned with characterising multiple driving forces and contexts for change in the future. The main results include both specific projections (GHG emissions rates) and statements about the general state or capacity of global economic or ecological systems. Many global scenarios share common intellectual roots, share convergent visions of the future (see Figure 1) and have applied the scenario-axis technique.[5]

National scenarios are an intermediate and less common category of scenarios. Here the work of the Dutch *planbureaus* and government research agencies (CPB, RPB, RIVM, ECN and MNP) stand out. Scenarios are especially strongly represented in Dutch policy-making at various governance levels.[6] A recent inventory of Dutch scenarios counted 150 publicly available scenario reports.[7] The major Welvaart en Leefomgeving (WLO, 2006) study, a collaboration between the CPB, MNP and RPB, is an especially broad-based domain scenario study and is the outcome of this major investment in scenario studies in The Netherlands over the past decade or more.[8]

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[3] The primary global scenarios applied to environment ans sustainability have been: Global Scenarios Group Scenarios (Gallopin, 1997); The Special Report on Emissions Scenarios (SRES, 2000); and the Millennium Ecosystem Assessment (MA, 2005).

[4] For recent reviews see: MA (2005) *Volume 2: Ecosystems and Human Well-Being*, Island Press, Washington DC; and T. Parson et al. (2006) *Global Change Scenarios: Their Development and Use*, US Climate Change Science Progam, Washington DC.

[5] S.A. van 't Klooster and M.B.A. van Asselt (2006) Practising the scenario-axis technique, *Futures*, 38: 15-30.

[6] Key among these are two CPB studies: Tang, P. and R. de Mooij (2003) *Four Futures of Europe*, CPB: den Haag; and Huizinga, F. and B. Smid (2004) *Vier vergezichten op Nederland, productie, arbied en sectorstructuur in vier scenario's tot 2040*, CPB: Den Haag.

[7] See also: www.toekomstverkenning.nl.

[8] CPB/MNP/RPB (2006) Welvaart en Leefomgeving, Den Haag.

GSG	SRES	WBCSD	GEO-3	WWV	OECD
Conventional worlds					
Market forces	A1	FROG!	Markets first	B-a-u	Reference
Policy reform	B1	GEOpolity	Policy first	Technology and economics	Policy variants
Barbarization					
Breakdown	A2				
Fortress world			Security first		
Great transitions					
Eco-communalism	B2				
New sustainability paradigm		Jazz	Sustain-ability first	Lifestyles and values	

Key: GSG Global Scenario Group, GEO-3 Global Environment Outlook, SRES Special Report on Emissions Scenarios, WBCSD World Business Council on Sustainable Development, WWV World Water Vision, OECD Organisation for Economic Co-operation and Development

Figure 2.1 Global Scenarios compared[9].

Domain scenarios are generally concerned with developments around single issues or domains. These may also be concerned with several driving forces and contexts at local, national and international levels, but they are typically more tightly-defined and less integrative in approach than global scenarios. The level of specification and quantification tends to be higher, and the focus is on narratives and projections for key variables (growth in transport or declines in environmental quality, for instance).

Scenario Study Objectives and Approaches

The underlying rationale of futures studies has shifted between the 1970s and 1990s from being *predictive*, to being what the French call *prospective*: to illuminate choices of the present in the light of 'possible futures'.[10] The aim is '...to clarify alternative world views and challenge conventional wisdom...'.[11] Good prospective studies are not necessarily those that are realised, but those which '...lead to action, avoiding the dangers, and arrive at the desired objective.'[12] One presumption underlying the work of the Prospective School was that the more specific the scenario, the more likely it is to lead to action. While 'global' scenarios may have an important role in providing the frame for integrated assessments, they tend to have limited direct impact on the decisions of policymakers, or the actions of organisations and individuals may be hard to measure. Domain scenarios are more likely to have such impacts on public and private sector decisions. The benefit of global scenarios is that they provide a context for nested

[9] MA, op cit.: 42.

[10] M. Godet and F. Roubelat (1996) Creating the Future: The Use and Misuse of Scenarios, *Long Range Planning*, 29, 2: 164-171.

[11] G.C. Gallopin and P. Raskin (1998) Windows on the Future: Global Scenarios and Sustainability, *Environment*, 40, 3, April: 6-31.

[12] op cit. p 164.

sectoral scenarios and projections, while permitting a more critical and imaginative attitude to analysis.

Dimensions of Change: Global and National Studies

Global futures studies are complex imaginative accomplishments. They are distinguished by being multidimensional, in the sense of being concerned with many underlying factors causing change in society and the economy of countries and global regions. Five main dimensions of change can be identified in these studies: economic development; the nature of governance; technological change; demographic change and social change.[13]

Economic Development

Economic development refers both to assumptions about the rate of economic development, measured in most studies in terms of gross world product (GWP) or gross domestic product (GDP) growth,[14] and the nature of economic development. Average rates of economic growth generally fall in the range of 1.5 -3.5 percent per year. This is a relatively unproblematic range based on long-term experience in the world economy. However, compounded over long time periods, small differences in growth assumptions will have a major effect on supply and demand assumptions for key environmental services.

The nature of economic change and its relationship with governance has also become a concern of many global scenario exercises. In particular, a dichotomy is explored between economic systems that are relatively more open and globalised, and economic systems that are shaped more strongly by social, political (and environmental) objectives. A trade-off is typically assumed to exist between the rate of economic growth and the quality of social and environmental development, although globalised 'sustainable development' scenarios argue that a reconciliation of the two objectives is possible, primarily through a focus on alternative technological paths and consumer behaviour.

Nature of Governance

Forms of socialised or communal economic development do not feature much in current scenarios. However, very different attitudes to the role of different levels of governance have become a concern. In general, the national government as the primary authority structure is seen as under threat, either by globalising capitalism, or by the rise of powerful international organisations (including the European Commission). In general, persistence of state authority is equated with politically less stable futures as in the 'Barbarization' scenario in Gallopin et al. (1997),[15] the 'Rough Neighbours'

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[13] SPRU/CSERGE/CRU/PSI, *Socio-Economic Futures Scenarios for Climate Impact Assessment: Non-Climate Futures Study*, SPRU: University of Sussex, November 1999.

[14] The WBCSD scenarios use an alternative measure, Index of Sustainable Economic Welfare (ISEW).

[15] Gallopin, G.C, Hammond, A., Raskin, R., and Swart, R (1997). Branch Points: Global Scenarios and Human Choice. Stockholm Environment Institute, PoleStar Series Report no. 7. Stockholm.

scenario in Chatham House (1996), 'Battlefield' in CEC DGXVII (1993)[16], B1 scenario in SRES (2000) and 'Order from Strength' in MA (2005).

Once again, two poles can be identified. In the first, governance structures become increasingly globalised and shared between states and interest groups. This is in response to greater needs for co-ordination and management of the global system, partly because of threats to its stability and the need to manage global environmental services collaboratively. The WBCSD 'Geo-Polity' scenario (1998) is an example of this, being a response to the shift of economic power and cultural values to Asia. In the second, international institutions remain weak compared with nation states which are unwilling to cede power to them. The capacity to respond to global environmental problems are therefore limited, and international relations continue to be dominated by states pursuing their own interests.

Technological Change

Technological change is widely regarded as a fundamental driver of economic and political change at the global level. However, it plays a less consistent role in the futures studies surveyed. At the more qualitative end, technology is treated as a second-order problem, dealt with more in terms of the general rate and direction of technological change towards or away from more innovative technologies.

More focused, quantitative studies take technological change as central in scenario-building. Typically this is in the form of substitutions (substitutions of fuel types and power technologies in energy scenarios), and assumptions about the rates of improvement of materials or energy efficiency in industrial systems. These technological assumptions can have a marked impact on results. For instance, much of the variance in performance of the family of four SRES A1 (IPCC, 2000) scenarios is due to differing assumptions about resource and technology mixes, rather than assumptions about economic development or governance. A general lesson appears to be that the more specific a scenario, to the extent that well-defined technological alternatives can be identified, the greater the final impact of technological assumptions.

Social Change

In general, global scenarios are less concerned with the 'demand' side of the economy and society than with the 'supply' side in assessing the drivers of future changes. To this extent they may be seen as economically, politically or technologically deterministic. Social and cultural changes affecting the demand for goods and services are dealt with less consistently, although many of the more idealised scenarios rely on substantially changed value systems prevailing in government, private enterprise and amongst citizens and consumers. The demand side is better represented in domain studies related to energy, transport and the built environment where prices, energy intensity and demand for transport and housing are better understood.

Demographic Change

[16] European Commission (1993). Global Perspective 2010: Tasks for Science and Technology. Report for the EC FAST Programme.

Population is one factor which will determine final demand, and this is the best characterised of future developments. A long tradition of modelling, systematic collection of population data, and 'demographic inertia' whereby future fertility rates can be accurately forecast on the basis of the structure of current populations, all mean that there tends to be less dispute about total numbers of people and their distribution between regions of the world. This does not mean that large changes in forecast population numbers do not occur. Over the past 10 years there has been a consistent need to adjust population forecasts as a result of behaviour change, and the impacts of population policy and disease. Demographic change was also taken as a starting point in recent Dutch scenarios studies – although here too adjustments have recently become necessary.

Indicators of Change

The level of quantification in global studies varies greatly. Some avoid quantification altogether, most use a small set of indicators to show change in system states, and a few are highly quantified. There has been a tendency towards greater quantification through time, with many scenario studies now being underpinned by demographic and economic models. Opportunities for quantification appear to depend on the role played by socio-economic dimensions in scenarios. Some dimensions (globalisation, equity, behaviour) are difficult to quantify, and their impacts on quantifiable factors of future development are seldom well-understood. Apart from this, there are differing attitudes to the use of quantified indicators to illuminate storylines. Different scenario user-groups have varying needs for the exploratory and visionary aspects provided by storylines, as opposed to concreteness and consistency offered by indicators and model outputs.

Domain Studies

Domain studies cover a wide range of sectors and interest domains including: Energy; Transport; Agriculture and Food; Built Environment; and Environment and Climate. The most comprehensive domain scenarios studies exist for the energy sector. Especially noteworthy are energy scenarios done on behalf of the European Commission, the International Energy Agency (OECD/IEA), the US Energy Information Agency, scenarios conducted for large energy-producing companies such as Shell and BP (often only partially in the public domain), and energy and emissions scenarios done for the IPCC (IPCC, 2000). These studies include both traditional forecasts, as well as scenario exercises. Energy, as a key, politically-sensitive, technologically mature and concentrated industry, based on well-known resources and with clear and easily measurable environmental burdens is perhaps the ideal sector for scenarios studies. The structure of demand is well understood (growth of about 1 percent per year in the EU), and the key questions are about improvements in the efficiency of energy supply and use, the penetration of radical new renewables technologies, and the capacity to secure new sources of fossil fuels.

Transport has many similar characteristics to energy, but scenario studies have been considerably less numerous and sophisticated. Forecasts of the demand for transport of people and freight are at the centre of these studies, and in general they are cautious about modal shifts and the penetration of radical new technologies. Interest in emissions from vehicles has risen substantially since the 1990s in relation to climate change and air quality management policies.

3. Socio-economic scenarios in climate assessments

Climate impact and adaptation assessments are 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 climate assessments 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[17]. In general, these studies examined a few exposure units and climate change scenarios (typically based on doubling of atmospheric carbon dioxide). Second, 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 Feedback mechanisms between the socio-economic and the climatic system (e.g. adaptation strategies) tend to be disregarded, although there is a 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 climate assessment, and assumes that socio-economic conditions can be held constant.

However, climate assessment must take account of change in socio-economic systems[18]. 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. Three epistemological problems must be overcome. First, climate assessments must account for agency and reflexivity in social systems. 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 – 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

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17 Arnell, N.W. 1998. Climatic change and water resources in Britain. Climatic Change, 39, 83-110; Stakhiv, E. Z. 1998. Policy implications of climate change impacts for water resources management. Water Policy, 1, 157-175; Bentham, G and Langford, I.H. 1995. Climate change and the incidence of food poisoning in England and Wales. Int J. Biomet., 39, 81-86.

18 Berkhout, F., Hertin, J. and Jordan, A., Socio-economic futures in climate change impact assessment: using scenarios as 'learning machines', *Global Environmental Change*, vol 12, no 2, 2002: 83-95.

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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.

A 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 thresholds and other non-linear events (such as a collapse of the thermohaline circulation). 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. This confidence does not extend to the social sciences, mainly because the assumptions of continuity and universality do not hold in many (and perhaps progressively fewer) social, political and economic systems. Although over 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 profoundly modify incentives, behaviours and social structures. Usually these processes of change are unexpected and poorly understood by participants, even as they are occurring.

Third, 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. The post-modern turn in social inquiry "…rejects all truth claims, accepting that there are multiple realities and no foundations for asserting the superiority on one interpretation over another"[19]. 'Scientific facts' are constructed through social processes and rituals. What is accepted as knowledge and what constitutes good scientific practice is the outcome of 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 climate assessment. 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.

These inter-related problems of agency, discontinuity and framing pose immense challenges for the analysis of future social time in climate impact assessment. Recent research has tended to make three arguments[20]. First, studies which seek to assess future impacts of and adaptation to climate change need to look at a range of different future

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[19] Rhodes, R. (1997) Understanding governance. Open University Press, Buckingham: 184.

[20] Parson, E.A. et al. (2006) Global Change Scenarios: Their Development and Use, US Climate Change Science Program, Draft for Public Comment, June 30th.

socio-economic conditions. Imposing future climate on only one (current or future) set of economic, technological and social conditions does not give a broad-enough 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. Climate assessments should 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. This also implies taking social and economic conditions may be taken as a starting point, with climate change added as a new variable. This process inverts the logic of assessments which foreground climate variability and change.

Third, climate assessment studies need to make underlying assumptions more transparent. New tools and wider participation in studies is leading to a broader and more integrated 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 knowledges and experience of diverse stakeholder groups and encouraging learning.

4. Development of socio-economic scenario studies for climate assessment

In a recent assessment by the US Climate Change Science Programme (Parson et al. 2006), this more generic function of socio-economic scenarios is acknowledged and placed in the context of other forms of scenario (see Figure 2 below). The assessment argues that while in the past there was a simple linear progression from socio-economic scenarios to emission scenarios and so on, it is now widely recognised that socio-economic scenarios also lie at the heart of impacts assessment.

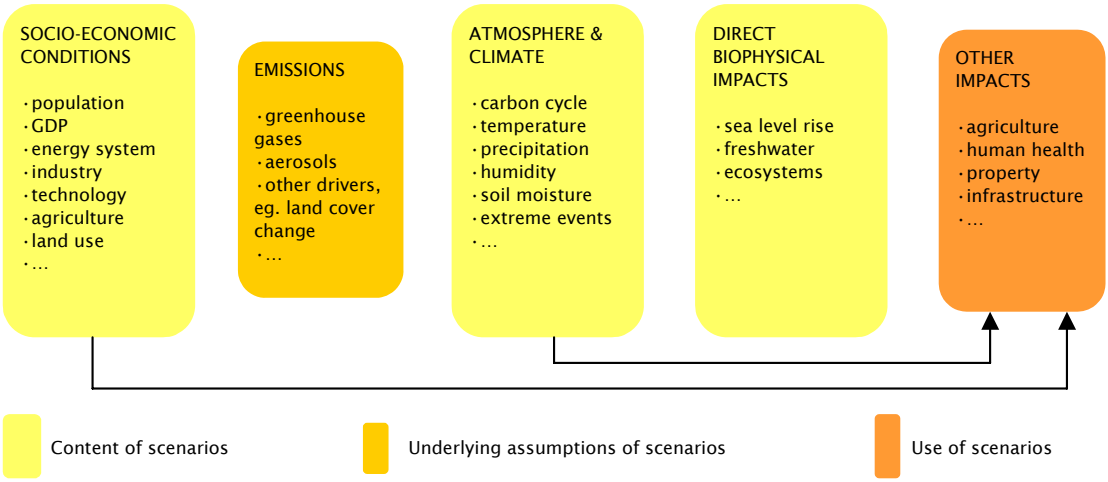

Figure 4.1 Scenarios for climate impact assessment (Parson et al., 2006)[21]

A set of socio-economic scenarios were developed by the UK Climate Impacts Programme for the United Kingdom.[22] The scenarios framework drew on earlier scenarios and have many parallels with the framework used in the later Dutch national scenarios such as WLO. The study reached six main conclusions about the generation and use of socio-economic scenarios for climate assessments:

1. There are many audiences for climate-relevant socio-economic futures scenarios: Climate change will have many and complex impacts on society and the economy. Climate scientists need to know what future societies will be like in order to predict vulnerability of different sectors and impact domains to these impacts. Policy interventions may be needed if major areas of vulnerability are identified. However, climate impacts models are not able fully to do justice to the uncertainty of socio-economic developments. Socio-economic futures scenarios provide a means for dealing systematically with these uncertainties in model-based climate impact assessments. Moreover, not all societal responses will be driven by public policy, but by adjustments

[21] Parson et al, op cit.

[22] UKCIP, 2001. Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme. Oxford, United Kingdom Climate Impacts Programme.

and adaptation by organisations and individuals. The UK Climate Impacts Programme seeks to encourage each of these actors to become engaged stakeholders in responding to climate change impacts. Many of these stakeholders have difficulty in envisioning what the future means for themselves. Futures scenarios are one tool for creating this awareness.

2. There is a desire among different stakeholder groups for a common framework against which to assess future vulnerabilities to climate change: While these different groups of stakeholders have very different perspectives and interests in thinking about the future, the study has revealed a broad-based desire for a common framework. There appear to be two motivations for this. First, different groups of stakeholders are looking for a robust and 'legitimate' approach to futures analysis. A common, peer-reviewed and widely accepted approach would provide this assurance. Second, since the way one thinks about the future will have ramifications for present-day actions, a common set of futures scenarios also have the potential to transmit messages about appropriate responses to climate change. At base, these futures scenarios aim to sharpen stakeholders' awareness of their vulnerability and resilience to futures climate impacts.

3. Informed stakeholders make the best use of socio-economic futures scenarios: The stakeholder-driven approach is central to the UKCIP. The process of establishing who are the relevant stakeholder groups at the UK national level is far advanced, but still in its early stages at the regional level (with some notable exceptions). While the futures scenarios designed in this study aim to provide a common framework for stakeholders to consider their vulnerability to climate change, and their adaptive capacity, this process of learning cannot happen without some prior knowledge. The futures scenarios are only useful as a planning tool in the hands of an informed stakeholder. Without a prior perception of vulnerability to climate impacts many organisations and individuals do not engage with the difficult task of visioning the future. And without some knowledge of climate change, the process of elaborating the scenarios in a way that is relevant to their own concerns is a frustrating task.

4. Even informed stakeholders find it difficult to accept the need to adapt to climate impacts: Elaboration of the scenarios should reveal for stakeholders something about their capacity to adapt to changes in climate. In principle, the risk that an organisation would have a low capacity to respond should lead to changes in practice. This study has revealed that most organisations find it very hard to conceptualise and evaluate their own capacity to accommodate change. Most organisations believe they are rather good at responding to change, without being able to say exactly why. Without a clearer notion of the conditions for and components of adaptive capacity, many organisations will continue to find it hard to know what responses they should make in the light of alternative futures. Futures thinking will only gain a focus in those sectors where there is broad acceptance that it will not be possible to 'muddle through'. This is another challenge for the UKCIP.

5. Changes of behaviour can be precipitated by crises: We have also been reminded several times that what worries most stakeholders most about the future is the random, catastrophic event, for which they have not planned, and in the face of which muddling through is not an option. The scenarios designed in this study do not identify these 'sideswipes', but concentrate on broad incremental changes in society and the economy.

Wars, revolutions, plagues and stock market crashes have occurred frequently in history, and no doubt will happen again. These kinds of changes lead to disjunctures in the rate and direction of socio-economic change, and often have a bearing on the vulnerability or resilience of society to other sorts of change. We acknowledge this weakness at the outset, but encourage users of these futures scenarios to stretch them wherever possible to 'think the unthinkable'.

6. Scenarios are considered a useful framework for thinking about the future: A wide variety of stakeholders find the scenario framework presented here a helpful way of visioning the future. There is widespread demand in the climate impacts community for a systematic approach for considering socio-economic changes over periods of several decades. Without a picture of socio-economic developments, there can be no plausible account of climate impacts and responses to them. However, the desire for a consistent approach needs to be balanced with a need also to encourage a diversity of approaches. The future is uncertain, and not all of that uncertainty can be captured in a single framework for thinking about the future. Robust decisions need to be based on deliberation based on many different perspectives.

In broad terms, these conclusions are endorsed in US CCSP review (2006). The main difference of emphasis in on the question of how to handle uncertainty. Parson et al (2006) argue that there should be more explicit use of probability statements in scenarios, especially in cases where there are relatively fewer variables and fewer users. They acknowledge that as scenarios become more multivariate and are used to communicate with more users, the role of statements about likelihood declines. The question of whether to apply probabilities to socio-economic scenarios has been the focus of scientific debate.[23] On the one hand, some analysts argue that without probabilities, decision-makers will find it hard to make sense of scenarios and integrate them into their analysis and procedures. They also argue that even if scenario-builders do not apply probabilities, users implicitly or explicitly will. If this is the case, it is better than the scenario-builder himself applies probabilities, even if these are subjective. On the other hand, there are those who argue that there are irreducible uncertainties (perhaps ignorance is a better word) - related to the emergence of unexpected novelty in the future, and also to the reflexivity of actors in response to these novelties (and to scenarios themselves) – that cannot be captured by the assignment of probabilities. They also argue that under conditions of uncertainty it is more appropriate to adapt to a wide set of plausible alternative outcomes (the notion of robustness), than to aligning decisions to a rank ordering of those outcomes as a result of assigning probabilities to them. Parson et al. offer a reasonable compromise in this dispute.

[23] Schneider, S. (2002) Can we estimate the likelihood of climatic changes at 2100?, *Climatic Change*. 52, 451-451; Dessai, S. and M.Hulme (2003) *Does climate policy need probabilities?*, Tyndall Centre Working Paper 34, Norwich: UEA.

5. Scenarios in practice

5.1 Principles in scenario development

Among the large amount of guidance material on scenario use that exists,[24] four criteria stand out. Most scenarios practitioners argue that they should be: relevant; consistent; plausible; and transparent. That is, scenarios need to be tailored to the needs of the user, rather than being seen as an end in themselves. In order to be useful, scenarios should be relevant to the worldviews and problem-framing of the user and they need to provide a stable pattern through which complex issues and un-certainties can be viewed. Scenarios, in order to speak to the user also need to achieve a special status of providing a lens onto the unexpected, while also remaining within the realms of the possible. Lastly, the construction of scenarios, either as a hermeneutic structure, or as a social process (who was involved, what interests did they represent) also needs to be plain to the user. Without these four characteristics, scenarios are likely to fail in their function of informing analysis and facilitating innovation.

Relevance depends primarily on the overall objectives of a study. The issue of relevance is pressing for many of the global studies. Their aim is to describe 'megatrends' and to develop storylines that suggest possible futures. Such narratives are not easily applied to public or private sector decision-making, and this has been widely regarded as a weakness. However, this may be an unfair critique since the role of global scenarios may rather be seen as providing a logical structure with which to tell different stories about the future – what van Asselt calls 'future telling'.

Consistency depends on the way in which a scenario exercise is set up - the 'dimensions' of change that are included - and whether the treatment of change is model-driven and quantified, or schematic and qualitative. Once again, this criterion is frequently harder to apply to more global scenarios, which may include several dimensions of change. The problem is that the relationship between different dimensions is typically not well specified, or treated in a simplified way, according to assumed correlations and causal relationships. So, for instance, liberalised markets are typically assumed to be correlated with more open trade, more rapid economic growth, weaker international institutions and less intensive environmental policy. Many of these relationships are subject to substantial academic debate.

Plausibility is related to the complex issue of probability or uncertainty in scenario analysis. Parson et al (2006) argue that representing and communicating uncertainty is perhaps the most fundamental purpose of scenarios. They argue that scenarios can be seen as fitting within a spectrum of methods for addressing the uncertainty of future states. At one end of the spectrum is a probability distribution for a single variable communicated to a well-defined audience. At the other end of the spectrum are complex scenarios describing future states of many variables whose relationships are incompletely known, where probability distributions are unknown and which are communicated to multiple audiences. Most global and domain studies do not treat

[24] For example: Ringland, G. (2002) Scenarios in Public Policy, Wiley: Chichester.

plausibility or uncertainty formally (through expressed probabilities, for instance) in any of the exercises reviewed here. The number of scenarios presented varies across different studies from 1 to 13. Where more scenarios are developed, these are typically organised within 3-4 'families' of scenarios with variants (ie. the four SRES (2001) scenario families).

Transparency is seen as crucial to the credibility and legitimacy of scenarios. Without a clear exposition of assumptions and approach it will be difficult for audiences to make sense of the results, or to trust them sufficiently to use them in their own decisions. Global and domain studies face different challenges with regard to transparency. Global scenarios need to make clear the frequently qualitative or narrative assumptions that underlie their projections. More specific scenario exercises often are based on quantitative models that may be extensive and harder to report. Such modelling exercises may be costly and time-consuming, unless the relationships being investigated are relatively well understood.

Scenario exercises may be defined as being either exploratory, extrapolatory or normative in approach. Exploratory approaches create a stylised 'model' of a system (such as the scenario-axes technique) and make projections for the system given assumptions about the determinants of change. Most scenario studies take an exploratory approach. Extrapolatory approaches come closer to classical forecasting in which existing numerical models – which make assumptions about the sign and strength of relationships between variables – are used to make projections of the future. While such models may be very useful to forecast the relatively near-term, they are typically poor at making projections over the longer-term, primarily because relationships between variables change with time. Normative studies posit a (desirable) state for the system at some future date and then 'backcast' to understand what changes need to occur for this to be achieved (Dreborg, 1996).[25] Many global scenario studies have normative elements in the specification of desirable and undesirable outcomes.

5.2 Scenario applications

In a related study carried out for the UK Foresight Programme,[26] the use of scenarios in research and public policy settings was investigated. The review found that that there were broadly two, markedly different, applications of scenarios.

Most frequently, the Foresight Scenarios were used in small-scale scenario planning exercises, usually one-off events, which contributed to medium and long-term business and policy planning. These included applications in a diverse range of sectors, including crime prevention and financial services. These processes usually involved: a participative process; a qualitative exploration of trends; drawing on the experience of practitioners; with scenarios being used primarily as a communication tool. Frequently this type of use depended on a 'champion' of scenario planning at a senior level of management. Their function was to attract interest and to stimulate creative thinking.

[25] Dreborg, K.H., 1996. Essence of backcasting. Futures 28 (9), 813-828.

[26] Berkhout, F. and Hertin, J., Foresight Futures scenarios – developing and applying a participative strategic planning tool, Greener Management International, 37: Spring 2002: 37-52.

These processes tended to engage participants unfamiliar with scenario approaches, and often unfamiliar with academic language and thinking.

Second, the scenarios were used in the context of research-based studies carried out over longer periods, often for Government. In these assessments, the main function of scenarios was to provide a heuristic framework for coordinating integrated assessments by allowing the construction of a coherent set of underpinning assumptions. In particular, scenarios were used in poorly-structured or complex (multi-variate) areas of research and policy, such as climate change impact assessment and water resources planning. These uses are characterised through: qualitative and quantitative assessment of potential outcomes; scientific methods combined with consultation based on data and expert knowledge; with scenarios used to parameterise models and to assess research results. One analytical challenge for this approach is to combine the 'soft' scenario tool with 'hard', quantitative scientific methods. Simple modelling and cross-impact analysis can be employed to ensure consistency and analytical depth. Parson et al. (2006) note that this type of application is frequently subject to politically-motivated attempts to influence their outcomes. This is mainly because scenario studies like this can have a role in framing public debates.

6. Conclusions: responses on key issues

Socio-economic scenarios are likely to have four functions in the KvR research programme:

- They will provide a heuristic frame for researchers to develop consistent models of the future;
- They will provide a range of values for parameters in quantitative analysis;
- They will serve as a means for coordinating and integrated appraisals by providing a set of standard assumptions about the future; and
- They will provide a means of communicating results of KvR research and activities to a wider set of stakeholders.

Based on this review of scenarios and their uses, we can offer some initial responses to the questions identified in the project proposal:

6.1 Scenarios as narrative

What is the right balance between narrative and quantitative aspects of scenarios?

While global and multivariate socio-economic scenarios have almost all tended to take a narrative form since early experiments with 'global models', there has been a growing tendency towards quantification. There are four main developments: the generation of quantitative indicators to illustrate narrative scenarios (UKCIP SES, 1999); the use of scenarios to generate parameter values as inputs for modelling exercises (SRES, 2000); the integration of numerical modelling into scenario exercises (WLO, 2006); and the use of probability statements with scenarios (Schneider, 2002).

Over what time-periods and spatial-scales should scenarios be expressed?

Time horizons used in scenario studies vary considerably and in general they should be tailored to the goals of the exercise. Generally, scenarios have time horizons that are outside conventional planning horizons, but within a foreseeable future. Socio-economic scenarios face significant challenges in reconciling the long-term projections of many climate scenarios (up to 80 or more years forward) and the salience of such time horizons for socio-economic projections and for scenario users. Reconciling these two perspectives typically leads to the segmenting of time horizons (for instance, scenarios to 2030, to 2060 and to 2100). But this segmentation may be difficult to sustain in narrative scenarios which project visions of future states, without saying much about processes or rates of change. There may therefore be a measure of arbitrariness in the association of specific time horizons to qualitative socio-economic scenario projections. This weakness may be reduced in scenarios using more quantitative modelling.

Somewhat different problems arise with respect to the spatial scale. Climate models are only partially-scaleable, although models continue to generate renditions of physcial

changes at ever-smaller scales of resolution.[27] This is in order to be able to make more specific predictions of the sign and rate of physical changes in different regions and locations. However, for many users, the spatial aggregation offered is still too coarse, and this, combined with the high uncertainties attached to regional projections, means that climate scenarios still convey only limited information. Socio-economic scenarios are, in principle, infinitely-scaleable – that is, a scenario can be presented at any geographical, economic or social scale. But the smaller the scale of resolution, the less informative the scenario is likely to be, since larger trends and uncertainties will become exogenous factors, rather than variables within the analysis. Global scenarios frequently choose a global region disaggregation, while many socio-economic studies are purely national in scope (often also taking account of global contexts). Here too, there may be a tension between the scale of the scenario and the real interests of the user – which will frequently be at a lower spatial level.

What domains and variables need to be reported on?

Socio-economic scenarios have proven extremely flexible instruments with the choice of domains and variables entirely at the discretion of the analyst or user. This may also include unconventional domains and variables that would be difficult to treat more formally, in models for instance. Socio-economic scenarios for climate assessments are likely to include climate-sensitive sectors and domains such as: eco-systems; water; coastal zones; agriculture; the built environment; resource-intensive sectors, infrastructures; and tourism.

How finely-specified should scenarios be?

Related to the question of scale, in principal the specification of scenarios should be determined by the purpose and users of scenarios.

6.2 Scenarios and user groups

Who are the main user communities?

There appear to be two major user communities for global and domain scenarios: public policy makers and researchers. The UKCIP study showed that these different groups used scenarios in particular ways. Policymakers use scenarios quickly as a way of framing or interpreting policy issues. Researchers use scenarios in a more on-going way as a means of generating parameters and insights, and to communicate results.

What are key climate-relevant uncertainties for different user groups and how are they currently handled?

It is clear that the climate impacts relevant to different user groups vary. While heat may be a primary consideration for architects and engineers of buildings, precipitation and windstorm may be the main consideration for farmers. Additionally, very different features of the socio-economic landscape will be relevant for such groups. Once again,

[27] For instance the Hadley suite of models have a range of spatial resolutions: regional climate models have a resolution of 0.44x0.44º; while the Hadley GCM has a resolution of 1.875x1.25º (Source: Arnell, N.W. et al. (2003) Climate change scenarios from a regional climate model: Estimating change in runoff in southern Africa, *Journal of Geophysical Research*. 108 (D16): 4519.

scenario development needs to be done with close attention for the expressed needs of users.

How should users and stakeholders be consulted in the development of scenarios?

While stressing the importance of involving stakeholders, the studies reviewed here are not very explicit about the best means for consulting them. Small workshops in which participants are encouraged to take part in scenario construction are often a feature, as are interviews. The US CCSP study argues that these interactions are most useful at the beginning and end of scenario exercises, and most useful when small groups are involved. The UKCIP experience is that consultation with wider stakeholder groups is possible and useful.

What are for them relevant features of scenario narratives and parameters?

Here too there is diversity. For some users, scenarios are useful in issue-framing, and for these groups the underlying logics are important. For other groups, the content of scenarios is unimportant, but their outputs in terms of parameter values are. For these groups, the status of scenarios – defined as their source or authorship – is sufficient to give them credibility and therefore make them useful. This partly explains why the SRES scenarios (developed in the context of the IPCC) have been so widely-used.

6.3 Communication of scenarios

What is the most effective way to communicate with potential users?

Most scenarios appear in the form of reports – often long ones. There have been attempts more recently to use visualisations (either in the text or virtually). In these kinds of applications, there is also the notion that it will be possible through simulation approaches to make it possible for users to interact with the scenario – an idea derived from gaming. In fact, there has been little progress towards this goal.

How should scenario narratives and resources be communicated so that they integrate with users' practices?

User practices and interests are diverse and this suggests that scenario outputs should be similarly diverse. This does not mean that the scenario developer will always be capable of providing these outputs. In those cases where specific outputs cannot be delivered – for lack of knowledge or method, for instance – the aim of the scenario-developer will be to place the scenario framework in the hands of the user, who can produce the outputs himself.

What is the right balance between consistency and the desire for flexibility in applying scenarios?

There is no clear answer to this question. Users frequently want both consistency – to be comparable and linked to an authoritative 'source' scenario – while also aiming for relevance and therefore specificity. Each scenario exercise needs to make these judgements separately.

What is the role of scenarios in pluralistic contexts?

Scenarios can have an important role in aligning the ideas and assumptions of different stakeholder groups. In this sense, they may serve to generate learning between different groups.

6.4 Treatment of uncertainty

How is uncertainty treated in scenario studies?

There seems to be a paradoxical course in which initial uncertainty awareness is compromised by increasing uncertainty intolerance and all kinds of solidifying efforts which in the ends lead to outlooks presented as definite and solid accounts about an uncertain future. On the one hand, it is clear that such ‘certainification’ enables practitioners to proceed.

Can discontinuities and extremes be dealt with in scenarios?

The idea of discontinuity seems to appeal to scenario specialists, especially in the early phases, it seems that in the course of a foresight endeavour, radical outlooks get increasingly disqualified as exotic, implausible or unrealistic. In the end, the discontinuous repertoire is often marginalised in the foresight practice.