Focus Article

Representing and using scenarios for responding to climate change

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Scenarios have become a standard tool in climate studies and provide the basis for our understanding of climate-related challenges, the mechanisms for adaptation, and options for mitigation. They can be thought of in two ways: either as products that describe outcomes resulting from specific driving forces, or as processes for establishing long-term planning targets. Common scenario types include emissions scenarios, climate change scenarios, and socioeconomic scenarios, all of which are used in strategic planning to compare the potential consequences of different future contexts. Scenario-based studies also shape the information that is used to motivate the changes in behavior that are needed to achieve mitigation goals. This review presents some of the issues that arise when using scenarios for responding to climate change. Uncertainties associated with scenario approaches are an apparent barrier to the development of policies regarding climate change, especially at local and national scales. Scenarios are also ineffective at addressing noncognitive influences on climate change perception and therefore do not stimulate behavioral change. *WIREs Clim Change* 2010 1 253–259

The science of climate change is often portrayed through graphs of rising greenhouse gas (GHG) emissions, maps of changes in temperature and precipitation, and descriptions of increasingly compromised natural resources. Behind much of this science lies a series of qualified assumptions about society and the environment that are articulated in the form of scenarios. The underlying aim of scenarios is to understand the impacts and interactions of the driving forces of change and to reveal alternative development pathways.[1] Scenarios are therefore commonly used to design and test strategies intended to have long-term consequences. In climate studies, scenarios are used to understand the risks of major biophysical change, evaluate targets so as to avoid undesirable impacts, and identify policy options that are robust to uncertainties.[2]

Scenario development tends to facilitate better communication between actors in decision-making processes and increases an appreciation of the differences in stakeholder concerns and perspectives. Scenarios attempt to make understandable what is essentially abstract and difficult to represent in the imagination. With much of human reasoning based on analogy rather than standard logic, the use of scenarios for responding to climate change depends on finding suitable analogical models grounded in the needs and capabilities of policy-makers and citizens.[3] As the next generation of scenarios for climate change study is created,[4] it is useful to reflect on how climate change is portrayed through scenarios and the value of scenarios as a decision-making tool. In this review, I highlight some common types of scenarios used in climate studies and describe how scenarios have been used to develop policies at local and national levels. I also address the role of scenarios for changing attitudes and behavior among individuals before concluding with a discussion of the need for tools that address the limitations of scenario-based representations of climate change.

THE NATURE OF SCENARIOS IN CLIMATE CHANGE STUDIES

The Intergovernmental Panel on Climate Change (IPCC) defines a scenario as 'a plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships' (Ref 5, p. 951). Using qualitative and/or quantitative models and information, scenarios

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TABLE 1 | The SRES scenarios consist of approximately 40 scenarios aggregated into four divergent families; each family consists of those scenarios that share the same basic storylines representing different demographic, economic, and technological development.[8]

Scenario family	Storyline
A1	Rapid economic growth, rapid introduction of new and more efficient technologies.
A2	Heterogeneous world with ever-increasing global population and regionally oriented economic growth.
B1	Move toward a globalized service and information economy and the introduction of clean and resource-efficient technologies.
B2	Focus on local solutions for sustainability and social equity with intermediate economic development.

depict the future as a range of possible outcomes. The future contexts described by scenarios are not forecasts or predictions. Rather, they should be seen as heuristic tools that provide a decision framework when complexity and uncertainty are high.

Scenarios can be thought of as either normative or exploratory, although the scenarios used in climate studies often have aspects of both approaches.[6] Normative scenarios are prescriptive and explicitly values-based. They describe a future that may be realized only through specific actions and generally provide the foundation for policy decisions where a particular goal—such as a reduced climate impact—is fulfilled. An example of a normative scenario is a stabilization scenario, which attempts to constrain GHG emissions within fixed bounds. Exploratory scenarios, on the other hand, address the question 'What can happen?' and describe the future according to known processes of change. Most climate scenarios can be regarded as exploratory as they describe future climates that might occur in the absence of explicit policies for reducing GHG emissions.

Among the most widely used scenarios for climate studies are the IPCC's emissions scenarios, which quantify how GHG emissions evolve over the 21st century in response to different combinations of change in population, economic growth and the supply and demand for fossil fuels. Table 1 describes the scenarios published in the Special Report on Emissions Scenarios (SRES), which were used as the basis for the IPCC's Fourth Assessment Report,[7] and illustrates how storylines are used to describe driving forces of change. The A1 and B1 scenario families consist of futures with rapid economic growth and low population growth; they differ from one another primarily in terms of energy consumption. The A2 and B2 families represent moderate economic growth coupled with strong population growth and differ in terms of technological developments.

Emissions scenarios are important inputs for generating scenarios of climate change. They are used to drive climate models that simulate the response of the climate system to different levels of GHG emissions and aerosols. The simulations produced by climate models are in turn used to calculate climate change scenarios, which represent the difference between some projected future climate and the current or control climate (Figure 1). There is a formal difference between a climate scenario and a climate change scenario, although the two terms are often used interchangeably. A climate scenario is a plausible representation of future climate constructed specifically for vulnerability assessments, usually as an input to impacts models.[9]

The motivation for using scenarios is to shift the analytical focus away from what is most likely to occur toward questions about the consequences of change and most appropriate responses under different circumstances. When using scenarios for policy-making, their value is to clarify uncertainties by 'determining the possible ramifications of an issue (in this case, climate change) along one or more plausible (but indeterminate) paths' (Ref 9, p. 744). The benefit of scenarios therefore lies in the ability to compare competing viewpoints within a single framework, thus allowing policies to be designed in a more robust manner.[1,11]

SCENARIOS IN PRACTICE

Climate change is recognized as one of the most challenging and complex problems facing society. Actions taken over the next decade will determine the rate and magnitude of climate change over the next century, and both adaptation and mitigation are seen as necessary responses.[12] It is also widely recognized that responses to climate change will require not only institutional change, but also change in individual human behavior.

Scenario-based approaches are an effective way of engaging actors who might otherwise be unresponsive to scientific information presented in more traditional forms such as scientific articles or reports. Many scenario exercises use participatory processes to develop the scenario storylines. At the larger scales of society, scenarios provide the context for understanding the consequences of climate change and help identify policy options to meet mitigation

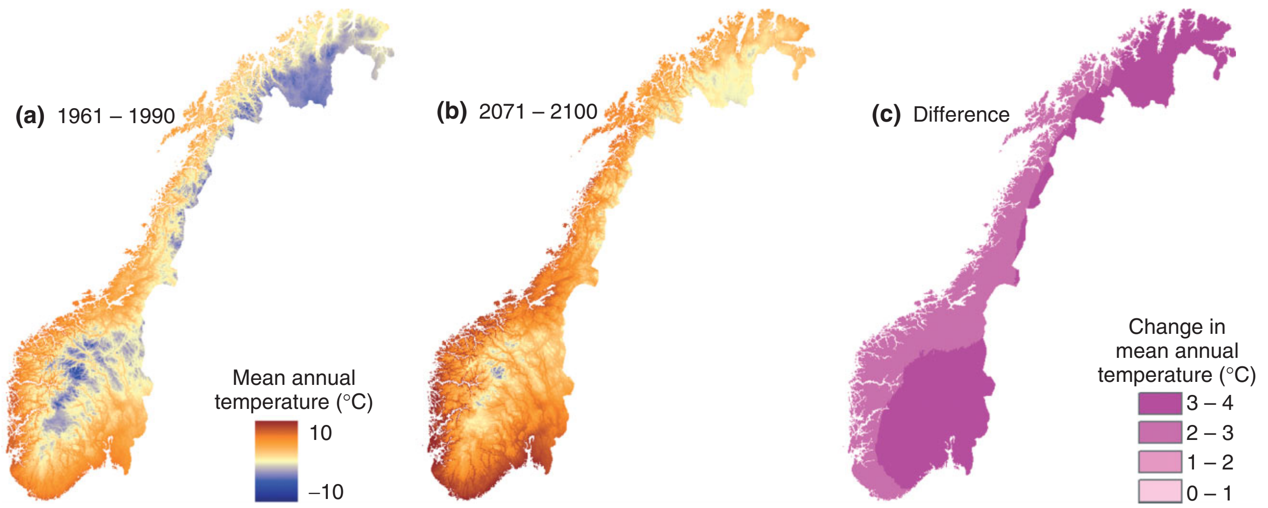

FIGURE 1 | Annual mean temperature in Norway is mapped for the control period 1961–1990 (A) and simulated by a climate model forced with the B2 emissions scenario for the period 2071–2100 (B). The difference between the two maps generates a climate change scenario (C).[10]

and adaptation goals. At finer scales, scenarios are used to shape the information that is communicated to individuals to encourage voluntary emissions reductions through lifestyle decisions.

Strategic Planning

Scenario analysis provides the means by which decision-makers can anticipate change and prepare for it in a responsive and timely manner. It routinely targets issues that are sensitive to stakeholder interests and can improve policy-making particularly when studies involve stakeholders as active participants with agency, not merely passive recipients of information. Stakeholders typically include people such as government officials, private business owners and local resource users, and the outcomes of these processes depend heavily on the contributions by participants. Recent examples of such exercises include the FINADAPT project[13] and RegIS.[14]

FINADAPT was a consortium of 11 institutions coordinated at the Finnish Environment Institute between 2003 and 2007, tasked with assessing the adaptive capacity of the Finnish environment and society to a changing climate. Targeted research was supported by three global scenarios, which were translated into a national context through empirical analysis, modeling, and stakeholder engagements. Each scenario had qualitative and quantitative elements. The qualitative elements were in the form of narratives describing plausible developments in demography, economic structure, land use, technology and governance in Finland. Quantitative elements included data on socioeconomic development, climate, CO_2 concentration, nitrogen deposition, and land use change. The resulting storylines—Global Markets, Sustainability and Retrenchment—are analogous to the SRES A1, B1, and A2 storylines, respectively but were intentionally designed to be national in scope and account for both mitigated and unmitigated GHG emissions.[15] Final outputs from the project include a collection of sectoral reports describing the basis for policies and management strategies that could serve both adaptation and mitigation goals.

RegIS (Regional Climate Change Impact and Response Studies in East Anglia and North West England) focused on the cross-sectoral interactions driving landscape-level changes for two regions in the United Kingdom (UK), and was designed to evaluate local impacts and adaptation options. Climate scenarios were provided by the UK Climate Impacts Programme (UKCIP)[16] while an intensive stakeholder engagement led to the development of local socioeconomic scenarios designed to provide quantitative inputs for the models used in an integrated assessment.[17] Four storylines emerged—Regional Enterprise, Global Markets, Regional Stewardship and Global Sustainability—that, like in the Finnish project, were broadly similar to the SRES storylines and provided the narrative context for interpreting outcomes. The project was carried out in two phases between 2000 and 2005: the first phase developed a methodology for stakeholder-led impact assessment; the second phase resulted in a freely distributed software application making that methodology broadly accessible to the stakeholder community.

What becomes clear from both of these examples is that scenarios, like the assessments themselves, can be viewed in two ways, as either products or processes.[18] Scenarios as products are the actual descriptions of possible outcomes resulting from specific driving forces. Scenarios as processes are the heuristic engagements required to compare the potential consequences of those different future contexts. When we view scenarios as processes, we must acknowledge two obstacles for their use in responding to climate change: (1) the tension that can arise between what stakeholders want and what science can reasonably deliver; and (2) the capacity of stakeholders to appropriately interpret and apply scenario-based results.

Biggs et al.[19] discuss the mismatch that often occurs between scientific models and policy needs, and both of the projects described above experienced some degree of discrepancy in this regard. Such exercises require information at national and sub-national scales, which necessitates the downscaling of aggregate data in a way that is consistent with global drivers of change. The FINADAPT study found that stakeholders needed scenarios at finer levels of spatial detail than scientists were able to develop, while the RegIS team identified a mismatch between the time horizon of the scenarios under development and the decision-making processes they were attempting to serve. Furthermore, participatory scenario exercises consume significant resources, with costs rising as the network of stakeholders involved broadens. Ultimately, the results of exercises like FINADAPT and RegIS must be relevant to nonspecialists with little or no experience with the science of climate change. Thus, the scenario process becomes one of intricate consultations between scientists and stakeholders.[20] Some argue that scenario-based studies lead to better-informed decisions by bridging the gap between scientists and stakeholders (cf. Ref 11) but both studies highlighted here found that tailored guidance and support were necessary to ensure appropriate use of the results.

For many nonspecialists, scenario development begs questions about which alternative future is most likely. Stakeholders commonly describe the desire for probabilistic outcomes, which are increasingly available (cf. Ref 16). However, there is an inherent level of interpersonal variability in the interpretation of probability expressions, which may in fact undermine the intended use of probabilities in scenarios. Probabilities have a tendency to be interpreted by nonspecialists less extremely than intended by their originators, which may lead to an underestimation of the magnitude being discussed.[21] Also at stake is whether assigning probabilities to scenarios undermines the non-predictive nature of scenario approaches. Therefore, as probabilistic climate change scenarios become more widely available, scenario developers should partner with psychologists, sociologists, and other social scientists to evaluate the limits and opportunities associated with using probabilities in decision-making contexts.

Behavioral Change

Climate change is caused by the cumulative, collective actions of people whose individual contributions are fairly small. Responding to climate change thus requires people to assume some responsibility for addressing the problem. Individuals play at least two complementary and mutually reinforcing roles: as citizens supporting legislation implementing decarbonization policies and as consumers who embark on lifestyle changes (i.e., by buying efficient vehicles, insulating their homes, and using public transportation). Yet, while individuals are essential to the success of emission abatement policies, climate change is an issue that is difficult to connect with for most people.

Lorenzoni et al.[22] explored the barriers to individual engagement with climate change. They define engagement as a state of connection derived from cognition, affect and behavior. In other words, in order to be meaningfully engaged, individuals not only need to know about climate change, they also need to be motivated and able to take action.

Cognitive engagement implies that individuals have a mental model of the process of climate change and understand the causes, consequences, and potential solutions to the problem. Mental models are representations in the mind of real or imaginary situations. Craik (Ref 23, p. 61) described them as ‘small-scale model[s] of external reality’ that people invoke and ‘run’ in their heads to understand and explain how the world works. Studies show that people have a variety of mental models about climate change, some of which mislead them regarding its causes and solutions. In surveys from the UK, for example, respondents identified ozone depletion as a cause of climate change and recycling as a solution.[22] Respondents to a US survey in 1992 also cited ozone depletion as a cause of climate change, but a 2008 follow-up study found that there is now a general recognition of the irrelevance of ozone depletion.[24] That study found that individuals’ understandings of climate change are, however, encumbered with many secondary and incorrect beliefs such as the conflation of climate change with natural weather cycles.[24,25]

The mental model an individual uses when thinking about a risk such as climate change is the fundamental cognitive representation from which other evaluations follow, such as the judged seriousness or controllability of a problem.[26] The conflation of weather and climate change therefore has major implications for individual behavior: weather is understood as a natural phenomenon beyond the realm of human control; conflating climate change with weather perpetuates the perception that climate change is also natural and that nothing can be done about it. Slovic et al.[27] suggest that this kind of affect heuristic is salient to individuals' decision-making processes.

Affect refers to the specific quality of 'goodness' or 'badness' that is experienced as a feeling, either with or without conscious awareness.[27] Affect is distinguished from emotion, which generally refers to specific states, such as anger, fear or happiness. It is also distinct from mood, which refers to transitory, low-intensity feelings that are undirected and lack specific cognitive content. Rather, affect refers to a person's positive or negative evaluation of specific cognitive contents or images. The consequence is that when information conflicts with the values and experience of an individual, it will tend to be ignored.[3] In the case of climate change, this can lead to skepticism about the reality of the problem or a lack of engagement in the issue.[28,29]

The behavioral aspect of engagement refers to the actions an individual may take in response to climate change. Despite evidence indicating widespread awareness of climate change coupled with a general concern,[30] there has been limited behavioral response among individuals which is consistent with the idea of a value-action gap. While an individual may express environmental values, in some instances other priorities such as safety or financial security may take precedence over environmental actions.[31]

Given the central role of scenarios in developing the public discourse around climate change, it is reasonable to question how effective they are in promoting behavioral responses. Lorenzoni and Hulme[28] looked specifically at the effect of scenarios on public perceptions of climate change and found that the abstract nature of scenarios limit their credibility. They suggest that using scenario representations on timescales relevant to individuals (i.e., 20 years into the future) may be one way to overcome some of the barriers to engagement with climate change. They also highlight the need for both targeted and tailored information addressing different beliefs and attitudes, although the authors note that credible science is a necessary but not sufficient condition for behavioral change.

CONCLUSION

Scenarios have become a standard tool in climate studies and provide the basis for our understanding of climate-related challenges and possible responses; however, it is not necessarily the case that scenarios lead to better decision-making or changes in individual behavior. When it comes to strategic planning, the use of scenarios requires involving stakeholders early in the development process, combining lay knowledge with expert knowledge, and embracing the heuristic nature of scenarios for enhancing social learning. For individuals, scenarios do not provide the necessary incentives for behavioral change and can in fact give rise to cognitive dissonance regarding perceptions of risk.

Challenges remain for how best to represent and use scenarios for responding to climate change. There is often a mismatch between the scale, resolution, and accuracy that scenarios provide and the needs of decision frameworks, both public and personal. Furthermore, the uncertainties associated with scenario approaches have been an apparent barrier to the development of new policies regarding climate change. This has led to the development of probabilistic representations of scenarios, but given the variability in how probabilistic assignments are interpreted, researchers should investigate the tradeoffs that exist when assigning probabilities to what is otherwise intended to be non-predictive. Scenarios assume that people process information analytically, while research shows that most decisions are based on experiential processing. Climate change is therefore likely to be understood only to the extent that it impacts everyday life. The question of how scientific imagery in the form of scenarios may be better used to catalyze institutional and behavioral change remains open.

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