2

SECTION

Scenarios in Global-Change Analysis and Decision Support

Analysts have tried to develop scenarios to support understanding of and decision-making for global environmental issues, beginning with the global models of the mid-1970s and early assessment of acid rain and stratospheric ozone in the late 1970s to early 1980s.[31] The reasons for using scenarios in global change are similar to those that apply in other decision domains: high-stakes decisions that must be made under deep uncertainty about the conditions that will determine their consequences, the values at stake, or the relevant set of choices and actors. As in other domains, well-designed scenario exercises can provide a structure for assessing alternative choices and help focus on the nature of the issue, the relevant choices and actors, the values that might be at stake, and the types of research or analysis that might help clarify preferred choices.

For climate-change applications, scenario exercises have been conducted and sponsored by governments, international organizations, non-governmental organizations, and collaborative groups. While these have been diverse in form, details, and purposes, they have tended to focus more on heuristic and exploratory uses than on supporting specific decisions. The boundaries of the climate-change issue are not sharply defined, however: climate change implicates and connects to many other areas of policy, including energy, agriculture, hazard protection, and broad questions of economic development. Consequently, there is substantial uncertainty about what all the relevant decisions, decision-makers, and potentially affected values are. While some decisions are clearly of primary relevance to climate change, many other decisions that appear to be connected have not yet incorporated consideration of climate change or even recognized the connection. Reflecting these fuzzy boundaries of the issue, scenario exercises developed for climate change have overlapped with other exercises primarily focused on ecosystems, energy, and broad issues of world development. The fuzziness of the climate issue's definition increases the challenge of developing useful scenarios, but also increases the potential value of well-crafted and executed scenario exercises.

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[31] See, e.g., Meadows et al. 1972, Barney 1981; summary of early ozone assessments in Parson 2003; and summary history of scenarios in global-change applications in Swart et al. 2004. What was the earliest scenario work in global change depends, of course, on how the boundaries of global change are defined. Kahn and Wiener 1967 might be considered an early example.

The decisions most directly related to climate change are conventionally sorted into two categories, mitigation and adaptation.[32] Mitigation consists of actions that reduce the human perturbations of the climate system, by reducing net anthropogenic greenhouse-gas emissions. Adaptation consists of actions to reduce the harm or increase the benefit from climate change and its impacts. Despite uncertainty about the precise decision agenda, we can identify in general terms the type of information scenarios might provide that would be useful to each type of decision.

To date, most climate-related uses of scenarios have not examined decisions directly, but have been embedded in larger exercises of assessment, modeling, or characterization of the issue.

Scenarios can help inform adaptation decisions by characterizing the nature and severity of relevant potential impacts; identifying key vulnerabilities, particularly those that might not otherwise have been recognized; identifying research or monitoring priorities that might give advance warning about impacts, particularly acute vulnerabilities; expanding the perceived set of potential responses; and providing a framework for evaluating alternative adaptation measures. They may also help to clarify the time structure of relevant decisions, identifying those near-term decisions that might have important but under-recognized connections to future impacts and vulnerability.

Similarly, scenarios can help inform mitigation decisions by characterizing the potential impacts of climate change and their severity, since these provide the motivation for mitigation. But, in addition, mitigation decisions can benefit from information about potential emissions trends, which determine the nature of the challenge of limiting emissions; about potential pathways of the extraction and depletion of current energy resources and development of new ones; and about potential pathways of technological development. Mitigation decisions may also benefit from scenarios representing the potential policy context in which they are made.

To date, most climate-related uses of scenarios have not examined decisions directly, but have been embedded in larger exercises of assessment, modeling, or characterization of the issue. These uses have included formal integrated-assessment models,[33] comprehensive assessments conducted by multi-disciplinary expert bodies (e.g., IPCC), and more narrowly focused assessment exercises targeting specific aspects of the climate-change issue. In these uses, scenarios represent components of the climate-change issue that are required inputs to an assessment or model.

The causal logic of the climate-change issue is complex, including multiple two-way causal links and feedbacks among socio-economic, geophysical, and ecological systems. Integrated-assessment models seek to represent many of these linkages and feedbacks explicitly; Figure 2.1 shows a typical example of the "wiring diagrams" that illustrate the increasingly dense linkages and feedbacks represented in these models. But while such diagrams might be taken to indicate that all relationships are represented explicitly within the model – endogenously – this is not the case. All models of the climate-change issue rely on scenarios to specify some future quantities exogenously, and in virtually all cases, scenario-specified inputs are not modified to account for results of the subsequent analysis: i.e., they are truly exogenous, and the causal logic does not close.

When scenarios are used to specify exogenous inputs to a model of some aspect of the climate-change issue, the causal logic of the analysis can be greatly simplified from that shown in Figure 2.1. Instead, the logic can be represented by a simple linear structure that extends from human activities to emissions to climate change to impacts. Figure 2.2 shows this highly simplified structure. This representation is even more suitable for the uses of scenarios in other types of global-change assessments, which have been organized around much simpler causal structures than those that integrated-assessment models seek to represent. Note that we are not claiming this simple logical structure adequately represents the true structure of the climate-change issue: only that it illustrates the ways that scenarios have been used to provide exogenous inputs to global-change models and assessments.

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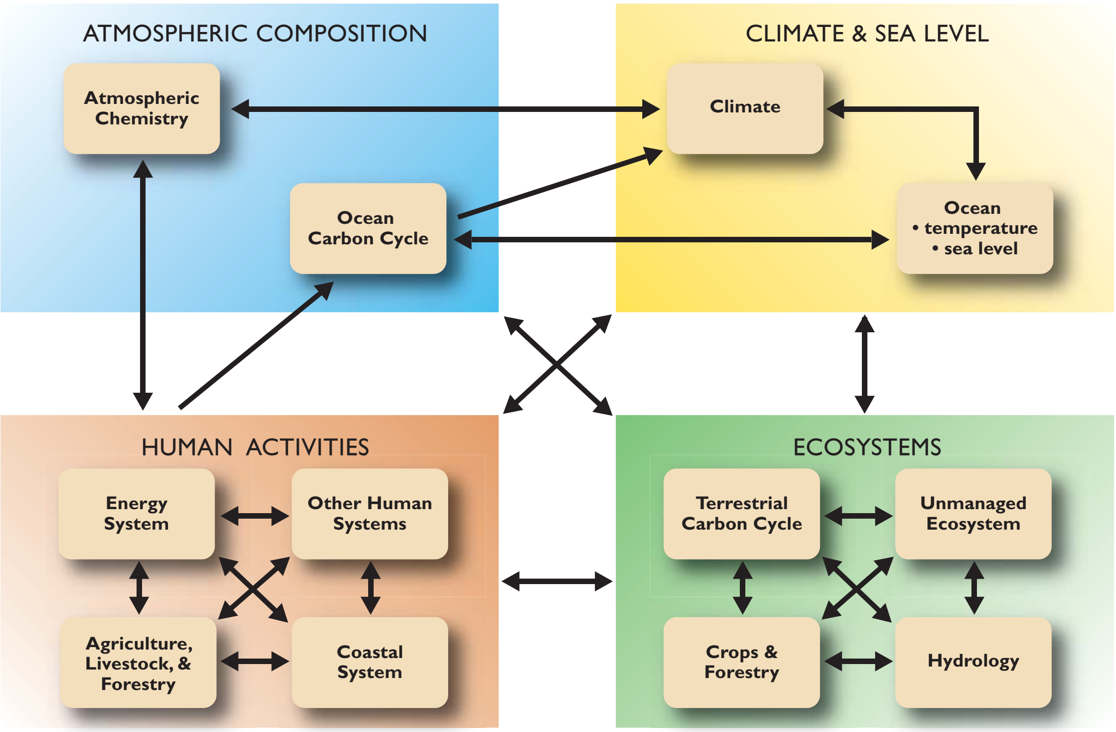
[32] While this categorization has frequently been criticized for neglecting actions with overlapping effects and the third category of direct interventions in the climate system (Schelling 1983, Keith 2000, Keith et al. 2006, Parson 2006), it remains a useful approximation for most currently proposed responses.

[33] Weyant et al. 1996, Parson and Fisher-Vanden 1997.

Figure 2.1. Wiring Diagram for Integrated Assessment models of climate change. *(Source: Weyant et al. 1996)*



This linear logical structure allows a simple, practical categorization of five types of scenarios that have been developed for the climate-change issue. These types are defined by what quantities they specify and what primary area of analysis they provide input to. Their differences can be represented by where they cut the causal chain in Figure 2.2, with the scenario specifying quantities lying on one side of the cut, and the assessment or other activity using the scenario lying on the other side. The next five subsections discuss these five types of climate-change-related scenarios in turn.

2.1. EMISSIONS SCENARIOS FOR FUTURE CLIMATE SIMULATIONS

Scenarios of greenhouse-gas emissions, sometimes including other human perturbations such as land-use change, are the best known type of climate-change related scenario. Emissions scenarios provide required inputs to model calculations of future climate change, as shown in Figure 2.3. As the focus and intended use of climate-model studies have shifted over time, so has the role of emissions scenarios. Early research studies examined the climate system's response to potential (rather than projected) emissions inputs in individual model studies or standardized model comparisons. In such exercises, the purpose of a scenario is to provide a known, consistent perturbation big enough to generate an informative model response. Such scenarios must be standardized, so differences between model runs can be traced to scientific uncertainties and model differences, but they can be simple and arbitrary, making no claim to being realistic. The earliest such scenarios showed a "step-change" increase in atmos-

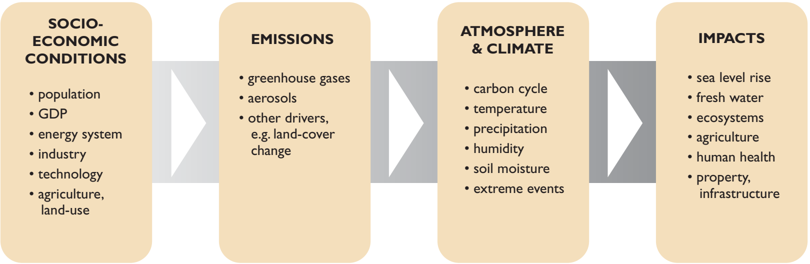


Figure 2.2. Anthropogenic climate change: Simplified linear causal chain.

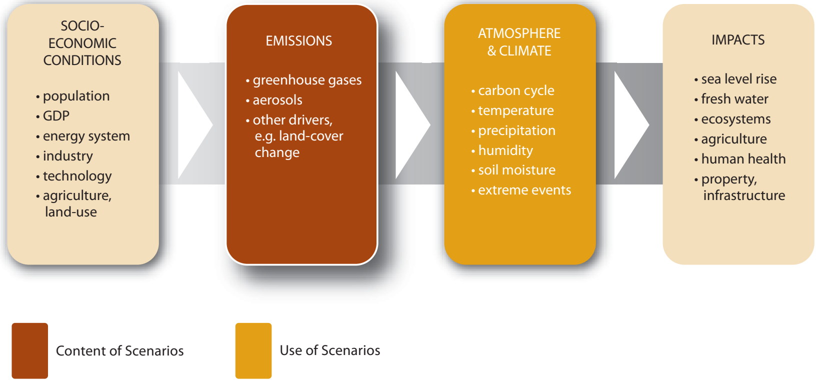
pheric concentration of CO_2 from its pre-industrial value, to either two or four times that value.[34] Models' equilibrium responses to doubled CO_2 provided a standard benchmark of model responsiveness, which has remained around the range of 1.5 to 4.5°C for more than 20 years. This range of modeled equilibrium responses to a standardized perturbation does not predict actual climate changes under human perturbations, although it has often mistakenly been taken as such.

The next generation of climate-model studies, beginning in the early 1990s, specified a time-path of atmospheric concentrations rather than a one-time perturbation. These studies for the first time allowed comparison of models' transient responses, by examining not just how much the cimate changes, but how fast it changes. They still used a simple, highly idealized standard scenario, most frequently a 1 percent per year increase in atmospheric concentration, expressed as CO_2-equivalent. Only two such transient simulations had been conducted by the first IPCC assessment (1990), but by the time of the second assessment (1996), most modeling groups had produced at least one.[35]

Since the mid-1990s, climate modelers have increasingly sought to produce realistic pictures of how the climate may actually change, requiring a new approach to emissions scenarios. Scenarios must now present well-founded judgments or guesses of actual future emissions trends and their consequences for atmospheric concentrations. The required emissions scenarios have been constructed either by extrapolating recent emissions trends, or, particularly for energy-related CO_2, representing emissions in terms of underlying drivers such as population, economic growth, and technological change and projecting these drivers using some combination of modeling and trend extrapolation. Driven by such scenarios, climate models for the first time can claim to be reasonable estimates of how the climate might actually change. In addition, comparisons using multiple models and emissions scenarios have allowed partitioning of uncertainty in future climate change into roughly equal shares attributed to uncertainty in climate science and models, and in emissions trends.[36] These comparisons have also allowed estimation of the climate-change benefits from specified emissions reductions.

As this shift occurred, advances in climate models – e.g., improved representations of atmospheric aerosols, tropospheric ozone, and atmosphere-surface interactions – produced mismatches between emissions scenarios and the input needs of climate models. For example, climate models now require emissions of several types of aerosols and reactive gases (principally the ozone precursors, hydrocarbons, CO and NO_x), explicit estimates of black carbon and organic carbon, and some disaggregation of different types of volatile organic compound (VOC) emissions. Moreover, because these emissions act locally and regionally rather than globally, they must be specified at the spatial scale of a model grid-cell, about 150 sq. km. Models of atmospheric chemistry and transport then use these emissions to generate the concentrations and radiative forcings used by the climate model. Since emissions scenarios often do not provide the required detail, cli-

Figure 2.3. Emissions scenarios for climate simulations.



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[34] e.g., Manabe and Wetherald 1967, Manabe and Stouffer 1979.

[35] Washington and Meehl 1989, Manabe et al. 1991, IPCC 1996a.

[36] Cubash et al. 2001.

mate modelers meet these input needs through various *ad hoc* approaches.

Changes in standard emissions scenarios pose challenges for maintaining comparability with past model results. For example, the IPCC's IS92 scenarios projected that future SO_2 emissions would roughly double, then stabilize, while the later SRES scenarios projected sharp decreases, giving 2100 emissions about one-quarter the IS92 value. This change caused significant increases in projected warming that were not due to any changed scientific understanding. To help maintain backward comparability, many climate-model groups have continued to run simulations using older standardized scenarios, to provide benchmarks for comparisons both among current models and between current and previous-generation models.

2.2. EMISSIONS SCENARIOS FOR EXPLORING ALTERNATIVE ENERGY AND TECHNOLOGY FUTURES

In addition to providing needed inputs to climate models, emissions scenarios have also been produced to examine alternative socio-economic, energy, and technological futures, as shown in Figure 2.4. As in Figure 2.3 the content of the scenario is emissions, but the scenario is now used to examine the socio-economic implications of alternative emission paths, which lie upstream or to the left in the causal chain. A scenario specifying a particular emissions time-path can be used to explore what patterns of demographic and economic change, energy resource availability, and technology development are consistent with that trajectory. Alternatively, scenarios can be used to examine what changes in policies, technologies, or other factors would be required to shift emissions from some assumed baseline onto a specified lower path, and to estimate the cost of such a shift. To be used in this way, an emissions scenario might be specified arbitrarily, or might specify some environmental target based on normative criteria as discussed in Section 1.2. Such scenarios have been most frequently used to examine emissions trajectories that stabilize atmospheric CO_2 concentrations at specified levels. More recent exercises have instead taken stabilization of radiative forcing as the target, to examine the role of non-CO_2 greenhouse gases in meeting stabilization goals.[37]

Models' equilibrium responses to doubled CO_2 provided a standard benchmark of model responsiveness, which has remained around the range of 1.5 to 4.5˚C for more than 20 years.

An important early example is the Wigley, Richels, Edmonds (WRE) scenarios, which presented emissions pathways that stabilized atmospheric CO_2 concentration at five levels, ranging from 450 to 1000 ppm.[38] Developed heuristically from a simple model of the global carbon cycle and two energy-economic models, these scenarios illustrated the large cost savings attainable by approaching stable concentrations through emission paths that initially rise and then decline steeply, rather than by beginning a more gradual decline immediately.

Several other sets of stabilization scenarios have been proposed and used for similar explorations. For example, the Energy Modeling Forum (EMF) has convened several multi-model scenario exercises focusing on emissions, emissions constraints, and their socio-economic effects. These have studied decision-making under uncertainty, international distribution of costs and benefits, the costs and

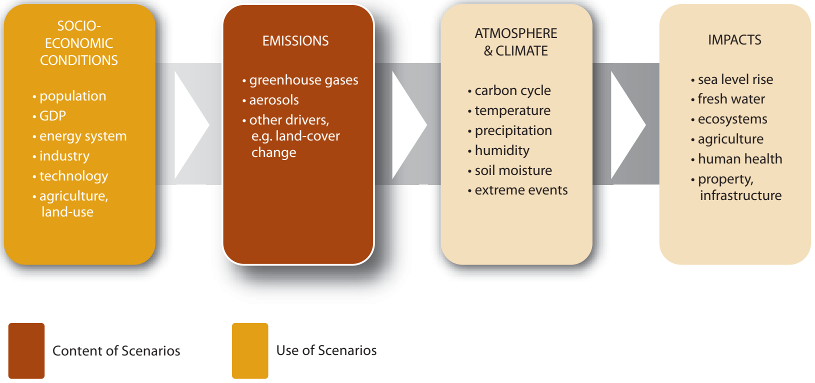

Figure 2.4. emissions scenarios for energy/technology futures.

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[37] de la Chesnaye and Weyant 2006, EMF 2006, CCSP 2007.

[38] Wigley et al. 1997.

benefits of the Kyoto Protocol, the implications of potential future energy technologies and technological change for emissions, and the implications of including non-CO_2 gases and carbon sequestration in mitigation targets and policies.[39]

In a recent scenario exercise of this type sponsored by the CCSP, three modeling teams constructed separate reference-case scenarios to examine the implications of stabilizing radiative forcing at levels roughly corresponding to CO_2 concentrations of 450, 550, 650, and 750 ppm. They examined the energy system, land-use, and economic implications of moving to stabilization. This project explored the role of multiple gases and alternative multi-gas control strategies in pursuing atmospheric stabilization. These scenarios may also provide a basis for future analyses by the CCSP, the Climate Change Technology Program (CCTP), or others.[40]

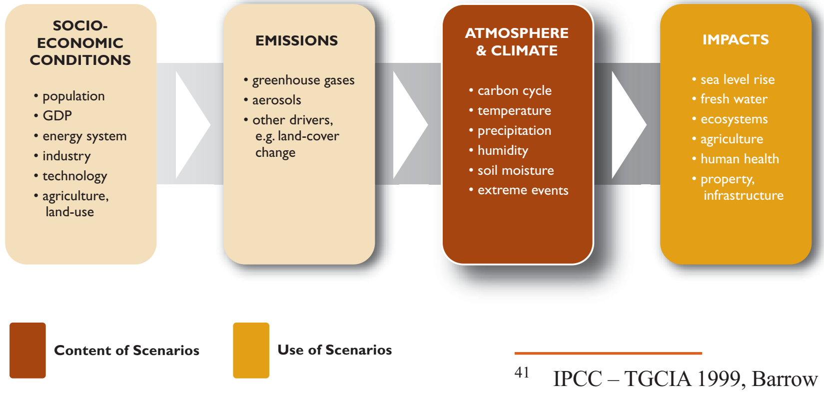
2.3. CLIMATE CHANGE SCENARIOS

Climate scenarios describe potential future climate conditions (Figure 2.5). They are used to provide inputs to assessments of climate-change impacts, vulnerabilities, and associated options for adaptation, and to inform decision-making related to either adaptation or mitigation. Depending on their specific use, climate scenarios may include multiple variables, such as temperature, precipitation, cloudiness, humidity, and winds. They may describe these at spatial scales ranging from the entire globe, through broad latitude bands, large continental and sub-continental regions, to climate model grid-cells or finer scales. They may project these at time resolutions ranging from annual or seasonal averages to daily or even finer-scale weather.[41]

Three major types of climate scenarios are distinguished by how they are produced: incremental scenarios, analog scenarios, and climate-model scenarios.[42] Incremental scenarios change current conditions by plausible but arbitrary amounts. For example, a region's temperature might be warmed by 2, 3, or 4°C from present conditions, or its precipitation increased or decreased by 5, 10, or 20 percent. Such adjustments can be made to annual or seasonal averages, to finer-period measurements of current conditions, or to the variability of temperature or precipitation over days, months, or years.[43] Like the simple emissions scenarios used for climate-model comparisons, incremental climate scenarios are simple to produce but make no claim to represent actual future conditions. They are used for initial exploratory studies of climate impacts and to test the sensitivity of impact models.

Analog climate scenarios represent potential future climates by the observed climate regime at another place or time. A spatial analog imposes the climate of one location on another, e.g., representing the potential climate of New York in the 2050s by that of Atlanta today or that of Illinois in the 2050s by that of Kansas today.[44] A temporal analog imposes climate conditions observed in the past, in the historical record or earlier paleoclimatic observations, e.g., using the hot, dry period of the 1930s to study impacts of potential future hot, dry climates.[45] Like incre-

Figure 2.5. Climate-change scenarios.



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[39] See, e.g., Weyant and Hill 1999; Weyant 2004; de la Chesnaye and Weyant 2006; EMF 2006.

[40] CCSP 2007.

[41] IPCC – TGCIA 1999, Barrow et al. 2004.

[42] Mearns et al. 2001.

[43] e.g., Mearns et al. 1992, 1996; Semenov and Porter 1995.

[44] E.g., Kalkstein and Greene 1997.

mental scenarios, analog climate scenarios are more useful for exploratory studies of the climate sensitivity of particular resources or systems than for projecting likely impacts. While they represent climate states that are known to be physically possible, they are limited as representations of potential future states since they do not consider the changes in greenhouse-gas concentrations that are the principal driver of climate change.

Climate-model scenarios use computers to produce a physically consistent representation of the movement of air, water, energy, and radiation through the atmosphere. Climate models, also called General Circulation Models or GCMs, approximate this calculation by dividing the atmosphere into thousands of grid-cells, roughly 150 km. square in today's models, with a dozen vertical layers, treating conditions as uniform within each cell and representing finer-scale processes by numerical relationships, called "parameterizations," that are defined at the scale of a grid cell. Climate models are used to study the present climate and its responses to past perturbations like variation in the sun's output or volcanic eruptions, and to construct scenarios of future climate change under any specified scenario of emissions and other disturbances.

Unlike incremental and analog scenarios, climate-model scenarios use emissions scenarios as inputs. Model-based scenarios have a greater claim than the other types to being realistic descriptions of how the climate might actually change, because they are based on specified assumptions of future emissions trends acting on modeled representations of known physical processes. Even with a given emissions scenario, model-based climate scenarios are uncertain. Since climate models are driven by the radiative effects of atmospheric concentrations of relevant species, some of this uncertainty comes from the carbon-cycle and chemical processes by which specified emission paths determine concentrations and radiative forcings. Some of the uncertainty can be seen in the slight differences among different runs of the same climate model, because the models are sensitive to small differences in starting conditions. And some of the uncertainty can be seen in differences between calculations by different models, mainly caused by differences in the computational methods they use to handle errors introduced by finite grid-cells, and the parameterizations they use to represent small-scale processes.

Just as modeling future climate change requires specification of future emissions trends, assessments of future climate-change impacts require specification of future climate change. Data from a climate-change scenario might be used as input to impact assessments of freshwater systems, agriculture, forests, or any other climate-sensitive system or activity. Impact studies can use various methods, including quantitative models such as hydrologic and crop models, threshold analyses that examine qualitative disruptions in the behavior of climate-sensitive systems, or expert judgments that integrate various pieces of scientific knowledge.

Just as modeling future climate change requires specification of future emissions trends, assessment of future climate-change impacts requires specification of future climate change.

As with all scenarios, the usefulness of climate scenarios depends on how well they meet users' information needs. The highly specific climate-data needs of impact analyses may not readily be provided by climate-model outputs, or may include results of whose validity climate modelers are not confident. For example, a common need of impact analyses is for data at substantially finer scales than the relative coarse grid of a climate model, which might have only 60 to 100 cells over the continental United States. One advantage of incremental and analog scenarios is that they can typically provide data at substantially finer scales. "Downscaling" techniques seek to combine the benefits of model-based scenarios – physical realism and explicit emissions-scenario drivers – and data at finer scales. The two major approaches are statistical downscaling and nested regional modeling.[46] Statistical downscaling involves estimating statistical relationships between large-scale variables of observed climate, such as regional-average temperature, and local variables such as site-specific temperature and precipitation.[47] These relationships are then assumed to remain constant under global climate change. A nested regional climate model provides an explicit physical representation of cli-

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[45] E.g., Rosenberg et al. 1993.

[46] Giorgi et al. 2001.

[47] Wilby and Wigley 1997.

mate for a specific region, including local factors such as mountain ranges, complex coastlines, and surface vegetation patterns, with initial and boundary conditions provided by a GCM. Regional climate models can provide projections at scales as small as 10 to 20 km. Although downscaled results are anchored to local features with well-understood climatic effects, downscaling introduces uncertainties beyond those already present in GSM results.[48]

2.4. SCENARIOS OF DIRECT BIOPHYSICAL IMPACTS: SEA LEVEL RISE

Although climate-change scenarios can provide inputs to studies of any impact, scenarios can also be constructed of particularly important forms of impact, such as sea level rise – one of the more costly and certain consequences of climate warming (Figure 2.6).[49] Changes in global mean sea level as the climate warms can be calculated using a GCM with a coupled ocean and atmosphere, which can simulate the transfer of heat to the ocean and the variation of ocean temperature with depth. To construct sea level rise scenarios for particular coastal locations, model-derived projections of global mean sea level rise must be combined with projections of local subsidence or uplift of coastal lands, as well as local tidal variations derived from historical tide-gauge data.

Sea level rise will increase circulation and change salinity regimes in estuaries, threaten coastal wetlands, alter shorelines through increased erosion, and increase the intensity of coastal flooding associated with normal tides and storm surge. Scenarios of sea level rise are consequently needed to assess multiple linked impacts on coastal ecosystems and settlements. In specific locations, these impacts will depend on many characteristics of coastal topography, ecosystems, and land use – e.g., coastal elevation and slope, rate of shoreline erosion or accretion, tide range, wave height, local land use and coastal protection, salinity tolerance of coastal plant communities, etc. – in addition to local sea level rise.[50]

In addition to its gradual impacts, sea level rise is subject to large uncertainties from the potential loss of continental ice sheets in Greenland and West Antarctica. The consequences of these events for global sea level rise are well known because they can be calculated quite precisely from the volume of the ice sheets – roughly 7 meters rise from complete loss of the West Antarctic Ice Sheet and 5 meters from Greenland – but the probabilities of these events and their likely speed of occurrence are both highly uncertain. One recent study has suggested a probability of a few per cent that the West Antarctic Ice Sheet will contribute an additional one meter per century beyond that calculated from gradual warming.[51]

There are several reasons to call out sea level rise from other climate-change impacts to be represented in separate scenarios. First, sea level rise is a powerful driver of other forms of climate-change impact, probably the most important driver of impacts in coastal regions. Since it is a direct physical impact of climate change that can be described precisely and compactly, a sea level rise scenario is an efficient way to transmit the most important information about climate change to coastal impact assessments. Moreover, since sea level rise does not depend on socio-economic processes and cannot be significantly influenced by human actions (other than by limiting climate change itself), it may be reasonably treated as exogenous for purposes of impact assessment. For all these reasons, sea level rise is a good proxy for the most important causal routes by which climate change will affect coastal regions.

Finally, because sea level rise is subject to large uncertainties with known consequences but unknown probabilities, it is a useful variable for exploratory analysis of worst-case scenarios in long-range planning. Other forms of climate impact might also merit being called out in separate scenarios: changes in snowpack in mountain regions, seasonal flow regimes in major river basins, or the structure and function of major ecosystem types. Based on present knowledge, however, only sea level rise has

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[48] Mearns et al. 2001, Giorgi et al. 2001.

[49] IPCC 2001a.

[50] Burkett et al. 2005.

[51] Vaughan and Spouge 2002.

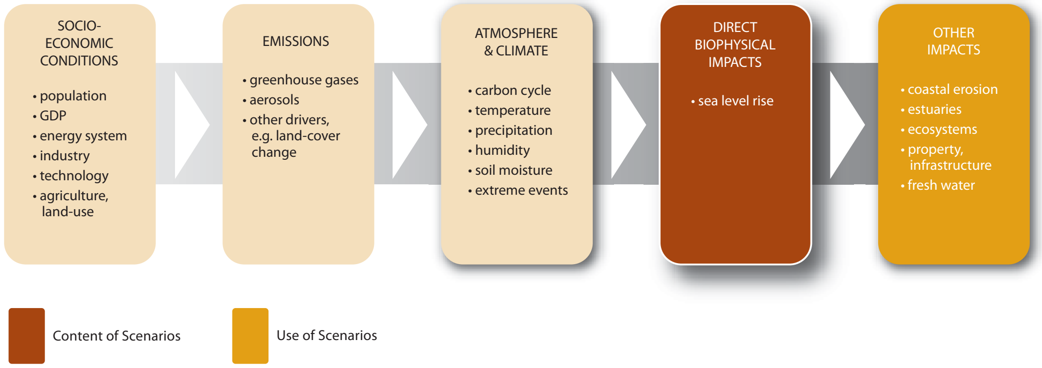

Figure 2.6.: Scenarios of direct biophysical impacts: sea level rise.

shown these characteristics strongly enough to motivate construction of separate scenarios.

2.5. MULTIVARIATE SCENARIOS FOR ASSESSING IMPACTS, ADAPTATION, AND VULNERABILITY

Many potentially important impacts of climate change cannot be adequately assessed by considering only how the climate might change. These impacts require multivariate scenarios that include climate change and other characteristics likely to influence impacts. This is the case, for different reasons, for both ecosystems and socio-economic systems, although the nature of the multivariate scenarios that are required – i.e., the number and identity of the characteristics that must be specified – will vary widely among particular impacts.

Ecosystems are affected by climate change, but also by many other changes in environmental conditions that are influenced by human activities, such as nitrogen and sulfur deposition, tropospheric ozone and smog, and changes in erosion, runoff, loadings of other pollutants, land use, land cover, and coastal-zone characteristics. Consequently, realistic assessments of potential future impacts on ecosystems require specifying the most important forms of human-driven stresses jointly, not just climate.[52]

In addition, many important forms of climate-change impact depend not just on climate change, its direct biophysical impacts such as sea level rise, and perhaps other forms of environmental stress, but also on the nature of the society on which these climate and other environmental changes are imposed – e.g., how many people there are; where and how they live; how wealthy they are; how they gain their livelihoods; and what types of infrastructure, institutions, and policies they have in place.[53]

Assessment of climate impact on ecosystems that are intensively managed for human use, such as agriculture, managed forests, rangelands, and hydrologic systems, must consider human management as a factor in impacts. The non-climatic factors that influence these management decisions – e.g., changes in market conditions, technologies, or cultural practices – must be considered for inclusion in scenarios if they are sufficiently important in mediating climate impacts.

In other domains, socio-economic factors can mediate climate impacts by influencing vulnerability and adaptive capacity. No general model of the socio-economic determinants of adaptive capacity exists. Important factors are likely to vary across specific types of impact, locations, and cultures, and may include many demographic, economic, technological, institutional, and cultural characteristics.

Some socio-economic characteristics that are likely to be relevant for many impact assessments – e.g., the size and sometimes the age structure of population, the size and sometimes the sectoral mix of GDP – are normally generated in the course of producing emissions scenarios. Consequently, when current emissions scenarios exist for the region for which an impact assessment is being conducted, it makes sense to strive for consistency with them.[54] Even for these variables, however, there may be significant problems of incompatible spatial

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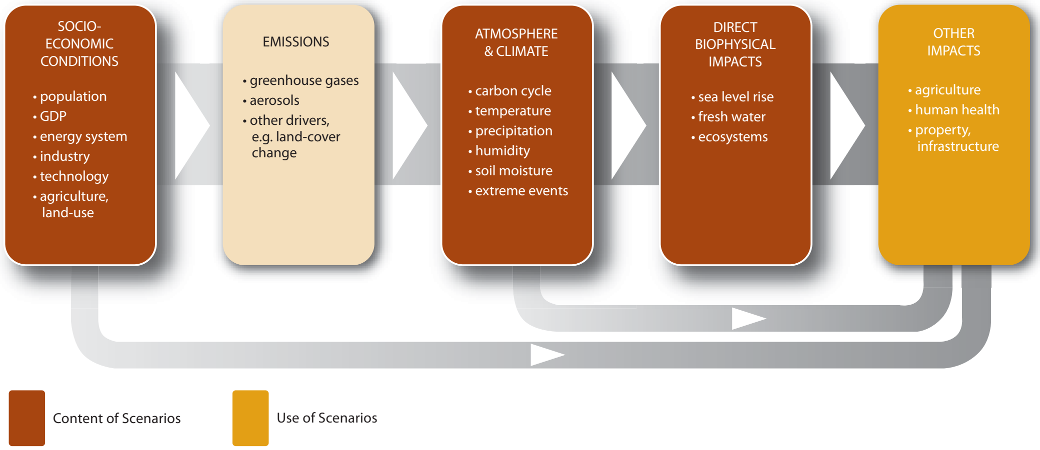
[52] MEA 2005.

[53] Parson et al. 2001, 2003; Arnell et al. 2004.

[54] Berkhout et al. 2001, citing UNEP 1994 guidelines.

Figure 2.7: Multivariate scenarios for impact assessment.



scale. Impact assessments often examine smaller spatial scales than emissions projections, so they may need these socio-economic data at finer scale than is available. Downscaling future socio-economic projections has proved challenging thus far. There is no generally accepted method for doing so, and several research groups are exploring development of alternative methods.[55]

In contrast to the few clearly identified aggregate characteristics needed to construct emissions scenarios, the socio-economic factors that most strongly shape adaptive capacity and vulnerability for particular impacts may be detailed, subtle, and location-specific. It may not even be clear what characteristics are most important before doing a comprehensive analysis of potential causal pathways shaping impacts. The most important characteristics may interact strongly with each other or with other economic or social trends, or may not be readily quantifiable. All these factors make the development of socio-economic scenarios for impact assessment a much more difficult endeavor than constructing emissions scenarios.

Because scenarios are schematic, not all factors that might be important for impacts can be included. Details are typically not included or treated as merely illustrative. But particular details, which cannot be identified in advance, may be crucial determinants of vulnerability to climate impacts.[56] Impact assessments have responded to this dilemma in two broad ways.[57] First, constructing scenarios of relevant socio-economic conditions has been delegated to local or regional teams with expertise in the impacts being assessed, subject to constraints to maintain consistency with other assessments. Second, since local or regional scenario groups may not have access to all knowledge relevant to understanding the main determinants of impacts, more open-ended approaches have been employed – e.g., exploratory analyses that iterate between considering particular characteristics that might be important, examining their implications for impacts using the data and models available, then re-assessing what variables are most important.

This section has sketched a typology of global-change scenarios and identified major types of decision-makers who might use global-change scenario-based information. The next section turns to current experience with global-change scenarios, summarizing the development, contents, and uses of four major exercises. Informed by these cases plus additional short scenario examples presented in text boxes, Section 4 will summarize and discuss the major challenges for making and using scenarios that are raised by this experience, providing the basis for the conclusions and recommendations presented in Section 5.

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[55] Toth and Wilbanks 2004, Pitcher 2005.

[56] Berkhout et al. 2002.

[57] Berkhout et al. 2001, Parson et al. 2001.