Chapter 2. Foundations for Decision-Making

Coordinating Lead Authors
Roger N Jones (Australia), Anand Patwardhan (India)

Lead Authors
Stewart Cohen (Canada), Suraje Dessai (UK), Annamaria Lammel (France), Rob Lempert (USA), Monirul Mirza (Bangladesh/Canada), Hans von Storch (Germany)

Contributing Authors
Werner Krauss (Germany)

Review Editors
Rosina Bierbaum (USA), Nicholas King (South Africa)

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Executive Summary

The purpose of this chapter is to offer foundational knowledge and important perspectives on how better decisions can be made in response to assessments of climate impacts, adaptation and vulnerability. [2.1.1] It introduces new material from a range of disciplines, broadening the decision-making methods used to date. In the past, IPCC-sponsored assessment methods and policy advice have been framed by the assumption that better science will lead to better decisions. [2.1.2] While better science is necessary, it is not sufficient, requiring additional decision-support processes and tools. [2.1.2, 2.2] The decision-sciences applied on scales from the individual to organizations to institutions provide a great deal of decision-making theory and practice that can inform process and methods. [2.2, 2.3]

All decisions involving uncertainty and valued outcomes involve risk management. [2.1.1] The international risk management standard defines risk as *the effect of uncertainty on objectives*. Risk management provides a useful framework for most CCIA decision-making. [2.1] A broad operational definition of risk is *a situation or an event where something of human value (including humans themselves) is at stake and where the outcome is uncertain.* [2.1.1]

Iterative risk management involves an ongoing process of assessment, action, reassessment, and response that may need to be applied under climate change, for decades, if not longer. [2.1.2, 2.3.1] Both the objective and subjective aspects of risk: 1) calculated risks derived through formal processes and 2) perceived risk, the subjective view of risk held by a stakeholder, need to be incorporated into the decision-making process. [2.1.2] In simple systems, calculated and perceived risks are more likely to be closely aligned. Complex decision-making contexts will require both the risks of various future outcomes and the risks of alternative actions to be assessed. [2.3.1] This places significant demands on people and organisations to manage that process within the context of their own aims. [2.3.1]

Scenarios are a vital part of managing uncertainty. They can be divided into those that explore how futures may unfold under various drivers (problem exploration) and those that test how various interventions may play out (solution exploration). [2.2.1.1] Historically, most scenarios used for CCIAV assessments have involved the former type. The new RCP scenario process is being constructed to cater for both problem and solution framing. [2.2.1.1]

Most social-ecological systems where adaptation takes place are reflexive, requiring the development of adaptive management techniques such as iterative risk assessment. In reflexive systems, decisions that are implemented will change the system itself, demanding ongoing monitoring and assessment in order to track those changes, as they are rarely predictable. [2.2.1.1] Formal processes of monitoring and periodic review, including revisiting ongoing aims and objectives, are required to support adaptive management. [2.2.1.3]

Decision-making on CCIAV has a very strong ethical basis that is expressed at a range of institutional scales and is strongly embedded into elements of risk governance on those scales. [2.2.2.1, 2.2.2.2, 2.2.3.4]

Decision support is situated at the intersection of data provision, expert knowledge and human decision-making at a range of scales from the individual to the organization and institution. Decision support is defined as a set of processes intended to create the conditions for the production of decision-relevant information and its appropriate use. [2.2.1, 2.2, 2.3] Such support is most effective when it is context-sensitive, taking account of the diversity of different types of decisions, decision processes, and constituencies. [2.3.1, 2.3.3, 2.3.4] Institutionally, boundary organisations are important in translating and transferring these messages. [2.3.1, 2.3.2]

Climate services aim to make knowledge about climate regionally accessible to a wide range of decision makers. [2.3.3] In doing so they have to consider information supply, knowledge competition and user demand.

Knowledge transfer is a negotiated process that can take a variety of cultural values, orientations and alternative forms of knowledge into account. [2.3.1, 2.3.3]

Climate change response can be linked with sustainable development through actions that enhance resilience, which is the capacity to absorb shocks and to change in order to maintain the same identity. Sustainable adaptation, disaster risk management, and new types of governance and institutional arrangements are being studied for their potential to support the goal of enhanced resilience. [2.4.2]

Transformation can be managed through transitional arrangements but these are notoriously difficult to control and are best managed through adaptive management or similar process. [2.4.3]

2.1. Introduction and Key Concepts

2.1.1. Decision-Making Approaches in this Report

This chapter addresses the foundations of decision-making with respect to climate change impact, adaptation and vulnerability (CCIAV) assessment. The Fourth Assessment Report (AR4) summarized methods for CCIAV (Carter et al., 2007), which we build on by surveying the broader academic literature to obtain knowledge on decision-making suitable for CCIAV. This expanded focus reflects the evolution of CCIAV assessments from the straightforward linear scenario-driven approaches described in the early literature to the wide range of decision-making approaches active today.

The overarching theme of the chapter is risk management. The International Standard ISO:31000 defines risk as *the effect of uncertainty on objectives* (ISO, 2009) and Rosa (2003) defines it as *a situation or an event where something of human value (including humans themselves) is at stake and where the outcome is uncertain*. Because all decisions on CCIAV are affected by uncertainty and involve valued objectives, all are decisions of risk (e.g., Giddens, 2009). To encompass both this broad theme and the specific nature of many kinds of decision-support, a three-tier hierarchy for decision-making is presented: approach, methodology and method (Figure 2-1). Approach describes the broad framing and scoping of an issue; methodology comprises the principles and rules governing the decision-making process; and that process is applied using methods and tools.

[INSERT FIGURE 2-1 HERE
Figure 2-1: Risk portrayed as an approach, methodology and method using definitions relevant to this report.]

Risk management frames the overall chapter approach, but at the methodological scale can be applied in many ways: e.g., financial, disaster, engineering, environmental and health risk. A range of different tools and methods can be applied to each methodology. Many other methodologies such as vulnerability, resilience and livelihood assessments may at first seem to be unconnected with traditional risk assessment, but may in fact be analysing, evaluating or managing risks within a larger risk management process. For example, developing resilience can be seen as managing a range of potential risks; sustainable development aims to developing a system robust to risks informed by values-based processes and outcomes.

The Fourth Assessment Report endorsed risk management as a suitable decision-support framework for CCIAV assessment because it offers formalized methods for addressing uncertainty, involving stakeholder participation, identifying potential policy responses, and evaluating those responses (Carter et al., 2007; Yohe et al., 2007). A risk management framework also facilitates the mainstreaming of climate-centric decision-making into broader decision-making processes. The AR4 report also summarized advances in many CCIAV assessment approaches and described how they can fit into a risk management framework. The literature shows significant advances on all these topics since AR4 greatly expanding methodologies for assessing impacts, adaptation and vulnerability in a risk context (Agrawala and van Aalst, 2008; Hinkel, 2011; Jones and Preston, 2011; Preston et al., 2011).

A major aim of risk management is to make better decisions. There are many definitions of decision in the literature but all involve choosing amongst alternatives, and some involve a course of action to enact that decision. **But what**

constitutes a "better" decision? *A better decision is one where the process of decision-making is judged to produce more acceptable outcomes within a given set of circumstances than previous decisions*. It may be highly precautionary, designed to avoid the worst possible outcomes (Hansson, 2006; Malik et al., 2010). Elwyn and Miron-Shatz (2010) argue that process be given more weight than outcomes under uncertain futures where many outcomes are possible. Many factors that influence how a decision can be assessed include: who is making the decision, its context and purpose, what information is used, who implements its actions, the resources invested in the decision-making process, the choice of method, who is affected by its outcomes, how those outcomes are valued and assessed over a given time horizon, and the extent to which the objectives being pursued are regarded as appropriate. Section 2.2.3.4 shows that ethics are an important aspect of such choices.

Two aspects of decision-making that distinguish climate change from most other contexts are the long time scales involved and pervasive uncertainties (Kandlikar et al., 2005; Ogden and Innes, 2009; Lempert and McKay, 2011). These uncertainties include not only future climate but also socio-economic change and potential changes in norms and values across generations. Process uncertainties also affect the choice of the most suitable decision-support applications for managing specific problems or seeking uncertain solutions within a given context.

Decision-makers range from individuals, to organizations to institutions, at the largest scale comprising systems of systems. Decision-makers are influenced by both individual and group factors, such as internal psychological and cognitive factors, their physical and socio-cultural environments, and the institutions within which they operate. They draw from a knowledge base and utilize a variety of methods and tools that they know and accept. Decisions are framed by aspirations and goals and informed by scenarios of how the future may play out.

The study of human reasoning has a long history, in eastern and western traditions and in widespread indigenous cultures. In recent decades, research describing the actual processes of human decision-making, note that the normative (the decision one should arrive at) and descriptive/positive (what people actually do) aspects often diverge (e.g., Raïffa et al., 2002). For example, people often fail to take simple preparations for disasters such as earthquakes or floods even when they have sufficient resources to do so and would, upon more careful reflection, come to believe that they should (McClure et al., 1999; McIvor and Paton, 2007). People may also act inconsistently with a particular formal analysis because they have values and goals not well represented in that analysis (Davies and Walters, 1998; Helsloot and Ruitenberg, 2004).

Previous assessments have described the methods and tools used for decision support, giving less regard to decision-making processes (Carter et al., 1994; Parry and Carter, 1998; Carter et al., 2001; Hulme and Mearns, 2001; Carter et al., 2007; IPCC-TGICA, 2007). Much method development has aimed for objectivity, often assuming that rational knowledge will induce 'rational' behavior. However, the decision sciences literature makes clear that people make decisions based on a whole variety of criteria (Karvetski et al., 2009; Tryhorn and Lynch, 2010); for example, stakeholder groups in a single region show multiple preferences for coastal protection leading to very different solutions for the same hazard (Mustelin et al., 2010). To date, the socio-cultural and cognitive-behavioural aspects of CCIAV decision-making have largely been restricted to descriptions of social learning processes; e.g., Section 2.3.2 on stakeholders in Carter et al. (2007). However, we see these factors as being just as important as specific knowledge brought into the decision-making process.

The next section (2.2) describes diverse aspects important to a full understanding of CCIAV decision making, including methods, tools, and processes (Sect 2.3.1); institutional (2.3.2); and social (2.3.3) contexts. Section 2.3 describes how understanding of these aspects can be used to improve decision making. Section 2.4 addresses the interaction between adaptation and mitigation, sustainable development and transformation.

2.1.2. Iterative Risk Management

Complexity is an important attribute for framing and implementing decision-making processes *[High confidence]*. Simple, well-bounded contexts involving cause and effect can be addressed by straightforward linear methods. When complex contexts interact with human values they become associated with wicked problems. Wicked problems are not well bounded, they are framed differently by various actors and groups, they harbour large scientific to existential uncertainties and have unclear solutions and pathways to those solutions (Rittel and Webber, 1973; Australian Public Service Commission, 2007). Such ‘deep uncertainty’ cannot easily be quantified (Dupuy and Grinbaum, 2005; Kandlikar et al., 2005). One important attribute of complex systems is reflexivity, where cause and effect feed back into each other. For example, actions taken to manage a risk will affect the outcomes, requiring iterative processes of decision-making. Under climate change, risks will also change with time (Ranger et al., 2010)

The CCIAV literature has increasingly adopted an iterative risk management framework (Carter et al., 2007; Yohe et al., 2007; Jones and Preston, 2011), which is also consistent with risk governance (Renn, 2008) and a wide range of approaches for structured decision-making involving process uncertainty (Ohlson et al., 2005; Wilson and McDaniels, 2007; Ogden and Innes, 2009; Martin et al., 2011). Iterative risk management involves an ongoing process of assessment, action, reassessment, and response (Kambhu et al., 2007; IRGC, 2010) that will continue – in the case of many climate-related decisions – for decades if not longer (Committee on America's Climate Choices National Research Council, 2011).

Two levels of iteration can be recognised within the iterative risk management process, two internal and one external (Figure 2-2). One internal iteration occurs during the assessment stage and addresses the interactions between the problem, proposed solutions and system feedbacks where managing risk feeds back into the risk itself. A second internal iteration occurs during the management stage following implementation when formal monitoring and review tracks how the system responds and reacts accordingly. The third iteration covers the entire process when an assessment has finished and the decision process returns to the scoping phase.

[INSERT FIGURE 2-2 HERE
Figure 2-2: Iterative risk management framework showing two loops in the assessment process, looking at system feedbacks on options and at the risk management stage where a decision is made and implemented. Adapted from Willows and Connell (2003).]

Idealised, Calculated, Perceived Risks

In complex situations, socio-cultural and cognitive-behavioural contexts become central to decision-making. This requires combining the scientific understanding of risk with how risks are framed and perceived by actors and institutions (e.g., Hansson, 2010). For that reason, formal risk assessment is moving from a largely technocratic exercise carried out by experts to a more participatory process of decision support (Fiorino, 1990; Pereira and Quintana, 2002; Renn, 2008), although this process is proceeding slowly (Christoplos et al., 2001; Pereira and Quintana, 2002; Bradbury, 2006; Mercer et al., 2008).

Earlier applications of risk involved the calculation of hazard × likelihood or probability and consequence, and communicated the results to decision-makers, similar to the way that early CCIAV assessments were carried out. More recent applications have moved from the objective analysis of risk to addressing values at risk and the governance of risk (Power, 2007; Renn, 2008), although hazard-based methodologies remain important when the hazard is the primary concern. Likewise CCIAV methods are expanding from a direct focus on specific climate risks to more mainstream settings where the management of climate risks is integrated with other areas of risk management (Hellmuth et al., 2011). For example, climate risks affecting a local government area will have planning, legal, financial, health and community aspects (Measham et al., 2011). Mainstreaming may require trade-offs between climate and other risks (Kok and de Coninck, 2007; Eakin et al., 2009).

Different epistemologies, or ‘ways of knowing’ exist for risk (Hansson, 2004; Althaus, 2005; Hansson, 2010), vulnerability (Weichselgartner, 2001; O'Brien et al., 2007) and adaptation assessments (Adger et al., 2009) affecting the way they are framed by various disciplines and are also understood by the public (Garvin, 2001; Adger, 2006; Burch and Robinson, 2007). These differences have been nominated as a source of widespread misunderstanding and disagreement. They are also used as evidence to warn against a uniform epistemic approach (Hulme, 2009; Beck, 2010), a critique that has been levelled against previous IPCC assessments (Hulme and Mahony, 2010).

The following five types of risk have been nominated as important epistemological constructs (based on Thompson, 1986; Althaus, 2005; Jones, 2012):

1) Idealized risk: the conceptual framing of the problem at hand. For example, dangerous anthropogenic interference with the climate system is how climate change risk is idealized within the UNFCCC.
2) Calculated risk: the product of a model based on a mixture of historical (observed) and theoretical information. Frequentist or recurrent risks often utilize historical information whereas single-event risks may be unprecedented, requiring a more theoretical approach.
3) Subjective risk: the mental state of an individual who experiences uncertainty or doubt or worry as to the outcome of a given event. Gives rise to:
4) Perceived risk: the rough estimate of an idealized risk derived informally by individuals and groups.
5) Observed risk: the risk observed once an event is realized. This will update to conceptualization of future risks.

These different types show risk to be partly an objective threat of harm and partly a product of social and cultural experience (Kasperson, 1992; Rosa, 2008). The aim of calculating risk is to be as objective as possible, but the subjective nature of idealized and perceived risk reflects the division between positivist (imposed norms) and constructivist (derived norms) approaches to risk from the natural and social sciences respectively (Demeritt, 2001; Hansson, 2010). Idealized risk will follow both formal and informal pathways through the assessment process. Acceptance of the science behind controversial risks is strongly influence by social and cultural influences (Leiserowitz, 2006; Kahan et al., 2007; Brewer and Pease, 2008); Figure 2-3). Risk perceptions can be amplified socially where events pertaining to hazards interact with psychological, social, institutional, and cultural processes in ways that heighten or attenuate individual and social perceptions of risk and shape risk behaviour (Kasperson et al., 1988; Renn et al., 1992; Pidgeon et al., 2003; Rosa, 2003; Renn, 2011).

[INSERT FIGURE 2-3 HERE
Figure 2-3: Schema for the chapter, showing a hierarchy of decision-makers in the centre and broad groupings of subjects addressed in the chapter. The decision-making environment is described by adaptation, mitigation and sustainable development, the methods and tools utilised include scenarios, decisions are made in the human context of individuals to groups and decisions can be assessed to measure varying degrees of success.]

Understanding of how these perceptions resonate at an individual and collective level can help overcome constraints to action (Renn, 2011). Science is most suited to calculating risk in areas where it has predictive skill and will provide better estimates than may be obtained through more arbitrary methods (Beck, 2000), but an assessment of what is at risk needs to be generally accepted by stakeholders. Therefore, the science always sits within a broader social setting, often requiring a systems approach where science and policy are investigated in tandem, rather than separately (Pahl-Wostl, 2007; Ison, 2010).

Despite there being a literature on the sociology of science relevant to climate change risks (Jasanoff, 1996; Demeritt, 2001; Wynne, 2002; Demeritt, 2006) only recently are these approaches being built into CCIAV assessments. The different types of risk listed above give rise to complex interactions between formal and informal knowledge that cannot be bridged by better science or better predictions but require socially mediated processes of engagement *[medium confidence]*, as discussed in later sections. Idealised risk is important for framing and conceptualising risk. Calculated risk covers the analytic side of risk that concentrates on quantitative decision analysis. Perceived risk is closely aligned with socially constructed risk that emerges from the psychological and behavioural sciences and from social sciences literatures such as anthropology, geography, ethics, sociology, political science, and other.

A large literature describes best practice methods for incorporating and communicating information about risk and uncertainties into decisions about climate change (Climate Change Science Program, 2009; Pidgeon and Fischhoff, 2011). This literature suggestions that effective communication of uncertainty requires products and processes that: i) closes psychological distance, explaining why is this information is important to the recipient; ii) establishes self-agency, explaining what the recipient can do with the information; iii) recognizes that each person's view of risks and opportunities depends on their values; iv) recognizes that emotion is a critical part of judgment; and v) provides mental models that help recipients to understand the connection between cause and effect. In addition, this literature emphasizes that information providers need to test their messages, since they may not be communicating what they think they are.

2.2. Aspects of Decision-Making

This section surveys aspects of decision-making important to understanding and improving CCIAV decisions. It begins (Section 2.2.1) with a survey of methods, tools, and processes potentially useful for improving such decisions. This literature emphasizes the importance of the organizational and cultural/psychological contexts of decision-making, which are addressed in Sections 2.2.2 and 2.2.3.

2.2.1. Methods, Tools, and Processes for Climate-Related Decisions

Since the AR4, the level of adaptation activity among organizations worldwide has increased substantially (Preston et al., 2009). This activity has delivered substantial experience on which practitioners can draw, as well as expanded needs and opportunities for research. This experience suggests that those faced with CCIAV decisions often require systematic methods, tools, and processes for effective risk management because the challenges they face are complex, complicated, and novel (whether or not the challenges had such attributes before climate change, they certainly do with climate change).

The heterogeneous field of decision sciences integrates ‘abstract’ decision theory with economic applications, cognitive psychology, and philosophy of action, theoretical computer science or neuroscience. It represents complementary links between cognitive psychology and economics and, more generally, cognitive sciences and social sciences (Kleindorfer et al., 1993; Buchanan and O'Connell, 2006).

Extensive evidence from the decision sciences shows that good scientific and technical information alone is rarely sufficient to result in better decisions *[high confidence]*. Better decisions result from effective decision-making processes that include access to appropriate scientific and technical information but also pay attention to institutional and organizational contexts. Based on the limited experience to date, there may now exist a sufficiently rich set of available methods, tools, and processes to support effective CCIAV decisions in a wide range of contexts *[medium confidence]*.

The concept of *decision support* provides a useful framework for understanding how risk-based concepts and information can help enhance decision-making (see McNie, 2007; National Research Council (US) Panel on Design Issues for the NOAA Sectoral Applications Research Program et al., 2007; Moser, 2009; Romsdahl and Pyke, 2009; Kandlikar et al., 2011; Pidgeon and Fischhoff, 2011). The concept also helps situate methods, tools, and processes intended to improve decision-making within appropriate institutional and cultural contexts.

Decision support is defined as “a set of processes intended to create the conditions for the production of decision-relevant information and its appropriate use” (National Academy of Sciences, 2009). Information is decision relevant if it yields deeper understanding or a choice or, if incorporated into making a choice, yields better results for decision makers and their constituents. These definitions, and criteria that can be used to judge the effectiveness of decision processes and decision support, are drawn from surveys of scientific communication and decision-making in many literatures, including public health, hazards management, natural resource management, environmental management and policy-making, land use planning, environmental risk communication, sustainability science, local air quality, as well as climate change mitigation and adaptation (National Academy of Sciences, 2009).

2.2.1.1. Treatment of Uncertainties (including Scenarios)

Methods and tools for addressing uncertainty are often central to risk management and effective CCIAV decision-making. Whether embodied in formal analyses or in the training and habits of decision makers, appropriate uncertainty frameworks are often needed because unaided human reasoning can produce mismatches between actions and goals under conditions of uncertainty (Kahneman, 2011). The literature also emphasizes the importance of quantifying uncertainty, because merely verbal descriptions can prove ambiguous and often fail to provide the information necessary to adjudicate trade-offs. Adopting frameworks for considering and quantifying uncertainty raises both technical challenges as well as those of organizing uncertain information so that it proves useful within a specific decision support process.

As one key aspect of these challenges, the literature recognizes a wide range of different types of uncertainty. Knight (1921) first contrasted as the difference between well-characterized risks and more poorly-understood, unquantifiable uncertainties. AR4 (Box 2-1) provides a taxonomy of characterizations of the future that distinguishes comprehensiveness, the degree to which a representation captures the full range of socio-economic and biophysical factors, and plausibility, the extent to which a future is possible and to which a probabilistic description can be ascribed (Carter et al., 2007). Recent taxonomies focus on both the level and location of uncertainty (Kwakkel et al., 2010). While the literature provides no consensus on definitions of such levels, in general uncertainty can range from shallow or well-characterized -- in which alternative futures can be specified and probabilities distributions placed over those futures with high confidence -- to deep uncertainty, severe, or extreme uncertainty -- in which not all alternative futures can be specified (that is, surprise is plausible) and probability distributions cannot be specified with confidence. These levels correspond to the confidence scale in the IPCC uncertainty guidance (Mastrandrea et al., 2010). For this assessment, the use of qualitative confidence levels (instead of quantitative) based on expert judgement determined through authors' evaluation of the evidence and levels of agreement, is recommended (Mastrandrea et al., 2010). In model-based analyses, uncertainty can be located in the specification of the system boundary, the conceptual model, the available data, and in different models used to represent the system in question. Both the level and location of uncertainty can affect the appropriate choice of methods and tools in a particular decision context.

_____ START BOX 2-1 HERE _____

Box on scenario building process developed with Chapter 21 regional context – forthcoming.

_____ END BOX 2-1 HERE _____

In recent years the literature has begun to describe two distinct processes for including uncertainty in decision support (Weaver et al., 2012). One process seeks to describe uncertainty as distinct information, independent of other parts of the decision problem. Probabilistic descriptions often take this approach, which follows the assess risks, identify options, evaluate trade-offs loop in Figure 2-2. For instance, probabilistic climate projections are generated to support a wide range of decisions, and thus not tied to any specific choice. In engaging with decision makers, information providers seek to understand what data would prove most useful, for instance temperature and precipitation time series at some level of spatial and temporal resolution, and then seek to provide that data to a wide community of decision makers. The basic structure of IPCC Assessment Reports also follows this pattern, with WGI laying out what is known and uncertain about current and future changes to the climate system. Working Groups II and III then describe impacts resulting from and potential policy responses to those changes. As one advantage, this process promotes a perception of objectivity because those who characterize uncertainty are functionally and often organizationally independent of those who use the uncertainty estimates to make decisions.

In contrast to this 'predict-then-act' process, a second approach seeks to describe uncertainty in the context of the sets of uncertainty factors that would affect judgments about and choices among alternative policies, following the identify options, assess risks, evaluate trade-offs loop in Figure 2-2. The literature offers several names for such approaches, including 'context-first' (Ranger et al., 2010), 'decision scaling' (Brown et al., 2011), 'assess risk of policy' (Lempert et al., 2004; UNDP, 2005; Carter et al., 2007; Dessai and Hulme, 2007) that characterize those uncertain states of the world that would cause a current or proposed policy to fail to meet its goals or the to illuminate the trade-offs among particular policy choices. For instance, Kirshen et al. (2008) provided decision makers in New York City plots that showed how the frequency of large-scale flooding would increase along the city's coastline, without changes to the current infrastructure, as a function of various assumptions about sea level rise. The IPCC's *Reasons for Concern* approach (Smith et al., 2009) aims to summarize the deleterious impacts implied by various greenhouse gas emissions trajectories. In engaging with decision-makers, this assess-risk-of-policy approach often requires that information providers work closely with decision makers to understand their plans and goals, before customizing the uncertainty description to focus on those key factors. This approach can be very effective at communicating risk and uncertainty, but often needs to be individually customized for each decision context (Lempert and Kalra, 2011; Lempert, 2012) and requires the producers and users to collaborate within a single process.

Within these processes, a number of approaches exist for dealing with uncertainty in CCIAV decisions. Traditional probabilistic approaches treat uncertainty with a single, well-characterized (joint) probability density function over future states of the world. Such approaches have been used in a wide variety of adaptation studies (Hobbs et al., 1997; Chao et al., 1999; Venkatesh and Hobbs, 1999), often within a predict-then-act process, and can prove most useful when the uncertainty is relatively well-characterized or when decision makers seek an authoritative expert judgment to inform their choices.

A variety of axiomatic approaches also exist (Smithson, 1989), such as belief functions (Shafer, 1976), imprecise probabilities (Walley, 1991), certainty factors (Clancey and Shortliffe, 1984), and fuzzy logic (Zadeh, 1983; Prato, 2009, 2011), which aim to provide formalized descriptions of multiple levels of uncertainty, generally combining likelihood with some additional measure of confidence (Climate Change Science Program, 2009). While some examples exist (e.g., Bass et al., 1997; Prato, 2009, 2011), such approaches have not been widely used for CCIAV decisions.

Sets of alternative representations can also be used to characterize uncertainty. Such approaches, often but not always used within a context-first process, aim both to decrease tendencies towards overconfidence as well as facilitate engagement with the analysis among parties with differing expectations and values. These set-based approaches can focus on non-probabilistically weighted collections of future states of the world or can retain a probabilistic formulation by considering a range of probability values or sets of plausible probability density functions, for instance as suggested in the IPCC uncertainty guidance (Mastrandrea et al., 2010). Examples include InfoGap, which has been used to inform CCIAV decisions in water management (Ben-Haim, 2001; Korteling et al., 2013); RDM (robust decision making), which has been used for water management and flood risk management planning (Lempert et al., 2003; Lempert and Groves, 2010; Lempert and Kalra, 2011; Matrosov et al., 2013); and robust control optimization and control theory (Hansen and Sargent, 2008). Note that the climate modelling community has also begun to adopt set-based characterizations of uncertainty (see Parker, 2006).

Scenarios

Scenarios are cognitive tools central to scoping and assessing risk, and in managing risk as adaptation planning *[very high confidence]*. A scenario is not a prediction of what the future will be but rather a description of how the future might unfold. A scenario includes an interpretation of the present, a vision of the future and an internally consistent account of the path from the present to the future (Jäger et al., 2008). Scenario use has expanded significantly as CCIAV research has become more integrated with mainstream activities. Their application has extended beyond climate as noted in the past two assessment reports (Carter et al., 2001; Carter et al., 2007). Climate change has also become a core feature of many scenarios used in regional and global assessments of environmental and socio-economic change (Carpenter et al., 2005; Raskin et al., 2005). Scenarios can be used at a number of stages within the assessment process or to underpin an entire assessment. They serve a variety of purposes, including informing decisions under uncertainty, scoping and exploring poorly understood issues, and integrating knowledge from diverse domains (Parson et al., 2006).

Existing scenario typologies tend to reflect the state of play at the time they are assembled, become outdated as the field evolves and often fail to capture the full range of contemporary scenario development (van Notten, 2006). They seem to be regarded as products of research, rather than as tools designed to function in particular sorts of inquiries (Wilkinson and Eidinow, 2008). Recently published typologies include descriptive (van Notten, 2006), philosophical underpinning (Börjeson et al., 2006) and decision-type (Wilkinson and Eidinow, 2008). These typologies can be grouped according to their function in decision-making. The major groupings are problem-based, solution- or actor-based and reflexive scenarios (Wilkinson and Eidinow, 2008). Exploratory scenarios that explore value-neutral 'what will happen if' questions and normative scenarios that represent explicit values in a forecasting or back-casting mode are also important pairings (Carter et al., 2007). Problem-based scenarios are developed using deductive and inductive methods whereas actor-based scenarios are normative, so map well onto exploratory and normative scenarios.

Reflexive scenarios are designed to work with wicked problems (Wilkinson and Eidinow, 2008). Problem (exploratory) and solution- or actor-based (normative) scenarios are combined to assess problems, implement decisions and apply ongoing learning in action-based research. Such scenarios require an institutional host, are linked to data measuring progress towards outcomes and periodically updated within an iterative assessment framework to revise decisions (Jones, 2012). Several generations of scenarios produced by IPCC assessments, national climate scenarios in the UK and Australia indicate this capacity may be developing (CSIRO and BoM, 2007; Gawith et al., 2009; Moss et al., 2010) but would require parallel development in a wider set of variables relevant to adaptation and a more institutionalised approach to decision-making support. The new scenario matrix being developed for climate change (Kriegler et al., 2010; Moss et al., 2010) is one vehicle where this may happen.

Linking these typologies with research methods, the major determinants of scenarios can be described as problem–actor, exploratory–normative, top-down–bottom-up (in terms of scale) and forward-looking–back-casting (or prescriptive-diagnostic in terms of time). In methodological terms this sets up a process-goal construct. Forward casting normative scenarios concentrate on the initial state and process, for example a set of specific policies, whereas back-casting will define a normative state in the future; e.g., sustainability, then diagnose how to achieve that state over time given specific starting conditions and a set of key drivers. Reflexive scenarios will combine these approaches.

Scenarios have a somewhat uncomfortable place within the standard research methods applied to assess CCIAV. As outlined in the earlier section on uncertainty, problem uncertainty can range from quantified distributions of variables and outcomes known with high confidence to those that can at best be said to be 'not implausible' (Strzepek et al., 2001; Malone and Yohe, 2002) that are linked to complex situations with deep uncertainty.

There is a tension between the development of climate forecasting as pursued by the modelling community who aim to improve future predictions and scenario development required by the CCIAV community, who require tools for decision support. In terms of calculating event risk, scientific prediction is limited to what is represented in a model, so while its theoretical application may be sound, in a system of multiple drivers and feedbacks, the model itself may be incomplete. Scenarios can fill that gap. For example, Carter et al. (2007) emphasize that climate scenarios are usually purpose-built for specific impact assessments, often modifying climate model output, but rarely use model output directly. Climate may also be only part of the total uncertainty if risk is being assessed from the interaction between climate impacts and social vulnerability.

On the solution side, representing hard-to-define goals is also a difficult issue for prediction. For example, both sustainability and 'dangerous climate change' are both difficult to define due to differing social and cultural constructions of what they may mean. This uncertainty is reflected in the expert literature (Harding, 2006). Uncertain predictions of uncertain goals invite controversy. Given that exploratory scenarios have the capacity to survey a range of plausible pathways and goals in such cases, a participatory process is likely to achieve broader agreement than expert judgment can by itself.

The inability to ascribe likelihood to a single scenario can be overcome by using scenario ensembles, allowing storylines to be compared and contrasted. Quantitative estimates such as warming or population growth can be assessed according to likelihood of exceedance because cumulative statistical functions are more robust to uncertainty than probability distribution functions. Likelihood can be addressed in a Bayesian manner, where participants use a scenario process to update their priors, but in a richer manner than can be achieved with straightforward prediction. For example, a stakeholder's prior model may be completely altered, they may step away from a focusing on the most likely outcome to survey the spectrum of potential likelihood consequence, or they may completely reframe the way they see the issue. The ability to do this collectively also fosters social learning, potentially building a community of practice (Wenger, 2000; Pahl-Wostl, 2002).

By separating risks into tame and wicked problem risks, the need for scenarios with the decision-making process can be better identified *[moderate confidence]*. For tame risks, if probabilities cannot be easily calculated then scenarios can be used to explore the problem and illustrate alternative solutions for evaluation. Wicked problems will probably need to be thoroughly scoped to select the most suitable decision-making process. They may require separate applications of problem and solution-based scenarios or the development of reflexive scenarios. Even if conditional predictions can be used to illustrate climate futures, scenarios may be needed to explore the solutions space involving strategic actions, options planning and governance using both process and goal-oriented methods.

2.2.1.2. Evaluating Trade-Offs and Multi-Metric Valuation

Effective CCIAV decision-making often requires making trade-offs among competing objectives and values. The methods and tools that exist to help evaluate such trade-offs employ a range of alternative decision criteria. The appropriate criteria for any given case depends on decision makers' the goals, the data available, and the types of uncertainties involved. Implicitly and explicitly, these decision criteria are used throughout the discussions of adaptation options, planning, and economics in Chapters 14 through 17 and WG III Chapter 2.

The decision theoretic literature divides criteria relevant to CCIAV decision making into two broad categories: outcomes-based, which compare alternative actions according to the consequences expected to result from them, and process -based, which compare alternative actions according to the process by which any decision is arrived at and, in particular, the extent to which various individuals consent to the risks, costs, and obligations being imposed upon them (Morgan et al., 1990). In general, CCIAV decisions can be judged by both types of criteria.

Process-based criteria focus on the credibility and legitimacy of a decision process. Institutional (Section 2.2.2) and cultural (Section 2.2.3) contexts will strongly influence the appropriateness and importance of such criteria. For some participants and in some situations, process criteria may prove decisive in any judgments about the decision irrespective of the outcome (Dietz and Stern, 2008; Sen, 2009). For instance, many environmental laws require advanced notice and periods of public comment before the government issues any regulations. Legal systems with water rights often give allocation decisions over certain water resources to individuals who can then choose, or not, to sell them to others during periods of drought. Participants may regard any decision that fails to respect these rights as illegitimate. One fundamental purpose of democratic deliberation and decision-making is to confer legitimacy on decisions (Sen, 2009). Process-based criteria can also depend on judgments about uncertainty. For instance, the precautionary principle contains an element of process-based criteria, placing the burden of proof on those introducing new impacts on the environment to prove that they are not harmful. Some utilitarian-based ethical frameworks distrust the ability to compare in any meaningful way social outcomes that make one person better off and another worse off, and thus seek to minimize the scope of decision processes that adjudicate broad social outcomes and seek to expand the scope of decision processes, often market-based, in which individuals only engage in transactions that transfer costs or risks with their explicit consent.

Outcomes-based criteria focus on the extent to which the consequences that flow from a decision met decision makers' goals. Most generally, these criteria fall within the domain of *multi-attribute decision theory* (Keeney and Raiffa, 1993), which provides a framework for balancing among multiple, potentially competing objectives (this branch of decision analysis is also known as multi-criteria decision analysis; for a CCIAV example see Korteling et al. (2013)). In some cases decision support uses decision criteria that recommend a single best decision, often by aggregating all the relevant objectives into a single metric. In other cases, decision support uses criteria that summarize trade-offs for decision makers.

Among criteria that recommend a single best decision, *optimality* provides the best possible outcomes-based choice in those situations where it is possible and appropriate to aggregate the relevant objectives, often expressed as monetary cost. *Cost effectiveness* criteria often prove useful in situations where decision makers can quantify the costs but not the benefits of alternative actions. For instance a water management agency might determine it necessary to be able to maintain a reliable supply of water in the face of the largest drought ever observed in their region, and then choose to invest in the least expensive reservoir able to meet that criteria. *Bounded cost* criteria often prove useful in situations where decision makers have fixed resources to address a problem. For instance, a city might have a fixed budget to address adaptation to climate change and may wish to allocate those resources in such a way as to reduce risks as much as possible.

Such criteria can also help to summarize trade-offs among multiple objectives. For instance, one could use a cost effectiveness criterion to compare the cost of achieving alternative objectives, such as different levels of reliability for a water agency. More generally, *modern portfolio theory* (Crowe and Parker, 2008) provides what are called Pareto optimal surfaces that balance among multiple objectives. Each point on the surface represents the combination of objectives achieved by some decision, such that it is impossible to perform better for any one objective without performing worse on some other.

The multiple levels of uncertainty addressed in Section 2.2.1.1 can affect the appropriateness of alternative decision criteria. While some criteria can be applied broadly, some are only applicable with some types of uncertainty characterizations (Dessai and Sluijs, 2007). *Optimality* can provide the best possible outcomes-based choice when uncertainties are well-characterized. Criteria also exist to recommend a single best decision in cases where uncertainties are deep. For instance, the *maxi-min* criterion suggests choosing the decision with the best worst-case outcome and the *mini-max regret* criterion (Savage, 1951) suggests choosing the decision with the smallest deviation from optimality in any state of the world. Proposals for 'no regrets' adaptation decisions (Callaway and Hellmuth, 2007; Heltberg et al., 2009) employ such criteria. Hybrid criteria that balance between optimal and worst case performance have also been used to support climate related decisions (Hurwicz, 1951; Aaheim and Bretteville, 2001; Froyn, 2005).

In some cases, however, higher levels of uncertainty can also motivate the use of decision criteria that summarize trade-offs for decision makers. For instance, some CCIAV literature has used robustness, a satisficing criteria (Rosenhead, 1989) that seek decisions that will perform well over a wide range of plausible climate futures, socio-economic trends, and other factors (Dessai and Hulme, 2007; Groves et al., 2008; Wilby and Dessai, 2010; WUCA, 2010; Brown et al., 2011; Lempert and Kalra, 2011). Robustness criteria can often illuminate trade-offs that help decision makers achieve consensus on actions event when they do not agree on expectations about the future. The literature offers differing statements about the relationship between robustness and resilience (Folke, 2006; Gallopín, 2006), but resilience, described in detail in Chapter 20, tends to describe a property of systems, which might be affected by decision makers' choices, while robustness is a property (or not) of the choices made by those decision makers. Methods also exist to summarize trade-offs for decision makers for multiple objectives and higher levels of uncertainty, for instance by suggesting decisions that are robust over many futures and objectives (Kasprzyk et al., 2013).

2.2.1.3. Learning, Review, Evaluation, and Reflexiveness

Learning is a crucial aspect of CCIAV decision-making because climate change is sure to surprise us, both in its impacts and in the technological and behavioural changes that will affect society's ability to respond (National Research Council, 2009a). Much adaptation literature, including the iterative risk management framework (Figure 2-2), thus stresses the importance of decisions, systems, and processes that effectively respond over time to new information. Such new information includes observations of events that have occurred and anticipation of events that may occur in the future. For instance, the resilience literature provides frameworks for identifying systems with the ability to respond successfully to shocks. The climate adaptation literature distinguishes between *coping* and *adapting* (IPCC, 2012), and between *planned* and *unplanned* adaptation, to explore the benefits of appropriate responding to anticipated future events. Chapter 18 discusses the monitoring of impacts, necessary to any successful response. Learning processes are central to the discussions in Chapters 14 through 17 and in Chapter 20.

The concepts of adaptive management and adaptive decision-making, important themes in the CCIAV literature, can help decision makers incorporate learning into their plans. Adaptive management has a specific meaning in the literature, referring to situations in which the choice of policy is strongly influenced by a requirement to generate reliable new information (Holling, 1978, 1996), but the term is often used more generally to refer to policies that are designed to respond to new information. The former, sometimes called active adaptive management, might involve forest managers who purposely pursue alternative management practices on similar plots of land to gather scientific data on the most effective practices. The latter, sometimes called passive adaptive management, might involve a water management agency that pursues a portfolio of supply investments, largely to manage risk, but also intending to shift investments in the future depending on which prove most successful. In both forms, adaptive management focuses on process and continuous learning (trial and error, small step→evaluate→adjust) (Dessai and Sluijs, 2007).

Methods and tools exist to help decision makers evaluate alternative adaptive strategies. These approaches are often used to represent the benefits and costs of learning in studies and simulation models that support climate-related decisions. The sequential decision approach, commonly used in the climate policy literature, represents policies as a sequence of choices over time, made with different amounts of information (Nordhaus, 1994). The real options approach draws from the finance literature to represent a near-term choice as creating the ability to make specific future choices under certain conditions. Real options approaches have recently been used in some adaptation studies (Hertzler, 2007) as well as those addressing greenhouse gas emissions reductions (Blyth et al., 2007) and investments in emissions reducing energy technologies (Mahnovski, 2007). Control theory provides another such representation (Funke and Paetz, 2011). Each approach can be used with many uncertainty representations and decision criteria.

Successful adaptive management and decision-making requires the inherently complex challenges of monitoring and evaluation (Governance and Social Development Resource Center, 2001). Decision makers concerned with monitoring and evaluation of adaptation policies, programs, and projects may determine what attributes to measure, for instance adaptive capacity, resilience, reduction of exposure, or vulnerability. Other dimensions include temporal scales, structural and non-structural measures (e.g., information sharing-flood forecasting and warning and behavioral changes) (Governance and Social Development Resource Center, 2001; Hedger et al., 2008). In some cases, it may also be useful to define an adaptation baseline(s) in order to evaluate the success of an implemented policy (Ebi et al., 2005; Vidhi and Sharma, 2010).

For example, Bangladesh has proposed a monitoring strategy for their already adopted national adaptation strategy and action plan. The action plan is comprised of six pillars – food security, social protection and health; comprehensive disaster management; infrastructure; research and knowledge management; mitigation and low carbon management; and capacity building and institutional strengthening (Government of Bangladesh, 2009). The plan calls for monitoring and evaluation of interventions for three purposes: their ability to reduce climate change vulnerabilities of human populations and natural and economic systems; their efficiency, flexibility, equity, results, cost-effectiveness and sustainability of the interventions (Hedger et al., 2008; Vidhi and Sharma, 2010); and their ability to avoid maladaptation (Mirza, 2009).

The decision support systems themselves can usefully be designed as learning processes. One useful approach, *deliberation* with analysis, provides an iterative process that begins with the many participants to a decision working together to define its objectives and other parameters, working with experts to generate and interpret decision-relevant information, and then revisiting the objectives and choices based on that information (Figure 2-4). Deliberation with analysis often proves most useful in situations with diverse participants to a decision in a changing environment whose goals emerge from deliberation and may change over time (National Research Council, 2009a; see Box 2-2 on the Louisiana Coastal Master Plan).

[INSERT FIGURE 2-4 HERE
Figure 2-4: Deliberation with analysis decision support learning process.]

Adaptive management and decisions can provide a means to develop strategies robust over a wide range of uncertainties, and has been increasingly pursued in many applications (Williams et al., 2009). However, adaptive management can be difficult to implement (National Research Council, 2009a), in large part because, without appropriate institutions, such strategies can be difficult to maintain. Monitoring and evaluation can prove difficult and costly, decision makers can be reluctant to gather data they may show their policies are not succeeding, and their organizations may not be sufficiently flexible to respond appropriately to new information (Lee 1993). In some cases decision makers may distrust the willingness or ability of their successors to respond to new information and will find it advantageous to enact policies that are difficult to change in the future.

The literature explores the relationships between learning and organizational change that can affect the ability of adaptive strategies to meet their goals in the face of uncertainty. The learning loop framework (Kolb and Fry., 1975; Argyris and Schön, 1978; Keen et al., 2005) divides learning processes into three categories, depending on the degree to which learning promotes transformational change in an organization's strategies. Single-loop learning processes focus on improving an organization's plans (Pelling et al., 2008) by adjusting policies based on the difference between what is expected and what is observed. Double-loop learning, in contrast, uses new information to question basis assumptions and reevaluate current knowledge, objectives, and strategies. Adaptive management, deliberation with analysis, and scenario practice are all processes that aim to routinely facilitate such double-loop learning by using data both to take corrective action and to change the frames through which issues are conceptualized. In triple-loop learning (Argyris and Schön, 1978; Peschl, 2007; Hargrove, 2008), decision makers may begin to question deep underlying principles (Pelling et al., 2008), for instance, considering how institutional and other power relationships determine perceptions of what is to be done and how (Flood and Romm, 1996). In response, they might seek to address how social structures, cultural mores, and other structures might be changed or transformed. The distinction between single-, double-, and triple-loop learning thus helps highlight the types of adjustments decision-makers can consider in the face of potentially significant, abrupt and surprising changes that may result from the interaction of climate change and socio-economic trends.

2.2.2. Institutional Context

Virtually all CCIAV decisions will be made by or influenced by institutions. The institutional context will thus prove an important influence on these decisions and on the way decision support is organized.

2.2.2.1. Institutions for Capacity Building

Institutions are imperative for effective management of climate change risks through proper governance. Institutions are defined as "…systems of rules, decision-making procedures, and programs that give rise to social practices, assign roles to the participants in these practices, and guide interactions among the occupants of the relevant roles" (IDGEC Scientific Planning Committee, 1999). Each institution has a set of objectives and goals that may be explicit or implicit and as such, each displays unique characteristics. The strength and nature of their role in maintaining a cohesive society enables societies to adapt to crises (O'Riordan and Jordan, 1999)**.** Institutions can facilitate environmental protection on one hand but on the other can also accelerate resource depletion by designing and implementing counter-productive policies (Scharpf, 1997). Institutions can constrain and shape human interaction through direct control, through incentives, and through processes of socialization (WGIII; SRREN). The rules and roles of institutions for whatever reason(s) they have been created can be of many forms: formal and informal, visible and latent, and conscious and unconscious (Arts et al., 2006). Governments create formal institutions that play an important role in vulnerability reduction and adaptation (Gupta et al., 2008). Agarwal et al. (2008) analyzed the roles of local institutions in adaptation and categorized them into local public, civil society and private institutions. As adaptation is generally a local issue, local institutions play important roles in the process by interacting with national and regional institutions.

Smit et al. (2001) identified institutions as one of the key determinants of adaptive capacity. Countries with strong institutions are generally assumed to have a greater capacity to adapt to current hazards and disasters as well to the future. However, this is not necessarily true in all cases. Hurricane Katrina of 2005 in the USA and the European heat waves of 2003 demonstrate that strong institutions and other determinants of adaptive capacity do not necessarily reduce vulnerability if not translated to actions (IPCC, 2007)(also see in section 2.3.2.2). Generally for economic and technological reasons, most of developing countries have weaker institutions that are less capable of managing hazards and disasters of catastrophic nature. For example, Lateef (2009) conclude that institutional weaknesses in healthcare and disaster preparedness led to high casualties from the cyclone Nargis in Myanmar in 2008.

Uniform presence of institutions can reduce vulnerability and contribute to increase adaptive capacity. Berman et al. (2012) suggest that institutions play a key role in mediating the transformation of coping capacity into adaptive capacity and in linking short and long-term responses to climate change. Institutions that can appropriately respond to climate challenges are unevenly distributed especially within marginalized regions or indigenous territories. Examples from Latin American demonstrates that institutional limitations can prevent the effective participation of indigenous people in climate change adaptation initiatives (Kronik and Verner, 2010).

Climate change is a development issue and the risks from climate change could significantly impact sustainable development in developing countries. Mirza (2003) argued that vulnerability to extreme weather events, disaster management and adaptation must be part of the long-term sustainable development planning in developing countries. This will require development assistance to explicitly consider climate change risks, and to include capacity-building to respond to climate change as a part of investments in recovery and infrastructure development. Multilateral institutions are responding to these challenges. For example, the World Bank supports both reactive and pro-active types of projects on adaptation (Agarwal et al., 2008).

Aid is becoming more focused on adaptation to climate change, disaster risk reduction and adaptation are merging at the policy to program levels and traditional activist and advocacy organizations are becoming more professional and being involved in program delivery. Bartley (2007) describes the latter as a form of channeling where foundation patronage and organizational field building is leading to social movement organizations becoming involved in mainstream project delivery. This model fits the growth of adaptation where aid funders such as USAid and foundations such as the Rockefeller and Gates Foundations are providing complementary funding that is fuelling program delivery involving environmental and development NGOs with local stakeholders (Ziervogel and Zermoglio, 2009; Kolk and Pinkse, 2010; Worthington and Pipa, 2010).

Understanding collective institutional or organizational frames offers a way to overcome barriers to adaptation when competing collective frames such as economy versus environment are preventing the integration of both into policy and action (e.g., Hoffman and Ventresca, 1999). Frame structure, content, dynamics and diffusion can be understood in order to encourage social movements to action around an issue, through diagnosis, prognosis and motivation (Benford and Snow, 2000). Discursive frame analysis that understands how various issues are described, the actors involved and their methods of organization. Brulle (2010) discourages targeted public campaigns intending to increase awareness and thus action that are based on cognitively and psychologically-designed appeals to the individual for a more participatory approach based on civic engagement using a process called Analytic Deliberation.

2.2.2.2. Governance, Legal Dimensions, and Decision Implementation

Governance is often visualized as a rigid, centralized, unitary, top-down process of rules and policy development in the public interest that have to be implemented at local level (Commission on Global Governance, 1995). Krahmann (2003) argues that governance is considered as a flexible, diffuse, bottom-up and top-down process that interact between different tiers of government and with a range of social actors. Governance and good governance are often seen as key institutional settings for addressing problems (Botchway, 2001). Climate change governance requires action for both adaptation and mitigation. IPCC (2007) stated that many early impacts of climate change could be effectively addressed through adaptation but the options for successful adaptation diminish and the associated costs increase with increasing climate change. However, adaptation alone is not expected to cope with all the projected effects of climate change, especially not over the long term as most impacts increase in magnitude (IPCC, 2007). Governance of adaptation requires knowledge of anticipated regional and local impacts of climate change (Meadowcroft, 2009).

Climate change and the associated risks have national and international legal dimensions. There are many *national level* legal implications of climate change. Considering Bangladesh as a case study, Freestone et al. (1996) identified that nationally climate change and sea level rise would affect property rights and land tenure, population displacement, rehabilitation and resettlement, and institutional frameworks involving with these issues. The *international legal aspects* of climate change impacts and risks would come from a variety of angles. Sea level rise could alter the *maritime boundaries* of many nations that may lead to new claims by the conflicting nations. The open waterways for shipping is very *likely* to change in specific, measurable ways in the next several decades

Reductions in sea ice in the Arctic may allow new trade passages such as the North West Passage to be established (Chapter 6). Climate change could also lead to access to resources that were previously technically inaccessible and that may result in new territorial claims. Runoff changes in the international rivers due to reduced seasonal precipitation could result in new *water conflicts* and *energy utilization* among the co-basin countries and can also pose challenges to the already signed sharing agreements (Kim, 2010). Additional *food insecurity* due to climate change will pose a moral challenge and human rights question regarding food supply from the developed countries to affected regions. Many national and international legal institutions and instruments need to be updated to face climate related challenges and decision implementation.

2.2.3. Social Context

Decision support for CCIAV must recognize that people and culture with its diverse values, language uses, ethics and human psychological dimensions play a crucial role in the way that people use and process information and take decisions (Kahan and Braman, 2006; Leiserowitz, 2006).

2.2.3.1. Value Setting

The majority of climate change research conceptualizes values as monetary worth, relative worth, or fair return on exchanges, drawing primarily on welfare economics and using cost-benefit analysis or contingent valuation to estimate losses (Watkiss, 2011). These values reflect a neoclassic economic framing of the issue. Increasingly, however, a number of authors have argued that a broader conceptualization of values is needed to understand and respond to climate change (Adger et al., 2009; O’Brien, 2009; O'Brien and Wolf, 2010). Chapter 17 investigates the use of tangible and intangibles in assessing the economics of adaptation, but here we take a broader look at how values influence decision-making.

In this broader conceptualization, values are understood as the subjective, qualitative and intangible dimensions of climate change and its impacts that are of importance to individuals and cultures (O'Brien and Wolf, 2010). Such values may concern how climate change affects, for example, place identity, land-based or traditional practices important for cultures, and the symbolic meanings of places and practices, in particular where irreversible losses may occur. Such values shape how the effects of climate change are perceived and how responses, including adaptation decisions, are addressed.

In the context of dangerous climate change, it has been acknowledged that judgment and “values matter for converting science into policy” (Oppenheimer, 2005, p. 1401). Others argue that the difficulty in compensating for irreversible losses due to incommensurable values points to a need for other principles, such as the precautionary approach, to be utilised in global climate policy (Adger et al., 2011). O'Brien and Wolf (2010) suggest that people’s value orientations be allowed to determine what is perceived to be worth preserving and maintaining through adaptation (and indeed mitigation) decision making. Despite a growing recognition that values matter, however, there is limited research that explicitly considers the role that such values play in shaping adaptation decisions.

The importance of values in decision making related to climate change are operating at two levels:

1) Larger socially shared values of a given culture and of groups and individuals within that culture
2) Values related to the work, including decision making, in modern organizations and in management.

The first issue is mainly studied by anthropologists, cross-cultural and environmental psychologists, revealing an important diversity of values across cultures that influence individual, local, national, even international decision-making. Values, as abstract entities, guide decision-making processes and are realized in real acts. The anthropological literature shows the importance of religious, sacred values related to climate (Goloubinoff et al., 1998; Katz et al., 2002; Lammel et al., 2008). Such values can inform the perception of climate change, as well as the actions to protect against its consequences (Crate and Nuttal, 2009).

The values of a given society are fundamental to the development of attitudes, cognition, emotions and behaviors. Kluckhohn and Strodtbeck (1961) identified five basic, relatively stable value orientations (Values Orientation Theory) that allow societies to find value-based solutions to universally important questions. Three of the five value orientations influence climate change related decisions: peoples' relations with time, nature and each other:

- For temporal values, the main cultural differences concern time orientation (past/present/future)
- For the relationship with nature, cultural differences involve mastery, harmony, submission
- For the relationship with each other, the three culturally different value orientations are: hierarchical (lineal); egalitarian (collateral) and individualistic.

Kluckhohn and Strodtbeck (1961) theory influenced a great number of cross-cultural and environmental psychological studies seeking 'universal' dimensions of values and their culturally different manifestations (e.g., Hofstede, 1980; Schwartz, 1992; Hofstede and Hofstede, 2001; Rokeach, 2008).

Environmental decision making is highly influenced by culturally elaborated values. Schultz et al. (2004) link values, attitudes, world views and behaviours to the environment. They differentiated three sets of values, described previously by Stern et al. (1995):

1) *Egoistic values* focused on values and goals oriented toward the interest of the self (me, my future, my wealth, my health)
2) *Altruistic values* focus on others (future generations, humanity, people of the community, children)
3) *Biospheric values* focus on the wellbeing of living things (plants, animals, marine life, birds).

Schultz et al. (2004) tested whether differences in a person's information processing could be correlated with their connection to nature. They concluded that a weak connection with nature is associated with local information processing; conversely, a greater connection is associated with more comprehensive information processing. Many studies have added new perspectives (e.g., Milfont and Gouveia, 2006; Soyez et al., 2009) showing that cultural values can substantially influence the decision-making processes. Values are also related to 'environmental concerns' (Stern and Dietz, 1994; Xiao and Dunlap, 2007) influencing public behaviour toward policies. Schaffrin (2011) insists that geographical aspects, vulnerability and benefits from policies are important in value orientation and can influence the vision global/local and short term/long term dimensions of climate change (e.g., (De Groot and Steg, 2007, 2008; Shwom et al., 2008; Milfont et al., 2010). Pelling et al. (2008) found that accounting for values within officially and unofficially-sanctioned relationships could enhance social learning and therefore adaptive capacity. Nyong et al. (2007) found that the moral economy in indigenous African communities provided direction for implementing both adaptation and mitigation actions.

The cultural theory of risk perception (Douglas and Wildavsky, 1982) has also been used to successfully group beliefs on contentious scientific issues such as climate change using the structural settings *hierarchical* and *egalitarian* with the value settings *individualist* and *communitarian* (Kahan et al., 2007; Kahan, 2008). It has been proposed that such knowledge could contribute to various policies on adaptation by tailoring the framing of those policies according to the belief structures inherent within cultural theory (Adger et al., 2009; O'Brien and Wolf, 2010).

National values also influence local organizational values. Hofstede (1980); Hofstede and Hofstede (2001) using a large database, collected in subsidiaries of the multinational corporation IBM, identified firstly in 40 and later in 76 countries (Hofstede et al., 2010), five value dimensions with significant cross-national differences: power distance, individualism/collectivism, uncertainty avoidance, masculinity/femininity and long/short term orientation.

While a substantive gap exists in research that can apply knowledge of personal and cultural values to decision-making on climate change, this area is receiving a good deal of attention (Nilsson et al., 2004; Leiserowitz, 2006; Lorenzoni et al., 2007; De Groot et al., 2010). The above studies on values can provide important theoretical and methodological tools for further research and its integration into decision making practices. Such research could assist in building legitimate, transparent and inclusive responses including policy on climate change [moderate confidence].

2.2.3.2. Cultural Determinants and Psychology

At the individual level, decision-making is a multi-directional and non-linear cognitive activity. Responses to new information can modify previous decisions, even producing contradictory results. Decision-making in climate change problems cannot be described as rational and can negatively affect environmental behaviour (Grothmann and Patt, 2005; Marx et al., 2007). Many strategies are used by individuals in making adaptation decisions (Fischer and Glenk 2011) suggesting that a uniform approach to problem solving is unlikely to succeed.

Ignatow (2006) distinguishes between two cultural models: the 'spiritual' and the 'ecological' that have different social bases. Western education generally involves the second but not the first. In the spiritual model, nature is sacred, has its own rights and should be kept separate from human society. It is threatened by science and technology and has to be respected. The ecological model represents nature as an ecosystem physically integrated into human society (Bocking, 1994). There is no inherent conflict between the society and nature, thus science and technology can be used to integrate modern society with the natural environment (Oates, 1989).

The perception and representation of nature and the environment are influenced by the dominant modes of thought in a society. Cultural psychology distinguishes between two main systems of thought: holistic and analytical thinking (Lammel and Kozakai, 2005; Lammel et al., 2011). Holistic thinking characteristic of collectivist societies consider that social obligations are reciprocal and individuals take part in a community with strong ties (Peng and Nisbett, 1999; Nisbett et al., 2001), such as in a gift economy. Such holistic thinking is built primarily on the knowledge gained through experience and not through abstract logic. It is dialectical and accepts contradictions and multiple perspectives, trying to find a middle stance between opposing propositions. Holistic thinking is associative and its computations reflect similarity and contiguity.

In more individualistic societies, the analytical model is central. Individual interests take precedence over societal interests; the self is independent and communication comes from separate fields: benchmarks are not common. The object is isolated from its context; the focus is on understanding the characteristics of the object to determine its category membership, and explain and predict events based on its intrinsic rules. Inferences are derived from contextualizing the content structure, using formal logic and avoiding contradiction. Analytical thinking circumscribes symbolic representation systems; instead its formalization is built on structures of rules. Several studies demonstrate the influence of this way of thinking on complex problem-solving (e.g., Badke-Schaub and Strohschneider, 1998; Strohschneider and Güss, 1999; Güss et al., 2010).

An increasingly extensive literature highlights the importance of taking into account cultural/local knowledge, traditional ways of thinking and traditional methods of decision-making when assessing CCIAV (Vedwan, 2006; Nyong et al., 2007; Dube and Sekhwela, 2008).

Psychological factors

The psychological literature on decision in context can help to understand how to make better decisions. Several theories, such as the multi-attribute utility theory (Keeney, 1992), prospect theory (Kahneman and Tversky, 1979; Hardman, 2009), and the cumulative prospect theory relate to decision making under risk or uncertainty (Tversky and Kahneman, 1992). Recent cognitive approaches, such as the one-reason decision process (e.g. (Gigerenzer and Goldstein, 1996) or the decision by sampling theory (Stewart et al., 2006; Stewart and Simpson, 2008) integrate even more psychological factors.

Personal dilemmas are frequently related to utility and probability (short/long term) (e.g., Hoch and Loewenstein, 1991). Social dilemmas are very important because individual utility maximization can cause collective loss ('commons problem') (Hardin, 1968). Decision-making can also be realized without thinking. The dual process theory of thought states that human being possess 'two minds'. System 2 is rational (trade-offs between utility and probability) meanwhile the System 1 is intuitive, an unconscious kind of thought (Myers, 2004; Stanovich, 2005), leading to frequently observed behavioral inconsistency. In terms of cognitive economy, decision making without thinking or by ‘feelings’ are automatic, unconscious, fast and effortless and widely used (Slovic et al., 2002; Evans, 2008).

Psychological factors important for decision-making on climate change include: perception, representation, knowledge acquisition, behavior, emotions and understanding of risk (Oskamp and Schultz, 2006; Gifford, 2008; Kazdin, 2009; Reser et al., 2011; Swim et al., 2011). Investigations of public perception and climate change representation (e.g., Böhm and Pfister, 2000; Lorenzoni et al., 2006; Sterman and Sweeney, 2007) suggest that certain perceived characteristics of climate change may lead individuals to underestimate the magnitude of risk (Böhm and Pfister, 2000; Sundblad et al., 2009). Different explanations include (Leiserowitz, 2006): (1) Optimism, downsizing personal risks; (2) The perceived signs of climate change seem to be “natural”; (3) Perceived as normal variations in weather; (4) Natural variation in the world’s climate is a low risk; (5) People probably do not have necessary emotional or cognitive capacities to make an adequate risk evaluation. These findings show the importance of experiential factors in understanding phenomena and the strong influence of experiential decision making as contrasted with analytic decision making.

Psychological obstacles in processing climate change information include psychological distances that have four theorized dimensions: temporal, social, and geographical distance, and uncertainty (Spence et al., 2012). Attitudes and behaviors relevant to climate change engagement, include place attachment (Scannell and Gifford, 2013), political affiliation (Davidson and Haan, 2011), and perceived costs and benefit (Tobler et al., 2012).

The relationship between cognition and behavior influences people’s adaptive actions, especially to perceived risk and the effectiveness of action. Grothmann and Patt (2005) apply a socio-cognitive model of proactive private adaptation to climate change impacts that predicts, for instance, if a high risk is combined with low capacities response is fatalism, denial and wishful thinking. Emotional factors also play also an important role in climate change perception, attitudes, decision making and actions (Meijnders et al., 2002; Leiserowitz, 2006; Klöckner and Blöbaum, 2010; Roeser, 2012) and even shape organizational decision making (Wright and Nyberg, 2012).

Knowledge about climate change is necessary to increase overall concern and greater perceived efficacy and responsibility (Milfont, 2012). However studies in education (Rajeev Gowda et al., 1997; Boyes et al., 1999; Andersson and Wallin, 2000) show the difficulties in understanding the scientific process of global climate change. Shepardson et al. (2012) insist that a systemic vision of climate is needed for such understanding. Even highly educated adults can have a very elementary cognitive representation of climate change, creating cognitive vulnerability (Lammel et al., 2012). In the USA, limited understanding has led to “wait-and-see policies” and to the absence of effective decision making on adaptation (Sterman and Sweeney, 2007; Dutt and Gonzalez, 2012). Even policy makers have cognitive difficulties in understanding climate change, for instance, in Sweden, their knowledge is less important than journalist’s knowledge (Sundblad et al., 2009).

Sterman and Sweeney (2007) propose to communicate climate change issues through clear analogies and metaphors. Other form of intervention to help the development of climate change knowledge and concern, without the experiential factor, can be the simulations by stirring artistic approaches (films, music, paintings) and the activation of emotions (Weber, 2006).

2.2.3.3. Language and Meaning

This section deals with: 1) the various terminologies used by different disciplines that intersect in decision-making on climate change; 2) the relationship between technical and everyday definitions exercised in the decision-making process and 3) the use of narratives to communicate meaning, values and experience.

The previous sections emphasise that decision-making processes need to accommodate both specialist and non-specialist meanings of the concepts they apply. Previous IPCC reports have provided technical definitions for a range of such terms in order to focus climate research and provide rational policy advice. However, the decision-making process surrounding vulnerability and adaptation assessment is broader than the technical aspects addressed in IPCC definitions and language (Adger, 2003; Füssel, 2007; O'Brien et al., 2007). Various disciplines often have different definitions for the same terms or use different terms for the same action or object, which is a major barrier for decision-making (Adger, 2003). For example, adaptation is defined differently with respect to biological evolution, climate change and social adaptation.

Covering both technical and everyday meanings of key terms can help bridge the analytic and emotive aspects of cognition. For example, words like danger, disaster and catastrophe have technical and emotive aspects (Britton, 1986; Carvalho and Burgess, 2005). Terms where this issue is especially pertinent include adaptation, vulnerability, risk, dangerous, catastrophe and disaster. Other words have definitional issues because they contain different epistemological frames; sustainability and risk being key examples (Harding, 2006; Hamilton et al., 2007). (Budescu et al., 2012) found that people prefer imprecise wording but precise numbers when appropriate and that people's personal lexicons are very different so that uncertainty terms are interpreted very widely, and in the IPCC's case, differently to the uncertainty ranges intended. Many authors advocate that narrow definitions focused solely on climate need to be expanded to suit the context in which they are being used (Huq and Reid, 2004; O'Brien et al., 2007; Schipper, 2007).

The language of risk, because of its central role in decision-making on climate change, is especially important. Risk is a polyseme, a word with multiple, related meanings. A definition of risk therefore needs to encompass its polysemic nature, which technical definitions generally do not (Hansson, 2004). Meanings of risk range from its ordinary use in everyday language to power and political discourse, health, emergency, disaster and seeking benefits. Meanings range from specific local meanings to broad-ranging concepts such as the risk society (Beck and Ritter, 1992; Beck, 2000; Giddens, 2000). Thus, the hierarchy of approach, methodology and methods presented in Section 2.1 can be used to organise such differences in meaning and use.

Linguistic studies conclude that dictionary definitions are inadequate for communicating the complex framings involved in the word risk (Fillmore and Atkins, 1992; Hamilton et al., 2007), finding much richer meanings in text databases. The word risk occurs as both a noun and a verb and reflects harm and chance with negative and positive senses (Fillmore and Atkins, 1992). Hamilton et al. (2007) found an emphasis on health with no overwhelmingly negative or positive tendencies. Informal use tended towards personal risk, whereas formal use was more abstract, being technical and pedagogical. *The only observable pattern is the association with some form of assessment of the risk involved and the uncertainty that defines this assessment* (Hamilton et al., 2007).

These studies suggest that people do assess risk, balancing likelihood and outcome in a similar manner to formal risk assessment, confirming that risk, at least when consciously applied, forms the core of decision-making under uncertainty. The broad, generic description revealed by linguistic analysis is also consistent with the recent move in the risk literature to broad definitions of risk away from narrow technical definitions (Rosa, 2003; ISO, 2009).

In complex situations, the change between the problem-oriented component of risk assessment to the solution-oriented component shows the wording risk changing from a noun to a verb. Problem analysis applies risk as a noun (at-risk), whereas risk management applies risk as a verb (to-risk) (Jones, 2011). This reflects a change from core risk types of Hamilton et al. (2007) such as *asset* and *harm* associated with at-risk to *action* and *agent* associated with to-risk. For simple risks this transition is straightforward, and can be assessed using linear methods because of agreement around values and agency.

In complex situations, problem risk (at-risk) and solution risk (to-risk) compete with each other, often becoming amplified socially and leading to action paralysis (Renn, 2011). For example, unfamiliar adaptations that are themselves risky will force a comparison between the risk of maladaptation and future climate risks, echoing the risk trap identified by Beck where problems and 'solutions' come into conflict (Beck, 2000). Decision support for such complex risks needs to allow for the emotive and cognitive aspects

Much mental representation and subsequent expression is non-verbal. Language is but not the only tool important for communication and learning: visualization, kinetic learning by doing and other sensory applications can be used to communicate science, art and through play (Perlovsky, 2009; Radford, 2009). Much of this is carried out through various narratives. Narratives are accounts of events with temporal or causal coherence that may be goal directed (László and Ehmann, 2012). They range between being individual to organizational and institutional to cultural narratives and are an innate property of the expression of mind in communication with one's-self or another. As such they are a "tool or process for making sense of events" (Gephart Jr, 1991) and have a strong role in creating social legitimacy. Narratives of issues such as climate change evolve over time and have a great influence on shaping public debate (Hamblyn, 2009).

Two aspects that scientific and adaptation narratives aim to address are (Cohen, 2011; Jones et al., 2013):

1) The transferral of knowledge and ideas to increase agency
2) The responses at an individual/institutional level to an aspect of adaptation, and communicate that experience with others.

The first aspect translates specialist knowledge into a common understanding so that actions can be implemented through a set of discursive frames (Juhola et al., 2011). This narrative bridges the route between scientific paradigm and adaptation methodology. This is often achieved by working with multiple actors in order to creatively explore potential solutions.

The second aspect concerns the stories that relate people's own responses to climatic impacts and other aspects of change (Bravo, 2009; Cohen, 2011). This is a complex area, as the narratives that inform these narratives relate strongly to identity, culture and perceptions of risk and are context specific. They provide the social construction within which decisions may be applied and also inform the nature of responses to future climate events. For example, a community that believes itself to be resilient and self-reliant is more likely to respond proactively, contrasted to a community that believes itself to be vulnerable (Jones et al., 2013). Bravo (2009) maintains that narratives of risk and vulnerability demotivate indigenous peoples whereas scientific and active citizenship narratives provide a framing that promotes resilience.

2.2.3.4. Ethics

The field of climate ethics has been developing over the last 20 years (Jamieson, 1992, 1996; Gardiner, 2004; Gardiner et al., 2010), resulting in a substantial recent literature (e.g., Garvey, 2008; Harris, 2010; O'Brien et al., 2010; Arnold, 2011; Brown, 2012; Thompson and Bendik-Keymer, 2012). Climate ethics can be considered as a social technology used to formalize values (Section 2.2.3.1) and rights into decisions, decision-making processes and actions.

However, the theoretical underpinning of climate change ethics, remains tenuous due to lack of experience, controversies and the complex nature of the problem. In climate change ethics the concept of vulnerability and adaptability do not concern only "nature", the land, in the sense of Leopold (1949), but also the ethical positions toward "some of the poorest and most economically disadvantaged societies of the world" (Pachauri, 2010; vii). It also concerns the co-benefits of the mitigation projects of developed countries (Pachauri, 2010). Climate ethics deals with scientific research results, economic as well as policy. It plays a fundamental role on global climate agreements and decision making.

Climate change can be considered as a primarily ethical question, because of important conflicts of interest (Broom, 2008) requiring complex ethical considerations at all levels. "The dominant discourses about the nature of the climate threat are scientific and economic. But the deepest challenge is ethical" (Gardiner, 2011; xii). The main ethical concerns include: intergenerational equity, distributional issues, scientific uncertainty, economic, policy decisions, international justice, low, voluntary and involuntary risk, cross-cultural relations, human relationship to animals and the rest of nature, technological and the socio-cultural worlds. From a philosophical perspective, climate change is related to environmental and ecological ethics, but previous ethical considerations did not have to consider the globality of the human condition, the distant future, nor the survival of humanity (Gardiner, 2011).

The notion of equity/inequity and responsibility are basic concepts in the United Nations Framework Convention on Climate Change (UNFCCC) Article 3 stating that "The Parties should protect the climate system for the benefit of the present and future generations of humankind, on the basis of equity and in accordance with their common but different responsibilities in respect to capacities" (United Nations, 1992).

Schneider and Lane (2006) distinguish three fields: (1) inter-country equity, (2) intergenerational equity, and (3) interspecies equity. Thomas and Twyman (2005) defined a 4th field, the intra-country or sub-national equity. A 5th topic on ethical factors concerns the necessity of a critical attitude toward future energy alternatives and, recently, geo-engineering. It is necessary to develop equitable solutions in view of protecting the most vulnerable groups and life forms (Wilkinson et al., 2007).

2.2.3.4.1. Inter-country issues

For CCIAV, the major discourse on equity is that the industrialized countries have caused most of the historical emissions, creating a natural debt (Green and Smith, 2002). There is an asymmetry between rich and poor nations concerning the higher impacts and greater vulnerability faced by developing countries and their lack of adaptive capacity with respect to developed countries. The neoclassic economic cost and benefit approach is ethically problematic because it does not cater for these differences (Broom, 2008). Recent policy developments at the international level involve the creation of an Adaptation Fund and fund for least developed countries, and include bilateral and multi-lateral aid agreements (Bouwer and Aerts, 2006; Clemencon, 2008).

2.2.3.4.2. Intergenerational issues

Intergenerational questions are frequently treated as an economic issue. The standard economic vision supposes that world economy grows continually, but important discussions (e.g., Nordhaus, 2007; Stern and Treasury of Great Britain, 2007) also relate to the duty to decide to act now (Stern, 2008). Future harm, and possibly catastrophe, may make the life of future generations difficult or impossible. These dilemmas involve ethical choices (Broom, 2008). Caney (2009) questions if the rights and interests of future people should be subject to a positive discount rate. Some philosophers consider that future generations can't defend themselves within current economic frameworks (e.g., Gardiner, 2011). Classical economics is based on Enlightenment notions and on the principle of abstract logic and disembodied rationality that cannot properly account for the dangers, interdependency and uncertainty under climate change (Nelson, 2011). Asymmetry between the present and future generations has changed: the future was once considered in the light of the past, now is considered in the light of the present (Bensaude-Vincent, 2009). Current economic discussions, in purely monetary terms, represent a unique view in history, as Gardiner (2011) stated, parents and grandparents did care about what they left to children and grandchildren, but this is not being reflected at the broader social scale.

2.2.3.4.3. Biotic ethics

Environmental ethics considers the decisions humans have to make concerning a range of biotic impacts (Schalow, 2000; Minteer and Collins, 2010; Nanda, 2012; Thompson and Bendik-Keymer, 2012). Some authors consider that up to 35% of the world's species could be in danger of extinction due to climate change's consequences (Thomas et al., 2004). These situations may require species relocation but 'assisted colonization' or 'managed relocation' but these proposals raise important ethical and policy questions. Minteer and Collins (2010) propose 5 key themes for decision making: 1. What criteria are used to select candidate populations? 2. How should these methods be combined with traditional ex-situ approaches? 3. Who should such decisions and implements them? 4. What are the key motivations and risks? 5. What constitutes environmental responsibility? Various claims are made for a more pragmatic ethics of ecological decision-making (Minteer and Collins, 2010) consideration of moral duties toward species (Sandler, 2009) and ethically explicit and defendable decision-making (Minteer and Collins, 2005a, b).

2.2.3.4.4. Intra-country inequity

Intra-country inequity relates to human and environmental exposure to risk or health impacts connected to climate change. Climate change ethics need to be further development in this field (Green and Smith, 2002). Of particular concern are indigenous or marginalized populations who are often exposed to current climate extremes and natural disasters, with climate change exacerbating such ethical dilemmas (Tsosie, 2007).

2.2.3.4.5. Future energy alternatives and geo-engineering

Ethical issues on decision-making related to the fields of adaptation, mitigation or transformation due to climate change are emergent issues and are linked to economic and political decision-making. The limits of adaptation creating a case for geoengineering has come under recent consideration (Travis, 2010) and Chapter 19.

Another feature of climate change ethics concerns individual responsibility. Global climate change may also concern individuals who are ‘world citizens’. Some authors advocate a new world ethics (Dower, 1998; Harris, 2010) consisting of moral values, norms and responsibilities applied globally. Cosmopolitan ethics and global justice can lead to successful mitigation and sustainability (Caney, 2006; Harris, 2010) and lead to collective decision-making on public matters through voting procedures (Held, 2004). Climate ethics argue for the necessity of effective responsible and ‘moral’ decision-making and action, not only by governments but also by individuals (Garvey, 2008). Hansson (2004) maintains moral appraisal is required for evaluating risks and benefits in order to establish equity, especially in the face of uncertainty.

Although the climate change ethics literature is rapidly developing, the related practice of decision-making and implementation needs further development. Moral and ethical issues are discussed at length in WG III, Chapter 3 *Social, Economic, and Ethical Concepts and Methods*.

2.3. Support for Climate-Related Decisions

Growing understanding of the aspects of decision-making (Section 2.2) can improve support for CCIAV decisions. This understanding informs the elements and principles of effective decision support (2.3.1), methods for impacts and vulnerability assessments (Section 2.3.2), the provision of climate information and services (Section 2.3.3), and a wide variety of other applications (Section 2.3.4).

2.3.1. Elements and Principles of Effective Decision Support

Decision support (Section 2.2) consists of three types of elements: 1) **products**: tangible deliverables including data, maps, projections, models and tools; 2) **services**: activities, consultations, and other forms of interactions with decision makers; and 3) **support systems**: individuals, organizations, communications networks, and supporting institutional structures that provide decision support products and services (NRC 2009a). For example, the institution (IPCC) that produced this report represents a decision support system. Much of this report, including Section 2.3.2 below, describes decision support products. These products can be used to inform decision support services, such as those in Section 2.3.3.

_____ START BOX 2-2 HERE _____

Box 2-2. Managing Wicked Problems with Decision Support

A well-designed decision support process, combined with auspicious political conditions, can effectively address ‘wicked’ (Section 2.1) decision challenges.

The State of Louisiana faces a serious problem of coastal land loss, imperiling the region’s economically vital fisheries and heightening the risk of storm surge damage to the City of New Orleans, facilities accounting for about 20% of U.S. oil and gas production, and one of the United States’ largest ports (CPRA 2012). Previous efforts at comprehensive coastal protection had been stymied by, among other factors, numerous competing jurisdictions and stakeholders with a wide range of conflicting interests.

In the aftermath of Hurricane Katrina, the state embarked on a new coastal planning effort, this time with extensive decision support. The Louisiana state Coastal Protection and Restoration Authority organized an extension decision support effort with a network of about a dozen research institutions interacting with a 33-member stakeholder group consisting of representatives from business and industry, federal, state, and local governments, nongovernmental organizations and coastal institutions. In dozens of workshops over the course of two years, these stakeholders influenced the development of and interacted with a decision support system consisting of two parts: 1) a regional model that integrated numerous strands of scientific data into projections of future flood risk (Fischbach et al., 2012) and 2) a multi-attribute planning tool that allowed stakeholders to explore the implications of alternative portfolios of hundreds of proposed risk reduction projects over alternative sea level rise scenarios (Groves et al., 2012). This decision support system allowed decision makers and stakeholders to first formulate alternative risk reduction plans and then to visualize outcomes and tradeoffs up to fifty years into the future.

The resulting Master Plan for a Sustainable Coast passed the state legislature on a unanimous vote in May 2012. Deviating strongly from past practice, the plan allocates far more resources to restoring natural barriers than to structural measures such as levees. The plan balances between the interests of multiple stakeholders and contains some projects that offer near-term benefits and some whose benefits will be largely felt decades from now. Many participants and observers of this process credited the extensive analytic decision support for significant contributions to this plan.

_____ END BOX 2-2 HERE _____

The effectiveness of decision support can be judged by the extent to which it increases the likelihood that decision-relevant information is produced and incorporated into decision making. Effective decision support provides users with information they find useful because they consider it credible, legitimate, actionable, and salient (e.g., Jones et al., 1999; Cash et al., 2003; Mitchell, 2006; Reid et al., 2007). Such criteria can be used to evaluate decision support (CITE) and such evaluations lead to common principles of effective decision support, which have been summarized in National Research Council (2009b) as:

1) Begins with user's needs, not scientific research priorities. Users may not always know their needs in advance, so user needs are often developed collaboratively and iteratively among users and researchers.
2) Emphasizes processes over products. While the information products are important, they are likely to be ineffective if they are not developed to support well-considered processes.
3) Incorporates systems that link users and producers of information. These systems generally respect the differing cultures of decision makers and scientists, but provide processes and institutions that effectively link individuals from these differing communities
4) Builds connections across disciplines and organizations, in order to provide for the multidisciplinary character of the needed information and the differing communities and organizations in which this information resides
5) Seeks institutional stability, either through stable institutions and/or networks, which facilitates building the trust and familiarity needed for effective links and connections among information users and producers in many different organizations and communities.
6) Incorporates learning, so that all parties recognize the need for and contribute to the implementation of decision support activities structured for flexibility, adaptability, and learning from experience.

These principles can lead to different decision support processes depending on the stage and context of the decision in question. For instance, decision support for a large water management agency operating an integrated system serving millions of people will have different needs than a small town seeking to manage its ground water supplies. A community in the early stages of developing a response to climate change may be more focused on raising awareness of the issue among its constituencies, while a community with a well-developed understanding of its risks may be more focused on adjudicating trade-offs and the allocation of resources. Each community will have different decision support needs.

Attributes and Resources

Better decisions need to be actionable and effective. Actionable decisions require a clear plan of implementation, have buy-in from stakeholders and if required, an institutional and governance framework. Effective decisions should produce the intended outcomes over a prescribed of time. Outcomes are subject to how a system responds to the decisions that have been made combined with internally and externally-driven change processes. In a simple system, the response will be proportional to the action, but in a complex system, many other factors can intrude. A better decision in the short term may not prove to be better over the long-term if a system changes its behavior or the definition of what is considered positive, changes.

Supporting good decisions requires appropriate resources and attention to the various attributes of decisions. The latter may be grouped into two broad categories: problem-based and solution-based.

Problem-based attributes may include the extent to which a situation is simple or complex. In the former, climate may be the dominant stressor and direct cause and effect can be identified. In the latter, climate may be one of multiple drivers of change, system feedbacks are strong and where adaptive responses are likely to change how the system behaves. Problem-based attributes also include spatial, institutional and time scales. Spatial and institutional scales tend to be associated with top-down and bottom-up directions of assessment. Spatial scales range from local (bottom) to global (top) and institutional scale from local to international. Time scales are associated with short- and long-term as temporal scales and fore- and back-casting in terms of directional scale. These scales can combine in a variety of ways.

Solution-based attributes strongly utilize creativity (Torrance, 1988). Creativity, as part of innovation provides the flexibility to explore the solution space combining problem solving within the broader context of normative goals. Creativity can be linked to the decision-making process and innovation to the development and implementation of tools, both cognitive and technological. Recent research into creativity suggests that rather than being uncontrolled brainstorming where anything goes, creativity is developed through a process of disciplined acts that seeks alternatives within a pre-defined set of boundary conditions (Sternberg, 1988; Sawyer, 2007). For CCIAV these conditions include scientific plausibility and factors such as economic efficiency, distributive fairness, scalability and so on.

In all but the simplest problems, a decision support process will iterate between the deliberation and analysis steps shown in Figure 2-4 (in Sec 2.2.1.3), exercising both problem and solution-based attributes.

Effective decision making also employs resources including leadership, institutions, and knowledge.

Leadership has been described as the ability to motivate others to achieve a set of goals and can be a characteristic of an individual within a group, or an organization (Vroom and Yetton, 1973; Chemers, 1997). Lack of leadership has been identified as a barrier to adaptation (Moser and Ekstrom, 2010). Although there are several theories attached to leadership, the most relevant to CCIAV is situational or contingency theory where leadership style is tailored to fit the situation at hand. This fits the wide range of situations encountered within CCIAV. Situational theory describes how normative or positivist methods are able achieve a particular set of goals. It also undertakes descriptive assessment of how effective different leadership styles are in achieving their normative aims and proposes models based on those findings (Vroom and Yetton, 1973; Margerison and Glube, 1979; Vroom and Jago, 1988; Chemers, 1997). Leadership can be understood through its role in a particular organization or institution via management lens through how innovations implemented by an individual or organization are transferred to other actors. While the expression of leadership may be in the operational arena (e.g., through inspiration by example) its overall aims are generally considered to be strategic to transformational. Three important styles of leadership are transactional, based on a reward/penalty strategy, laissez-faire and transformational, leaders who state goals, develop plans and encourage others to achieve them in a variety of ways (Bass et al., 1996; Eagly et al., 2003).

Institutions have a large number of attributes that encompass the spectrum between defined roles and informal narratives. In some cases institutional change may be required if that institution is contributing to market failures associated with climate change, the perpetuation of unsustainable practises or maladaptation. Institutions in opposition to responses on climate change also influence decision-making, especially that affecting mitigation policy. Institutions can also respond to particular decisions on a need basis as an actor without altering its identity or path in the process. Institutions also act at different scales – some will be actors, some will provide resources and yet others governance.

Boundary organisations that link different disciplines and or institutions are increasingly being recognised as important to CCIAV decision support (Guston, 2001; Cash et al., 2003; McNie, 2007; Vogel et al., 2007). *A boundary organization is a bridging institution that acts as an intermediary between science and policy, whose goal is to shape perceptions of salience, credibility and legitimacy of available information, and effectively balance any trade-offs among them. This organization carries out information functions, including communication with decision makers, translation of science, and mediation between different views of how to interpret new information.* To serve as this bridge, this organization requires the ability to recognize the importance of location-specific contexts (Ruttan et al., 1994), to create a forum in which information can be co-created by interested parties (Cash et al., 2003), and to facilitate the creation of boundary objects, such as scenarios, and model-based decision support systems (White et al., 2010). Adaptive and inclusive management practices are essential to the functioning of such organizations, particularly in addressing wicked problems such as climate change (Batie, 2008).They also provide a bridge between adaptation to climate and to other processes managing global change processes and sustainable development.

Knowledge is a cultural resource that people can draw from and may also be generated for specific decisions. Malaska and Holstius (1999) describe an Aristotelian approach to good decision-making that requires three kinds of knowledge: purpose and objectives, situational knowledge and knowledge about means and resources. Situational knowledge for CCIAV requires historical and current knowledge of the system and scenarios and/or forecasts of the future. Some of the main challenges for knowledge are to transfer information from specialised sources, such as the scientific knowledge of climate change, through to where it can inform decisions. Often the transfer requires a transformation from specialised statistical knowledge to a generalised form of everyday information, such as may be used by a market or public good climate service. Knowledge generation, demand and transfer are cross-cutting issues that have a huge bearing on decision-making processes.

These resources and attributes can be viewed in how they influence the decision process itself. Figure 2-5 divides the decision-making process into four stages: scoping, analysis, implementation and review, outlining institutional and leadership, and knowledge and information characteristics for each stage. The two loops reflect the loops in Figure 2-2. Most effort in CCIAV research has been put into the first two stages, whereas decision implementation and follow up have been minimal. This does not imply that the analysis stage is discounted – problem analysis and solution evaluation is a significant undertaking in any decision-process, but that is where most current assessments stop.

[INSERT FIGURE 2-5 HERE
Figure 2-5: Selected attributes and characteristics relevant to the decision-making process itself. The two loops in the decision-making process relate to the two loops in Figure 2-2.]

Figure 2-6 combines the time element in planning adaptation to climate change with a systems planning approach at the organisational level. The coping range of climate (covering the spectrum between thriving and tolerance) that a location or actor is adapted to will need to change over time if to avoid increasing vulnerability. The coping range for any activity, location or organisation may be unique. This is combined with scenario use, visioning and strategic planning carried out in an organisational environment. A simplified systems approach builds in levels of leadership with research and development, strategic management and operations. Resources and directions are fed down through the system and feedback detailing progress and exceptional circumstances fed back up. All levels take in the environmental information needed for decision-making and where they cannot make decisions within limits set, send that signal up the line. The risk of crossing a critical threshold may require actions grading from the exercise of different options, revisiting strategic directions or, in extreme cases, revisiting the original vision.

[INSERT FIGURE 2-6 HERE
Figure 2-6: Planning frameworks for climate change showing the coping range, changing climate, thresholds and vulnerability for a single-variable climate scenario with idealised adaptation pathways (top) shows with a systems planning framework for organizations showing how vision, strategy and action can combine in a reflexive manner.]

The cases that follow are intended to elaborate on the role and importance of these attributes and ways in which they may matter. The cases are intended to be examples of situations where decisions could not (or were not) reached and why and where there were effective decisions and why.

2.3.2. Assessing IAV on a Range of Scales

If the goal of decision-making on climate change is to manage climate risks, then decision-making needs to ensure this goal is being achieved. Progress in CCIAV has been gradual, evolving as the scientific understanding of climate change improves. A number of global initiatives are taking place to enable knowledge generation, transfer and use, including the Programme of Research on Climate Change Vulnerability, Impacts and Adaptation – PROVIA (PROVIA web site: http://www.provia-climatechange.org/), the Nairobi Work Programme on impacts, vulnerability and adaptation to climate change – NWP (NWP web site: http://unfccc.int/adaptation/nairobi_work_programme/items/3633.php), and work by the World Bank and regional development banks (World Bank climate change web site: http://climatechange.worldbank.org/).

As noted in Section 2.3.1, boundary organizations contribute to knowledge transfer, and there are examples of such entities contributing to regional CCIAV assessments, including Great Lakes Integrated Sciences and Assessments Center – GLISA (GLISA web site: http://www.glisa.umich.edu/), the UK Climate Impacts Program – UKCIP (UK Climate Impacts Program, 2011), and institutions working on water issues in the U.S., Mexico and Brazil (Kirchhoff et al., 2012; Varady et al., 2012).

2.3.2.1. Assessing Impacts

Climate impact assessment draws on interdisciplinary studies that focus on the interaction between nature and society. An early description of impact models is found in Kates (1985), who summarize various case study experiences based on historic events in determining direct cause and effect, and then proposing a more interactive model, in which initial societal responses would lead to a different impact in the future for a similar climatic event. A short term adjustment could ultimately lead to longer term adaptation by societies, as illustrated for drought adjustment in the Great Plains of the United States, in which a ‘lessening’ of impacts was observed during subsequent drought events (Warrick, 1980).

Scenario-based climate impact assessments differed from assessments of observed events, however, in that it challenged prevailing models of stability in climate-society relationships. A number of cases of historic events identified how decision makers, when faced with an extreme weather/climate event, held on to old views of such relationships and pursued a ‘muddling through’ approach (Glantz, 1988). Impact assessment of future climate change would therefore challenge prevailing decision frameworks that implicitly assumed climate stationarity (Milly et al., 2008).

In order for scenario-based impact assessments to contribute to vulnerability and risk assessment, there needs to be a series of translations carried out. Scenarios of projected greenhouse gas concentrations are converted to changes in atmospheric conditions, subsequently to impacts without proactive adaptation, and finally, to an assessment of the effectiveness of various adaptation options. As discussed in Chapter 1, and Section 2.2.1.6, climate change scenarios themselves have changed dramatically since the 1980s with the continued evolution of climate models and emission scenarios. A new scenario process aims to provide Representative Concentration Pathways (RCP) and corresponding climate projections and socio-economic driving scenarios(van Vuuren et al., 2012) that can be used for impact assessments.

This series of translations requires the transformation of data across various scales of time and space, between natural and social sciences, utilizing a wide range of analytical tools created by different fields of study, including agriculture, forestry, water, economics, sociology, and systems modelling. For example, scenarios for climate variables such as temperature and precipitation need to be translated into scenarios or projections for biophysical and socio-economic impact variables such as food supply, coastal erosion, health outcomes, species distribution and so on. Establishing these connections and supporting the translation process is an important function of climate services, described more fully in Section 2.3.3.

The assessment of impacts leads to placing the projected changes within the context of local management and governance, and to anticipate how possible future changes in management and governance over the scenario time frame of 50–100 years might influence the linkages between climate change and the associated socio-economic consequences for the location being assessed. This represents a combination of top-down biophysical assessments of futures and bottom-up socioeconomic assessments of the past and present (Figure 2-7a,b). This inconsistency hampers assessments of future adaptation responses (see Chapter 16). An important challenge, therefore, is to construct impact assessments in which biophysical futures are superimposed on socioeconomic futures (Figure 2-7c). An ongoing effort to address this inconsistency is the construction of a new set of socioeconomic futures, known as Shared Socioeconomic Pathways (SSP), which are storylines corresponding to the new RCPs (Moss et al., 2010; Kriegler et al., 2012).

[INSERT FIGURE 2-7 HERE
Figure 2-7: Approach Used to Inform Adaptation Policy (modified from Dessai and Hulme 2004 (Dessai and Hulme, 2004).a – biophysical and socioeconomic assessments based on historical observations; b –biophysical impact scenario superimposed on historical socioeconomic condition; c – biophysical and socioeconomic assessments based on future scenario.]

More recently, a new generation of scenario-based impact assessments has emerged in which regional case studies are linking biophysical, economic and social analysis tools, in order to describe the interactions between projected biophysical changes and managed systems, assuming various responses by the actors of those managed systems. For example, Ciscar et al. (2011) estimated the costs of potential climate change impacts, without public adaptation policies, in Europe in four market impact categories (agriculture, river floods, coastal areas, and tourism) and one nonmarket impact (human health). They found that if the climate of the 2080s were to occur today, the annual loss in household welfare in the European Union resulting from the four market impacts would range between 0.2–1%. A similar study was conducted in the UK (Hunt, 2008). Net benefits were projected for tourism, health and transportation maintenance in winter, while net losses were projected for buildings and transportation infrastructure due to increased flood risk, and for residential water supplies in Southeast England. In the U.S., Backus et al. (2013) assessed national and state level GDP and employment impacts, assuming the SRES-A1B scenario across the range of climate projections from the CMIP3, incorporating direct impacts on water resources, direct responses to these impacts by agriculture and other water interests, and indirect responses through inter-state migration of affected populations. The combination of direct and indirect responses resulted in an average cumulative GDP loss of 1 trillion U.S. dollars for 2010- 2050.

Another recent innovation is the application of decision support tools within scenario-based impact and adaptation assessments. One example is an assessment of the ability of a community water system in British Columbia, Canada, to meet regulated in-stream flow requirements within scenarios of climate and forest cover changes. In this case, the decision tool used was the Water Evaluation and Planning System model. Of seven scenarios tested, the community water system failed in six scenarios due to projected climate impacts on local stream flow. The exception was the case where forest cover was depleted due to an insect epidemic, similar to what other regions in British Columbia have already experienced, and which is also a projected impact of climate change (Harma et al., 2012).

2.3.2.2. Assessing Vulnerability and Risks

The adaptation to climate change, disaster risk management, and resilience literatures all address the concept of vulnerability, defined as a susceptibility to loss or damage (Adger, 2006; Füssel, 2007), or, the propensity or predisposition to be adversely affected (glossary). Within IPCC AR4 Schneider et al. (2007) identified those vulnerabilities that might be considered 'key', and therefore potentially 'dangerous' (see glossary). What makes an impact 'key' depends on certain criteria related to the climatic event itself, but also to the location or activity of interest. Criteria related to the event itself include the magnitude and timing of the event, its persistence and reversibility, and the likelihood and confidence that the event would occur. In Chapter 19, persistence of conditions of high susceptibility to the climate event is identified as a vulnerability of the activity. Other aspects of the location or activity include its importance in supporting society, its exposure to the event, and its capacity to adapt.

Adaptive capacity has been defined as the ability to adjust, to take advantage of opportunities, or to cope with consequences (Adger et al., 2007; glossary). However, adaptive capacity is context specific, related to both availability of resources and strong governance measures (see Chapter 14). As noted in Section 2.2.2.1, recent experiences in developed countries, such as with the 2003 heat wave in Europe (Haines et al., 2006) and Hurricane Katrina in the USA (Committee on New Orleans Regional Hurricane Protection Projects, 2009) have led to questions about attribution of causes for weather and climate-related impacts. High property damage and loss of life occurred in both cases because of failures in support systems (e.g., flood defence structures, coordinated heat relief programs). In New Orleans, development choices over a lengthy period increased this city's vulnerability to hurricanes by destroying the region's natural flood defences (wetlands, cypress swamps) in favour of navigation channels and flood control levees (Freudenberg et al., 2009).

The concept of 'adaptation deficit' (Burton and May, 2004) may be applicable to cases such as Katrina. Adaptation deficit represents a gap between a deficient state of adaptation and a state of adaptation that avoids adverse impacts (Chapter 17, glossary). Barriers unrelated to scientific knowledge can hamper effective decision making (Adger and Barnett, 2009; Berrang Ford et al., 2011). This may help to explain why an observed hurricane or other weather or climate event can create surprising levels of damage within developed countries. It has also been related to 'residual impacts', which occur due to insufficient adaptation to current or future climate (IPCC, 2007).Within developing countries, Narain et al. (2011) consider the adaptation deficit to be within a larger 'development deficit'. IPCC (2012) cite other 'deficit' indicators, including a Disaster Deficit Index (impact of extreme event combined with financial ability to cope), structural deficit (low income, high inequality, lack of access to resources, etc.), and risk communication deficit.

This difficulty in parsing out the relative influences of climate and development patterns has been identified within assessments of observed trends in property damage from atmospheric extreme events. For example, recent increases in economic losses may be attributed to changes in probabilities of extreme events, changes in human development patterns (more people in harm's way) without changes in climatic extremes, or a complex combination of both (Pielke, 1998; Mills, 2005; Munich Re Group, 2011). IPCC (2012) concluded that increasing exposure has been the major cause, but a role for climate change has not been excluded. Similar challenges will influence assessments of projected damage trends within future scenarios of climate change and development. .

Assessing damage within future scenarios of climate change will require approaches that link both bio-physical futures and socio-economic futures, providing opportunities to expand scenario assessments beyond expressing future human behaviour only through the lens of population growth, GDP growth and discount rates. An example is the assessment of climate change effects on human health, including research-to-decision pathways, monitoring of social vulnerability indicators and health outcomes (English et al., 2009; Portier et al., 2010), and tools for enabling adaptive management (Hess et al., 2012). An example of a regional scale scenario-based vulnerability assessment incorporating sensitivity, exposure, impact and adaptive capacity is a case study for North Rhine-Westphalia in Germany (Holsten and Kropp, 2012). An example of a larger scale study is a vulnerability assessment of ecosystem services for Europe, in which future adaptive capacity was based on indicators from the SRES storylines(Metzger and Schröter, 2006).

It may be difficult to anticipate how a development choice taken in the current or near term could influence future vulnerability to projected climate change, hence the interest in the study of ***emergent risks***, which is the focus of the review in Chapter 19. Interactions between development pathways, climate change impacts, and climate change responses, could create situations for which there is little or no precedent. Assessments based on gradual shifts in mean conditions could underestimate future risk and consequent damage, suggesting the need for process-based methodologies that focus on enhancing resilience (see Section 2.4.2). An example of assessing this type of risk, and the costs and benefits of potential adaptation responses, is a resilience assessment framework for infrastructure networks (Vugrin et al., 2011; Vugrin and Turnquist, 2012).

2.3.3. Climate Information and Services

Climate Services are the link between generation and application of climate knowledge. There is a growing body of literature concerning the development of such services; on their history and concepts (2.3.3.1.); on decision support as its main feature (2.3.3.2.), and the policy implications of climate service as a global practice (2.3.3.3.).

As the concept of Climate Services becomes ever more relevant for the generation and application of climate information on local, regional and national levels; numerous questions arise for decision makers, stakeholders and other private or public users concerning climate variability, monitoring of risks and adaptation planning “as an important component of sustainable development” (Vaughan and Dessai, 2013). The Global Framework for Climate Services (Hewitt et al., 2012) sets as a goal to “enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale” (http://www.wmo.int/pages/gfcs/index_en.php). Miles et al. (2006) define climate services with a strong focus on the connection between climate science and the public demand for information. But many other disciplines are needed to support the development and delivery of climate services. This extended reach, which includes social sciences, is still fragmented and weak. To support the development and delivery of climate services, more than climate projections and scenarios are needed; observations from a variety of sources are needed as well as case-specific communication skills.

While many countries have already established national and regional climate services or are on the way to do so, the literature shows significant differences in the evolution, organization and practice of Regional Climate Services in different countries and parts of the world. The development of Regional Climate Services in the US and parts of Europe is well documented, with an increasing focus on the aspect of communication and decision support. The European Environmental Agency EEA established a clearinghouse, which provides access to the European data centre on greenhouse gas emissions and climate change impacts, vulnerability and adaptation (http://www.eea.europa.eu/themes/climate/intro). It is linked to the European Climate Adaptation Platform, which provides legal and practical information of regional adaptation measures (http://climate-adapt.eea.europa.eu/). Examples for national and regional Climate Services are: Europe and Eastern Asia (Ebinger et al., 2010); Germany’s Climate Service Centre CSC (http://www.climate-service-center.de/) and the HGF Regional Climate Offices (Schipper et al., 2009); the Swedish ‘SweClim’ (Rummukainen et al., 2004), or the UK Climate Impacts Programme (http://www.ukcip.org.uk/).

An awareness of the need for climate services in developing countries is also growing (Semazzi, 2011), which is reflected in an increasing body of literature mostly from science and technology studies on the migration of standardized regional climate models into the ‘global South’. While in 2001 only around 21 countries were running regional climate models (RCMs), mostly in OECD states, there are today about 104 countries trained in using the PRECIS RCM (Edwards, 2010). These show considerable differences in size, scope and practise, ranging from large-scale administrative services to ad hoc interventions of research institutes (von Storch and Zwiers, 2012). Regional Climate Services are expanding from the global North to the global South, shifting from simple understandings of climate information covered by linear approaches to ever more complex and wicked problem situations, and finally, increasing in interdisciplinarity by incorporating the social and communication sciences.

2.3.3.1. Climate Services: History and Concepts

In the peer-reviewed literature, the development of North American climate services is well documented (Changnon et al., 1990; Miles et al., 2006; DeGaetano et al., 2010). The idea of establishing climate services on both national and regional levels resulted from the growing concern over the consequences of climate fluctuations and the difficulties to provide and to distribute adequate information. In the beginning, climate services were merely understood as an expansion of the tasks provided by weather services and similar operational organizations, mainly dealing with forecasts, seasonal outlooks, and assessments of risks in a mostly stationary but variable climate. As it turned out, this restricted and mainly technical understanding of those services were barely effective. For example, decision makers had difficulties understanding and using climate data for planning purposes (Changnon et al., 1990; Miles et al., 2006; Visbeck, 2008). Furthermore, data were delivered slowly and were of poor quality; there were problems in obtaining data on appropriate time and space scales, and there was an "inability to access available datasets held by the private sector, states, regional and some federal agencies" (Changnon et al., 1990).

Attempts were made to provide regional climate services with increasingly sophisticated methods, infrastructure, tools, and collaborations. Early definitions of the mission and scope of climate services focused on being user centric, on active research, data stewardship and effective partnership (National Research Council, 2001). More sophisticated and broader agendas understood climate services as a clearinghouse and technical access point to stakeholders, providing education and user access to experts; they should inform the climate forecast community of the information needs, and propose and evaluate adaptation (Miles et al., 2006). But those general definitions and approaches do not reflect the diverse origins of climate services, mainly the difference between private services aimed at specific consumer needs and public ones with a broader agenda.

This static approach does not reflect changing consumer needs or even natural climate change; instead of being supply-focused, public climate services need communicate in the highly challenging environment of technical and institutional networks, monitoring systems, and collaborations with other institutions, stakeholders and decision-makers, as DeGaetano et al. (2010) suggest. Historic approaches and concepts did not meet this challenge in an effective way, being too static, supply oriented and not recognizing the need to include other sciences and methods.

2.3.3.2. Climate Services: Practices and Decision Support

Decision support is an integral part of the climate service concept and is generally acknowledged among government agencies and researchers as necessary for its healthy functioning (Miles et al., 2006; DeGaetano et al., 2010). There is an intense discussion in the climate services literature about the role of decision-support and its products, services and support systems fuelled a growing awareness of the issue of how the supply of scientific information can be reconciled with user demands. These debates focus on the possibilities, ranges and modes of communication. Social-planner models of society and environment relations (Hasselmann, 1990) provide for example insight into the possible economic outcomes of maximal cooperation when properly embedded in an iterative process of contested assumptions. Critics argue that these models present science as a monolithic knowledge provider, free of conflicts about the quality of data and the nature of facts, which is supposed to provide decision-makers with cost-effective solutions for adaptation and mitigation (c.f. Nordhaus, 1991). In its pure form, this 'linear model' approach is said to reveal many deficits in how science, policy-makers and the public interact, so is considered to be inefficient and sometimes misleading (Pielke and Carbone, 2002; McNie, 2007; Pielke, 2007; Sarewitz and Pielke Jr, 2007; Meyer, 2011).

Instead, the dynamic relationship between information and knowledge supply and demand is considered as the focal point for a successful climate service; the supply of scientific information has to be reconciled with user demands in order to produce scientific information which is relevant and suitable for decision making (McNie, 2007; Moser, 2009; Romsdahl and Pyke, 2009; Kandlikar et al., 2011; Pidgeon and Fischhoff, 2011). Furthermore, the communication of uncertainty and risk play a special role in framing science, and scientific data have to be turned into useful information (Shafer, 2004). According to Moser (2009) decision support is a diverse set of meanings and definitions that has come to mean "processes of interaction, different forms of communication, potentially useful data sets or models, reports and training workshops, data ports and websites, engaging any level of governance, at any stage in the policy- or decision- making process". For Regional Climate Services, this more dialogic approach challenges the communication process as suggested by the National Research Council (National Research Council, 2009a); instead of beginning with users' needs, it seems more useful to link users and producers to ensure that all parties are involved in order to find out what the needs actually are. It also seems counterproductive to seek institutional stability per se, as the NCR suggests; sometimes it is necessary to identify where institutions need to change and to be sufficiently flexible and/or robust to change in line with, and in response to, climate, social and ecosystem changes.

Capacity building remains a crucial problem, especially in the absence of knowledge and awareness. Educational levels, geographic relevance and scale of information or the status of science in society vary highly among stakeholders as does their abilities to use various types of knowledge. It is important to include here both users and providers of knowledge to ensure a successful learning process. This is also true for more informal educational dialog in form of schools, on the web, in zoos or museums. In any case, communications should also include how climate services can be used, as well as their limitations.

For Shafer (2004), the climate service is a "process of two-way communication" and "involves providing context that turns data into information". For von Storch et al. (2011), climate services are "knowledge brokers" that have to establish an effective dialogue between science and the public. This dialogic communication contains two main tasks: "One is to explore the range of perceptions, views, questions, needs, concerns and knowledge in the public and among stakeholders about climate, climate change and climate risks. The other task is to convey the content of scientific knowledge into the public, to media and the stakeholders. This includes communicating the limitations of such knowledge, the known uncertainties and the unknowable, as well as the limited role of science in complex decision processes."

These demands outlined in the discussion and evaluation of decision-support on the regional level rely on and strongly support interdisciplinary approaches, combining information gained from climate science with knowledge gained from the social and communication sciences.

2.3.3.3. The Geo-Political Dimension of Climate Services

An emerging body of literature from the social sciences is observing practices associated with climate knowledge expansion and the implications of this expansion within a policy-relevant context (Yearley, 2009; Grundmann and Stehr, 2010). Science and technology-inspired studies focus on the mobility of climate knowledge into the "global South' or developing countries. Decision support tools developed in universities in the global North such as the climate model PRECIS from the UK Met Office spread all over the world and serve as a link between the developed and developing countries seeking to adapt to future climates. Earth system models such as PRECIS contribute to capacity building in direction to regional or national climate change management. This mobility of knowledge at the interface of science and politics has far reaching implications for the shaping of global geographies of climate knowledge production; these models strengthen the influence of epistemic communities such as the IPCC and other global governance mechanisms (Mahony and Hulme, 2012). Thus, while regional climate models play an increasingly important role in decision making processes (Dessai et al., 2009), critics argue that climate becomes the focal point of planning and development strategies and renders local forms of knowledge subordinate to this 'climate reductionism' (Hulme, 2011).

A growing number of ethnographic studies of local or regional climates and cultures shows the increasing relevance of indigenous forms of knowledge for the practice of Regional Climate Services (Strauss and Orlove, 2003; Crate and Nuttal, 2009; Crate, 2011; Ulloa, 2011). Anthropological studies demonstrate that local forms of knowledge and scientific climate models are not necessarily mutual exclusive; instead, individual case studies show how both forms of knowledge inform each other to the benefit of a place based adaptation to climate variations (Strauss and Orlove, 2003; Orlove and Kabugo, 2005; Orlove, 2009; Strauss, 2009; Orlove et al., 2010). Indigenous knowledge for climate change adaptation was reviewed in IPCC AR4 (IPCC, 2007), in which various examples of local knowledge systems are now being applied to the newer challenge of proactive adaptation to projected climate change. This increased attention to oral histories is leading to new experiments in which these are compared or combined with remote sensing technologies and model-based scenarios, to co-produce new knowledge, and to create a new discourse on adaptation planning (Nakashima et al., 2012). The challenge will be to carry out these collaborations in a manner that enables their integration into a holistic narrative on future adaptation choices.

A case study from high arctic Canada, demonstrates the initial incommensurability of Inuit and scientific observations of changing weather patterns (Gearheard et al., 2010), followed by a strong correlation when the appropriate phenomena for measurement and appropriate analyses are identified by meteorologists (Weatherhead et al., 2010). Nakashima et al. (2012) analyse how scientists tend to initially discount indigenous observations, when in actual fact, shortcomings in understanding may derive from the practice of science (see also the discussion in chapter 12.3). These cases show that adaptation is and needs to be local; Endfield (2011) argues for a 'reculturing and particularizing of climate discourses' in order to successfully localize global and scientific meta-narratives. The growing number of this kind of study reveals that one strategy will not suite every local situation, and that climate service development is indeed a dialogic process that challenges the knowledge basis of all sides involved.

Social, cultural and communication sciences play a decisive role in this process (Pidgeon and Fischhoff, 2011; von Storch et al., 2011). Cultural values, social actors, national and regional politics enter the stage; science becomes part and parcel of the negotiation process entailing mitigation and adaptation decisions on various scales. To position itself and to react according to the diverse demands, science-based climate services have to become "rooted in society" (Krauss, 2011). The climate science community does not necessarily takes the lead, but becomes part of an inter- and transdisciplinary process, where politics, culture, religion, values etc. become part of climate communication.

2.3.4. Climate-Related Decision Support in Practice

At the societal scale, decision-making generally aims to achieve multiple objectives. A watershed may be managed for domestic water supply, hydroelectricity, agriculture, navigation, recreation, and in-stream requirements for aquatic ecosystems. These may be influenced by requirements for flood control, including maintenance of engineered structures that control flow and levels of lakes, rivers and water storage for later use (dams, reservoirs, canals). A forested region can include timber supply areas, lands set aside for parks and wildlife habitat, and other lands managed to support biofuels. These may be influenced by changes in disturbance regimes (insects, disease, fire, invasive species), and requirements to protect endangered species.

Climate change could influence the achievement of these and similar management objectives. Recent literature on potential climate change effects on natural resources, public health and community planning and management is reviewed in chapters 3–12. As the complexity of management challenges increases due to development and other pressures, including climate change impacts, new decision-making paradigms are emerging. Examples include Integrated Water Resources Management (IWRM), Sustainable Forest Management (SFM), and Sustainable Fisheries Management.

Bates et al. (2008) briefly reviewed the IWRM, describeding it as a participatory process. Sustainability of ecosystems, demand management, and integration of water within social and economic development, would all be explicitly considered as part of a participatory approach to water and land resources planning and implementation (Agarwal et al., 2000; Snellen and Schrevel, 2004). Many countries have recently acknowledged IWRM principles (Garcia, 2008; Jønch-Clausen, 2010), but they contain implementation challenges that may be exacerbated by climate change effects on water cycles and extreme events. Jønch-Clausen (2010) gives examples for the state of Orissa, India and Martz et al. (2007) for the South Saskatchewan River Basin, Canada. Additional discussion on IWRM is found in chapter 3.

SFM aims to maintain and enhance the economic, social and environmental values of forests, but is still an abstract concept (Seppälä et al., 2009). This is in contrast to the more narrowly defined timber-dominant forest management (Wang, 2004). Criteria and indicators for SFM assessment have been identified (McDonald and Lane, 2004; Wijewardana, 2008; Montréal Process, 2009), focusing on biological diversity, productive and protective functions of forests (e.g. maintenance of soil and water resources), maintenance of social and economic benefits (e.g. wood products, social and spiritual needs), and governance. Climate change is seen as relevant to achieving SFM objectives (Montréal Process, 2009), and consequently, climate change may pose new kinds of vulnerabilities and risks. An example of a vulnerability assessment is illustrated for a case study of SFM in the Austrian Federal Forests of the Eastern Alps (Seidl et al., 2011). At the same time, however, governments and companies are considering assisted migration as an adaptation strategy (Pedlar et al., 2012). Additional discussion of SFM is found in chapter 4.

Sustainable fishing is defined as long term fishing at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations (FAO, 2013). Climate change has generally not been included in strategic guidance for fisheries management (Brander, 2010). Industrial fishing has led to depletions of some populations (Pauly et al., 2002), and climate change would create additional stress on marine biodiversity through warming-induced species invasion in high latitudes, and local extinction in tropical regions (Cheung et al., 2009). Ecosystem-based fishery management or EBFM (Zhou et al., 2010), seeks a balance in exploitation of various species. This is complemented by emerging discussion on evaluating harvest management strategies, including a management strategy evaluation or MSE (Sainsbury et al., 2000; Bunnefeld et al., 2011) incorporating monitoring and model simulation of managed systems, enabling simulation of proposed decision rules. Additional discussion of fisheries management is found in chapters 3 and 5-7.

At the national level in the least developed countries (LDCs), National Adaptation Programmes of Action (NAPA) was an important initiative launched by the UNFCCC (2009). NAPAs must be action-oriented and country-driven and be flexible and based on national circumstances. The key preparatory steps include the synthesis of available information on vulnerability to and impacts of climate change and variability, via extensive public participation and consultation. The NAPA process has assisted least-developed countries to assess climate sensitive sectors and prioritize projects to address the most urgent adaptation issues for vulnerable regions, communities, and populations (Lal et al., 2012; UNFCCC, 2012). For example, Sudan prioritized projects through a two-part process of quantitative and consultative criteria and stakeholder involvement (World Resources Institute et al., 2011). The integration of NAPAs with other socio-economic programs can help develop resilience. Rwanda and Bangladesh linked their NAPAs and Poverty Reduction Strategy Papers (PRSPs) in order to facilitate mainstreaming of climate change adaptation. The Bangladesh NAPA also identified adaptation strategies that complimented the PRSP (OECD, 2009). Although many countries have linked their NAPAs with development programs, Hardee and Mutunga (2010) argue that they have not been entirely successful in aligning the NAPA priorities with existing national development planning processes. In this context, they cited ‘population pressure’, which is recognized as an issue for adapting to climate change but not incorporated into national adaptation planning or poverty reduction strategies.

Scaling up and institutionalization of the NAPA process has already begun. Under the Cancun Adaptation Framework developed at COP16, a process was established enabling LDCs to formulate and implement national adaptation plans (NAPs) that would build upon the NAPA experience (UNFCCC, 2013). The main objectives of the NAPs are to identify vulnerabilities, medium- and long-term adaptation needs and to develop and implement strategies and programmes to address those needs and also to mainstream climate change risks.

Many developed countries have made progress towards developing adaptation strategy documents at different levels of governance. Swart et al. (2009) analysed National Adaptation Strategies (NAS) of nine European nations examining their decision making aspects, finding both ‘top-down’ and ‘bottom-up’ (delegation of authorities to local governments) approaches. Dissemination of information on weather, climate, impacts, vulnerability, scenarios, etc. was found to be very critical elements for adaptation decision making. Swart et al. (2009) also identified multiple scales and actors involved in the adaptation decision-making process, these actors having different and contradictory views of adaptation measures.

Climate risk-based decision making is becoming an increasingly widespread practice in both developing and developed countries. For example, the aquaculture industry is rapidly developing in coastal Vietnam but the dikes and structures that protect this industry can be severely damaged by storm surges. In response, Vietnam has initiated large-scale mangrove restoration and rehabilitation programs with the support of international institutions (World Resources Institute et al., 2011). The Tsho Rolpa glacier lake in Nepal was at the risk of outburst due to rapid melting of the glaciers (Adger et al., 2007). Considering the risks, the Government of Nepal started implementing both short- and long-term measures to prevent the outburst flood event (World Resources Institute et al., 2011). There are many instances of risk-based decision making in developed countries as well. Taking lessons from the 2003 heat waves that killed some 35,000 people across Europe, many European countries have already implemented health-watch warning systems (Alcamo et al., 2007; WHO, 2008).

Awareness of climate change risks has propagated to local levels in many countries. Some municipal governments are already embracing the idea of incorporating climate change adaptation planning within municipal planning instruments, including energy and water system design, disaster risk reduction and sustainability plans (Ford and Berrang-Ford, 2011; Rosenzweig et al., 2011).

Although there is a rapidly growing list of adaptation plans being generated at national and local scales (Berrang Ford et al., 2011), an evaluation of adaptation plans from Australia, United Kingdom and the United States suggests that these plans are largely under-developed. This reflects a preference for capacity building over the delivery of specific vulnerability-reduction measures, indicating that current adaptation planning efforts are still informal and ad hoc, with many institutions ‘muddling through’ the process (Preston et al., 2011). At the same time, however, anthropologists and other social scientists are documenting the growth in community-based adaptation initiatives, in part through climate change reception studies, which explore how local communities receive and act on climate change information (Baer and Risbey, 2009; Rudiak-Gould, 2011). Details of adaptation planning within urban and rural settlements are addressed in chapters 8 and 9, respectively.

Various enabling factors have been identified in stakeholder engagement processes. Such factors include access to human, social and economic resources, sharing observations and ICT tools (e.g., wireless broadband and wireless sensor networks, geographic information systems and Web based tools), high levels of local awareness, providing information allowing for good public understanding of stresses, risks and trade-offs, mainstreaming strategies, or political leadership and institutions. These factors allow new strategies to be explored and implemented (Shepherd et al., 2006). Enabling factors also include the availability of customized impact and vulnerability assessments for the community of interest and for local practitioners (engineers, planners, resource managers, political leaders) who would serve as champions for adaptation planning, and the existence of local social influences/networks and capacity that enable long term strategic planning and mainstreaming (Gardner et al., 2009; Cohen, 2010). These factors are further discussed in chapter 15 and 16.

Local government officials often lack training on climate change adaptation and require comprehensive guidance. To fill this gap, guidebooks have been produced, in which the process of adaptation planning is framed as both a team-building and project management exercise, activities that are already part of usual practice (Snover et al., 2007; Bizikova et al., 2008; ICLEI Oceania, 2008; CARE International in Vietnam, 2009; Ayers et al., 2012). Practitioner engagement in decision ‘games’ offers another training resource (Black et al., 2012).

Local scale visualization of impacts and adaptation measures, depicted on realistic landscapes, has become an emerging technology that is being tested to support dialogue on adaptation planning at the local scale (Schroth et al., 2011; Sheppard, 2012). Although visual representations of scenario-based impact assessments may be available for a location, scenario-based adaptation assessments are not, so artistic depictions of potential adaptation measures and outcomes are negotiated with local stakeholders. This kind of exercise is currently being tested in communities within Metro Vancouver, British Columbia, Canada (Shaw et al., 2009; Burch et al., 2010; Sheppard et al., 2011).

2.4. Linking Adaptation with Mitigation and Sustainable Development

2.4.1. Assessing Synergies and Tradeoffs with Mitigation

The IPCC AR4 explored interactions between adaptation and mitigation (Klein et al., 2007). Capacities to adapt and mitigate are driven by similar sets of factors, and opportunities for synergies may be available particularly for agriculture, forestry, urban infrastructure and some other sectors. However, the AR4 concluded that a lack of information made it difficult to assess these synergies.

Similarly, assessments of trade-offs were at an early stage. The AR4 cited some case studies which indicated that if both the effects of mitigation efforts on climate, and the costs of implementing mitigation measures were accounted for, any benefits from reduced climate change impacts (for example, on malaria) would be offset by losses due to reduced rates of economic growth. However, the general state of the literature was that information on trade-offs was scarce, since mitigation studies rarely addressed implications for adaptation, while adaptation studies did not assess implications for emissions ('adaptive emissions').

An illustration of potential trade-offs and synergies, created by individual adaptation and mitigation actions, are shown in Figure 2-8. The upper left and lower right quadrants illustrate trade-offs that can result from actions within particular local-regional circumstances. The potential of these trade-offs to indirectly influence other adaptation and/or mitigation outcomes do not necessarily mean that such actions should be omitted from a climate change response portfolio, but decision making could benefit from the availability of a quantitative analysis of such trade-offs. Recent literature on potential interactions between mitigation and adaptation is reviewed in Chapters 15 and 16.

[INSERT FIGURE 2-8 HERE
Figure 2-8: Adaptation – mitigation trade-offs and synergies (adapted from (Cohen and Waddell, 2009).]

Chapter 20 offers detailed discussion of recent literature on the relationship between adaptation, mitigation, and sustainable development. This includes sustainable risk management (Section 20.3.3). However, the central theme of Chapter 20 is the strategic objective of enhancing climate resiliency.

2.4.2. Linkage with Sustainable Development – Resilience

The idea that climate change response and sustainable development should be integrated within a more holistic decision framework has been broadly discussed, including within IPCC AR4 (Robinson et al., 2006; Klein et al., 2007; Yohe et al., 2007). Practical aspects are being explored as local and sub-national scale actors (such as municipalities, regional districts, states/provinces) seek to incorporate proactive adaptation within long-term official development plans. This has enabled local case studies to be initiated, engaging researchers and practitioners (planners, engineers, water managers, etc.) in scenario-based exercises, building local capacity to plan for a range of climate change scenarios (Bizikova et al., 2010).

Folke et al. (2010) argue that people and nature are interdependent systems, and adaptability is enhanced when actors can enable systems and places to absorb disturbance and reorganize while undergoing change, so as to retain the same function, structure and identity. In other words, this characteristic, known as resilience, is the capacity to change in order to maintain the same identity (see Glossary). The idea of climate-resilient pathways is a central theme of Chapter 20.

Assessment of resilience is described as an approach that focuses on identifying and understanding processes that produce thresholds for fundamental change in a system, and identifying where resilience resides (see Section 2.2.1.2). This can be learned through participatory processes with local experts (Tyler and Moench, 2012), or through system modelling. In an ecosystem study, for example, there would be an evaluation of local sources of exceptional productivity and biodiversity, and how well these sources confer resilience within larger ecoregions. This is being used in the Arctic to map local ecosystem resilience, and to assess future persistence of the capacity of these local sources to support resilience of larger ecoregions, within scenarios of climate change (Christie and Sommerkorn, 2012). Another example is resilience analysis of supply chains, as illustrated by the case of petrochemical supply chains exposed to a hurricane in south-eastern United States (Vugrin et al., 2011).

Enhancing resilience is seen as an important component of increased adaptive capacity. In King County (Seattle) Washington, USA, collaboration between researchers and practitioners enables translation of scientific information from the global scale to local conditions (Snover et al., 2007). This conveys local ownership on impacts and adaptation assessments that feed into long-term decision making, creating a climate plan that is meant to be flexible, adjusting to new information as it becomes available, and supporting permanent research and monitoring of local environmental changes and evaluation of results of actions taken (Saavedra and Budd, 2009).

The King County example describes a shared learning approach to promoting climate change adaptation without being solely focused on ‘hard’ (technology, infrastructure, etc.) paths. Strengthening adaptive capacity promotes resilience by creating a place-based constituency for long-term monitoring, evaluation and assessment of changing conditions, and of local system performance. However, King County already has strong adaptive capacity, and is well endowed with human and financial resources that could be engaged in proactive adaptation within long term sustainable development planning. Tschakert and Dietrich (2010) indicate that in regions with high and chronic poverty, coupled with low awareness of drivers of global change, there is a gap in understanding about adaptation as a process, and that tools are needed to enable anticipatory learning.

Part of learning about adaptation as a process that can promote resilience, is good communication about management paradigms within various disciplines and fields of practice, and how these paradigms can shift as awareness of climate change and global change increases. Adaptation can have unintended consequences, and so the concept of sustainable adaptation has been proposed (Eriksen et al., 2011). Sustainable adaptation considers effects on social justice and environmental integrity, challenging current (unsustainable) development paths rather than seeking adjustments within them. This concept would recognize the role of multiple stressors in vulnerability, the importance of values in affecting adaptation outcomes, and potential feedbacks between local and global processes.

Within renewable resource management, there has been a paradigm shift from a focus on exploitation to ecosystem stewardship, in which the central goal is to sustain ecosystem capacity to provide services that benefit society as a whole. Chapin et al. (2009) identify differences in characteristics between steady-state resource management and ecosystem stewardship, in that the former would aim to achieve ecological integrity through managing stocks, while the latter’s goal would be attaining sustainability benefits through managing feedbacks. For example, with the growing interest in hydraulic fracturing (fracking) to increase production of shale gas, as a cleaner alternative to other fossil fuels, regulation and adaptive environmental management are the subjects of new research on planning and decision making approaches, given the potential for negative feedbacks on water resources. Cases include regulation of coal seam gas exploration in Queensland Australia (Swayne, 2012), and new institutional arrangements to integrate water and energy decision making in Northeastern U.S. (Scott et al., 2011).

For urban areas, Leichenko (2011) categorize 4 types of urban resilience studies: a) urban ecological resilience, b) urban hazards and disaster risk reduction, c) resilience of urban and regional economies, and d) urban governance and institutions. Boyd et al. (2008) promote resilience as a way of guiding future urbanization that would be better ‘climatized’. The Asian Cities Climate Change Resilience Network is applying a resilience planning framework, with attention given to the role of agents and institutions (Tyler and Moench, 2012).

Further consideration of disaster risk reduction is provided through the Hyogo Framework for Action (HFA), which considers climate change as an underlying risk factor, and promotes integration of risk reduction and climate change adaptation (UNISDR, 2007). The HFA mid-term review includes discussion on progress and challenges in its implementation, and calls for guidance on good practice for risk assessments, and for effective synergies between national and local levels (UNISDR, 2011).

One recent approach is the concept of Climate Smart Disaster Risk Management (CSDRM). The CSDRM approach seeks to integrate social development with disaster risk management in order to enhance adaptive capacity and address the structural causes of poverty, vulnerability and exposure. Emphasis is placed on strategies to manage uncertainty associated with both the physical and societal nature of disaster risk, with ongoing national and regional consultations throughout Africa and Asia (Mitchell et al., 2010). In small island states, integration of disaster risk management and climate change adaptation is enabled through focused institutional coordination, greater engagement of stakeholders and promotion of community-based adaptation and resilience-building projects (UNISDR, 2012b). Similar initiatives are underway in urban areas (UNISDR, 2012a).

Chapter 15 provides more detailed review of literature on disaster risk reduction.

Beyond paradigm shifts within individual fields of practice, resilience is also being explored as an outcome of social contracts which underpin governance. O'Brien et al. (2009) use examples from Norway, New Zealand and Canada to illustrate how resilience thinking would frame climate change as a challenge that does not easily fit into existing social contracts of individual communities and nation states, and that new types of arrangements may better serve the goals of resilience and sustainable development within the context of climate change.

Chapter 20 provides more detailed discussion on climate-resilient development pathways, as an explicit objective of long-term planning and decision making.

2.4.3. Transformation – How Do We Make Decisions Involving Transformation?

There is now a growing literature that highlights the importance of transformative adaptation, particularly in the context of a world where the global temperature target of 2°C is exceeded. A recent World Bank report (PIK, 2012), highlights the significant, non-marginal change possible in a ‘4°C world’. Such climate change outcomes are likely to require new approaches for adaptation decision-making (Stafford Smith et al., 2011). Similar arguments are made by Kates et al. (2012), who suggest that transformational adaptation may be required in situations where incremental adaptation may be insufficient. There is a growing, though still sparse literature that examines such transformational adaptation in different sectors and systems. For example, Rickards and Howden (2012) consider transformational adaptation in Australian agriculture.

Adaptation that is transformative marks a shift towards an approach that includes adaptive management, learning, innovation and leadership, among other elements (O'Brien, 2012). This can be observed in the many adaptation projects that emphasize learning about risks, evaluating response options, experimenting with and rectifying options, exchanging information, and making trade-offs based on public values using reversible and adjustable strategies (McGray et al., 2007; Leary et al., 2008; Hallegatte, 2009; Hallegatte et al., 2011). Learning is an essential element of decision-making that supports transformative change (Tschakert and Dietrich, 2010).

Previously in the chapter we have indicated that complex decision problems often require active stakeholder engagement and participation in the decision-making process. Irvin and Stansbury (2004) identify situations where participatory processes may be most effective for bringing about positive social and environmental change. Recently, Park et al. (2011) have proposed the Adaptation Action Cycles concept as a means to delineate incremental and transformative adaptation and the role of learning in the decision-making process. They suggest that decision-making processes dealing with incremental adaptation are different from those used for transformative adaptation. Supporting transformational adaptation may also require a close examination of the legal and regulatory structures underlying environmental and natural resource management; Ruhl (2010) identifies a number of factors that will determine the connection between environmental law and adaptation, (Craig, 2010) suggests how a flexible approach could support increasing resilience and adaptive capacity of socio-ecological systems.

Much of the existing literature examines gradual adjustment or accommodation to change, and therefore, as (O'Brien, 2012) argues, there is a need to develop a body of research that will provide insights into how systems and structures may be transformed in an ethical and sustainable manner for resilience. This would be accompanied by a revolution in education at all levels of society (O'Brien et al., 2013).

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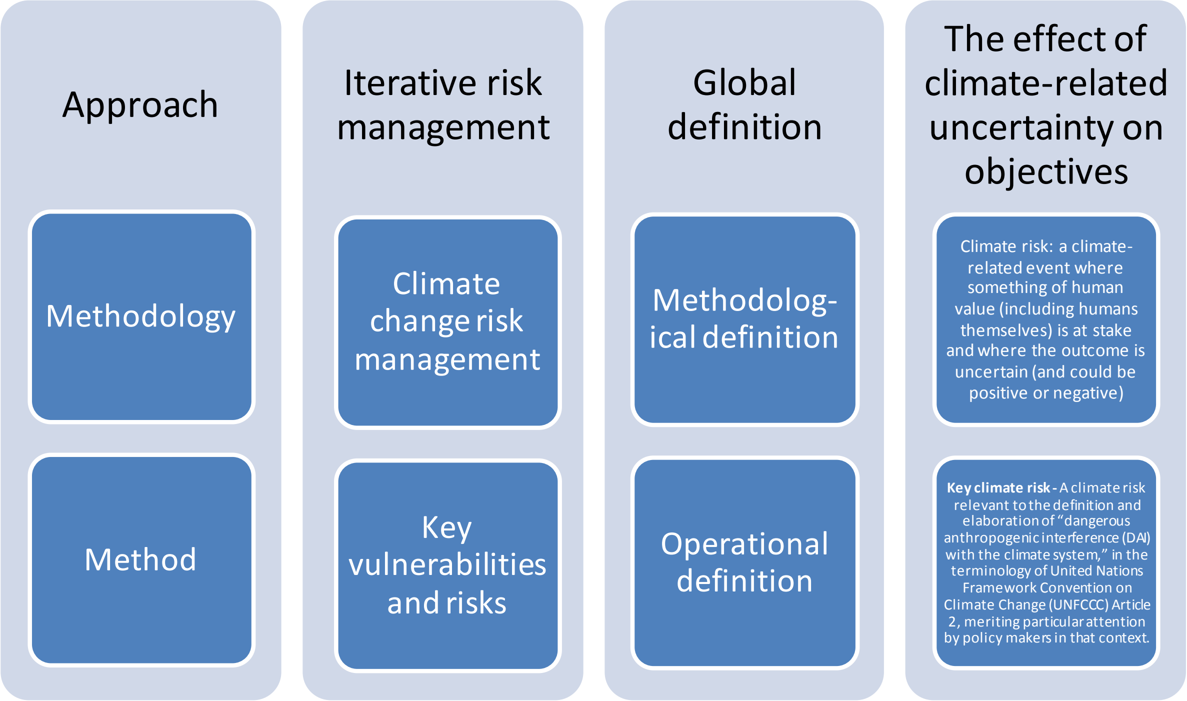


Climate risk: a climate-related event where something of human value (including humans themselves) is at stake and where the outcome is uncertain (and could be positive or negative)

Key climate risk - A climate risk relevant to the definition and elaboration of "dangerous anthropogenic interference (DAI) with the climate system," in the terminology of United Nations Framework Convention on Climate Change (UNFCCC) Article 2, meriting particular attention by policy makers in that context.

Figure 2-1: Risk portrayed as an approach, methodology and method using definitions relevant to this report.

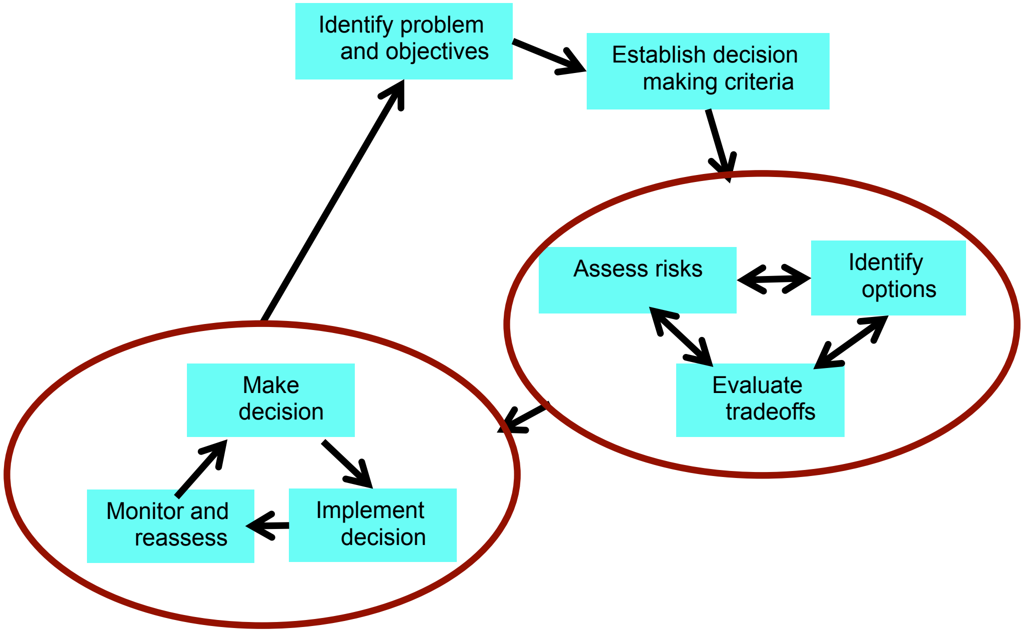
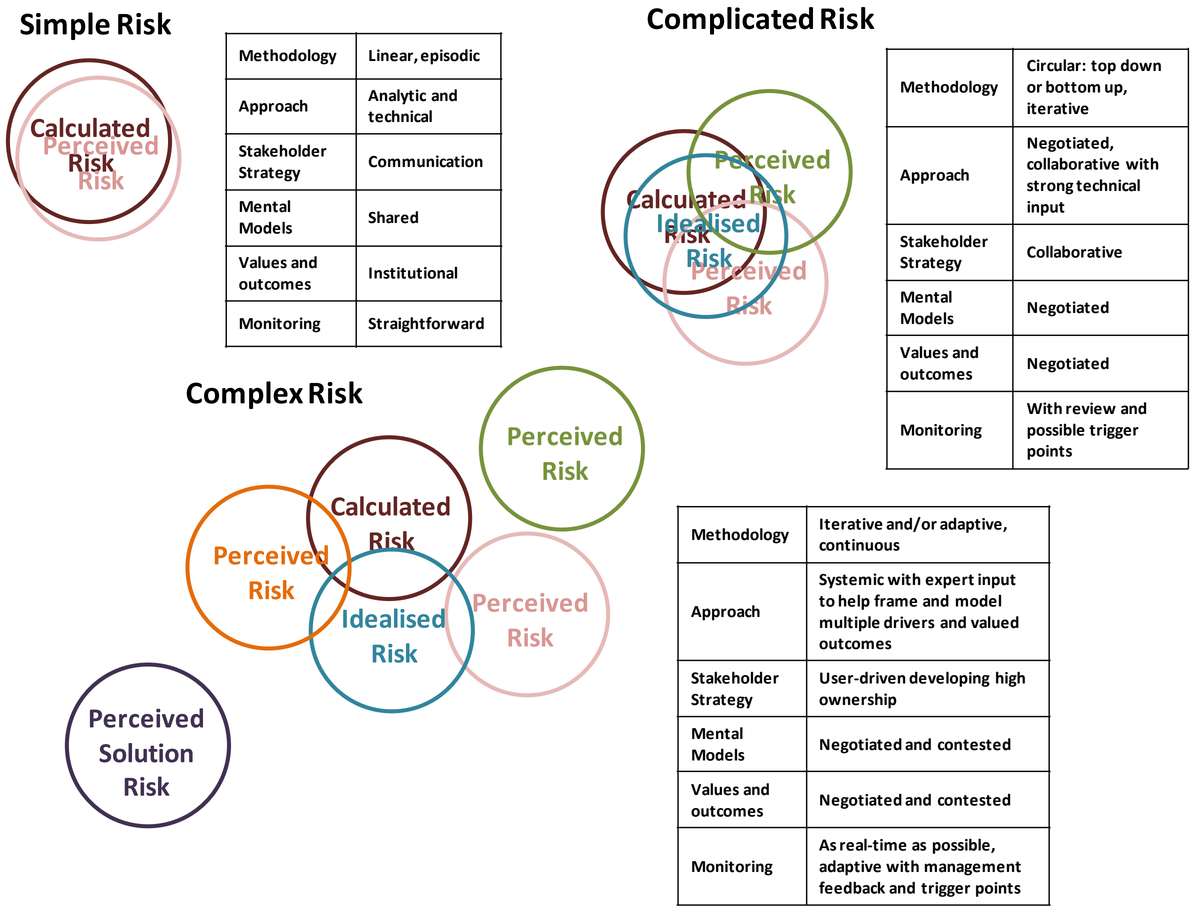


Figure 2-2: Iterative risk management framework showing two loops in the assessment process, looking at system feedbacks on options and at the risk management stage where a decision is made and implemented. Adapted from Willows and Connell (2003).



Simple Risk

Methodology	Linear, episodic
Approach	Analytic and technical
Stakeholder Strategy	Communication
Mental Models	Shared
Values and outcomes	Institutional
Monitoring	Straightforward

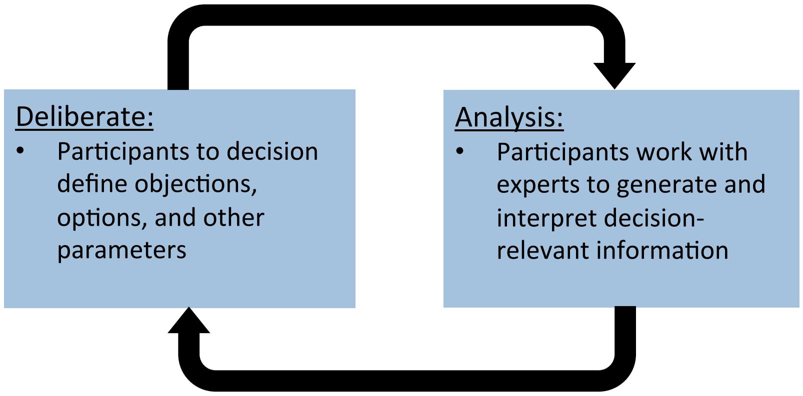
Complicated Risk

Methodology	Circular: top down or bottom up, iterative
Approach	Negotiated, collaborative with strong technical input
Stakeholder Strategy	Collaborative
Mental Models	Negotiated
Values and outcomes	Negotiated
Monitoring	With review and possible trigger points

Complex Risk

Methodology	Iterative and/or adaptive, continuous
Approach	Systemic with expert input to help frame and model multiple drivers and valued outcomes
Stakeholder Strategy	User-driven developing high ownership
Mental Models	Negotiated and contested
Values and outcomes	Negotiated and contested
Monitoring	As real-time as possible, adaptive with management feedback and trigger points

Figure 2-3: Schema for the chapter, showing a hierarchy of decision-makers in the centre and broad groupings of subjects addressed in the chapter. The decision-making environment is described by adaptation, mitigation and sustainable development, the methods and tools utilised include scenarios, decisions are made in the human context of individuals to groups and decisions can be assessed to measure varying degrees of success.



Deliberate:
- Participants to decision define objections, options, and other parameters

Analysis:
- Participants work with experts to generate and interpret decision-relevant information

Figure 2-4: Deliberation with analysis decision support learning process.

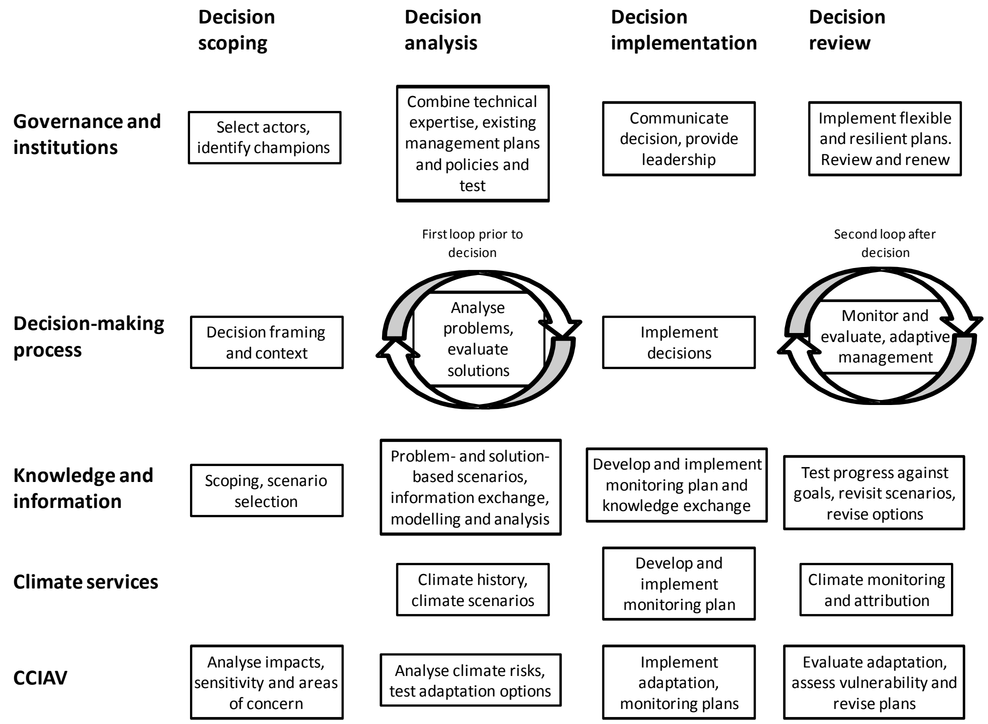


Figure 2-5: Selected attributes and characteristics relevant to the decision-making process itself. The two loops in the decision-making process relate to the two loops in Figure 2-2.

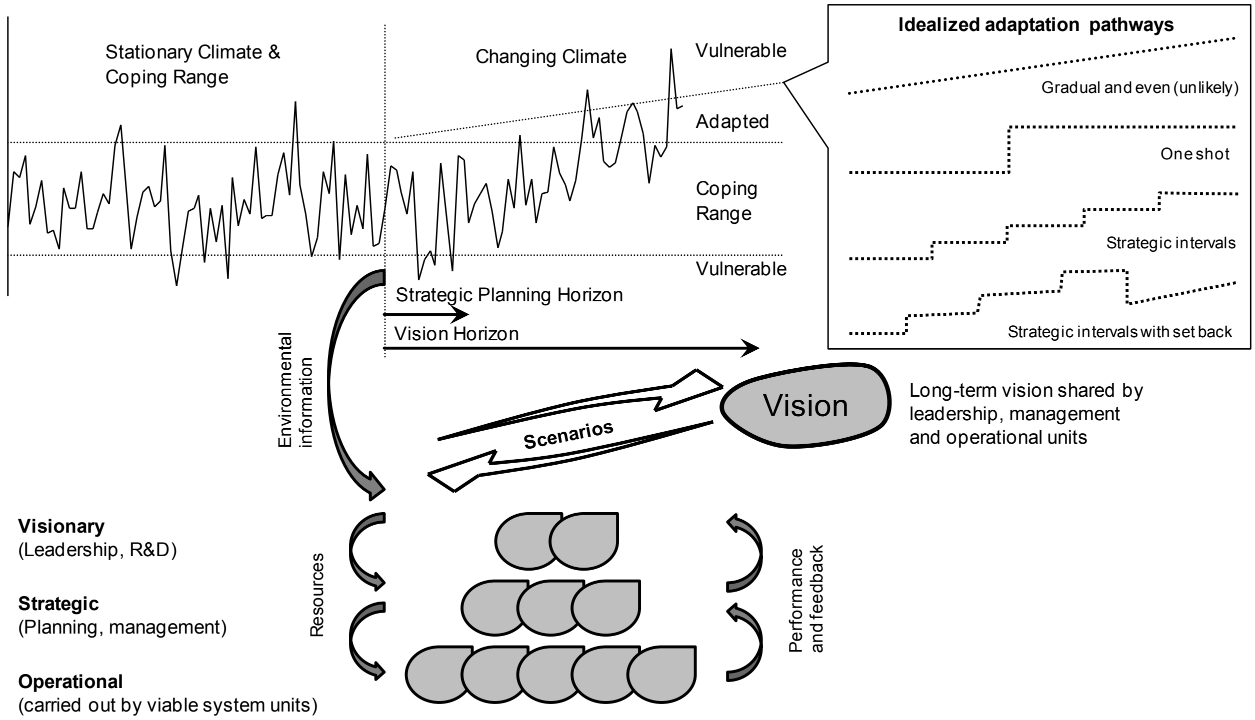


Figure 2-6: Planning frameworks for climate change showing the coping range, changing climate, thresholds and vulnerability for a single-variable climate scenario with idealised adaptation pathways (top) shows with a systems planning framework for organizations showing how vision, strategy and action can combine in a reflexive manner.

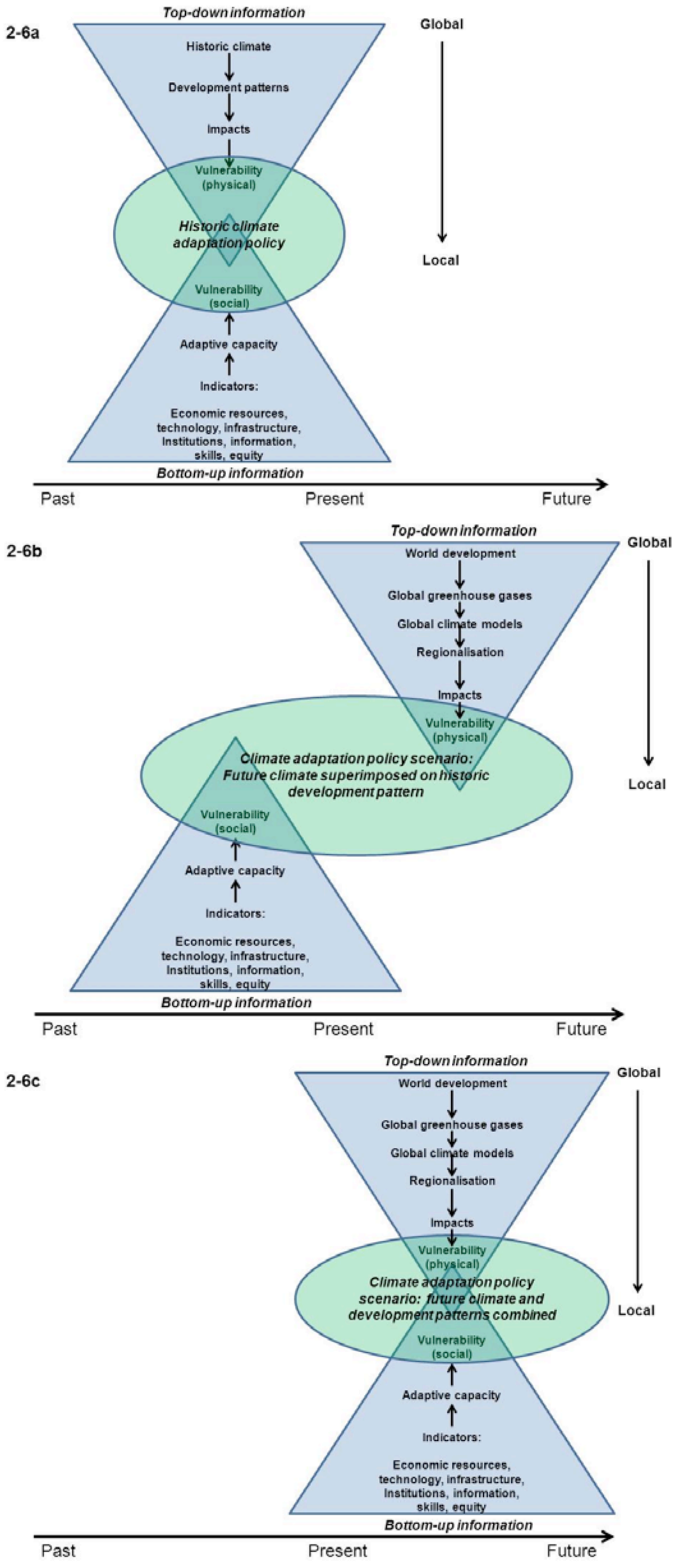


Figure 2-7: Approach Used to Inform Adaptation Policy (modified from Dessai and Hulme 2004 (Dessai and Hulme, 2004).a – biophysical and socioeconomic assessments based on historical observations; b –biophysical impact scenario superimposed on historical socioeconomic condition; c – biophysical and socioeconomic assessments based on future scenario.

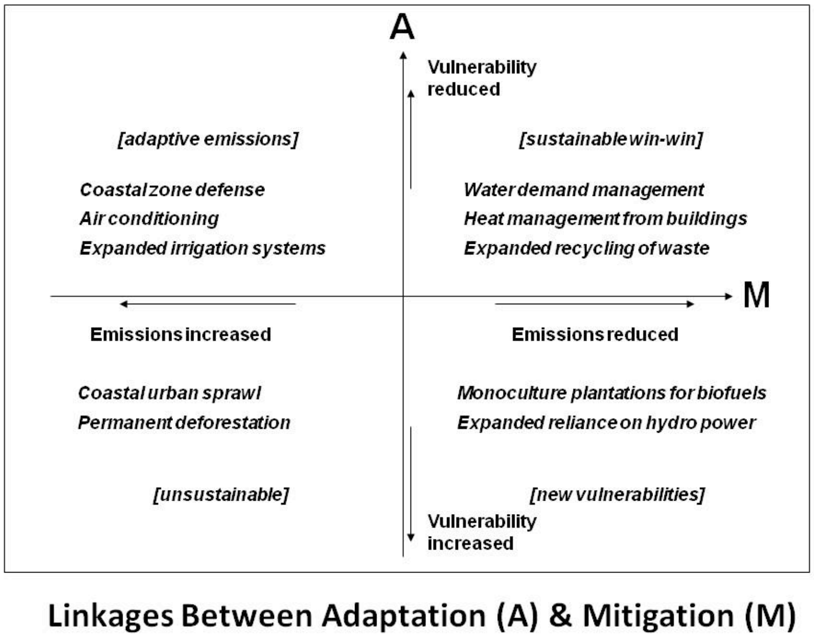


Figure 2-8: Adaptation – mitigation trade-offs and synergies (adapted from (Cohen and Waddell, 2009).