1 Guidance 'Dealing with uncertainty in adaptation planning' (UNDER CONSTRUCTION)

1.1 Introduction to guidance

A core challenge for adaptation planning is preparing for a future that is uncertain and risky. This is a challenge that is not new. People deal with uncertainty and probability all the time. What is somewhat new is that climate change adaptation is an area where on one hand there is a lot of scientific information available that can play a role in decision-making, whereas on the other hand this information has significant uncertainties associated with it. Although uncertainty may be reduced through research, uncertainty cannot be eliminated before decisions must be made.

This guidance aims to help decision makers in understanding the sources of uncertainty in climate information that are most relevant for adaptation planning. It also provides suggestions for dealing with uncertainty in adaptation planning and for the communication of uncertainty.

This guidance is organised in three main sections:

- Sources of uncertainty for adaptation planning
- Coping with different sources of uncertainty in adaptation planning
- Reporting about different sources of uncertainty

For each of these Sections the guidance first provides basic background reading and next addresses a list of 'Frequently asked questions' related to uncertainty in adaptation planning. The guidance borrows from existing guidelines for modelling, interpreting, and communicating uncertain. These sources are listed as background reading.

A word of caution: notwithstanding the advice in this guidance, dealing with uncertainty can never be reduced to a simple cookbook. In the end each adaptation planning process will have its own characteristics. The debate among decision makers and other involved parties about how to deal with uncertainty in the planning process is a crucial element of policy making. The authors of this guidance hope that the answers and examples provided in the guidance can stimulate this debate.

Contents and frequently asked questions:

1.2 Sources of uncertainty for adaptation planning

Uncertainty has a large variety of sources. It derives from climate models, from the assessment of climate impacts, and from the policy context of decision-making. Some of these uncertainties have to do with imperfect knowledge (called "epistemic uncertainties") other relate to the intrinsic variability in the climate system (called "stochastic uncertainties"). Below two classifications of sources of uncertainty are presented. Both are useful to understand the nature of uncertainty that adaptation planning has to cope with and can be found in literature.

Firstly, one can distinguish the following four main sources of uncertainty:

1. The uncertainty about the functioning of the climate system, and the responses of biological and social systems to changes in climate, is high. Continued scientific research may help to resolve some of this uncertainty, although it may also uncover additional uncertainty, such as particular feedbacks.

2. Projections of the future depend on the quality of measurement of the current and past climate. More complete measurement of current climate variables may help to resolve some of this uncertainty. This uncertainty is particularly important in making projections about the climate over the next 20 years.

3. The climate will be influenced by future emissions, which in turn depend on uncertain long-term economic and technological development and by policies that aim to reduce emissions.

4. There is a great deal of uncertainty about how adaptation policies will work, and indeed what policy measures can contribute to increasing adaptive capacity.

Another way to classify sources of uncertainty that one may find in climate literature is on a gradual scale running from ‘knowing to exist' to ‘unknown' (see Figure 1).

Figure 1: Uncertainty levels between determinism and total ignorance (Walker*et al.*, 2003)

Figure 1 distinguishes four classes of uncertainty (for more details see Dessai and van der Sluijs, 2007):

- ‘Statistical uncertainty': this concerns the uncertainties, which can adequately be expressed in statistical terms, e.g., as a range with associated probability (examples are statistical expressions for measurement inaccuracies, uncertainties due to sampling effects, uncertainties in model-parameter estimates, etc.). In the natural sciences, scientists often focus on this uncertainty class if they speak of uncertainty, thereby often implicitly assuming that the involved model relations offer adequate descriptions of the real system under study, and that the (calibration)-data employed are representative of the situation under study. However, when this is not the case, ‘deeper' forms of uncertainty are at play, which can surpass the statistical uncertainty in size and seriousness and which require adequate attention.

· ‘Scenario uncertainty': this concerns uncertainties which cannot be adequately depicted in terms of chances or probabilities, but which can only be specified in terms of (a range of) possible outcomes. For these uncertainties it is impossible to specify a degree of probability or belief, since the mechanisms, which lead to the outcomes are not sufficiently known. Scenario uncertainties are often expressed in terms of ‘what-if' statements.

· ‘Recognized ignorance': this concerns those uncertainties of which we realize – some way or another – that they are present, but of which we cannot establish any useful estimate, e.g., due to limits to predictability and knowability or due to unknown processes. A way to make this class of uncertainties operational in climate risk assessment studies is by means of surprise scenarios. Usually there is no scientific consensus about the plausibility of such scenarios even if there is some scientific evidence that they may occur in reality.

· Continuing on the scale beyond recognized ignorance, we arrive in the area of ‘total ignorance' (‘unknown unknowns') of which we cannot yet speak and where we inevitably grope in the dark.

The clearinghouse covers these uncertainties in two ways. First of all it presents statistical uncertainty where this is has been made available by data providers. Secondly, it offers planning approaches that have been developed to deal with uncertainty in adaptation planning.

Related questions:

>> How (un)certain is climate change?

>> How to make decisions in the face of uncertainty?

Resources for further reading:

- Part 1: Sources and types of uncertainty (Granger Morgan*et al.*, 2009)

1.2.1 How (un)certain is climate change?

Uncertainty stems largely from limitations of our scientific knowledge of the climate system, and of how future greenhouse gas emissions will change. However, significant advances in our understanding of climate change in recent decades have enabled us to be reasonably confident about the main expected changes.

In general, uncertainties are larger for local projections than for large regions, larger for precipitation than for temperature projections, and larger for projections of extreme events such as storms than for gradual, average changes. These factors arguably make adaptation more difficult than setting goals for mitigation, which more depend on long-term global changes. However, this does not mean that adaptation is impossible, especially where significant confidence exists in projections, such as sea level rise, temperature increases or enhanced risk of droughts in some regions in Europe. Adaptation planning is served by distinguishing among sources of uncertainty across regions, climate indicators and forecast lead times, and clearly communicating them in public and policy background studies.

Uncertainties in climate change projections arise from three primary sources:

- *Natural climate fluctuations* that over relatively short time scales can amplify or moderate trends resulting from anthropogenic climate change;
- *The climate system's response* to a given concentration of greenhouse gasses, which is reflected in the range of responses incorporated into climate model simulations, particularly at a time scale of decades;
- *Future emissions* of greenhouse gasses by human society, and thus the scale of future radiative forcing, which becomes a dominant source of uncertainty on long time scales of 50 years or more.

>> read more

Uncertainty in climate change scenarios based on the output of models derives from a number of sources. They include:

(i) Future emissions scenarios: The starting point for projecting future climate change are scenarios of future emissions of the greenhouse gases and other pollutants that affect climate (e.g. sulphur dioxide). Such scenarios rely on combining data on past emissions (with associated data uncertainty) with estimates of how emissions may change with future changes in technology, demography, economic development, etc. All these factors, and hence future emissions of greenhouse gases, are uncertain. Hence, future greenhouse gas emissions are essentially unknowable, albeit within extreme bounds, and therefore present an area of uncertainty that cannot be removed. The most comprehensive attempt so far to characterise global emissions is the IPCC Special Report on Emissions Scenarios (SRES). It should be noted that the consequence of uncertainty in emissions for climate projections is much less for the near future climate (2020s) than for the distant future (2080s). Climate pathways for the four SRES scenarios do not start to diverge significantly until just before mid-century. Near-future climate is dominated by historic emissions of greenhouse gases, and natural variability in climate. The projected rate of change in climate is particularly important since it affects the time available for adapting to the changes.

(ii) Imperfect representation of the processes in the climate system, e.g. clouds, ocean circulation, soils, vegetation and the interactions between them. Because different climate models represent these processes in different ways, their outcomes (for the same emissions scenarios) will be different. Ways of quantifying uncertainties in climate models include running many versions of a model, with slightly different model parameters and starting conditions (a form of sensitivity or uncertainty analysis). Improving climate models will remain a significant long-term scientific challenge. In order to provide climate change information at a scale smaller than global models give (typically 300km), national institutes often use regional models. Regional climate models take account of geography and topography (e.g. mountains and oceans), and small-scale weather phenomena, and are therefore better at representing local variations in climate. Regional climate models inherit errors from the global models that drive them and add new ones. For obtaining high-resolution climate change information from relatively coarse-resolution global climate models, alternatively statistical downscaling can be applied, using statistical relationships between observed small-scale (often station level) variables and larger (global model) scale variables.

(iii) Global and regional climate models provide information on future climate for a restricted range of climate variables and at a spatial resolution determined by the climate model. The coarse scale of the modelling, particularly in global climate models, does not adequately represent local variations in climate. Even regional models often do not generate the detail required for climate impact assessments and models, and further downscaling may be required.

Resources for further reading:

- Section 4.1.1 Greenhouse gas emissions and 4.1.2 Global climate change in (Dessai and van der Sluijs, 2007)
- http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf
- Figure 4; Hawkins and Sutton 2009 (Ekwurzel*et al.*, 2011).

1.2.2 How (un)certain are climate impacts?

When addressing climate risk and impact problems, knowledge of the affected system (e.g. a river or city) and its relationship to climate is clearly important. While relevant monitoring data may be available for some systems, experimental evidence of its response to climate change will rarely be available, so the risk assessment stage may need to be informed by impact modelling studies. Impact models summarise the relevant information and knowledge about how climate change and other important non-climate factors could affect the system under a variety of decision options. These modelling studies generally take climate scenario data as input, and model additional processes, often at finer spatial and temporal resolution, to generate information more closely related to the specific impact and decision being considered.

In this context, a ‘model' may range from conceptual insights into the influence of climate and other variables on a system, to more sophisticated and technical approaches using computer-based mathematical or other forms of model (e.g. wind tunnel or wave tank physical model).

Process influence diagrams, conceptual models, dependency mapping are frequently used, preceding and possibly providing a basis for development of quantitative models and methods. Such techniques will often be more appropriate than detailed process modelling, which may not be supported by the available data.

These additional modelling studies cannot reduce the uncertainty stemming from the original climate model. In fact, as all models are subject to model uncertainty, the use of an impact model adds to the uncertainty inherited from the climate model. In the majority of cases an impact model will require other types of input, in addition to those dependent on climate, such as information on socio-economic circumstances. Some of these inputs may reasonably be assumed not to change over the period of the assessment (i.e. show no time-dependent trend). However, they may still be subject to variability and other forms of uncertainty. Other inputs may be expected to change over the period of the assessment, and forecasts for these variables will be needed.

All these approaches will carry with them particular assumptions and other sources of uncertainty. Some of these uncertainties may be amenable for quantification, using the model, as part of a probabilistic risk assessment. However, others will remain unquantified and the results of any probabilistic risk assessment will be contingent on these assumptions. It is therefore an important requirement of any risk assessment that such assumptions are clearly identified, communicated and justified in terms of their importance for any conclusions. Hence it should not be assumed that the uncertainty associated with future climate change (e.g. summarised within the climate scenarios) is necessarily more important or significant, in terms of its relevance to a particular decision, than that contained within the impact model. Both contribute towards the overall uncertainty associated with an impact assessment. Indeed, in order to reduce uncertainty in climate change risk assessments, a decision-maker may find that increasing knowledge of how a particular system responds to present-day climate variability, or to uncertain future values of non-climate variables, may be more important than reducing the uncertainty over the extent of future climate change. It is also important to note that usually *potential* impacts are assessed and reported, i.e. the impacts that may occur in the absence of adaptive responses. Taking into account autonomous or policy-induced adaptation will reduce negative impacts and enhance positive impacts.

Resources for further reading:

- Section in EEA report
- Section in IPCC report
- 4.1.3 Global climate change impacts, 4.1.3 Regional climate change and 4.1.4 Regional/local impacts (Dessai and van der Sluijs, 2007)
- (Willows and Connell, 2003)

1.2.3 What methods can be used to assess uncertainty in climate information?

A mixture of methods is used to analyse uncertainty in climate change and impact assessments. Statistical methods and models play a key role in the interpretation and synthesis of observed climate data and the projections of numerical climate models. Such methods are especially important in addressing the question, "What long-term changes in climate are occurring?". In addition there are methods to assess how well alternative mathematical models fit existing evidence and to assess uncertainty in stakeholder preferences. The following tools are relevant for supporting climate adaptation policy-making (in random order):

- Scenario analysis ("surprise-free")
- Expert elicitation
- Sensitivity analysis
- Monte Carlo
- Probabilistic multi model ensemble
- Bayesian methods
- NUSAP / Pedigree analysis
- Fuzzy sets / imprecise probabilities
- Stakeholder involvement
- Quality Assurance / Quality Checklists
- Extended peer review (review by stakeholders)
- Wild cards / surprise scenarios

Context matters so place-based handling of uncertainty will be necessary according to the characteristics of different localities.

Resources for further reading:

- Chapter 4 Methods and tools to assess climate change uncertainties relevant for adaptation planning + Chapter 5 (Dessai and van der Sluijs, 2007)
- Part 4: Statistical Methods and Models (Granger Morgan*et al.*, 2009)
- Appendix 3 Summary of tools and techniques (Willows and Connell, 2003)

1.3 Coping with different sources of uncertainty in adaptation planning

When confronted with the uncertainty in climate information, a natural reaction is to ask climate scientists to improve knowledge and understanding, and to provide, as soon as possible, reliable forecasts of future conditions. Of course, one can expect that climate science will progress in the future and that the range of climate projections will narrow, making their use easier. There is increasing evidence, however, that improved knowledge does not mean narrower projection ranges. Indeed, even if models were perfectly accurate, uncertainty would not disappear. First, future levels of greenhouse gas emissions, which by nature cannot be forecasted, largely determine future climate change. But there are also large differences between the projections of different climate models that do not seem to be diminishing with time. For example, new evidence that land-based glaciers (such as those in Greenland) may respond more quickly to warming and in less gradual and predictable ways has recently reduced the confidence in the IPCC's latest sea-level-rise projection range. So, climate models may well be unable to provide the information current decision-making frameworks need. Also, climate models are based on a set of common assumptions. The range of their results, therefore, underestimates the full range of uncertainty. If climate models disagree, will climate observations tell us which one is right? Unfortunately, even though they will eventually, they will do it quite late in the century. For instance, changes in precipitation patterns in the Mediterranean basin may remain undetectable by statistical methods until 2050 (IPCC, 2007, Table 11.1). If we wait for climate change to be detectable and models to be fully validated, many investments designed before that time will be ill-adapted by the end of the century, with potentially large economic costs.

Moreover, observations can be dangerously misleading: worst-case scenarios can arise from the difficulty in attributing observed changes to global climate change. For instance, multi-decadal variability can modify precipitation patterns over long periods. If these transitory modifications are understood by economic actors as anthropogenic climate change patterns, i.e. as permanent modifications, ill-designed adaptation strategies could be implemented and make the situation even worse than without adaptation.

Since climate models and observations cannot provide what current decision-making frameworks need, the only solution is to amend these frameworks to make them able to take this uncertainty into account. To do so, adaptation decisions should acknowledge (i) that it will need to cope with a larger range of climate conditions than before; and (ii) that this range is and will remain highly uncertain.

In such a context, for example optimizing infrastructure design for a given climate may not be the best strategy. If it were possible to attribute probabilities to possible future changes, probabilistic optimization strategies could easily be introduced. But these probabilities are not available; even though some have been produced at the regional scale, they are still heatedly debated.

A more suitable approach is to develop new strategies, especially those created to cope with the inherent uncertainties of climate change. For instance, it is possible to base decisions on scenario analysis and to choose the most robust solution, i.e. the one that is the most insensitive to future climate conditions, instead of looking for the ‘‘best" choice under one scenario. More realistically, robustness can be included as an additional criterion in multi-criteria decision-making processes. In the public domain, the precautionary principle is another example of decision-making strategy that takes into account in an explicit manner the uncertainty.

Resources for further reading:

- (Hallegatte, 2009)

1.3.1 How to make decisions in the face of uncertainty?

The good news is that different approaches have been developed to deal with uncertainty in planning. Unfortunately no comprehensive framework exists to select a particular approach. Yet, two important factors to decide on what approach to use are generally acknowledged: the level of uncertainty in the information supporting the decision and how controllable the system is that decisions are taken for. Figure 2 illustrates how these two factors relate to four complementary approaches for planning under uncertainty that are introduced here. Adaptive management, for example, functions best when both uncertainty and controllability are high, which means the potential for learning is high and the system can be manipulated (Allen and Gunderson, 2011). Other important factors to consider in decision-making are the uncertainty due to the time it takes for the decision to be implemented and stakeholders' consensus.

Uncertainty	High	Scenario planning	Adaptive management
	Low	Build robustness / resilience	Decision analysis / optimal choice
		Low (uncontrollable)	*High (controllable)*
		Controllability	

Figure 2: Uncertainty and controllability are important factors to consider in planning an adaptation process. Together they frame four complementary approaches for adaptation planning.

A set of ideas and analytical methods called "**decision analysis**" has been developed to assist in making decisions in the face of uncertainty. Classical decision analysis provides an analytical strategy for choosing among options when possible outcomes, their probability of occurrence, and the value each holds for the decision maker, can be specified. Decision analysis identifies an "**optimal**" choice among actions. The principle idea is that complex decisions can be navigated in a consistent and rational way if one can identify the alternatives that are available, identify and estimate the probability of key uncertain events, and specify preferences (utilities) among the range of possible outcomes. Of course, even if they want to, most people do not make decisions in precise accordance with the norms of decision analysis. A large literature, based on extensive empirical study, now exists on "behavioural decision theory". This literature describes how and why people make decisions in the way that they do, as well as some of the pitfalls and contradictions that can result.

For both theoretical and practical reasons, there are limits to the applicability and usefulness of classic decision analysis to climate-related problems. Especially in complex and highly uncertain contexts, such as those in many climate-related decisions, the conditions needed for the application of conventional decision analysis may not arise. Two strategies may be especially appealing in the face of high uncertainty:

- **Robust (or sometimes called Resilient) Strategies**: In this case, the idea is to try to identify the range of future circumstances that one might face, and then seek to identify approaches that will work reasonably well across that range.
- **Adaptive Strategies**: In this case, the idea is to choose strategies that can be modified to achieve better performance as one learns more about the issues at hand and how the future is unfolding.

Both of these approaches stand in sharp contrast to the idea of developing **optimal strategies** that has characterized some of the work in the climate change integrated assessment community, in which it is assumed that a single model reflects the nature of the world with sufficient accuracy to be the basis for decision making and that the optimal strategy for the world will be chosen by a single decision maker.

The ideas of robustness, resilience and adaptation have been strongly informed by the literature in ecology. A key feature of adaptive strategies is that decision makers learn whatever they can about the problem they face and then make choices based on their best assessment and that of people whose advice they value. They seek strategies that will let them, or those who come after them, modify choices in accordance with insights gained from more experience and research. Adaptive strategies work best in situations in which the decision timescales are well matched to the changes being observed in the world. There exists no single definition of robustness. Most commonly, authors have defined robust strategy as one that performs well, compared to the alternatives, over a very wide range of alternative futures. A familiar example of a robust strategy is portfolio theory as applied in financial investment, which suggests that greater uncertainty (or a lesser capacity to absorb risks) calls for greater portfolio diversification. Decision support tools for robust decision-making are under development. For instance, Dessai and Hulme (2007)have presented an application for adaptation in water resource management in the United Kingdom.

Faced with deep uncertainty, decision makers may choose to consider multiple cases. This is the approach taken by **scenario analyses**. Scenarios may present a set of different, plausible future conditions (or states of the world). Decision analysis is than often implemented by comparing how well alternative policy decisions perform under these different future conditions. In addition to providing a useful description of uncertainty, scenarios can also play an important role in the acceptance of the analysis when stakeholders to a decision have differing interests and hold differing, non-falsifiable, perceptions. In such cases, an analysis may prove more acceptable to all sides in a debate if the scenarios encompass all the varying perspectives rather than adopting one view as privileged or superior.

The "**precautionary principle**" is another decision strategy often proposed for use in the face of high uncertainty. There are many different notions of what this approach does and does not entail. In some forms, it incorporates ideas of resilient or adaptive policy. In some forms, it can also be shown to be entirely constant with a decision analytic problem framing.

For decision-makers, these approaches and strategies are consistent with those commonly used to manage exchange-rate risks, energy cost uncertainty, research and development outcomes, and many other situations that cannot be forecast with certainty. Such robust decision-making methods have already been applied in many long-term planning contexts. For most decision-makers, the novelty will be the application of these methods to climate conditions. This requires users of climate information to collaborate more closely with climate scientists and to adapt their decision-making methods to the climate change context.

Resources for further reading:

- Section 3 in: (Dessai and van der Sluijs, 2007), includes 3.2 Precautionary principle versus Prevention principle, and a discussion of bottum-up versus top-down approaches
- Part 7: Making Decisions in the Face of Uncertainty (Granger Morgan*et al.*, 2009)
- NeWater curriculum Adaptive Water Management http://www.newatereducation.nl
- Critical review of adaptive management (Allen and Gunderson, 2011; Williams, 2011)
- Overview of approaches in relation to the level of certainty about cause/effect relations and the preferences of actors (de Boer*et al.*, 2010)
- A worthwhile new framework for risk-management approaches: Smith (2011), based on three factors determine the appropriate risk management approach to adaptation decision making: 1. Decision lifetime: short to long, 2. Driver uncertainty: monotonic or indeterminate, 3. Adaptation response: no regret, same type but different extent, different type
- UKCIP Guidance (Willows and Connell, 2003)

1.3.2 What are strategies to adapt to uncertain climate change?

Different types of adaptation strategies have proposed to deal with uncertainty in climate information. Strategies include:

(i) Selecting ‘‘no-regret" strategies that yield benefits even in absence of climate change;

(ii) Favouring reversible and flexible options;

(iii) Buying ‘‘safety margins" in new investments;

(iv) Promoting soft adaptation strategies, including long-term prospective;

(v) Reducing decision time horizons.

For each of these strategies it is essential to consider both negative and positive side-effects and externalities.

To be included: short definition of strategies (Hallegatte, 2009).

Related questions:

>> What are no regret adaptation measures?

Resources for further reading:

- (Hallegatte, 2009)

1.3.3 Should I delay action until better information is available?

Many decisions come with a long-term commitment and can be very climate sensitive. Examples of such decisions include urbanisation plans, risk management strategies, infrastructure development for water management or transportation, and building design and norms. These decisions have consequences over periods of 50–200 years. Urbanisation plans influence city structures over even longer timescales. These kinds of decisions and investments are also vulnerable to changes in climate conditions and sea level rise. For example, many building are supposed to last up to 100 years and will have to cope in 2100 with climate conditions that, according to most climate models, will be radically different from current ones.

So, when designing a building, architects and engineers have to be aware of and account for the future changes that can be expected. For example, up to 140 million people and US$ 35,000 billion of assets could be dependent on flood protection in large port cities around the world by 2070 because of the combined effect of population growth, urbanisation, economic growth, and sea level rise. But previous coastal defence projects (e.g., the Thames Barrier) have shown that implementing coastal protection infrastructure typically has a lead-time of 30 years or more. Also, urbanisation plans are very efficient to influence flooding risk, but they can do so only over many decades. This inertia suggests that action must begin today to manage impacts expected by the middle of this century.

Table 1 lists sectors in which adaptation should not be delayed, because they involve long-term planning, long-lived investments and some irreversibility in choices, and are exposed to changes in climate conditions.

Table 1: List of sectors in which climate change should already be taken into account, because of their investment time scales and their exposure (estimated empirically by author) to climate conditions (Hallegatte, 2009).

Sector	Time scale (year)	Exposure
Water infrastructures (e.g., dams, reservoirs)	30–200	+++

Land-use planning (e.g., in flood plain or coastal areas)	> 100	+++
Coastline and flood defences (e.g., dikes, sea walls)	> 50	+++
Building and housing (e.g., insulation, windows)	30–150	++
Transportation infrastructure (e.g., port, bridges)	30–200	+
Urbanism (e.g., urban density, parks)	>100	+
Energy production (e.g., nuclear plant cooling system)	20–70	+

Resources for further reading:

- (Hallegatte, 2009)

1.3.4 What scenario to use for adaptation planning?

There are a number of sources of information for climate scenarios:

- the output of climate models;
- simple incremental scenarios; and
- climate analogues.

The type and time-scale of the adaptation plan will determine the most appropriate scenarios to use. For initial assessments of vulnerability or sensitivity assessments incremental scenarios can provide information across a wide range of climate variations. For decision time horizons of less than 20 years, scenarios will be required representing ‘near future' and possibly ‘present-day' climates. However, for longer-term decisions (time-scales exceeding 20 years), such as decisions with long-lasting consequences and concerning long-lived assets, a range of climate scenarios developed from global climate model output should be used.

Scenarios are often developed in a set. If decision-makers do not have the time or resources to explore all scenarios in a set, an alternative would be to use the scenarios associated with the highest and lowest emission scenario. However, for applications with major policy recommendations or major investment decisions, it is recommended that decision-makers should make use of the full range of scenarios.

This will:

- assist in the identification of critical thresholds in the response of the exposure unit to climate change
- allow decisions to be taken which are robust to the uncertainties in future climate

Resources for further reading:

- IPCC Third Assessment Report, Working Group II (IPCC, 2001b)

- Section 3.6 ‘Climate and non-climate scenarios: tools for climate change risk assessment and decision-making' *in* (Willows and Connell, 2003)

1.3.5 What are no regret adaptation measures?

‘‘No-regret" measures are activities that yield benefits even in absence of climate change. In many locations, the implementation of these actions constitutes a very efficient first step in a long-term adaptation strategy. For example, controlling leakages in water pipes is almost always considered a very good investment from a cost–benefit analysis point-of-view, even in absence of climate change. Improving building insulation norms and climate-proofing new buildings is another typical example of no-regret strategy, since this action increases climate robustness while energy savings can often pay back the additional cost in only a few years. Considering its large-cost, on the other hand, it is unlikely that the climate proofing of existing buildings is no-regret.

Whether a measure is no-regret also depends on location. For example, additional irrigation infrastructure is an interesting measure in some regions in the current climate. In others, considering the high investment costs that are needed, it would be beneficial only if climate change decreases precipitations. So, irrigation is a no-regret strategy only in some regions. Also, in many locations, especially coastal cities, building sea walls would be economically justified by storm surge risks with the current sea level, and sea level rise will only make these walls more socially beneficial.

Once no-regret measures have been identified, it is important to know why these no-regret actions are not implemented yet. Many obstacles explain the current situation, including (i) financial and technology constraints, especially in poor countries; (ii) lack of information and transaction costs at the micro-level; and (iii) institutional and legal constraints. These can than be addressed in adaptation planning as a first step in a long-term adaptation plan.

Resources for further reading:

- (Hallegatte, 2009)

1.3.6 How to avoid overspending?

To avoid overspending it is wise to favour strategies that are reversible and flexible over irreversible choices. The aim is to keep as low as possible the cost of being wrong about future climate change.

An examples of such an adaptation measures are 1) ‘‘easy-to-retrofit" defences, i.e. defences initially designed to allow for cheap upgrades if sea level rise makes them insufficient; 2) the climate proofing of new buildings and infrastructures, which has an immediate cost but can be stopped instantaneously if new information shows that this measure is finally unnecessary;

and 3) insurance and early warning systems that can be adjusted every year in response to the arrival of new information.

[>> idea: list to case examples in database as appropriate]

For many infrastructure decisions, waiting is not an option, since all climate-sensitive decisions (e.g., in water management or housing) cannot simply be delayed by decades. The valuation of reversibility has thus to be applied to the comparison of adaptation strategies with different ‘‘irreversibility levels".

Related questions:

>> What are strategies to adapt to uncertain climate change?

>> What are no regret adaptation measures?

1.4 Reporting about different sources of uncertainty

Because humans have a need for predictability, uncertainty can be uncomfortable. Predictability helps people feel in-control, whereas uncertainty can lead to anxiety. Furthermore, predictability allows people to plan and budget for the future. Particularly when talking about complex topics like global climate change, it is important to find effective ways to communicate inherently uncertain information. Climate change uncertainties vary in type and significance. One of the first key tasks for communicators is to put that uncertainty into context by helping audiences understand what is known with a high degree of confidence and what is relatively poorly understood.

To address this problem, IPCC scientists developed a "confidence terminology" to communicate estimates of uncertainty via everyday language. For example, "very high confidence" was used to refer to a prediction that has at least a nine out of ten chance of being correct. Other such terms included "high," "medium," "low," and "very low" confidence. "Very low confidence" referred to a prediction that had less than a one out of ten chance of being correct. Although such terms have greatly permeated public discourse on climate change, there is evidence that suggests people interpret such probability descriptors more subjectively than scientists intend. Discussing uncertainty with unspecific language can lead to an unintentional overstatement and consequent criticisms. When significant uncertainty remains about a specific effect, the causes of uncertainty ought to be illustrated (e.g., the systems involved are so complex that science has yet to understand them sufficiently). This section of the guidance reports on lessons for reporting about uncertainty in adaptation planning.

Resources for further reading:

- (Kloprogge*et al.*, 2007)

1.4.1 How to communicate uncertainty?

For some time climate scientists overlooked or even advised against trying to communicate about uncertainty to non-scientific audiences. It was suggested that uncertainties are hard to understand and that decision makers want definitive answers. Initiatives like the EU clearinghouse show that this time is over. People deal with uncertainty and probability, all the time. While technical details may be hard, people, for the most part, manage to deal with probabilistic weather forecasts about the likelihood of rain or snow and similar probabilistic information. The real issue is to be open about the consequences of uncertainty for adaptation planning and to frame these in familiar and understandable terms. One key finding of practitioners is that empirical study is absolutely essential to the development of effective communication between providers and users of information. No one can tell ahead of time (i.e., without empirical study) how uncertainty can best be communicated.

Uncertainty also offers people who have an agenda an opportunity to "spin the facts". In addition, many reporters are not in a position to make their own independent assessment of the likely accuracy of scientific statements and on how to report the views of those holding widely divergent views. Especially in recent years, communication about climate change, adaptation and the associated uncertainties has been a challenging issue in the media. The negative way in which statements about climate change sometimes have been seized upon has discouraged parties to engage in the public debate that is required for adaptation planning and its legitimacy.

This said, a number of guidelines are available as listed below. Some do's and don't from these publications are:

DO:

- Employ participatory methods to decide on parameters of scenarios
- Make scenarios locally relevant
- Explore new tools such as visualizations

DON'T:

- Avoid normative elements of scenarios
- Consider response strategies in isolation
- Assume that provision of data is sufficient to stimulate action

Resources for further reading:

- IPCC Guidance (focus on climate researchers / information producers)
- Evaluation of IPCC guidance(Curry, 2011; Yohe and Oppenheimer, 2011)
- Part II Analysis of context and audiences, and customising the communication accordingly (Kloproggee*t al.*, 2007)
- Granger Morgan et al., 2009
- PBL Guidance/checklist
- Burch, S. 2010. Hot in my backyard: Addressing uncertainty in climate change impacts and response options through participatory scenario development and visualization. p XVI. In van Pelt, S., D. Avelar, T. Capela Lourenco, M. Desmond, M. Leitner, C. Nilsson and R. Swart, 2010. Communicate uncertainties – design climate adaptation measures to be flexible and robust. Proceedings of CIRCLE-2 workshop on Uncertainties in Climate Change Impacts, Vulnerability and Adaptation, Stockholm, 11-12 November 2010. http://www.circle-era.eu/np4/194.html

1.4.2 How can uncertainty be presented visually?

Most guidance documents have been developed for scientists rather than decision makers and practitioners. Yet guidance can provide useful inspiration for presenting information during adaptation planning. In addition this guidance can be helpful to interpret different representations of uncertainty one may come across.

Resources for further reading:

- (Mastrandrea and Mach, 2011; Mastrandrea*et al.*, 2011)
- Neset, T., J. Johansson, and B.-O. Linnér (eds). State of Climate Change Visualization, CSPR Report No. 09:04, Centre for Climate Science and Policy Research, Norrköping, Sweden. Linköping University Electronic Press. http://www.ep.liu.se/ecp/045/ecp09045.pdf
- PBL Guidance - http://www.pbl.nl/en/publications/2005/Guidance_on_communication_about_uncertainties
- U.S. Climate Change Science Program Synthesis and Assessment Product 5.2 Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making (http://www.climatescience.gov/Library/sap/sap5-2/final-report/sap5-2-final-report-all.pdf)

1.4.3 What do probability density functions (PDFs) mean?

Probability density functions (PDF) are used to represent the relative likelihood that a parameter or variable will have a particular value. Where there is discrete set of possible values (e.g. heads or tails), the function represents the probability itself (e.g. 0.5, 0.5). Where the variation in values is continuous, the probability distribution function defines the probability that the value lies between two values, a and b. This is represented by the area under the function. Different distributions are appropriate for different processes and types of variability. A cumulative PDF represents the probability that the value of a parameter is greater (or less than) a particular value. The Poisson, binomial, normal (or ‘bell curve'), log-normal, exponential and gamma are examples of forms of PDFs used in quantitative risk assessment. PDFs such as the Weibull are frequently used to represent distributions of hazards, or to represent likelihoods of failure. Rectangular (or uniform), triangular and other geometric distributions are used in semiquantitative risk assessment, frequently in conjunction with techniques of expert elicitation, fuzzy analysis and probability bounds analysis.

1.4.4 How are uncertainties presented in European national portals?

name	link	Uncertainty guidance provided
Austrian Database on adaptation	http://www.klimawandelanpassung.at/newsarchiv/schwerpunktthema/unsicherheiten/	Contains a page on uncertainties. Lists uncertainties as one of the guiding principles (Leitprinzipen) for adaptation. Advocates stepwise planning, implementation and improvement of adaptation measures. Highlights sustaining / building resilience for sectors with a long planning horizon.
UKCIP	http://www.ukcip.org.uk/index.php http://ukclimateprojections.defra.gov.uk/content/view/675/500/	Uncertainty guidance accompanying the UKCP09 scenarios (see above). http://ukclimateprojections.defra.gov.uk/content/view/1115/500/(Willows and Connell, 2003)contains the wizard + background reading, glossary, refs
Danish Portal for Adaptation to Climate Change	http://www.klimatilpasning.dk/en-us/Sider/ClimateChangeAdaptation.aspx	No specific guidance. Reference is given to various external documents (e.g. Willows and Connell, 2003; Hallegatte, 2009).
KomPass	http://www.anpassung.net	Provides some uncertainty guidance (in German) in various part of "Klimalotse" tool. http://www.klimalotse.anpassung.net/klimalotse/DE/02_Intensivdurchlauf/2_klimaveraenderungen/3_klimaprojektionen_d/projektionenen_node.html http://www.klimalotse.anpassung.net/klimalotse/DE/02_Intensivdurchlauf/3_risiken_und_chancen/1_unsicherheiten/unsicherheiten_node.html http://www.klimalotse.anpassung.net/SharedDocs/Downloads/DE/beschreibung_von_wahrscheinlichkeiten_und_

			risiken.pdf?__blob=publicationFile http://www.klimalotse.anpassung.net/klimalotse/DE/weiterfuehrend/unsicherheiten_bei_klimafolgen_und_anpassung.html?nn=1137830
:	Norwegian Climate Change Adaptation Programme	http://www.regjeringen.no/en/dep/md/kampanjer/engelsk-forside-for-klimatilpasning.html?id=539980	No specific (English) guidance. Refers to background study [Vestlandsforsking memo 10/2009] and courses.
(	Dutch National Climate Research	http://www.climateresearchnetherlands.nl/nl/25222734-Home.html	Work in progress as part of research project. Provides background doc with terminology (Kwakkel*et al.*, 2011)(no link to PBL uncertainty guidance)
.	Finlands Climate Portal.	http://www.climateguide.fi/	Work in progress online in September 2011

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