Uncertainty Communication
Issues and good practice

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This document refers to sections of the 'RIVM/MNP Guidance for Uncertainty Assessment and Communication' (www.mnp.nl/guidance) The separate publications of the Guidance can be downloaded from:

- Mini-checklist & Quickscan Questionnaire:
  http://www.rivm.nl/bibliotheek/digitaaldepot/Guidance_MC_QS-Q.pdf
- Quickscan Hints & Actions List:
  http://www.rivm.nl/bibliotheek/digitaaldepot/Guidance_QS-HA.pdf
- Detailed Guidance:
  http://www.nusap.net/downloads/detailedguidance.pdf
- Tool Catalogue for Uncertainty Assessment:
  http://www.nusap.net/downloads/toolcatalogue.pdf
- Alternative download link for all documents:
  http://www.nusap.net/sections.php?op=viewarticle&artid=17

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Introduction

In 2003 the Netherlands Environmental Assessment Agency (MNP) published the RIVM/MNP Guidance for Uncertainty Assessment and Communication. The Guidance assists in dealing with uncertainty in environmental assessments. Dealing with uncertainty is essential because assessment results regarding complex environmental issues are of limited value if the uncertainties have not been taken into account adequately. A careful analysis of uncertainties in an environmental assessment is required, but even more important is the effective communication of these uncertainties in the presentation of assessment results. The Guidance yields rich and differentiated insights in uncertainty, but the relevance of this uncertainty information may vary across audiences and uses of assessment results. Therefore, the reporting of uncertainties is one of the six key issues that is addressed in the Guidance. In practice, users of the Guidance felt a need for more practical assistance in the reporting of uncertainty information. This report explores the issue of uncertainty communication in more detail, and contains more detailed guidance on the communication of uncertainty. In order to make this a 'stand alone' document several questions that are mentioned in the detailed Guidance have been repeated here. This document thus has some overlap with the detailed Guidance.

Scope

This report offers background information on uncertainty communication, and contains suggestions and guidance on how to communicate uncertainties in environmental assessment reports to several target audiences in an adequate, clear, and systematic way. It is not claimed that this is the only way or the best way to communicate uncertainty information, but the guidance in this report draws upon insights from the literature, insights from an international expert workshop on uncertainty communication (Wardekker and Van der Sluijs, 2005), and several uncertainty communication experiments in the Utrecht Policy Laboratory (Kloprogge and Van der Sluijs, 2006a, 2006b; Wardekker and Van der Sluijs, 2006a, 2006b).

The report contains three parts. Part I gives a general introduction to the issue of communicating uncertainty information. It offers guidelines for (fine)tuning the communication to the intended audiences and context of a report, discusses how readers of a report tend to handle uncertainty information, and ends with a list of criteria that uncertainty communication needs to meet to increase its effectiveness. Part II helps writers to analyze the context in which communication takes place, and helps to map the audiences, and their information needs. It further helps to reflect upon anticipated uses and possible impacts of the uncertainty information on the policy debates. Finally, in part II assistance is offered in customising the (uncertainty) information of an assessment for communication and reporting purposes. Part III contains practical information on how to communicate uncertainties. It addresses aspects of uncertainty that might be important in a specific situation, do's and don'ts, pitfalls to be avoided, and hints on how to communicate this uncertainty information.

The report focuses mainly on uncertainty communication in written material (especially reports), since the major part of the RIVM/MNP communication takes place by means of reports. For scientific audiences there are reasonably well-established protocols for communicating uncertainty. Therefore, this report mainly focuses on written communication towards non-technical audiences. Since policy makers are the primary target audience of RIVM/MNP publications, special attention is given to this audience.

Using the report

The difficulty with developing generic guidelines for communicating uncertainty is that each situation is unique: there is a particular topic; there are particular uncertainties, there is a particular political/societal context concerning the topic, there are particular intended audiences, etcetera. It is not possible to sketch every possible situation and to offer the writers custom-made guidance on how to communicate uncertainties in that particular situation. However, the basic insights offered in part I, together with the results of the analysis done in part II, will help the writer in determining which items of the practical information in part III are relevant in his or her specific situation.

The report uses cross-references. These will be presented in the text as (part; section; question) (question is optional). For example, 'II; 3.2;1' means: see part II, section 3.2, question number 1.

A concise version of this guidance report is available separately in Dutch ('Stijlgids Onzekerheidsommunicatie') and English ('Styleguide for Uncertainty Communication'). The *Syleguide* is a supplement to the RIVM/MNP Guidance for Uncertainty Assessment and Communication. For a glossary, we refer to the detailed guidance of the RIVM/MNP Guidance for Uncertainty Assessment and Communication or to www.nusap.net.

Part I

Background information on communicating uncertainty

I. Background information on communicating uncertainty

This first part of this report summarizes some basic insights in the communication of uncertainty information. The first section addresses the various roles that the reporting of uncertainty may have. Using the concept of ‘progressive disclosure of information’, guidelines are provided for adjusting the communication of uncertainty information to the intended audiences and the context of the report at hand. The second section provides an overview of how uncertainty information is handled by readers of a report. The insights of these two sections lead to a list of criteria for the communication of uncertainty information, which is presented in the third section.

1. Reporting uncertainty in a gradual and custom-made form

Central in this report is the idea of ‘progressive disclosure of information’. Guimarães Pereira and Corral Quintana (2002; p. 104) define progressive disclosure of information (PDI) as follows:

> Progressive Disclosure of Information *'entails implementation of several layers of information to be progressively disclosed from non-technical information through more specialised information, according to the needs of the user'.*

Through the use of PDI when reporting uncertainty, the uncertainty information is offered gradually without overwhelming the reader with all possible information on uncertainty. It also offers the readers the possibility to ‘zoom in’ according to their own information needs and look for more detailed information if desired.

Although the concept of PDI originates from the design of ICT decision tools and information systems, the PDI concept can fruitfully be applied to the ways in which the MNP and the RIVM communicate assessment results. For a specific topic the most ‘outer’ PDI layer may be a press release (or even one step further, a one-liner for the eight o'clock television news), the summary of an assessment report can be viewed as the next PDI layer in line, followed by a layer consisting of the chapters in the assessment report dealing with the topic. Finally, a footnote in a technical appendix of a detailed background report on the topic may be the most inner PDI layer where one can report uncertainty information.

The outer PDI layers of MNP/RIVM publications are generally directed towards non-scientific audiences and are intended for policy advice. The inner PDI layers are generally intended for scientific audiences and contain a detailed account of the approach and results of the assessment for scientific purposes. Although it seems obvious to state that policy-critical uncertainty information should not be hidden in a footnote of a technical appendix of a background report, studies into the dynamics of risk controversies have shown many examples where such footnotes, once discovered and exposed became the dynamite that destroyed the credibility and acceptance of risk assessment studies. On the other extreme, technical details on uncertainty information that have no policy relevance, should not be presented in the one-liner for the eight o'clock news, but may be highly interesting for colleague researchers.

Because of the differences in purpose and audiences of different PDI layers, the role of reporting uncertainty is different for inner and outer PDI layers. In outer PDI layers the main purpose of the reported uncertainties is to put the assessment results and policy advice in context. In inner PDI layers providing a scientific account of the approach and results of the environmental assessment is the main purpose of reporting uncertainty. When making use of the concept of PDI in uncertainty communication, the contents, the style and degree of detail of the reported uncertainties are adjusted to the PDI layer. Some general guidelines are shown in Table 1.

	Outer PDI layers	**Inner PDI layers**
Contents	Uncertainties can be integrated in the message (implicit in the wording used, such as using the word "may" or "might")	Uncertainties mentioned separately and explicitly
	Uncertainties as essential contextual information on the assessment results	Uncertainties as part of scientific accounting on the approach used in the study and on the assessment results
	Uncertainties translated to the political and societal context	Account of the ‘bare’ uncertainties from a scientific point of view
	Emphasis on policy relevance of uncertainties	Balanced account of uncertainties in all parts of the assessment
	Emphasis on implications of uncertainties	Emphasis on nature, extent and sources of uncertainties
	Implications of uncertainties for the assessment results and the policy advice given	Implications of uncertainties for representativeness of a study, value of the results, and further research
Style	Scientific information translated into ‘common language’	Scientific information with a high technical sophistication
	Use of jargon to be avoided	Use of jargon allowed
Degree of detail	Details only if considered policy relevant	Highly detailed (each layer offers more detailed information than the previous PDI layer)

Table 1: General guidelines on the contents, style and degree of detail of reported uncertainty information at different PDI layers

2. The reader’s perspective

As mentioned in the introduction in this report we mainly focus on communicating uncertainty to non-scientific audiences. In this section we analyze how uncertainty information in a specific report or document is handled by these audiences.

When communicating uncertainty regarding an environmental assessment, it is important to realize that the reported uncertainties will become part of an entire process of information handling by the reader. With an emphasis on uncertainty information, the following steps can be distinguished in this process (figure 1):

access to report/ document	chapters/sections /sentences paid attention to	processing of uncertainty information	interpretation of uncertainty information	use of uncertainty information

Figure 1: the handling of uncertainty information of assessment reports by non-scientific readers

These aspects of the information handling process are discussed below in more detail (sections 2.1 to 2.5). In section 2.6 the writers' influence on the audiences' handling of uncertainty information is discussed.

2.1 Access to report/document

In current society where Internet services are widely available, access to reports and documents are not likely to be a problem, if they can be downloaded from the MNP/RIVM website. However, in order for the reader to obtain the report he has to be informed of the existence of the report and any background documents.

In short:

- *audiences have to know about the existence of a report and any background documents;*
- *audiences need to have access to the report and any background documents.*

2.2 Chapters/sections/sentences paid attention to

Readers spend limited time on reading a report on a specific topic. Generally, there is a lot of written information on other topics as well that compete for the readers' attention and in case of professional readers (that is: readers who read a specific report for occupational reasons) there is also an enormous amount of other reports and documents on the topic at hand that compete for the readers' attention. Neutelings (1997) found that members of parliament on average read only one quarter of a policy text. Vaessen (forthcoming) even found that policy makers read only 9% of policy reports. Since in this study the policy makers were requested to read a report they were required to read for their work (instead of begin able to choose a report as in Neutelings' study), the time for the report was limited and interruptions such as phone calls were taken into account, this percentage seems more in accordance with reality. Reports can basically be divided into a 'primary' or 'prominent layer' and a 'secondary' or 'background layer' (Vaessen and Elling, 2000). The primary layer usually contains the summary, introduction, and conclusion and recommendation chapter. Also chapters that contain essential answers regarding the questions addressed in the report can be considered part of this layer. Depending on what questions the reader is interested in, different chapters can be considered to hold essential answers by different readers. So, which of these chapters belong to the primary layer is not fixed, but context dependent. The other chapters – where mostly the majority of the uncertainty information is reported – can be considered as the background layer. Reading studies (studies in which readers are observed while reading and commenting on a report) among a number of policy makers, members of parliament and NGO representatives showed that these readers spend significantly more time on parts of the primary layer than on parts of the secondary layer. Besides this, information in the primary layer is often the basis for the readers' decisions on which parts of the text they will read: this selection is often based on the contents, index, summary and introduction of the report. Besides using these specific sections for the selection of sections to read, readers will often browse through chapter titles, section and paragraph titles to see whether the information in those chapters and sections is relevant to them (Vaessen en Elling, 2000). Professional readers try to spend as little time as possible in retrieving information that is relevant to them by making strict selections.

The selection behavior can, however, be influenced by the attitude of the reader towards the conclusion of the report. Vaessen and Elling (2000) found that readers with a negative attitude read significantly fewer parts of the text than the ones with a positive attitude.

If the reader pays attention to a chapter or section, in most cases not all sentences are read. The study of Vaessen and Elling (2002) showed that readers read considerably more sentences of the primary layer, than of the background layer. Both in a relative and absolute sense the readers spend more time on the primary layer. Especially sentences in the summary and conclusions are relatively well read.

With regard to uncertainty information, Vaessen (2003; p. 124) concludes: 'By far not all information in a report is read, and also important information on uncertainties that is needed to assess the strength of the conclusions is often not read.'

In short:

- *time spent on reading the report is often limited because of competition from other reports/documents on the topic, and because of competition from other topics*
- *most reading time is spent on the primary layer (summary, introduction, conclusions and recommendations, and chapters containing essential answers with regard to the report's topics)*
- *the contents, index, summary and introduction are often used to select the chapters and sections that the reader will read*
- *selecting the sections that the reader will read is also done by browsing chapter, section and paragraph titles*
- *readers with a negative attitude towards the conclusion of the report read fewer parts of the text than readers with a positive attitude*
- *compared to the background layer, more sentences of the primary layer are read*
- *the information eventually read is quite limited; also important uncertainty information needed to understand the strength and scope of the conclusions is often not read*

2.3 Processing of uncertainty information

People tend to select and interpret information in order to support their existing worldview. This is known as ‘confirmation bias’, ‘belief perseverance’ or ‘selective perception’ (Poortinga and Pidgeon, 2004; Vaessen, 2003). Whether or not the main conclusion of a report is in line with the readers’ views may therefore influence the processing of (uncertainty) information.

Readers with a positive attitude towards the conclusion of a report tend the read more sections of a report than readers with a negative attitude (Vaessen and Elling, 2002). A reader with a positive attitude may, however, be less open to uncertainty information, as this weakens the conclusion that is in line with his views. He may process it in a fast and frugal way or skip it (Vaessen, 2003).

If the reader has a negative attitude towards the conclusion of the report, he may feel that the report is not worthwhile putting a lot of effort into (Vaessen and Elling, 2002). He will spend little time reading it, and will come across little (uncertainty) information. However, a reader with a negative attitude may also do the opposite: he then searches for information in the report that *does* support his views (Vaessen, 2003). He will use prior knowledge and analytical thinking to look for arguments that undermine the – in his view – incorrect approach and conclusions of the report. In this case, he will be interested in uncertainty information that undermines the main conclusion.

In discourses on highly controversial risks with high decision stakes, looking for information that undermines the main conclusion can take the form of ‘stretched peer review on unwelcome results’ (Myhr and Traavik, 2003; Myhr, 2005, Van der Sluijs, 2007). Some readers actively search for weak points in a study in order to use that to attack unwelcome conclusions and undermine the credibility of the authors. For instance, analyzing controversies on risks of Genetically Modified Organisms Myhr found that scientists that publish preliminary findings indicating the possibility of serious harm by GMOs are aggressively jumped upon by a powerful network of scientists from the pro-GMO lobby that heavily criticize and actively discredit the scientists that bring the message that potentially constitutes an early warning of risk. This takes the form of attacks on the scientists’ credibility via newspapers and other fora. This phenomenon stretches the peer review process of healthy critical debate beyond the scientific journals and scientific communities and into an area of an unhealthy war against the whistleblowers through personal attacks in the public- and policy arenas. This may cause that scientists refrain from publishing preliminary research findings that may constitute an early warning, which is an undesirable development seen from the viewpoint of precautionary risk governance. Similar phenomena were reported on health risks of tobacco smoke (Michaels, 2005) and ecological risks of systemic pesticides (Maxim *et al.*, 2007).

Note that the attitude towards the conclusion of a report will strongly depend on whether the author or the institute that produced the report is trusted by the reader. Social robustness of knowledge claims (Nowotny, 1999, Nowotny et al, 2001), trust, and perceived uncertainty are closely linked.

In short:

- *People tend to look for information that is in line with their existing world views*
- *Readers with a negative attitude towards the conclusions of the report may spend little time reading it since it does not support their views* ***or*** *they specifically look for uncertainty information that* ***does*** *support their views. In discourses on highly controversial risks with high decision stakes this can take the form of stretched peer review of unwelcome results.*
- *readers with a positive attitude towards the conclusions of the report may be less open to uncertainty information, since this information is not in line with their views. They may process it in a fast and frugal way or skip it.*

2.4 Interpretation of uncertainty information

When uncertainty information is read, the ideal situation would be that every reader would interpret the uncertainty information in the same way as the writer has intended. However, interpreting uncertainties is – even for policy makers –difficult. The reader's level of knowledge may be insufficient to interpret the information correctly: for instance, the reader may not be familiar with Probability Density Functions (PDFs) or probabilities and therefore cannot interpret the uncertainty information presented by a PDF or a Cumulative Density Function (CDF) correctly. The level of understanding may also be a bottleneck: an example is a reader who does not understand a PDF, even though an explanation is being provided. Also, interpretations may be biased, and interpretation differences between individuals may occur.

Especially uncertainty information concerning probabilities is prone to biases, as the concepts themselves are not easy to understand fully (Van de Vusse (ed), 1993, Slovic, 1987, Cosmides and Tooby, 1996, Brase et al. 1998, Rode et al., 1999, Hoffrage et al. 2000, Gigerenzer, 2002,2003). This is because in such a highly artefactual situation, ordinary intuition is not a reliable guide to an estimated answer. The human mind also has problems with correctly combining probabilities. For example, suppose that 2% of a population has a given disease and a test to this disease performs such that anyone with the disease will test positive (there are no "false negatives"), while 90% of those without the disease will test negative. If people are asked to estimate the chance that a person with a positive test result actually has the disease, estimated chances seriously overestimate the probability that follows from mathematical logic (16.9 % in this example). This is because people put too much weight on the higher percentage, the reliability of the test, and not enough to the small prevalence of the disease baseline probability and the false positives (Department of Health (UK), 1997).

This tendency to forget the baseline probability also results in a problem when risks are framed in different ways. The perceived message of communication on a risk depends critically on whether risks are given in absolute terms (chance was 2% and is

now 4%) or in relative terms (the chance has doubled). The relative expression sounds more alarming and newsworthy, but it can be seriously misleading if the baseline risk is not made clear (Department of Health (UK), 1997).
Another problem is that the brain tends to manipulate probabilities, to employ simplified ways of managing information (heuristics), in order to reduce difficult mental tasks. Although they are valid and useful in most situations, they can lead to large and persistent biases with serious implications (Department of Health (UK), 1997; Slovic et al., 1981). The most relevant heuristics and biases are availability, confirmation bias, and overconfidence effect/bias (Kahneman et al., 1982):

- Due to the *availability heuristic*, people judge an event as likely or frequent if instances of it are easily brought to mind. While this is often appropriate, because frequently occurring events are generally easier to imagine than rare events, availability is also affected by numerous factors unrelated to frequency of occurrence. Memorable events, a recent disaster, or even vivid films can increase imaginability and therefore seriously bias judgments. An example of this is that people tend to overestimate rare causes of death and underestimate common causes of death. Rare causes are often dramatic or sensational, while common causes tend to be unspectacular. People's personal experiences can also bias views due to the availability heuristic: people take risks time after time without mishap and therefore often consider themselves personally immune. Moreover, indirect experience through the media shows that when accidents happen, they happen to others. A particular important implication of availability is that discussing risk may increase its imaginability and therefore its perceived riskiness, regardless of what the evidence indicates. This would explain the fact that the amount of media coverage enhances perceived riskiness.
- The *confirmation bias* results in a situation where, once a view has been formed, new evidence is generally made to fit. Strong initial impressions structure the way that subsequent information is interpreted. New evidence will appear reliable and informative if it is consistent with one's initial belief and it is seen as "proof positive". Contrary evidence may be seen as unreliable, erroneous, or unrepresentative, and therefore filtered out. Ambiguous data may be interpreted as a confirmation. As a result, strongly held views will be extraordinarily difficult to change by informational presentations. One's own actions can also make these expectations self-fulfilling.
- The *overconfidence effect/bias* implies that people typically have too much confidence in their own judgments. This appears to affect almost all professions as well as the lay public. The few exceptions are people who receive constant feedback on the accuracy of their predictions, such as weather forecasters. The psychological basis for this unwarranted certainty seems to be insensitivity to the weaknesses in assumptions upon which judgments are based. (Slovic et al., 1981; Slovic et al., 1984, Department of Health (UK), 1997, Wardekker, 2004).

In contrast, Cosmides and Tooby (1996) argue that a large part of these biases are due to the way in which probability information is offered to people, and they illustrate that a more frequentist-based presentation greatly improves the human performance of probabilistic reasoning, causing various cognitive biases to disappear. See also Brase et al. 1998, Rode et al., 1999, Hoffrage et al. 2000, Gigerenzer, 2002, 2003, Gigerenzer et al. 2005, Krämer and Gigerenzer, 2005.

Another effect that may play a role in the interpretation of probabilities is that people in their brain do not separate the probability and magnitude components of a risk and thus tend to take the magnitude of effects into account when translating probability language into numbers and vice versa. If experts artificially separate probability and magnitude, and in their communication use probability language that reflects the probability component of the risk only, this mechanism causes the reader to perceive the chance for low magnitude events to be higher and the chance of high magnitude events to be lower than what the expert intended to communicate. (Patt and Schrag, 2003). See also Hansen et al., 2004 for an interesting illustration on the use and interpretation of weather forecast information by users (farmers).

Besides these 'technical' interpretation issues, interpretation can also be influenced by how the information is formulated ('framing'). For example, introducing environmental policy measures in order to 'improve the situation' sounds more positive than in order to 'avoid deterioration'. Uncertainties can be presented as an omission, as a marginal note or as essential policy relevant information.

In short:

- *when uncertainty information is processed, interpretation differences between individual readers, misunderstandings and biases may occur (such as availability heuristic, confirmation bias, overconfidence effect/bias)*
- *relative changes in risks can sound alarming, but can be seriously misleading if the baseline risk is not clear*
- *risk experts artificially separate the probability and magnitude components of a risk, but non-scientific audiences don't, leading to an under-appreciation of low probability high impact events*
- *framing influences the interpretation of uncertainties*

2.5 Use of uncertainty information

When uncertainty information has been read and processed, the question remains whether and how this information is used (for example, in the policy process, public debate or to form a personal opinion), and whether it is used 'correctly'. Uncertainty information that was processed may simply be forgotten after reading it. Also, a reader may not have the opportunity to use uncertainty information. For example, in a debate, time may be too limited to thoroughly discuss a topic, and uncertainties may not be addressed. Uncertainty information that has been processed may be dismissed by the reader as not being policy relevant or not important, and thus not put to use. Also, strategic use can be made of uncertainty information, for example by picking a part of an uncertainty range that leads to conclusions supportive of the reader's political viewpoints. Of course, biases in the interpretation of the uncertainty information of the reader will also exist during the use of the information by that reader.

Policy makers in general seem to consider uncertainty information as a useful input in the policy process. It can be used for prioritisation and determining the efficiency and effectiveness of policy measures. In the political process, uncertainty information may

also be used as a form of hedging, as interest in uncertainty information seems to be limited until problems arise. According to a limited enquiry of policy makers (Wardekker and Van der Sluijs, 2006a), they think that too much emphasis on uncertainty can however give rise to unnecessary discussion, and that therefore uncertainty information needs to be as limited and policy relevant as possible.
The usefulness and relevance of uncertainty information on a specific issue will highly depend on the position of the issue in the policy cycle. For example, during the phase of problem formulation and framing, there will often be a need for uncertainty information on e.g. the (potential) effects and magnitude of these effects. Later stages of the policy cycle call for uncertainty information on e.g. causes, and once policy measures are being taken, on the question of whether policy targets are being met. Information that is relevant to other (previous or later) stages of the policy cycle does not necessarily become irrelevant for the current stage. Especially when issues are topical, controversial or relatively new, uncertainties in the problem formulation and framing will stay relevant even in later stages of the cycle. (Wardekker and Van der Sluijs, 2006a).
Finally, the use of the information also depends on the organisational level: policy makers at the national level may have different needs than those at regional and local levels (Wardekker and Van der Sluijs, 2006a).

In short:

- *uncertainty information may be forgotten before it is used*
- *the reader may not have the opportunity to use uncertainty information (for example, because there is not time in a debate for addressing uncertainties)*
- *uncertainty information may be dismissed because it is not considered policy relevant or considered unimportant*
- *strategic use may be made of uncertainty information*
- *for policy makers the usefulness of uncertainty information is related to the position in the policy cycle of the problem at hand*
- *the use of uncertainty information by policy makers partly depends on the organisational level of the policy makers (local/regional/national)*

2.6 The writers' influence on the audiences' handling of uncertainty information

The writers of MNP or RIVM reports cannot determine and control which information is read by the target audiences, how it is processed, how it is interpreted, or how it is used. However, the locations where uncertainty information is presented can be carefully chosen, and a clear and consistent way of describing the uncertainties will be beneficial to a correct interpretation of this information by the audiences. Further, by specifically giving attention to policy relevant uncertainties, and by discussing the possible policy-implications of these uncertainties, the uncertainty information becomes meaningful to the policy process into which it feeds, and useful for the audiences.

3. Criteria for uncertainty communication

From the previous sections the following general good-practice criteria for adequate uncertainty communication can be deduced that ideally should be met:

1. *uncertainty communication deals with information on uncertainty that is required by good scientific practice and that readers and users need to be aware of*
2. *the audiences should have access to the uncertainty information, and know where to find (more detailed) uncertainty information*
3. *The uncertainty information offered should be consistent (across different reports, different issues, different authors, et cetera).*
4. *essential uncertainty information should be located in sections of the report that are most likely to be read by the audiences*
5. *the information on uncertainty is clear to the readers*
    - *minimise misinterpretation*
    - *minimise bias*
    - *minimise differences in interpretation between individuals*
6. *the information on uncertainty is not too difficult to process by the readers*
    - *not too much effort and time required to understand the method of representation*
    - *not too much effort and time required to retrieve the information itself*
7. *uncertainty communication meets the information needs of the target audiences, and therefore is context dependent and customised to the audiences*
8. *the overall message (that is: knowledge claims and uncertainty information) is useful to the audiences for making policy decisions and/or for use in political/societal debates and/or for forming personal opinions (for assessments for policy advice)*
9. *the overall message (that is: knowledge claims and uncertainty information) is credible to the readers (well underpinned and unbiased)*

Part II

Analysis of context and audiences, and customising the communication accordingly

II. Analysis of context and audiences, and customising the communication accordingly

This part of the report helps to explore the context and audiences of communication of uncertainty information (sections 1 and 2). Next, section 3 assists in restructuring the main findings of the environmental assessment and the uncertainty information for the purpose of communicating this information in the varying PDI layers. What information to communicate in what PDI layer is explored in section 4.

Together with the basic insights presented in part I of this report, this analysis serves as a preparation for part III (Practical suggestions on reporting uncertainty information) by enabling writers to make a well argued choice regarding which issues are relevant in the situation at hand.

1 Context of Communication of Uncertainty

To get a clear picture of the context of communication of uncertainty as a starting point for a communication strategy, the following diagnostic questions can help:

1. What is the role of the analysis/assessment that is being reported? Check all that apply:
   - ❑ Ad hoc policy advice
   - ❑ To evaluate existing policy
   - ❑ To evaluate proposed policy
   - ❑ To foster recognition of new problems
   - ❑ To identify and/or evaluate possible solutions
   - ❑ To provide counter-expertise
   - ❑ To provide background information on earlier communications by the MNP
   - ❑ To report new scientific insights/methods
   - ❑ Tt forms part of a much broader assessment
   - ❑ Other (specify)

2. What contextual factors add to the need for communicating uncertainty? Check all that apply:
   - ❑ To serve a political purpose
   - ❑ To conform to good scientific practice (for scientific purposes)
   - ❑ Practice of the institution that carries out the environmental assessment
   - ❑ Required by legislation
   - ❑ Requested by stakeholders involved in the process
   - ❑ Other (specify)

3. What PDI layers can be distinguished? Check all that apply:
   - ❑ Press release
   - ❑ Presentation for specific target audiences
   - ❑ Background article for the website
   - ❑ Summary
   - ❑ Conclusions and recommendations
   - ❑ Summaries of the chapters

- ❑ Chapters
- ❑ Appendices
- ❑ Background report (again with a summary, conclusion, etc.)
- ❑ Scientific articles
- ❑ Other (specify) .....

4. What other contextual issues are relevant to consider in the design of a strategy regarding what uncertainty information to communicate how?

2. The target audiences

A next step is to make a well argued choice regarding what audiences one needs to address when communicating uncertainty information and what specific information needs and contexts of use are relevant for each of these audiences.

2.1 Who are the Target Audiences?

A distinction can be made between 'primary target audiences' for which the communication/report is specifically intended and 'secondary target audiences' which can be described as 'others who may have an interest in the subject matter'. Primary target audiences for the MNP and the RIVM are often (national) policy makers and politicians who use the assessment results to design new policies and to evaluate existing policies. Of course, the client/customer of the assessment is part of the primary target audience. Secondary target audiences may correspond to the other stakeholders identified for the problems of concern. It might not correspond to the whole set of stakeholders but it is surely a subset of those.

1. Who are the primary target audiences (including client/customer)? (list according to your stakeholder list; see section 2.1 of the detailed Guidance)

2. Who are the secondary target audiences? (list according to your stakeholder list; see section 2.1 of the detailed Guidance)

2.2 Information Needs of the Target Audiences

In this section the information needs of the client/customer of the environmental assessment are addressed, and the information needs of other audiences are addressed.

2.2.1 The client/customer

In section 2.3.1 of the detailed Guidance the issue of 'discussing uncertainty in the environmental assessment with the client/customer' was addressed. Because this is directly related to the information needs of the client with respect to uncertainty, the questions posed in that section are repeated here.

1. What are the client's minimal requirements with respect to uncertainty management? Check all that apply:

- ❑ Uncertainty is not an issue
- ❑ The robustness of the conclusions with respect to uncertainty should be assessed
- ❑ Uncertainty in the major outcomes should be indicated
- ❑ The major causes of the uncertainty should be determined
- ❑ The implications of uncertainty for the policy issue at hand should be indicated
- ❑ Other (specify) ....

2. What form of uncertainty information is requested by the client in this uncertainty assessment?

- ❑ Qualitative information
- ❑ Quantitative information

3. Explain why this is the (minimal) requirement with respect to uncertainty management.

4. Describe any further requirements by the client about the form in which uncertainty should be presented.

2.2.2 Other target audiences

1. If members of the target audiences have been involved during the assessment process, what conclusions can you draw from the interaction with them with respect to their information needs on uncertainty?

2. Which questions, problems and tasks can be identified among target audiences? What are the problem frames of the stakeholders (see section 1.1 of the detailed Guidance). What are their likely beliefs, agendas and value positions (see section 2.2 of the detailed Guidance)? Based on this, what uncertainties are likely to be of importance to them or interesting to them?

3. Do specific stakeholders want the primary audiences to receive specific uncertainty information? (for example, do policy advisors want policy makers to receive specific information?)

4. What is the position of the problem at hand in the policy cycle? Based on this, what are likely information needs of policy makers regarding uncertainty? (see I; 2.5)

5. Are there any particular information needs regarding uncertainty to be expected by policy makers at different organisational levels (local/regional/national)?

6. Are there, do there seem to be or do you expect to occur, any misunderstandings among the audiences regarding the topic at hand?

7. How have target audiences reacted to uncertainty information in prior publications? Based on this, is it possible to draw conclusions with regard to their information needs on uncertainty?

2.3 Anticipating impacts on target audiences

1. What are the target audiences likely to do with the received uncertainty information? What use (including strategic use) could be made of uncertainty information?

2. Are there any risk related issues in the assessment that relate to fright factors or media triggers (see Box 1 and 2)?

3. In case of assessment results indicating a low risk: are the audiences expected to distrust these results because the public perception is that the risk is serious?

4. Are the audiences likely to distrust the results due to low or fragile confidence in the researchers or the organisation that performed the assessment?

Box 1: Fright Factors

In their 'pointers to good practice' for communicating about risks to public health the UK Department of Health identified a number of risk characteristics that make risks generally more worrying for audiences (Department of Health UK, 1997).

Risks are generally more worrying (and less acceptable) if perceived:
1. to be **involuntary** (e.g. exposure to pollution) rather than voluntary (e.g. dangerous sports or smoking)
2. as **inequitably distributed** (some benefit while others suffer the consequences)
3. as **inescapable** by taking personal precautions
4. to arise from an **unfamiliar or novel** source
5. to result from **man-made, rather than natural** sources
6. to cause **hidden and irreversible** damage, e.g. through onset of illness many years after exposure
7. to pose some particular danger to **small children or pregnant women** or more generally to **future generations**
8. to threaten a form of death (or illness/injury) arousing **particular dread**
9. to damage **identifiable rather than anonymous victims**
10. to be **poorly understood by science**
11. as subject to **contradictory statements** from responsible sources (or, even worse, from the same source).

Box 2: Media Triggers

In their 'pointers to good practice' for communicating about risks to public health the UK Department of Health identified a number of characteristics of risks to public health that make it more likely to become a major story in media coverage (Department of Health UK, 1997).

A possible risk to public health is more likely to become a major story if the following are prominent or can readily be made to become so:
1. Questions of **blame**
2. Alleged **secrets and attempted "cover-ups"**
3. **"Human interest"** through identifiable heroes, villains, dupes, etc. (as well as victims)
4. Links with **existing high-profile issues or personalities**
5. **Conflict**
6. **Signal value**: the story as a portent of further ills *("What next?")*
7. **Many people exposed** to the risk, even if at low levels *("It could be you!")*.
8. Strong **visual impact** (e.g. pictures of suffering)
9. Links to **sex** and/or **crime**

For environmental topics we can add the following media triggers:
- Environmental problems where **human health** is at stake (as opposed to damage to nature or animals)
- If animal suffering is involved: a high **'pet factor' of the animals**
- Topics in which **substantial political tensions** play a role

3. Restructuring the (Uncertainty) Information

Through use of the Guidance and tools from the Toolbox insight in and information on uncertainty in the environmental assessment is obtained throughout the assessment process. This section aims to assist in bringing the uncertainty information together and restructure and customise it for communication and reporting purposes. It is analysed which uncertainties are (policy) relevant for the audiences and how the main messages should be presented in view of the uncertainties.

3.1 Uncertainty Information Collected

1. What methods were used to address uncertainty management?
Check all that apply (see the Tool Catalogue of the Guidance):

- ❑ Uncertainty analysis (e.g. statistical analysis)
- ❑ Quality assurance (e.g. NUSAP, Pedigree)
- ❑ Explanatory frameworks (e.g. cultural theory)
- ❑ Other (specify) ....

2. Uncertainty methods can operate in the foreground when applied explicitly to produce information on uncertainty (e.g. written material, graphs), or in the background as when run behind a model and results are embedded in the output (e.g. model outputs, scenarios).
Are the methods used primarily:

- ❑ Background
- ❑ Mixed
- ❑ Foreground

3. Indicate the main uncertainties in the environmental assessment and discuss how this may influence findings.

- Consider the main statistical uncertainties, scenario uncertainties, ignorance
- Consider the main weaknesses in the knowledge base
- Consider what important choices were made with respect to the Contents of the assessment (including problem framing, selection of indicators, assumptions and points of departure)
- Consider what important methodological choices were made, which may have affected the outcomes (including methodological limitations concerning the selected method).

4. Indicate the main implications of these uncertainties and discuss how this may influence findings.

- Consider implications for the representativeness of the results and conclusions
- Consider implications for the robustness of the conclusions

- Consider implications for different settings of the burden of proof[1]
- Consider implications for policy, politics and society

5. Indicate which important uncertainties could possibly be reduced in the future and discuss what is needed to do so.

6. Indicate which important uncertainties are not expected to be reduced in the future, and discuss the implications of this for the issue at hand.

3.2 Identifying Policy-Relevant Aspects of Uncertainty

When uncertainties in an environmental assessment are being communicated for scientific reasons, the main goals are to make the assessment transparent and reproducible and to identify new research foci. When uncertainties are being communicated in an assessment meant for policy advice, uncertainties are particularly important if they have a great impact on the policy advice given in the assessment or if they lead to inconclusive policy advice. Uncertainties in the assessment that are subject to debate among stakeholders can also be policy relevant.

1. In situations like the ones listed below, uncertainties in the assessment are likely to be more policy relevant. Check all that apply.
    - ❑ The outcomes are very uncertain and have a great impact on the policy advice given.
    - ❑ The outcomes are situated near a policy target
    - ❑ The outcomes are situated near a threshold set by policy
    - ❑ The outcomes are situated near a standard/norm set by policy
    - ❑ A wrong estimate in one direction will have entirely different consequences for policy advice than a wrong estimate in another direction.
    - ❑ Possibility of morally unacceptable damage or 'catastrophic events'.
    - ❑ There is social controversy about the topic.
    - ❑ There are value-laden choices/assumptions that are in conflict with the views and interests of stakeholders.

2. What aspects are relevant in view of the position of the issue in the policy cycle? Check all phases that are relevant (see I; 2.5):
    - ❑ Recognition of a problem and agenda setting: fundamental matters such as the boundaries of a problem, level of scientific knowledge available, research methodology, environmental quality, causes, effects, etc.
    - ❑ Policy formulation: impacts, emission data, scenarios, expected policy effects and policy costs (environmental, economic, social), etc.

[1] The *burden of proof* here is the obligation to prove allegations in a procedure of risk regulation. This can differ from case to case and amongst countries. One setting can be that the one who undertakes an activity that is suspected to pose risks has to prove that the risk is within acceptable limits, another setting can be that those who may suffer the risk have to prove that the activity poses unacceptable risks to them.

- Policy implementation and monitoring: emission data, future projections, environmental quality, the achieved and expected policy effects and policy costs, etc.
- Evaluation and adaptation of policy: matters relating to previous phases.

3. What uncertainties have a great impact on the policy advice given in the assessment or lead to inconclusive policy advice?

4. What uncertainty issues are subject to controversies among stakeholders?

5. What value-laden choices and assumptions made in the environmental assessment could be in conflict with stakeholder views and interests?

6. Are there non-scientific uncertainties (legal, moral, societal, institutional, proprietary, situational) that are policy relevant (see section 1.5 of the detailed Guidance)?

7. What uncertainties, assumptions or limitations of methods used do not seem policy relevant at first sight, but may turn out to be so at the end (for instance, because they could have a significant (but unquantifiable) influence on the outcomes of the indicator and/or the policy advice eventually given?)

3.3 The Main Messages/statements in view of the uncertainties

In this section the main messages are explored, in view of the uncertainties. There is some overlap with section 3.1. However, in section 3.1 uncertainty is the central issue being explored, whereas here the main messages are the point for departure.

1. Are there any (sub)results of the assessment that you do not want to communicate at this point due to the fact that the study is too preliminary and there are too many uncertainties to base a policy advice on?

2. Identify the main messages to be conveyed and argue why these are the main messages.

3. Which of these main messages are well-founded conclusions and which ones are speculative or something in between?

4. How should the knowledge claims in the main message be presented/formulated in view of:

  - the main statistical uncertainties, scenario uncertainties, ignorance
  - the main weaknesses in the knowledge base
  - important choices in the assessment (including problem framing, selection of indicators, assumptions and points of departure)
  - important methodological choices (including methodological limitations of the method chosen).

5. What are implications of the uncertainties for the policy process/decision/social context?

6. What are implications of the uncertainties for different risk management strategies?

7. Verify how robust the main messages are in view of the choices made, the assumptions used, the strength of the knowledge base and the uncertainties in data, models, and other knowledge.

4. Developing a strategy for Progressive Disclosure of Information

In order to report uncertainties in an adequate manner several issues have to be taken into account. It is not simply a matter of presenting a range instead of a single number. In order for the audiences to make sense of the uncertainties, it helps if they have some knowledge on the context of the assessment and the assessment itself (that is, how it was conducted). It is not merely a matter of reporting the uncertainties themselves, but they also need to be properly reflected in the formulation of the main messages that are conveyed. Moreover it can be of importance to inform the audiences on the implications of the uncertainties and what can be done about it. It will often be relevant to inform them with insights in how the uncertainties were dealt with in the assessment and additionally offering them educational information on uncertainties in general.
It will definitely depend on the situation at hand (purpose of the report, which audiences, etcetera) to what degree these aspects need to be addressed in the reporting phase. In order to provide audiences with uncertainty information in a gradual and tiered fashion, customised to their information needs, we use the strategy of Progressive Disclosure of Information (PDI; see section 1 of part I of this report). In this section a table is constructed indicating which uncertainties need attention in what PDI layers.

4.1 Filling in the PDI table

In Table 2 a template for a ‘PDI table’ is given that assists in the making of a plan regarding what uncertainty information to communicate in what PDI layer. When environmental assessment results concerning a topic are reported, this Table can be used as an aid to provide the audiences with a gradual flow of (uncertainty) information, customised to their needs. How to fill in the Table will be discussed below.

General remarks

- Fill in the Table cells using key words (not the literal text to be used in the written material).
- When determining what aspects of uncertainty should be given attention in a specific PDI layer, consider:
    - the purpose of the PDI layer at hand (see part II, section 1, question 1)

    - the purpose of reporting uncertainty (see part II, section 1, question 2)
    - the information needs of the audiences (see part II, section 2.2)
    - the expected willingness to read of the audiences and the time they are likely to put into it
- Background reports belonging to a specific report may take some time to be published. If there is a considerable time period between the publishing of the main report and that of the background report, one can choose to discuss uncertainty issues in the main report in more detail (because interested audiences will be unable to find inner PDI layers with more detailed information for some time). This information should, however, be customised to the general style and contents of the main report. That is, the text will need to be more compact than in the background report.
- Make sure that all essential uncertainty information is included and properly reflected in the formulations chosen in those parts of a report that are mostly read: the summary, introduction and conclusion and recommendations chapter.
- If stakeholders are involved in the assessment process, discuss with them what information they would like to find in which layer.
- Make sure that the uncertainty information is consistent across the different PDI layers.
- If unfamiliar with the contents of part III of this report, reading part III before filling out the PDI table will help to avoid overlooking aspects of uncertainty to be communicated.

How to fill in the columns of the PDI table

PDI layer
Indicate the PDI layers that are relevant for the topic at hand (see part II, section 1, question 3).

Intended audiences
Indicate for each PDI layer the main audiences. In general, outer PDI layers have multiple and broader audiences (policy makers, the public, scientists) and inner layers are usually intended for smaller, less diverse audiences (mainly scientists and lay persons who take a specific interest in the subject).

Space available
In general, in outer PDI layers less space is available for information on a single topic than in inner layers. Indicate how much space is available for (uncertainty) information regarding the topic. Can the available space best be expressed in sentences, paragraphs or pages? How many sentences/paragraphs/pages are available?

Context of and insight in the assessment
What minimal information should the reader in a specific PDI layer have in order to be able to understand the context of the environmental assessment (for example, positioning in view of prior studies), and to understand how this assessment was conducted?

Main messages
What are the main messages to be communicated in a specific PDI layer? (see part II, section 3.3). Main messages in outer PDI layers generally are statements of a more political/societal nature (for example, 'particulate matter is a policy problem that requires action'), whereas the main messages in inner PDI layers tend to (also) convey 'scientific' information (for example, 'ambient particulate matter concentrations amount to....').

Main statistical uncertainty/scenario uncertainty/ignorance
What are the main statistical uncertainties, scenario uncertainties and ignorance to be communicated in a specific PDI layer? (see part II, sections 3.1 and 3.3). For outer PDI layers: pay extra attention to policy relevant aspects (see part II, section 3.2).

Main weaknesses in knowledge base
What are the main weaknesses in the knowledge base (including methods used) to be communicated in a specific PDI layer? (see part II, sections 3.1 and 3.3). For outer PDI layers: pay extra attention to policy relevant aspects (see part II, section 3.2).

Main value laden choices
What are the main value laden choices in the assessment that need to be communicated in a specific PDI layer? (see part II, sections 3.1 and 3.3). For outer PDI layers: pay extra attention to policy relevant aspects (see part II, section 3.2).

Implications of the uncertainties
What are implications of the uncertainties that need to be communicated in a specific PDI layer? (see part II, sections 3.1 and 3.3). For outer PDI layers: pay extra attention to policy relevant aspects (see part II, section 3.2). This includes implications of *excluded* uncertainty types and sources of uncertainty (could the findings be radically different if these excluded uncertainties would be systematically assessed)?

(Ir)reducibility uncertainties
What are aspects of (ir)reducibility of uncertainties to be communicated in a specific PDI layer? For outer PDI layers: pay extra attention to policy relevant aspects (see part II, section 3.2).

How uncertainty was dealt with
What aspects of how uncertainty was dealt with in the environmental assessment have to be communicated in a specific PDI layer? (see part II, section 3.1) What types and sources of uncertainty were included in / excluded from the analysis?

Educational information on uncertainty
What educational information on uncertainty is to be communicated in a specific PDI layer?

4.2 Internal coordination using the PDI table

The text of a MNP report is never written by a single person. It is a joint effort of analysts, team coordinators, supervisors, and communication specialists. Among the members of this ‘writing team’ there may be disagreement on what to communicate. Furthermore, changes are often made in the text in the process of editing that also may influence the contents (for example, shortening of the text). Discussing the PDI table among the writing team – or better yet: developing this table jointly within the writing team – will provide everyone involved with a basic structure for communication. If changes are proposed it can be evaluated whether such changes fit within the communication strategy agreed on beforehand.

PDI layer	Intended audiences	Space available	Context of and insight in the assessment	Main messages	Main statistical/ scenario uncertainty/ ignorance	Main weaknesses in knowledge base	Main value laden choices	Implications of the uncertainties	(Ir)reducibility of uncertainties	How uncertainty was dealt with	Educational information on uncertainty

Table 2. Template for a table to assist in developing a plan for progressive disclosure of uncertainty information.

Part III

Practical suggestions on reporting uncertainty information

III. Practical suggestions on reporting uncertainty information

This third part of the report offers hints, tips, cautions regarding pitfalls, and do's and don'ts regarding communicating uncertainty. Section 1 presents practical guidance on *'what and how'* to report uncertainty information. Practical guidance on different *forms of presentation* (numeric, linguistic, graphic) is presented in section 2. This part of the report contains some examples, which are placed in boxes[2].

Wherever insights from part I and part II of this report are relevant, this will be indicated. This will have the form of *(part; section; question)* (question is optional). For example, 'II; 3.2;1' means: see part II, section 3.2, question number 1. If new insights emerge from working with part III, writers may want to review the PDI table that they filled in when working with part II, section 4.

The hints, pitfall warnings, do's and don'ts in this part of the report are intended to help avoid incorrect interpretations of uncertainties in a specific assessment, and to help make the uncertainty information useful and meaningful for the audiences. If – besides this – attention is paid to the locations in a report where this information is offered, the presentation of the uncertainty will be better customised to the processes by which readers deal with (uncertainty) information (see part I, section 2).

1. Reporting uncertainty information – What and how

As presented in part II, section 4 the following aspects related to uncertainty may be communicated to the audiences:
- Context of and insight in the assessment
- Main message in which uncertainties are reflected or taken into account.
- Reporting sorts and types of uncertainties and how these propagate to the outcomes of interest
- How uncertainty was dealt with in the analysis
- Implications of uncertainties
- What can be done about uncertainties
- Educational information on uncertainty

Below, what and how to communicate will be discussed per item.

1.1 Context of and insight in the assessment

– Report the reasons why the present study was conducted. Indicate how it relates to policy questions and policy developments.
– Indicate the (potential) position of this assessment in the policy/societal debate, and in what way it can contribute to this debate.

[2] Part of the examples are based on our findings of a communication experiment in the Utrecht Policy Laboratory (Kloprogge and Van der Sluijs, 2006b). In this session uncertainty information from the Dutch Environmental Balance 2005 was tested on a number of 9 lay persons. It should be noted that due to the limited numbers of participants, the conclusions of this study are preliminary. The examples mentioned here are only intended as illustrations of the main text.

- Indicate the (potential) position of this assessment in the scientific debate, and in what way it can contribute to this debate.
- If desired, position the present study in relation to previous studies, and clarify in which respect this study is different concerning both set-up and results. Explain or motivate the differences. Clearly indicate the added value and meaning of the present study.
- If applicable, position the study in relation to other studies that are presently being conducted by the RIVM/MNP or other institutes.
- If a topic is ‘hot’ or important, provide the readers with an overview of the MNP/RIVM reports published on this topic. If possible put a ‘dossier’ on the internet that puts the assessment in its societal context and lists the main findings of the MNP/RIVM studies.

> The MNP website contains several dossiers on environmental topics (e.g., large scale air pollution and acidification, biodiversity, energy and energy supply). The dossiers contain information on latest developments, facts and figures, frequently asked questions, policy evaluations, MNP/RIVM publications related to the topic, models, and links to other organisations doing work on this subject.

- For integrated assessment studies (in particular the environmental and nature balances and outlooks), explain the procedures and methods used. Do this, for example, in the ‘reading instructions’ or the introduction to the report.
- If useful, comment on the methods that are *available* and the methods that have been *selected for use* in the assessment. (So that the choices made and the consequences of these choices can be put in the context of available methods.)
- Mention essential steps in the calculation procedure for an indicator in order for the reader to understand how the results for a specific indicator were calculated.
- Provide the underlying reasons for steps in the assessment.
- The writers will be familiar with the topic and with the way of thinking in an environmental assessment study. They may therefore not be explicit about aspects that seem obvious to them. If possible, pre-test the text on members of the audience. What parts of/steps in/way of thinking in the assessment are not obvious to them?

1.2 Main message in which uncertainties are reflected or taken into account.

- Check whether the main messages you want to convey match the interest and needs of the receiver(s) and what they intend to do with the information (II; 2.2 and 2.3)
- Check whether the proposed message can be seen as inconsistent with previous messages. If inconsistency has a reason (for instance, new insights), provide the audiences with a clear explanation. If it has no reason, avoid inconsistency. Formulate the message in such a way that there is no confusion when it is compared to 'old' messages.
- Writing assessment reports is mostly a joint effort involving several people (analysts, team coordinators, supervisors, and communication specialists, and sometimes employees from other institutes.) If there is dissent on the main messages, be aware of processes in which text sections are kept 'vague' or ambiguous on purpose, in order to accommodate all views of those involved. Also be aware of skipping or ignoring issues that involve conflict or moving them to less important sections of the report (for instance, footnotes and appendices).
- If debates in politics and society show persistent misunderstandings regarding specific topics, pay additional attention to messages regarding these topics. (II; 2.2.2; 6)
- Pay extra attention to formulating messages that involve issues related to fright factors or media triggers (II; 2.3; 2).
- Make sure that the message is underpinned by arguments.
- State the essential conclusions in a clear and concise form. For this purpose use can be made of the 'LOOK/SINCE/THUS' rule of thumb in order to express in a few short sentences the essence of the message.

> E.g., LOOK: RIVM has concluded that the costs of medication and medical appliances in the Netherlands will increase with 7 to 11%. SINCE population growth and ageing will lead to a higher demand. Also the potential for custom-made goods will grow and these are often more expensive. THUS additional policy measures are required or politicians should accept that a larger part of the total budget for medical care is spent on these items.

- Be honest and open about what you do not know. Do not make statements that you cannot back to a satisfactory level.
- Aim for policy-relevant conclusions that are robust with respect to the underlying uncertainties (II; 3.3).
- Make sure that the firmness of the conclusion is obvious from the wording used. The formulation should make the reader clear whether he is dealing with a well-founded or a speculative conclusion or something in between. (III; 2.1)
- Pitfall: In situations where the problem or problem definition is barely recognised by important stakeholders, one is tempted to present the results as more certain than they really are.
- Make sure that the conclusion contains an appropriate level of precision in view of the uncertainties and the state of science. If quantitative statements are made: how many significant digits can be used? (III; 2.2)

- When formulating conclusions, uncertainty information can be integrated in the formulation of the knowledge claims made. Another option is to separate the two by presenting the knowledge claim in one sentence and reporting underlying uncertainties in the following sentence(s). The reader can even be referred to a different section in the report where the uncertainty information is provided. In case of separate presentation, there is a risk that only the knowledge claim is used by the readers (including the press), lifted out of its proper context. The uncertainties are then lost in the use of the assessment results. (Note that this mechanism is in some way the reverse of the stretched peer review mechanism discussed in section 2.3). This caution is particularly important in case of outer PDI layers (for example, press releases and summaries of policy advice reports).

> In the sentence 'X is very likely to be related to Y', the knowledge claim that X is related to Y is integrated with the uncertainty information that this relationship is 'very likely'. A separate presentation would be: 'X is related to Y. However, ...[arguments that X is not related to Y]'. In the latter case there is a risk that the audience will only see or use the information that X is related to Y.

- When describing risks, be aware of the framing effects of wording, for example, the use of the expression 'lives lost' versus 'lives saved'.
- Avoid errata in which the contents of the main message are altered. The conclusion may seem less firm to the readers than the original conclusion and the conclusion may seem less credible.

> In the Dutch Environmental Balance 2005 it is concluded that it is *likely* that the Kyoto obligations for greenhouse gas emissions will be met. In an erratum it is explained that several definitions and assumptions in the calculations were changed at a later stage, which resulted in the conclusion that there is a *fifty-fifty* chance of meeting this target. When this information was tested on a group of ten readers, more than half of the group indicated that because of the fact that these alterations took place the main message on the chance of meeting the target seemed less firm to them.

- If possible try to involve matters in the message that are close to the daily (professional) lives of the audiences.

> The finding that climate changes are noticeable in the Netherlands is illustrated in the Dutch Environmental Balance 2005 by showing that the yearly chance of having an 'Elfstedentocht' (a national event in which natural frozen waters are used to skate a route along eleven Dutch cities) has declined over the last decades. The Elfstedentocht is widely known among the Dutch and of considerable cultural significance. It is something people can easily relate to.

1.3 Reporting sorts and types of uncertainties

- Similar to a patient information leaflet accompanying medicines, numbers and conclusions of environmental assessments should come with uncertainty information that puts these statements in their context and gives some clues on how the assessment should and should not be used. Add informative and relevant information on uncertainty to the knowledge statements made.

- Information on the following aspects of uncertainty may be presented in reports[3]:
    - nature of uncertainties
    - magnitude of uncertainties
    - sources of uncertainties
    - statistical uncertainties
    - scenario uncertainties
    - ignorance
    - weak backing/underpinning
    - level of theoretical understanding
    - level of empirical information
    - ability to build a model structure based on state of the art knowledge
    - theoretical knowledge that is lacking
    - empirical data that are lacking
    - degree to which evidence proves something
    - quality of data
    - quality of theoretical insights
    - quality of model structure
    - conflicting scientific evidence
    - scientific controversies
    - societal controversies
    - different interpretations of data, theories, lines of evidence
    - confidence in data, theories, lines of evidence
    - acceptance of data, theories, lines of evidence by experts
    - choices with respect to problem framing
    - controversies with respect to problem framing
    - choices with respect to methods
    - limitations of methods
    - choices with respect to indicators
    - controversies concerning the indicators
    - aspects that were not considered in the study / system boundaries chosen for the analysis
    - points of departure
    - important assumptions
    - practical limitations (e.g., time constraints)
    - legal, moral, societal, institutional, proprietary and situational uncertainties (II; 3.2; 6)

- Make sure that the precision level of the uncertainty information is adapted to the existing scientific understanding. In the following scheme (table 3, Risbey and Kandlikar, 2007), an analyst starts at the top-level. If there is no justification for a full probability density function, he moves down one or more level, until he reaches the level that corresponds with the scientific understanding. One can also start at the bottom level of the table.

[3] This list is not intended to be complete, and lists a sample of partly overlapping issues.

	Measure of likelihood	Justification
1	Full probability density function	Robust, well defended distribution
2	Bounds	Well defended percentile bounds
3	First order estimates	Order of magnitude assessment
4	Expected sign or trend	Well defended trend expectation
5	Ambiguous sign or trend	Equally plausible contrary trend expectations
6	Effective ignorance	Lacking or weakly plausible expectations

Table 3: Characterizations of likelihood for a graduated range of precision levels ranging from fully specified probability distributions through to qualitative declarations of knowledge and ignorance (Risbey and Kandlikar, 2007).

- Besides from which uncertainties actually play a role in the assessment, the uncertainties that should be reported depend on the PDI layer and the information needs of the audiences regarding the topics. In outer PDI layers the uncertainties to be reported are mainly those that may affect the policy advice given, as well as those that are subject to (political and societal) debate, and controversies. Detailed background reports (inner PDI layers) require a systematic account of the uncertainties in the assessment (in order to make the assessment procedures transparent and reproducible). (I; 1)
- Pay additional attention to reporting uncertainties if:
    - they highly influence the policy advice given (II; 3.2)
    - the indicator outcomes are close to a policy goal, threshold or standard set by policy (II; 3.2)
    - the indicator outcomes point to a possibility of morally unacceptable harm or catastrophic events (II; 3.2)
    - being wrong in one direction (of the indicator outcomes) is very different than being wrong in the other when it comes to policy advice (II; 3.2)
    - controversies among stakeholders are involved (II; 3.2)
    - value-laden choices and assumptions are in conflict with stakeholder views and interests (II; 3.2)
    - fright factors/media triggers are involved (II; 2.3; 2)
    - there are persistent misunderstandings among audiences (II; 2.2.2; 6)
    - the audiences are expected to distrust outcomes that point to low risks because the public perception is that the risks are serious (II; 2.3; 3)
    - the audiences are likely to distrust the results due to low or fragile confidence in the researchers or the organisation that performed the assessment (II; 2.3; 4)
- If conflicting scientific information is reported (with arguments for each of the positions), indicate how widely a specific interpretation is supported within the scientific community. If lay persons are confronted with conflicting scientific information they tend to base their position on the reliability and expertise of the scientists, rather than on arguments.
- If a comparison is made between different models or between models and results from measurements, explain the significance and the consequences of this.
- Overexposure or underexposure of uncertainties in the various subjects dealt with in the assessment should be avoided. However, the presentation of uncertainty has to be tuned to the audiences. If the report is written primarily for scientists,

uncertainties throughout the assessment need to be reported consistently. If the report is primarily written for policy related audiences the information has to be tuned to their information needs and should discuss the policy relevance of uncertainties identified. Some uncertainties will be more important for these audiences than others. A seeming imbalance in the presentation of uncertainties may be the result.

> In a detailed background report for scientific audiences on the deposition of the substances X and Y, for both substances the main uncertainties are reported systematically throughout the calculation steps that lead to the conclusions on the deposition (emission, dispersion, atmospheric chemical processes and atmospheric transport). Let us say that the deposition of substance X is near the threshold set by policy and the deposition of Y exceeds the threshold for Y by far. In a report for policy makers the uncertainties in the calculation of the deposition of substance X will be more important than those of substance Y: in the case of Y it is clear to the policy makers that they will have to take policy measures to decrease its deposition. In case of X they have to take the uncertainties of the assessment into account in their decision on whether to take policy measures or not.

- The detail and style of the reported uncertainties depend on the PDI layer.
  - Outer PDI layers:
    - implicit integration of knowledge claims and uncertainty information is acceptable
    - non-technical information
    - avoid use of jargon
    - details only when relevant
    - uncertainties ‘translated’ to the political and societal context
  - Inner PDI layers:
    - separate and explicit treatment of uncertainties
    - technical information
    - use of jargon is acceptable
    - details to achieve good scientific accounting
    - uncertainties reported in a ‘literal’ way (e.g., ranges)
- When reading uncertainty information in a section, readers should be informed on where they can learn more about these uncertainties:
  - Refer to other sections in the report or to other MNP/RIVM reports.
  - State the sources that were used to base the uncertainty information on
  - Point readers to other reports, websites or MNP/RIVM employees that may be of interest to them in view of the uncertainties discussed.
- Make sure that the uncertainty information in the summary, main conclusions, main text, background documents, figures, tables and graphs, etcetera is consistent. That is, that the content of the uncertainties in these sections are not in contradiction to each other (they may be formulated differently, but they should tell the same story).
- Strive for a consistent way of communicating uncertainties regarding different topics within one report and for a consistent treatment across reports and PDI layers. The latter is especially important for integral studies, where conceptual harmonisation and consistency is desirable to avoid misunderstandings.

– Place the main uncertainties in those sections of the report that the audiences generally spend the most reading time on: the summary, introduction and conclusion and recommendation chapter (I; 2.2).
– If uncertainties play a major role in a topic and the topic is 'hot' in politics and/or society, consider publishing a separate 'facts and uncertainties report', providing an overview of the state of the art knowledge on the subject.

> Because of political developments and as a result of MNP/RIVM communication on the subject of Particulate Matter (PM), in 2005 there was a lot of political and media attention to this subject. The debates showed considerable confusion on the facts and uncertainties on PM. The MNP published a new report ('Fijn stof nader bekeken/A closer look at PM'). It contained no new information, but provided an overview of 'what we know for sure about PM', 'what the uncertainties are regarding PM' and 'where to go from here'.

- Uncertainty information may be presented in a separate section (for example, in a text box or appendix). As parts of the audience will not read these separate information sections, make sure that this information is not absolutely needed to interpret the statements in the main text correctly.
- Include a glossary on uncertainty terms used. Refer to the glossary (for example, by printing terms in the main text that can be found in the glossary in italics).

1.4 How uncertainty was dealt with in the analysis

- Indicate explicitly how uncertainty is dealt with, without arousing false expectations. Indicate how and why scenarios were used. Indicate how ignorance and controversies were dealt with.
- Indicate, if applicable, how stakeholders and stakeholder views were involved in the management of uncertainties.
- If outcomes of quantitative uncertainty analysis are presented, make very clear what uncertainties were included and what uncertainties were excluded from the analysis and why.
- Indicate how uncertainty is communicated in the report. For example, are scales being used to communicate uncertainties (see part III; section 2)? If detailed information on uncertainty is provided in separate sections (for example, box texts, appendices), explain this to the reader, and clearly indicate the relation of these separate texts to the main text.
– If applicable, explicitly include in (external) reviews the issue of how uncertainty was managed in the assessment. Explicitly adding the issue of uncertainty management as a criterion to be addressed in external review is particularly advisable in cases where there are many uncertainties, and stakeholders or policy makers are prone to exhibit resistance to accepting the outcomes of the assessment as a basis for decision making. When an external review by independent experts shows that – in view of the current knowledge on the topic – the uncertainties were treated in a correct manner, the credibility and acceptance of the assessment results may be increased. Include a reaction of the MNP/RIVM to the review findings.

The Dutch manure policy has had a great impact on the agricultural sector in the Netherlands. Farmers had to make a considerable effort to comply to the rules and regulations and a part of the businesses experienced financial problems and had to shut down. However, despite all efforts, after studying this topic, the RIVM had to conclude that the policy goals were still not going to be met and that more had to be done. This is a message that will meet with a lot of resistance from the agricultural sector, and will lead to heavy criticism on the studies. The RIVM commissioned an independent review of their study by a number of renowned scientists from several Dutch universities and institutes. In the RIVM report evaluating the Dutch manure policy ('Mineralen beter geregeld. Evaluatie van de werking van de Meststoffenwet 1998 – 2003') the findings of this scientific committee was included in an appendix. The committee addressed the following questions:

- Are the research methods used accepted and state of the art?
- Are the data used the best available data?
- Are there any caveats in the studies that can still be addressed?
- Are there any caveats in the studies that can only be addressed through further long term research?
- Are the conclusions scientifically sound, and are the conclusions sufficiently backed by the facts presented and the analysis of these facts?
- Have the analyses been correctly and fully conducted in relation to the conclusions?
- Has sufficient attention been paid to uncertainties?

Also included in the report was a reaction of the RIVM on the findings of the committee.

1.5 Implications of uncertainties

– Uncertainties in assessments (including choices made and assumptions used) have implications for the meaning and scope of applicability of the assessment results and the representativeness of the results and conclusions. In reports mainly intended for scientific audiences (inner PDI layers), this is usually extensively discussed in the discussion section as part of good scientific practice. In outer PDI layers the implications of the uncertainties for the policy process and decisions need to be at the centre of attention. A translation has to be made of the value and representativeness of the results to the policy context. (I; 1)
– Make clear what the uncertainties imply for the main policy relevant conclusions. How robust are the conclusions in view of the choices made, the assumptions used, and the uncertainties in data, models, and other knowledge used? (II; 3.3)
– Often, uncertainty analysis is partial and includes for instance parameter uncertainty and no model structure uncertainty. Use the Uncertainty Matrix (see Appendix I of the Quickscan Hints & Actions List) to identify and make explicit types and sources of uncertainty that were not systematically addressed. Reflect on how results might be different if those types and sources of uncertainty that were not systematically addressed in the analysis so far, would have been analysed systematically.

Sometimes uncertainties that are not included in the analysis can be essential for the resulting policy conclusion. An example in the graph below (figure 2, taken form Saltelli et al. 2000) illustrates that the uncertainty regarding the choice of indicators can dominate the uncertainty in the data. If only Eurostat indicators were used to address the policy question whether landfill or incineration of waste is preferred, we see that despite significant uncertainty (the distribution has a large spread) the outcomes clearly favour the landfill option. However, if an other set of indicators is selected (here the Finish indicators) and the analysis is re-done with exactly the same data and the same assumptions for the data uncertainties, the outcome is the other way around and clearly favours incineration. This indicator-choice uncertainty is highly policy relevant but often ignored in practice.

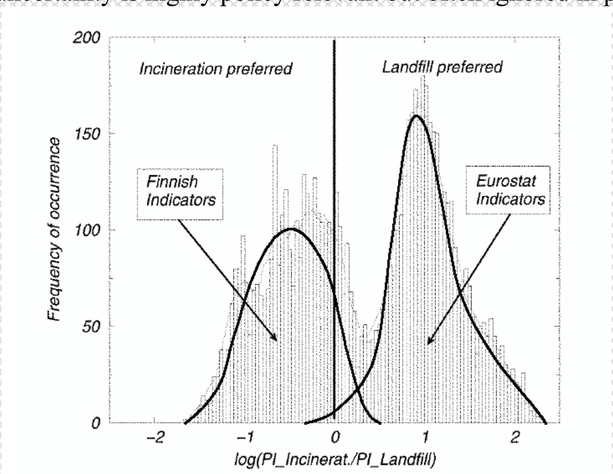


Figure 2: Results of an uncertainty analysis of an overall "pressure to decision index" (*PI*) for two options for waste treatment. The right-hand distribution shows the results when using Eurostat indicators, the left hand distribution shows the outcome when a Finish set of indicators is used instead. (For details, see chapter 20 of Saltelli et al, 2000)

- Reviewing the recognised ignorance regarding the issue at hand, to what extent do politicians need to anticipate the possibility of significant changes in insights on the issue (for example, safety or risk of a technology) in the near future?

In case of the BSE case, the Institute of Science in Society and Save British Science argued that:
"*if the Government's position on BSE up to 1996 had reflected more accurately the uncertainty of the underlying science, both the public and the authorities would have been better prepared for the shift in scientific consensus which prompted the notorious change of policy (ISIS p 339, SBS p 399)* "
In: Science and Technology - Third Report. House of Lords. 2000.

- Indicate potential consequences of the uncertainties for dealing with the problem at hand. What are consequences for policy, politics and society? What are implications of the uncertainties for different risk management strategies? (II; 3.3; 5 and 6)
- Is it conceivable that the answer(s) or conclusion(s) would have been different if aspects that have not been dealt with in the research questions or method had been included?
- Indicate what would happen if reality departs from assumptions made in the assessment.

1.6 What can be done about uncertainties

– Indicate – in outer PDI layers if considered policy relevant – what can be done about the uncertainties in the assessment. Indicate which uncertainties are reducible and how, and which ones are not (and therefore should be considered as inevitable). (II; 3.1; 5 and II; 3.1; 6)
– Indicate which uncertainty aspects deserve additional attention in the future in view of obtaining insights for the policy problem at hand. This will facilitate the assignment of priorities for future research.
- Indicate whether something can be done about the bottlenecks in the knowledge base. In some cases little can be done about ignorance or a lack of knowledge (think of, for example, the unpredictability of the daily weather more than two weeks ahead), in some other cases it is a matter of collecting more data and information or conducting further research. In the latter case, typically a trade-off will be involved between the costs and efforts of this task and the benefits which are expected to result from it.

1.7 Educational information on uncertainty

– For audiences that are not used to dealing with scientific uncertainties, educational information may be useful. This information could, for instance, be included in an appendix of a report. It should be noted, however, that not many people will read information in appendices. Especially if the appendices are not directly related to the topic of interest.
– Explain that there are different aspects to and dimensions of uncertainties (location of uncertainty, level of uncertainty, etcetera; see Appendix A of the detailed Guidance or Appendix I of the Quickscan Hints & Actions List).
– Explain that a 'high-quality' assessment does not imply low uncertainty, and, vice versa, that high uncertainty does not imply that the assessment is of poor quality.
– Explain that science has its limitations when dealing with complex (societal) problems where there are many system uncertainties, and where facts and values are intertwined.
– Explain that some uncertainties are irreducible. Explain that further investigating complex problems may bring forward more new uncertainties than that it succeeds in reducing existing uncertainties.
– Explain that insights from assessments are not static. Especially where recognised ignorance prevails, insights may change over time as new information becomes available. This is especially the case in fields of knowledge that are rapidly progressing.
– Pay attention to an explanation of specific types of uncertainties related to a topic. (For instance, on the topic of emissions, explain that a distinction can be made between monitoring uncertainty ('diagnosis') and uncertainty regarding future emissions ('prognosis'))
– Explain that a statement on the probability of an event (for example, meeting a policy goal) does not provide any information on what the quality and subsequently the reliability of this estimate is.

In the Dutch Environmental Balance 2005, the following is stated: 'With the planned policies, the Netherlands will very probably not meet the obligations of the NEC-emission ceilings for sulfur dioxide and will probably not meet those for nitrogen dioxide'. This information was tested in the Utrecht Policy Laboratory on a group of readers. They were asked to indicate whether they agree with the following statement: 'We are better able to estimate whether the NEC-emission ceiling of sulfur dioxide will be met, than whether the NEC-emission ceiling of nitrogen dioxide will be met.' 4 out of the group of 9 readers indicated correctly that this cannot be determined based on the information statement. 1 person disagreed with the statement and 4 persons agreed. A likely explanation for this is that the persons who agreed on the statement think that 'very probable' points to a more reliable estimate than 'probable'. However, in the text no information was provided with respect to the quality and reliability of the estimate.

2. Reporting uncertainty information – Forms of presentation

Uncertainty information can be presented in a linguistic, graphic or numeric way. All three forms have their advantages and disadvantages. In the following sections these will be discussed, together with hints and tips on how to present uncertainty information with the use of words, graphs or numbers. Section 2.1 deals with verbal expressions of uncertainty information, section 2.2 with numeric expressions and section 2.3 with graphical expressions. Finally, in section 2.4 several remarks are made with respect to expressing uncertainty using multiple presentation forms.

2.1 Verbal expressions of uncertainty information

Advantages and disadvantages

- Most readers are better at hearing, using and remembering uncertainty and risk information in words than in numbers.
- Words can better be adapted to the level of understanding of lay audiences. Many levels of simplification are available. However, in the simplification nuances of uncertainty information may get lost, and the information may be oversimplified.
- The use of qualitative expressions will typically lead to different interpretations by different people and/or in different settings. Uncertainty statements can therefore be understood differently.

An extreme case of different interpretations by different people is the word ‘possible’. In a study in which people were asked to indicate the probability that is expressed by this word the answers may range from circa 0 to circa 1 (figure 3).

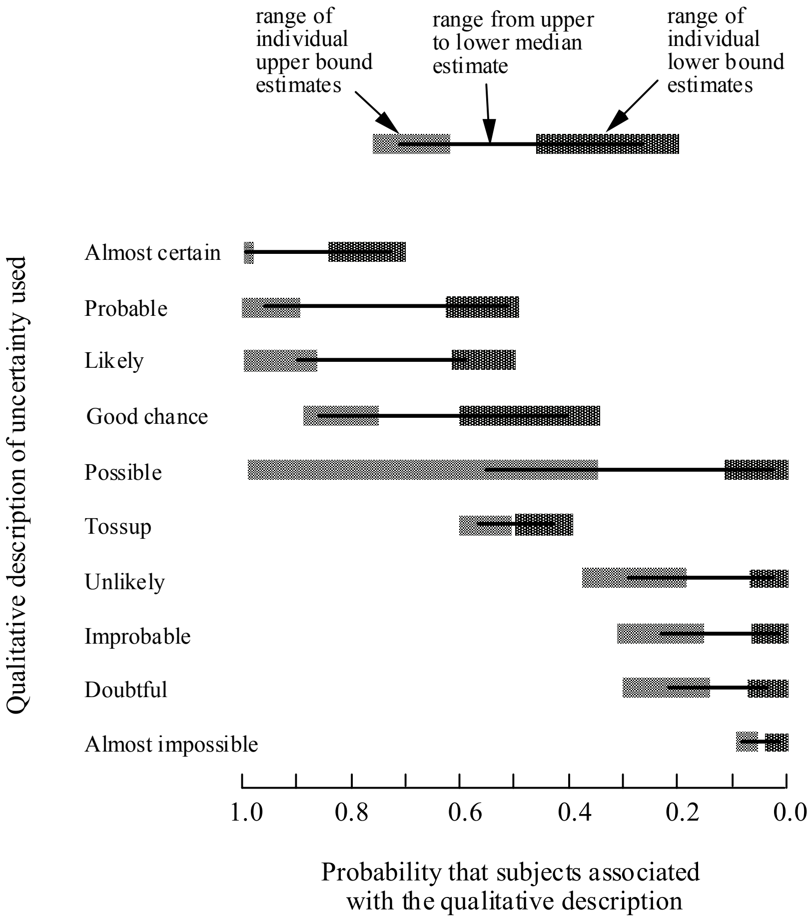


Figure 3: Words have different meanings for different people. Figure from Granger Morgan (2003), adapted from Wallsten et al., 1986.

- There is a risk that normative opinions of the writers enter verbal statements. The numeric information ‘200 animals/year killed by traffic’ may be reported verbally as ‘A large number of animals is killed per year by traffic’. However, different readers may hold varying opinions on whether a number of 200 is large or actually small. The writer can accentuate his opinion even more by formulating the verbal statement as: ‘A great number of animals is killed by traffic *each* year’.

Constructing verbal expressions

- Pitfall: if several people or institutes are involved in writing a report, all of them have to agree on the final text. If there are disagreements on topics, this may (consciously or unconsciously) lead to the use of vague formulations in which several points of view are accommodated at the same time, without making the disagreement explicit
- Avoid using ambiguous language.

– Readers feel that words that appear frequently in a text must be important. They tend to see this as important information for basing their conclusions on. Use therefore the same expressions for important returning uncertainty information.
– Many words and expressions of common language can be used to express uncertainties:
    - ‘uncertainty wording’ (such as ‘likely’, ‘probably’, ‘not certain’)
    - auxiliary verbs (such as ‘may’, ‘might’ ‘seem’)
    - statements that indicate the status of the study (‘preliminary findings’, ‘as a first approximation’, ‘further research is needed’, ‘based on current insights’)
    - statements regarding the scientific consensus concerning a claim (‘there is considerable trust in [claim]’, ‘many scientists consider [claim]’, ‘it is widely held that [claim]’)
    - if – then constructions (‘if we may assume [assumption], then [claim]’)
    - constructions with conjunctions (‘however’, ‘although’; [statement], however [uncertainty]; Example: "*To the best of our knowledge* it is likely that we will meet the Kyoto target without additional policies, *however*, our knowledge is limited by .... and *that implies that* .....")
– Make sure that the wording that is used is not contradicting the numbers. Compare the relationships between numbers and words for different topics, and aim for consistency in their use.
– Add quantitative statements to the linguistic description if they make sense and are feasible, and if they indeed have added value.
– Use scales or classifications to describe uncertainties. In this case also, everyday language is used, but the words used are clearly defined in the text. A fixed scale’s (fixing probability terms to chance intervals) consistent use of language makes it easier to remember and consistent messages are perceived as more credible. It also enables readers to make comparisons between topics. Be aware of the fact that readers may not consult the section (for instance an appendix or a footnote) in which the scale or classification is clearly defined.
– Table 4: a scale for expressing probability in linguistic terms (as used in the Environmental Balance 2005; in Dutch):

Dutch term:	**English synonym (IPCC)**	**Likelihood:**	**Colour code tables**
Nagenoeg zeker	Virtually certain	>99%	green
Zeer waarschijnlijk	Very likely	90% – 99%	green
Waarschijnlijk	Likely	66% – 90%	green
Fifty-fifty; circa 50%	About as likely as not (new) Medium likelihood (old)	33% – 66%	yellow
Onwaarschijnlijk	Unlikely	10% – 33%	red
Zeer onwaarschijnlijk	Very unlikely	1% – 10%	red
Nagenoeg uitgesloten	Exceptionally unlikely	<1%	red

Table 4. Example of ‘Verbal’: IPCC’s ‘likelihood scale’ (IPCC, 2005) as used in the Environmental Balance 2005

Linguistic scales can not only be used to express uncertainty on the probability of events. Linguistic scales can also be used for making statements on, for example, the evidence or to describe the level of understanding. Examples from the literature are given in table 5 and figure 4 below.

Level	Legal standard
11	virtually certain
10	'beyond a reasonable doubt'
9	'clear and convincing evidence'
8	'clear showing'
7	'substantial and credible evidence'
6	'preponderance of the evidence'
5	'clear indication'
4	'probable cause'/'reasonable belief'
3	'reasonable indication'
2	'reasonable, articulable grounds for suspicion'
1	'no reasonable grounds for suspicion'/'inchoate hunch'/'fanciful conjecture'
0	Insufficient even to support a hunch or conjecture

Table 5: A scale for scientific certainty based on legally defined standards of proof (Weiss, 2006)

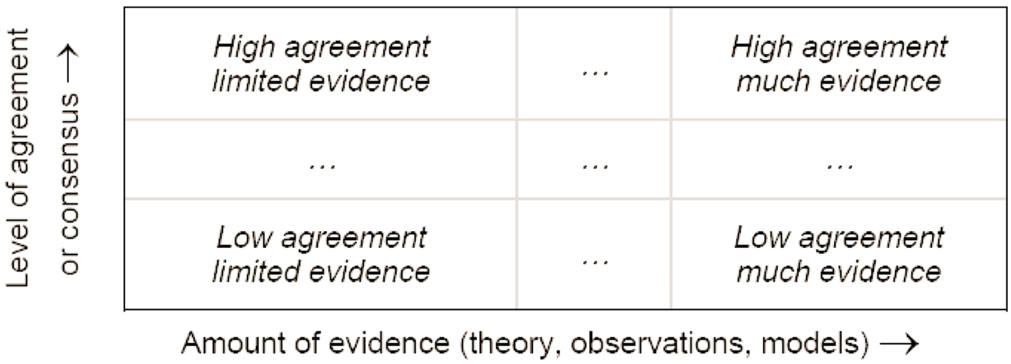


Figure 4: a scale for assessing the "qualitatively defined levels of understanding" (IPCC, 2005)

- A disadvantage of a fixed scale is that it doesn't match people's intuitive use of probability language. People translate such language taking the event magnitude (severity of effects) into account, which may result in an overestimation of the probability of low magnitude events and an underestimation of the probability of high magnitude events, when a fixed scale is used for communication. Problems appear to be most pronounced when dealing with predictions of one-time events, where probability estimates result from a lack of complete confidence in the predictive models. In general, the context of an issue influences the interpretation and choice of uncertainty terms.(Patt and Schrag, 2003; Patt and Dessai, 2005)
- Another issue of the use of scales is that they privilege attention to quantifiable and probabilistic uncertainty. It is much harder to address 'deep uncertainty' (e.g., problem framing uncertainty, methodological unreliability or recognised ignorance).

– Try to avoid using words that are part of the 'uncertainty vocabulary' in sections were information is given where the vocabulary is not specifically meant for. Use other words instead to prevent confusion.

> In the Dutch Environmental Balance 2005 probability intervals were used, which were indicated by names such as 'Virtually certain', 'Likely', 'Unlikely'. In the section on ammonia emissions a recent study with new insights is mentioned. 'If this study turns out to be representative, it becomes less likely that the (...) target in 2010 will be met.' By using the term 'likely' readers may associate and confuse this information with the probability intervals. An alternative would be for instance: 'chances that the target will be met will become lower'.

2.2 Numeric expressions of uncertainty information

Advantages and disadvantages

– Numbers are more specific than words. Provided that the readers understand the way in which the numeric information is presented (for example, if they know what a confidence interval is, and know how to interpret this), interpretation differences between individuals will be smaller than when the information was conveyed in a verbal way.
– If information is only presented in numbers, some of the readers will translate this information into verbal expressions (either for themselves or when communicating the information to other people). If this 'translation' is done incorrectly, this will lead to miscommunication.
– Numbers are prone to the pitfalls of suggesting unwarranted precision if used without mastering basic "craft skills with numbers" (Funtowicz and Ravetz, 1990).

Constructing numeric expressions

– When presenting numbers in inner PDI layers: indicate why the presented numer is of importance (state the significance of the number, compare it to other numbers, if applicable).
– Avoid pseudo precision and pseudo imprecision. Pseudo-imprecision occurs when results have been expressed so vaguely that they are effectively immune from refutation and criticism. Pseudo precision is false precision that occurs when the precision associated with the representation of a number or finding grossly exceeds the precision that is warranted by closer inspection of the underlying uncertainties.

> The following joke illustrates an incorrect use of precision level (Funtowicz and Ravetz, 1990): A museum visitor asks a museum attendant how old the dinosaur bone is which is on display. 'It is fifty million and twelve years old.', replies the museum employee. 'Really?', is the surprised reaction of the visitor. 'How can you be this precise?' 'Well', says the employee, 'When I started working here this fossil was 50,000,000 years old. And I have been working here for twelve years now'.

– The number of significant digits used and the use of zeroes should be tuned to the uncertainties when numbers are presented. See Box 3.

Box 3: Significant digits and the ambiguity of zeroes in numbers

In a tutorial the Department of Physics of the University of Guelph summarize good practice in the use of significant digits and zeroes:

General rule:
When reporting a number, the last significant digit should usually be of the same order of magnitude (that is: should be in the same decimal position) as the error bar.

In reported numbers, when are Digits Significant?
Provided that numbers are reported with correct use of the rule for significant digits, non-zero digits are always significant. Thus, 22 has two significant digits, and 22.3 has three significant digits.

With zeroes, the situation is more complicated:
1. Zeroes placed before other digits are not significant; 0.046 has two significant digits.
2. Zeroes placed between other digits are always significant; 4009 kg has four significant digits.
3. Zeroes placed after other digits but behind a decimal point are significant; 7.90 has three significant digits.
4. Zeroes at the end of a number are significant only if they are behind a decimal point as in (c). Otherwise, it is impossible to tell if they are significant. For example, in the number 8200, it is not clear if the zeroes are significant or whether they are fillers. The number of significant digits in 8200 is at least two, but could be three or four. To avoid ambiguity, use scientific notation to place significant zeroes behind a decimal point:

8.200×10^3 has four significant digits
8.20×10^3 has three significant digits
8.2×10^3 has two significant digits

Significant Digits in Multiplication, Division, Trig. functions, etc.
In a calculation involving multiplication, division, trigonometric functions, etc., the number of significant digits in an answer should equal the least number of significant digits in any one of the numbers being multiplied, divided etc.

Thus in evaluating sin(kx), where $k = 0.097\ m^{-1}$ (two significant digits) and x = 4.73 m (three significant digits), the answer should have two significant digits.

Note that whole numbers have essentially an unlimited number of significant digits. As an example, if a hair dryer uses 1.2 kW of power, then 2 identical hairdryers use 2.4 kW:

1.2 kW {2 sig. dig.} x 2 {unlimited sig. dig.} = 2.4 kW {2 sig. dig.}

Significant Digits in Addition and Subtraction
When quantities are being added or subtracted, the number of decimal places (not significant digits) in the answer should be the same as the least number of decimal places in any of the numbers being added or subtracted.

Example:

5.67 J (two decimal places)
1.1 J (one decimal place)
<u>0.9378 J</u> (four decimal place)
7.7 J (one decimal place)

Keep One Extra Digit in Intermediate Answers
When doing multi-step calculations, keep at least one more significant digit in intermediate results than needed in your final answer.

For instance, if a final answer requires two significant digits, then carry at least three significant digits in calculations. If you round-off all your intermediate answers to only two digits, you are discarding the information contained in the third digit, and as a result the second digit in your final answer might be incorrect. (This phenomenon is known as "round-off error.")

The Two Greatest Sins Regarding Significant Digits
1. Writing more digits in an answer (intermediate or final) than justified by the number of digits in the data.
2. Rounding-off, say, to two digits in an intermediate answer, and then writing three digits in the final answer.

Source: http://www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm

- When presenting ranges, clearly specify what they refer to (for instance, min/max, 95% confidence interval, plus or minus two standard deviations, 'what-if' results, etc.).
- Indicate what aspects of uncertainty are taken into account in a reported uncertainty range. If, for example, there is an uncertainty of 2% regarding greenhouse gas emissions in a specific year in the future, indicate whether monitoring uncertainty, prognosis uncertainty and/or trend uncertainty are taken into account, and whether parameter uncertainty and/or model structural uncertainty and/or model completeness uncertainty were included in the calculation of the range. If some were left out, be explicit about that and explain why this was done.

In appendix 3 of the Dutch Environmental Balance 2005 the uncertainties regarding the emission projections of the report are explained. It is explained that for greenhouse gases the monitoring uncertainty is neglected, because this uncertainty is assumed to be of equal magnitude for the first year of analysis and the target year. For other substances, the policy targets are absolute. Therefore, in these cases the monitoring uncertainty has been taken into account. This section is clear on what uncertainty was taken into account in the analyses. However, when this information was tested on a number of lay readers, this uncertainty information did not turn out to be clear to them. Only after it was explained to the readers (additional to the text) that the way in which the policy targets were formulated was the cause of this difference (explanation *why* the uncertainties were taken into account differently) they understood the explanation. (In case of greenhouse gases there is a *relative* policy target. Uncertainty regarding measurements were assumed to be irrelevant, since in absolute terms they were assumed to be roughly the same magnitude in both the first year of analysis and in the target year. If the policy target is formulated in an *absolute* way, both monitoring and prognosis uncertainty matter, since they both quantitatively influence the emission projections for the target year.)

- If probability information is presented, indicate whether these are frequentist (probabilities that can be measured) or Bayesian probabilities (probability/reliability as estimated by experts).
- If probability information is presented, be aware of possible distorting effects in the readers' interpretation: forgetting baseline probabilities, biases due to availability, confirmation and overconfidence. In general, formulation in terms of frequencies (e.g., 1 in 1000) instead of percentages is less prone to distorting effects. (see I; 2.4).

2.3 Graphical expressions of uncertainty information

Advantages and disadvantages

– Graphics allows a lot of information to be conveniently summarised. However, many graphical expressions of uncertainty are not straightforward to understand. The reader is required to spend time in retrieving the uncertainty information in the figure, and – if the method of representation is new to him – has to spend time in understanding the method of representation.
– Since conclusions are not stated explicitly in figures (they may be stated in the main text), figures are 'inviting' readers to draw conclusions based on what they see. If they do not adequately study the figure (for example, do not take the time to look at the scale used) or if they lack the ability to interpret the information in the figure (for example, because they are not familiar with error bars), they may draw incorrect conclusions. They may even extract information from the figure that is not displayed. The crucial point is how to set-up and present your figures such that misinterpretations are prevented as much as possible.
– Text alone in a report may come across as boring and tedious to readers. Readers will appreciate a variety in forms of presentation. When presenting various forms one should take care that the implied messages are consistent.

Constructing graphical expressions

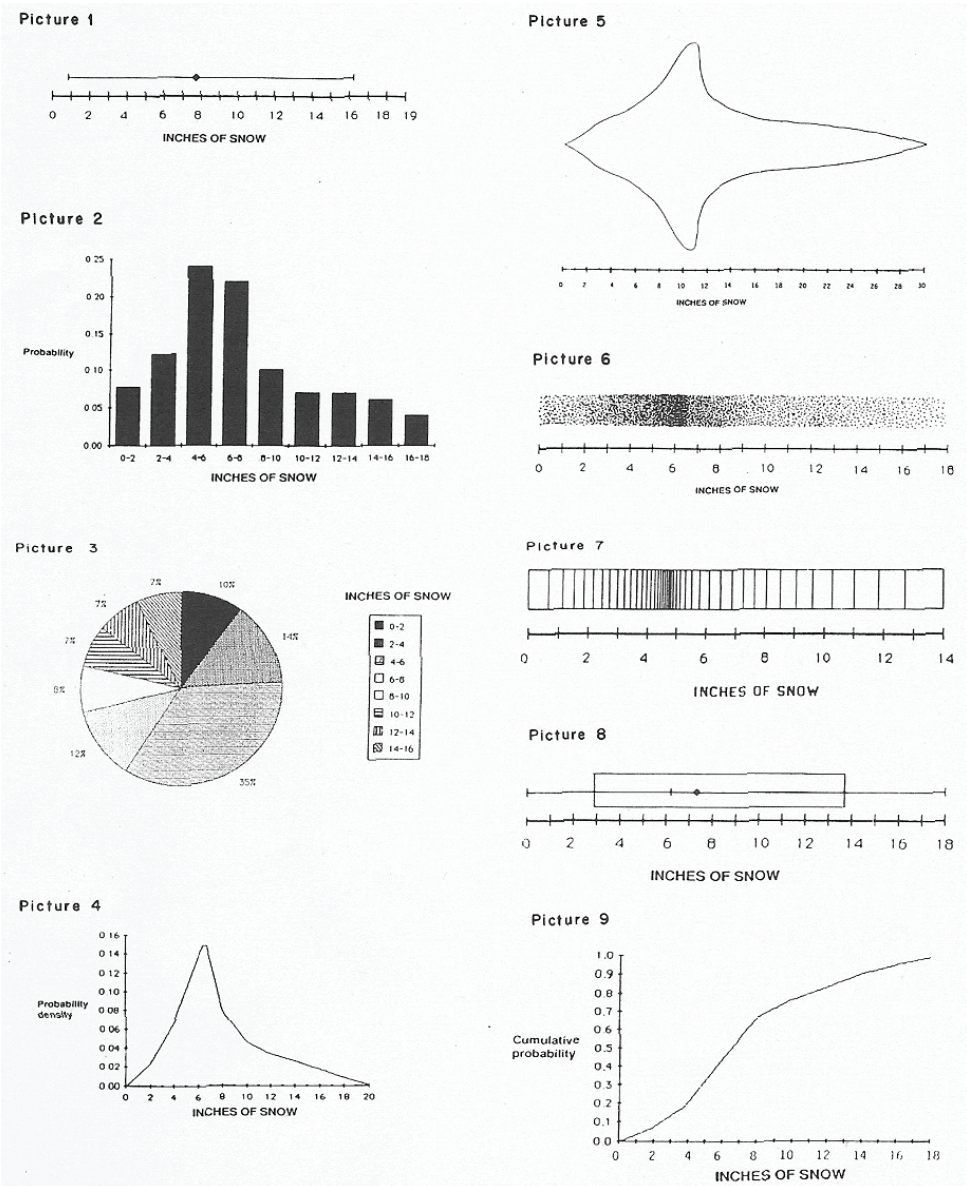


Figure 5: a few examples of graphical presentations of uncertainty (Ibrekk and Morgan, 1987 cited in: Morgan and Henrion, 1990)

1. Traditional point estimate with an "error bar" that spans a 95% confidence interval
2. Bar chart (discretised version of the density function)
3. Pie chart (discretised version of the density function)
4. Conventional probability density function (PDF)
5. Probability density function of half its regular height together with its mirror image
6. Horizontal bars of constant width that have been shaded to display probability density using dots
7. Horizontal bars of constant width that have been shaded to display probability density using vertical lines
8. Tukey box modified to indicate the mean with a solid point
9. Conventional cumulative distribution function (CDF), the integral of the PDF.

- Figure 5 lists a number of ways to graphically represent probability information. What method of graphical presentation (for example, Probability Density Function (PDF), Cumulative Density Function (CDF), Tukey Box Plot, or pie chart) is most suitable in a situation, depends mainly on the information the writer wants the readers to extract (for example, 95% confidence interval, the mean). Make sure that the information you want to convey is marked explicitly in the graph. For example, if people are asked to estimate the 'best estimate' based on a figure, explicitly mark the mean. People tend to select the mode, if the mean is not indicated. (Ibrekk and Morgan, 1987)

PDF and CDF

A Probability Density Function represents the relative likelihood with which values of a variable may be obtained. In a graph, it has the values that variable may obtain on the X-axis and the relative probability on the Y axis. It can be understood as a histogram with infinitesimal intervals.
In mathematical terms, a Probability Density Function (PDF) is any function f(*x*) that describes the probability density of the distribution of variable *x* such that

$$\int_a^b f(x)\,dx = \Pr[a \le X \le b]$$

It is non- negative for all real *x*. The integral of the function is one. Unlike error bars, which only give a range in which the solution should fall, PDF's attach a likelihood to each possible value. The probability density function can be integrated to obtain the probability that the random variable takes a value in a given interval *a* to *b*.

A Cumulative Density Function (CDF) shows the same information but with on the Y-axis the cumulative probability that the true value (or sampled value) of the variable is smaller or equal to *x*. In fact, a CDF is the mathematically integrated version of a PDF.

- A CDF alone does not seem to be effective methods for communication. A CDF with a PDF plotted directly above it (with the same horizontal scale and with the location of the mean clearly indicated on both curves) seems to be a good approach for displaying probability information. (Ibrekk and Morgan, 1987)
- Clearly indicate what the depicted uncertainty represents, which types of uncertainties are displayed, and what is being compared and the significance and consequences of this.
- Do not include too many different aspects in one figure. If possible, distribute the information over two figures (for example, one figure concerning developments in the past and one with developments in the future)
- Pay attention to the scale. The magnitude of uncertainty should be easy to read in the figure. Avoid that a different order of magnitude is suggested by the scale.
- Pitfall: especially when writers have been working with a specific type of figures for many years, it is hard to imagine that they may not be clear to some of the readers. Test the figures on a few members of the intended audiences, especially on those who are not familiar with the figures.
- Be aware of the fact that readers may extract information from figures that is not even displayed in it. If there is a risk of this happening, state clearly in the text what the figure does *not* show.

The figure presented below indicates the effect of policy measures on emissions in the past and indicates what effects are to be expected in the future.

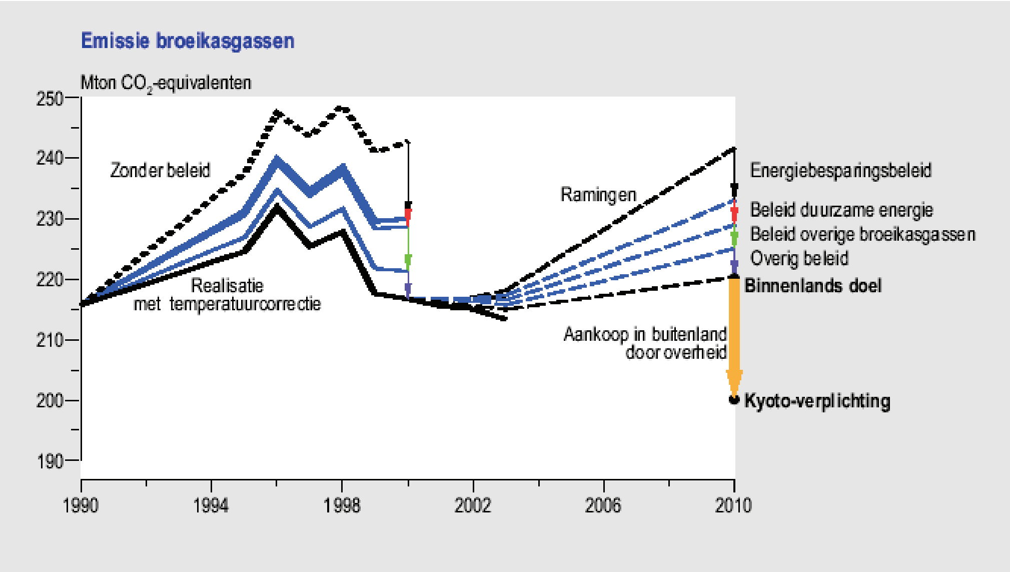
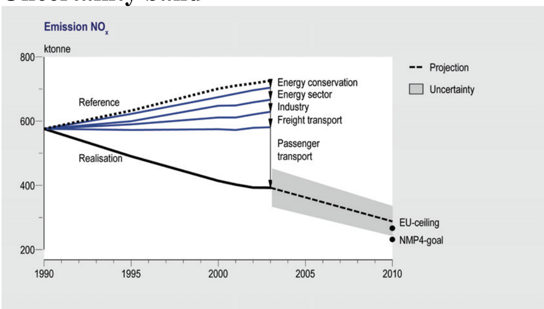


Figure 5: The effects of Dutch policy and the purchase of emission reduction abroad on reaching the Kyoto-obligation. (source: Erratum Environmental Balance 2005: Greenhouse gas emissions, 2005)

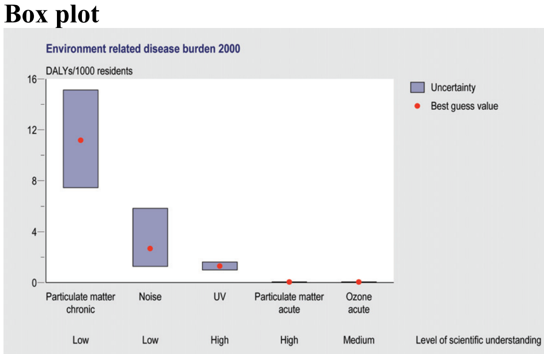
Because the figure already contains a lot of information (or even too much information), it was decided in the writing phase of the report to omit the uncertainty bands. However, when lay readers were asked in a test-situation how they would characterise the uncertainty regarding the emissions in the year 2010 (based on this figure only) only 2 of the 9 readers indicated correctly that this could not be based on the information of the graph. The answers given by the other readers showed a large spectrum of opinions: 1 person answered the uncertainty was small, 2 that is was not small/not large, 2 that it was large, and 2 that is was very large. (The answers they could choose from were: very small; small; not small/not large; large; very large; cannot be determined based on this information; I do not know).

- Be aware of the fact that some elements in figures may be suggestive, such as magnitudes of surfaces, colors, scales etc.
- Besides the construction that uncertainty information is ‘added’ to figures depicting results, figures can also be used to display solely the uncertainties. These kind of representations are not necessarily complex, but the readers do need extra information on what is being displayed in figures like these. It requires them to think on a different, more abstract level. Examples of such representations are given in figure 6.

Uncertainty band

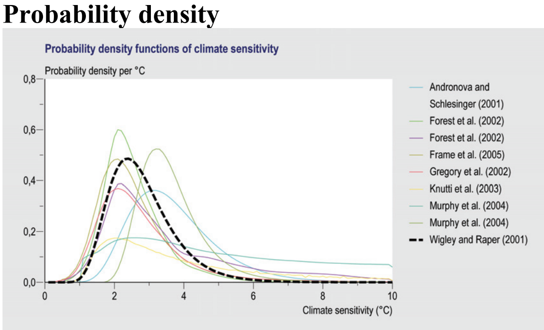


Box plot

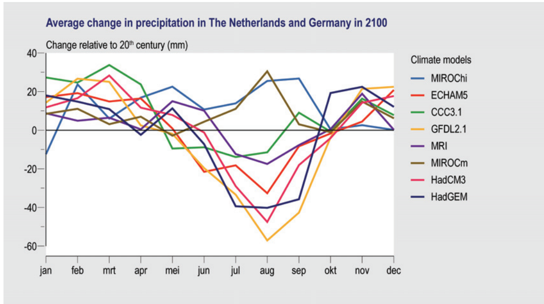


Uncertainty band and box plot (both uncertainty ranges) are commonly-used graphical forms. Easy and suitable for a non-technical public.

Probability density

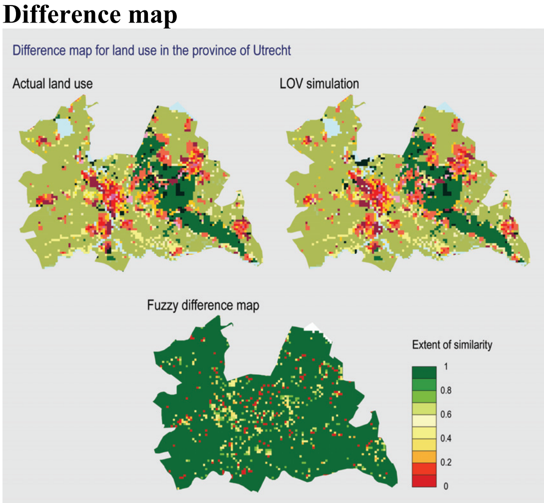


Multi-model ensemble

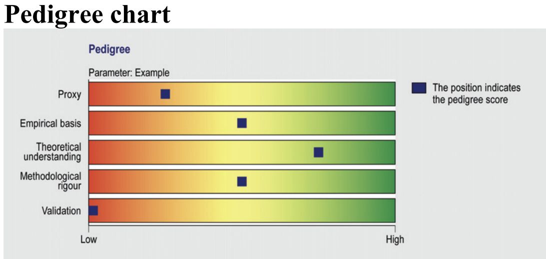


Probability density functions and multi-model ensembles are more difficult to understand. Additional information is required about the meaning of the figure and, in particular, about the implications/implications of the differences between model results.

Difference map



Pedigree chart



Technically speaking, specialised figures such as a difference map (indicates spatial uncertainty, see Visser et al, 2005) and pedigree chart (indicates 'level of underpinning' of a topic; see Wardekker and Van der Sluijs 2006c) are not necessarily complex, but they do require additional information about what the figure actually represents.

Figure 6: Several examples of graphics intended specifically for depicting uncertainty

2.4 Combinations for expressing uncertainty information

Uncertainties can be reported in verbal, numeric and graphical form simultaneously: in this case the text of a specific section describes the uncertainties using language, but also includes numbers, and the section contains a figure in which the uncertainties are graphically displayed. This may have the following advantages:

- The repetition may result in a better understanding of the uncertainty, since it is explained in different ways
- Since a description of the uncertainties occurs at several locations in a specific section of the report, chances are higher that the reader will notice this information
- Users may have preferences for a specific form of presentation: he may browse through the report and mainly pay attention to the figures or, for instance, scan the text for numbers. If the uncertainty information is reported in all three forms, readers who mainly pay attention to one of these forms will not miss uncertainty information that is only reported in the presentation forms he does not pay attention to.

Presenting the uncertainty information in several presentation forms will require more space in the sections of the report where the topic is discussed and requires consistency in the messages displayed.

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