RIVM/MNP Guidance for Uncertainty Assessment and Communication

Quickscan Hints & Actions List

Peter H. M. Janssen, Arthur C. Petersen, Jeroen P. van der Sluijs, James S. Risbey and Jerome R. Ravetz

Contents

This brochure contains the *Quickscan Hints & Actions List* of the *RIVM/MNP Guidance for Uncertainty Assessment and Communication*. The Guidance has been developed under the direction of Peter Janssen (RIVM/MNP) and Jeroen van der Sluijs (Utrecht University) as part of the strategic research project 'Uncertainty Analysis' (S/550002) at RIVM.

The following volumes are currently scheduled for publication in the *RIVM/MNP Guidance for Uncertainty Assessment and Communication Series*:

1. *Mini-Checklist & Quickscan Questionnaire*, A. C. Petersen, P. H. M. Janssen, J. P. van der Sluijs *et al.*, RIVM/MNP, 2003
2. *Quickscan Hints & Actions List*, P. H. M. Janssen, A. C. Petersen, J. P. van der Sluijs *et al.*, RIVM/MNP, 2003
3. *Detailed Guidance*, J. P. van der Sluijs, J. S. Risbey *et al.*, Utrecht University, 2003 (to be published in the summer)
4. *Tool Catalogue for Uncertainty Assessment*, J. P. van der Sluijs, J. S. Risbey *et al.*, Utrecht University, 2003 (to be published in the summer)

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Instructions for Using the Quickscan Hints & Actions List

- The *Quickscan Hints & Actions List* is linked to the *Quickscan Questionnaire*, and renders (optionally) a number of specific recommendations related to the various questions listed in the *Quickscan Questionnaire*.

- These recommendations are presented in the first column of the tables below.

- The second column in these tables ('More details in') refers to specific parts of the *Detailed Guidance*, which the user can optionally consult for further elaboration. The *Detailed Guidance* is available as a report published by the Copernicus Institute for Sustainable Development and Innovation, Utrecht University (available from www.nusap.net).

- In the last column ('Priority') the user can indicate, e.g., by means of a marker, whether a specific hi nt/action is considered useful, and if so, assign a priority to it (L: low; M: middle; H: high). After completion of the list, it can be seen at a glance which priority actions are deemed necessary.

- At some places reference is made to the *Tool Catalogue for Uncertainty Assessment*. Also this document is available as a report published by the Copernicus Institute for Sustainable Development and Innovation, Utrecht University (available from www.nusap.net).

- This list is available as a Word document upon request. Please send an e-mail to arthur.petersen@rivm.nl.

Quickscan Hints & Actions List

<table>
<tr><th rowspan="2">1. Problem Framing</th><th rowspan="2">More detail in</th><th colspan="3">Priority</th></tr>
<tr><th>L</th><th>M</th><th>H</th></tr>
<tr><td>⇨ 1a-H1: To obtain a clear picture of the various different views on the problem, it is recommended to answer the question on stakeholder involvement (question 2) first. If further elaboration is required, see §1.1 ‘Problem Frames’ of the Detailed Guidance.</td><td>§1.1</td><td></td><td></td><td></td></tr>
<tr><td>⇨ 1a-H2: Consider whether it is important to take other views into account when formulating the research questions. Discuss this with the client at the initial stage of the project. See also section 1b below.</td><td>§1.4
§2.2</td><td></td><td></td><td></td></tr>
<tr><td>⇨ 1a-H3:
<table>
<tr><th rowspan="2">Other problem</th><th colspan="3">Relation to problem</th></tr>
<tr><th>Somewhat</th><th>Strong</th><th>Explanation</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
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</table>
Treating a problem in isolation from other, related problems can lead to suboptimal policy advices. Use the table above to indicate the interwovenness with other problems. If in the end the problem will still be studied in disconnection from the other problems, then make explicit the reasons and motivations to do so, and discuss the potential consequences of the chosen problem framing with the client and other people involved (e.g., project board, co-contractors, advisory panel, steering group, stakeholders) at the initial stage of the assignment. Document this also during the final stage of the project, when reporting on the study (e.g., in the introduction and conclusions of the final report).</td><td>§1.1</td><td></td><td></td><td></td></tr>
<tr><td>⇨ 1b-H1: Try to state the research questions as falsifiable hypotheses – if feasible. This helps to obtain a sharp focus in the research questions.</td><td></td><td></td><td></td><td></td></tr>
</table>

⇨ ***1b-H2:*** Document the choices made with respect to the problem framing and the associated research questions. Motivate these choices/selections and discuss the various consequences (e.g., for the meaning and scope of the assessment to be made, for the involvement [yes/no] of stakeholders, etc.). Discuss this with the client, the project board, advisory panel, the steering group and stakeholders at the initial stage of the project. Consider whether certain aspects should still be included. Document the results of these discussions in the project plan.	§1.1				
⇨ ***1b-H3:*** Pay attention in your analysis to the robustness of the answer(s) and conclusion(s) in the light of the choices made and the aspects which are not dealt with in the research questions. Discuss this explicitly in the final report (e.g., in the discussion chapter). The guiding question should be: Is it conceivable that the answer(s) or conclusion(s) would have been different if these aspects had been included?	§6.2				
⇨ ***1c-H1:*** Check to what extent the assessment to be made is in accordance with the expected role of the results in the policy process, and how this role can be optimally fulfilled. Depending on the role of the assessment, specify the potential consequences for dealing with uncertainties during the assessment, including the communication about uncertainties (see, e.g., question 5 on uncertainty assessment and question 6 on reporting). Go to §§1.2, 1.4 and 1.5 of the *Detailed Guidance*, if further elaboration is needed.	§1.2 §1.4 §1.5				
⇨ ***1c-H2:*** Use the knowledge and expertise built up in earlier studies when planning and designing the assessment to be executed; if desired, position the present study in relation to previous studies, and clarify in which respects this study is different concerning both set-up and (expected) results. Explain or motivate the differences. Clearly indicate the added value and meaning of the present study; this should be done both at the initial stage, when elaborating the project plan, and at the final reporting stage.	§1.2				

2. Involvement of Stakeholders

	More detail in	Priority L	Priority M	Priority H
⇨ ***2a-H1:*** Map the controversies which relate to the various problem views (use the stakeholder-identification and value-mapping checklists from §§2.1 and 2.2 of the *Detailed Guidance*, if further elaboration is required). In order to guarantee robustness of, acceptance of and support for the policy advice, it can be necessary to study the controversies and plurality in views in more detail, on the basis of the perspectives (basic assumptions, interests, values, roles) underlying the various views.	§2.1 §2.2			
⇨ ***2a-H2:*** Pitfall: In situations where the problem or problem definition is barely recognized by important stakeholders, one is tempted to present the results as more certain than they really are. As a result, the study can backfire. Openness and transparancy about uncertainties and assumptions strenghten the credibility of the study.	§1.3 §1.4 §1.5			
⇨ ***2b-H1:*** Involve the stakeholders or their views in defining and framing the problem and selecting the indicators (see also question 3); be explicit about the limited scope of the study and its results.	§1.3			
⇨ ***2b-H2:*** Be transparant and open: let stakeholders 'take a look behind the scenes' (in all stages of the study; cf. 2c-H1); aim for a broad composition of the advisory panel; involve stakeholders in the review of the study.	§1.3			
⇨ ***2b-H3:*** Discuss and – if possible – use knowledge produced or put forward by stakeholders (including other research institutes); motivate the chosen approach (especially the choices about involving certain scientific disciplines) and state the potential limitations; signal and discuss the controversies with respect to the knowledge base, and account for deviating theories and approaches to the problem; provide for external review.	§1.3			
⇨ ***2b-H4:*** If feasible, use knowledge and information produced or put forward by stakeholders, including knowledge and information derived from non-scientific sources, in order to be able to come up with a study of the required quality. When communicating intermediary and final results, be specific on the lack of knowledge and clearly state the consequences for the quality and the scope of the conclusions. Provide for external review or even counter-expertise. Deliver a clear mapping of the uncertainties (see also question 5).	§1.3			
⇨ ***2c-H1:*** Disclaimer: If the debate is very strongly polarized, the involvement of stakeholders in the study cannot be expected to lead to success. There must be some prospect of fruitful dialogue. In this situation, explicit attention should be given to the various different problem views, e.g., by using an ideal-typical perspectives approach.	§1.3 §2.2 §2.3			

3. Selection of Indicators

	More detail in	Priority L	M	H
⇨ ***3a-H1:*** Map which alternative indicators are conceivable or are used by others.	§1.2 §4			
⇨ ***3a-H2:*** Substantiate why the selected indicators have been chosen and others have not, e.g., representativeness (of the subject matter or the policy goal at hand), controllability/manageability, determinability/ predictability, availability of data, scientific validity, appeal/ recognizability, involvement of stakeholders. Discuss also the shortcomings of the used indicators. Consider also potential controversies concerning the indicators. Document all this when reporting the study.	§2.2			
⇨ ***3a-H3:*** While deciding on the role of the stakeholders in the assessment (see question 2), consider specifically to involve stakeholders in the selection of indicators.	§2.3.2			
⇨ ***3b-H1:*** Examine how to deal with a potential lack of support; discuss the causes of this lack of support when reporting the study results. While communicating with stakeholders and reporting the results, give attention to differences in views and interests. Specify what the consequences of these differences can be for the meaning and value of the study to be performed.	§2.3.2 §6.2			
⇨ ***3b-H2:*** Consider giving stakeholders a role in defining or revising the indicators. Consult the advisory panel on the indicator selection.	§2.3			

## 4. Appraisal of Knowledge Base	More detail in	Prioritty		
		L	M	H
⇨ ***4a-H1:*** Hint: The quality criteria for the answers can vary per indicator. Examples of criteria are: accuracy, reliability, plausibility, scientific backing, robustness.	§1.2 §2.2 §2.3.1			
⇨ ***4b-H1:*** Consider not only controversies between main camps within the scientific arena, but also those that involve individuals on the fringes of the mainstream, who often play the controversy by way of the public and the media. It is especially important to pay attention to scientific controversies which are policy relevant – irrespective of whether they mainly take place inside or outside of science. A more detailed assessment of the uncertainties in the available knowledge base is the subject of question 5.	§1.3 §3 §6.2			
⇨ ***4c-H1:*** Clearly indicate where the crucial knowledge gaps and methodological limitations, which interfere with a successful completion of the assessment, are expected to occur, and also where these gaps stem from (e.g., is there a limited availability and quality of (a) expertise, (b) empirical data, (c) theoretical underpinning and models, (d) analysis methods, (e) resources, and for which parts of the assessment is this the case?). Also mention why these gaps are considered crucial.				
⇨ ***4d-H1:*** Indicate what bottlenecks can be expected when 'filling' these knowledge gaps, and indicate the impact of such bottlenecks on the scope and quality of the study results.				
⇨ ***4d-H2:*** If the knowledge base is insufficient, then inform the client and the advisory panel/steering group at an early stage of what will be/not be within reach, and adjust the assignment accordingly.	§2.3.1 §2.3.3			
⇨ ***4d-H3:*** Consider whether it is possible within the assignment to improve the knowledge base, and discuss with the co-contractors which activities should be given priority, on the basis of usefulness and achievability. Document the decisions, e.g., in the project plan or in project reports.	§2.3.1 §2.3.3			
⇨ ***4d-H4:*** In practice, lack of knowledge is often covered by making assumptions. Make these assumpions explicit when reporting and indicate the consequences for the policy advice.	§6.2			

⇨ ***4e-H1:*** It is important to know whether something can be done about the bottlenecks in the knowledge base, either during the project or in the future; statements about this subject could be included in the report(s), which would facilitate the assignment of priorities for future research. In some cases little can be done about a lack of knowledge (think of, e.g., 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. Additional research can consist of obtaining (more or better) measurements, making (new or improved) models or consulting experts. Peer review is also a useful instrument to determine whether controversies have been adequately dealt with.	§2.3			

5. Mapping and Assessment of Relevant Uncertainties

	More detail in	Priority		
		L	M	H
⇨ ***5a-H1:*** Determine whether presently already enough information is available to meet the needs for adequately dealing with uncertainties in the policy advice to be given.				
⇨ ***5a-H2:*** Determine what is additionally required to fullfill these needs (Where are the most important knowledge gaps? What resources – expertise, data, time, tools – are available for this purpose?).				
⇨ ***5b-H1:*** Be explicit about points of departure, assumptions and framing of the study; evaluate the critical choices made and discuss the consequences for the robustness of the conclusions most relevant to policy.	§6.2 §7.6			
⇨ ***5b-H2:*** Pay additional attention to uncertainties for the indicator(s) concerned: • indicate the nature of the uncertainties, e.g., uncertainty due to limited knowledge or due to intrinsic variability (in nature, human behaviour or social systems); • give attention to how these uncertainties can be translated in terms of accomplishing/not accomplishing policy goals, or exceeding/not exceeding norms, and to the potential size and seriousness of effects and risks; • investigate the possibilities to reduce (policy-relevant) uncertainty, and discuss these.				

⇨ ***5b-H3:*** Pay additional attention to the role of value-laden uncertainties and stakeholder views and interests. Discuss the implications of uncertainties for the socio-political context/arena.	§1.2 §1.5 §2.2			
⇨ ***5b-H4:*** Pay additional attention to the influence of views and values on the selection of indicators and on the conclusions. Discuss the implications of uncertainties for the socio-political context/arena.	§1.2 §1.5 §2.2			
⇨ ***5b-H5:*** Pay additional attention to the issues where the points of view differ most with respect to the (type of) knowledge required, and discuss the effects on the conclusions.	§1.2 §1.5 §2.2			
⇨ ***5b-H6:*** Pay additional attention to the consequences of this uncertainty for the conclusions. Be explicit about ignorance and controversies, and about what these mean for the conclusions.	§6.2			
⇨ ***5b-H7:*** Determine which specific uncertainties are associated with the chosen assessment method (measurements, models, scenarios, expert judgement).	§3 §4			
⇨ ***5c-H1:*** Use the uncertainty matrix of appendix I to indicate the *most important* uncertainties (by stating their location and further characterising them) in the context of the application at hand and/or the statements made. Rank the uncertainties according to their importance (e.g., using codes or a yellow marker), and mark the uncertainties for which a further uncertainty assessment is absolutely needed (e.g., using a red marker). Briefly motivate the choices made in selecting, ranking and marking the uncertainties.	§4			
5d-H1: Use the localisation and further characterisation of uncertainties established in the previous subquestion (see hint 5c-H1 and the uncertainty matrix of appendix I) to judge which tools and techniques are suitable for doing the actual uncertainty assessment. For this purpose, use the *Tool Catalogue for Uncertainty Assessment* and also §§4 en 5 of the *Detailed Guidance*. As a complement, one can consult experts on uncertainty analysis as well as experts on the specific problem in order to arrive at a judgement concerning the usefulness and achievability of applying the proposed tools and analyses. Be clear about what the focus should be on. Translate all this into specific uncertainty-assessment activities and include these activities in the project plan. Describe bottlenecks and limits to what can be achieved given the available resources (money, expertise, tools, data, time, manpower), and analyse their potential effects on the quality of the study results. Discuss these issues with the client at an early stage, and decide on how uncertainties shall be dealt with (keeping in mind the responsibility of the MNP for the scientific quality of the assessment).	§4 §5			

6. Reporting of Uncertainty Information

	More detail in	Priority L	Priority M	Priority H
⇨ ***6a-H1:*** Before writing the report, determine how uniform and recognizable the target group(s) is (are) and what is their role with respect to the problem at hand.	§7.2			
⇨ ***6a-H2:*** Identify the main messages to be conveyed and argue why these are the main messages.	§7.1 §7.6 §7.4			
⇨ ***6a-H3:*** Adjust both the form(s) of communication (written material, model demonstrations, multimedia material, etc.) and the style to the main message(s) and to the interests of the target group(s). The messages should be clear and transparent. Consider how misunderstandings and misinterpretations of terms, statements, results, etc. can be avoided	§7.5			
⇨ ***6a-H4:*** State the essential conclusions in a clear and concise form. Avoid the use of jargon. 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 Nederlands will increase with 7-11%. 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.	§7.3			
⇨ ***6a-H5:*** Use the principle of the 'progressive disclosure of information' when presenting the results of the study. Particularly publication on the Internet provides good possibilities to offer information in a gradual and tiered fashion, taking account of the variety of needs and wishes of the users with respect to the level of detail and the possibility to 'zoom in'.				
⇨ ***6b-H1*:** Make explicit the choices and assumptions which have been made in deducing the main conclusions. Verify how robust the main conclusions are in the light of the choices made, the assumptions used, and the uncertainties in data, models, and other knowledge used.	§6.2 §7.6			
⇨ ***6b-H2:*** Be explicit – as far as possible – about ignorance and controversies, and discuss how these issues have been dealt with. Make clear what all this means for the main conclusions. Ditto with respect to the points of departure, crucial assumptions and problem frames.	§7.6			
⇨ ***6b-H3:*** Also indicate the limitations of the study performed.	§7.6			

⇨ ***6c-H1:*** Make use of question 5 and the associated hints to determine the policy-relevant aspects of uncertainty.	§4			
⇨ ***6d-H1:*** For integrated assessment studies (e.g., balances and outlooks), explain the procedures and methods used (do this, e.g., in the 'reading instructions' or the introduction to the report). Also indicate explicitly how uncertainty is dealt with, without arousing false expectations.				
⇨ ***6d-H2:*** Provide clear information on the nature[1] and causes of policy-relevant uncertainties and on their potential effects/consequences, if this is relevant in the given context. • Accentuate the consequences for policy, politics and society, and indicate what these mean in terms of effects and risks (e.g., risky uncertainties, uncertain risks). • Indicate – if considered policy relevant – what can be done about these uncertainties, and which uncertainty aspects deserve additional attention in the future.				
⇨ ***6d-H3:*** If considered relevant for the main conclusions, explicitly discuss controversies and the limitations to what we know; explain how these issues have been dealt with and what this means for the robustness of the main conclusions and the positiveness with which they are stated. Ditto with respect to the points of departure, crucial assumptions and problem frames.	§7.6			
⇨ ***6d-H4:*** Aim for informative and relevant statements about uncertainty. Consider the importance of a clear use of language that is tailored to the target group(s). Jargon must be avoided when reporting to policy makers and society at large.	§7.3			
⇨ ***6e-H1:*** Consult the suggestions contained in §7 of the *Detailed Guidance*.	§7			
⇨ ***6e-H2:*** The summary, main conclusions, main text, background documents, figures, tables and graphs must be consistent, also with regard to uncertainty information.				
⇨ ***6e-H3:*** Aim for policy-relevant conclusions that are robust with respect to the underlying uncertainties.	§6.2			

[1] E.g., uncertainty due to limited knowledge or due to intrinsic variability (in nature, human behaviour or social systems).

⇨ ***6e-H4:*** If uncertainty is considered policy relevant, then uncertainty has to be explicitly mentioned in the summary. • In the summary, relevant information on the uncertainties concerned must be given, including the nature of the uncertainties, what can be done about them (or that they will remain), and what this all means for the policy process/decision (e.g., how robust is this process/decision in the light of the uncertainties? What would happen if reality departs from the assumptions made?). • The uncertainty information offered in the summary must be traceable to the main text and background documents.				
⇨ ***6e-H5:*** Attune the tone, style and idiom to the established or assumed uncertainty (that is, the degree of firmness/positiveness in the statements about uncertainty must be well-founded). Be consistent.				
⇨ ***6e-H6:*** See to a balanced depiction of uncertainty; prevent over-exposure or underexposure of uncertainties in the various subjects dealt with in the assessment. Take the social and political stakes of the issues into account. This can sometimes lead one to opt for a seeming imbalance in the presentation of uncertainty information.				
⇨ ***6e-H7:*** When presenting ranges, clearly specify what they refer to (e.g., min/max, 95% confidence interval, 'what-if' results, etc.)				
⇨ ***6e-H8:*** Remember that the use of qualitative expressions will typically lead to different interpretations by different people and/or in different settings, and that uncertainty statements can therefore be interpreted differently. Try to establish clarity and unequivocality in qualitative statements used, and, furthermore, use quantitative statements at places where these make sense and are feasible.				
⇨ ***6e-H9:*** Be careful with terms such as 'likely', 'possibly', 'almost certain', 'very likely'. Use of guidelines such as those put forward by the IPCC can be helpful (cf. table 2 in appendix II hereafter).				
⇨ ***6f-H1:*** Give due references (also for graphs and tables), traceable documentation and underpinning of the most important conclusions, statements, figures and tables. Specific 'accounting' documents can be written to this end.				
⇨ ***6f-H2:*** Distinguish between well-founded conclusions and conclusions which are speculative. Report on this distinction in the main text if that is considered policy relevant. Consider to use 'pedigree analysis', a tool described in the *Tool Catalogue for Uncertainty Assessment*, to document the backing for the material presented. This can be done in background documents or in specific 'accounting' documents.				
⇨ ***6f-H3:*** Discuss the main messages with both MNP team leaders and other experts.				

Appendix I

Uncertainty Matrix and Typology of Uncertainties

UNCERTAINTY MATRIX			Level of uncertainty *(from determinism, through probability and possibility, to ignorance)*			Nature of uncertainty		Qualification of knowledge base (backing)			Value-ladenness of choices		
Location ↓			Statistical uncertainty (range+ chance)	Scenario uncertainty (range as 'what-if' option)	Recognized ignorance	Knowledge-related uncertainty	Variability-related uncertainty	Weak –	Fair 0	Strong +	Small –	Medium 0	Large +
Context		Ecological, technological, economic, social and political representation											
Expert judgement		Narratives; storylines; advices											
Model	**Model structure**	Relations											
Model	**Technical model**	Software & hardware implementation											
Model	**Model parameters**												
Model	**Model inputs**	Input data; driving forces; input scenarios											
Data (in general sense)		Measurements; monitoring data; survey data											
Outputs		Indicators; statements											

Table 1a: Uncertainty Matrix

Brief description of the selected sources of uncertainty	**Explanation and justification of the specifications given in the matrix**
Source 1:	**….**
Source 2:	**….**
….	**….**
….	**….**

Table 1b: Background Information on the Uncertainty Sources

[A] Instructions for Filling Out the Uncertainty Matrix

1. Indicate in the uncertainty matrix (table 1a) where the most relevant uncertainties or uncertainty sources are to be expected:
   - Indicate first in which *row* of the matrix the uncertainty source is located (location dimension).
   - Subsequently, further characterize the uncertainty source by use of the *columns* (representing four uncertainty dimensions other than location).
   - While doing this, use an 'ABC' coding to indicate the relevance of the specific uncertainty sources (do not fill in anything if the source is considered hardly important or unimportant):

     - A= of crucial importance
     - B= important
     - C= of medium importance

   By attaching an index to this coding – e.g., A_1, B_1, C_1, A_2, B_2, C_2, etc. – one can kan explicitly indicate to which uncertainty source the coding refers (e.g., index 1 refers to source 1, index 2 to source 2, etc.). Notice that a specific source of uncertainty can appear at different points in the matrix, dependent on how the source manifests itself and how it can be characterized (see sub [B] below for more explanation).

2. Use table 1b to briefly describe each uncertainty source, and explain or motivate the specifications given in the uncertainty matrix (e.g., concerning the location and further uncertainty characterisation, and concerning the ABC code scored), adding references to the literature, if deemed appropriate.

[B] Detailed Information on Purpose and Function of the Uncertainty Matrix

The uncertainty matrix is an instrument for generating an overview of where one expects the most important (policy-relevant) uncertainties to be located, and how these can be further characterized in terms of a number of uncertainty dimensions. Using the matrix can serve as a first step towards a more elaborate uncertainty assessment, in which the size of uncertainties and their impact on the policy-relevant conclusions is explicitly assessed (see also hint 5d-H1). The matrix[2] features five principal dimensions of uncertainty, 'location', 'level of uncertainty', 'nature of uncertainty', 'qualification of knowledge base' and 'value-ladenness of choices', which will be subsequently explained below:

(i) The dimension **'location'** indicates where uncertainty can manifest itself in the problem configuration at hand. Five categories are distinguished along this dimension:

> ⇨ The ***'context'*** concerns the framing of the problem, including the choices determining what is considered inside and outside the system boundaries ('delineation of the system and its environment'), as well as the completeness of this representation in view of the problem issues at hand. Part of these context-related choices is also reflected in the other location categories, such as 'data' which are considered

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[2] The uncertainty matrix shown in table 1a is based on the material presented in the paper "Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support" by W. E. Walker, P. Harremoës, J. Rotmans, J. P. van der Sluijs, M. B. A. van Asselt, P. H. M. Janssen en M. P. Krayer von Krauss (submitted to *Integrated Assessment*, 2003). The typology and the associated uncertainty matrix in that paper classify uncertainty according to three dimensions: its 'location' (where it occurs), its 'level' (where uncertainty manifests itself on the gradual spectrum between deterministic knowledge and total ignorance) and its'nature' (whether uncertainty primarily stems from knowledge imperfection or is a direct consequence of inherent variability). We have extended this typology – and the associated uncertainty matrix – by adding two additional dimensions (represented by columns) denoted 'qualification of knowledge base' and 'value-ladenness of choices'. These additional characteristics were also briefly mentioned by Walker *et al.* (2003), as being specific features of knowledge-related uncertainty. Due to their importance for assessing and communicating uncertainties, we have decided to explicitly incorporate these dimensions in the uncertainty matrix as two additional columns. Moreover, we have also slightly modified the location axis of Walker *et al.* (2003), which was specifically designed for model-based decision support studies. Two novel location categories have been added, namely 'expert judgement' and 'data', since these can often be clearly distinguished from the other categories. Finally, the 'model' category has been extended by classifying the originally separate categories of 'inputs' and 'parameters' as subcategories of 'models'.

to play a role, 'models' which are chosen to be used, and 'outcomes' which are taken to be of interest.

⇨ ***'Data'*** refers to measurements, monitoring data, survey data, etc. used in the study, that is, information which is directly based on empirical research and data collection. Also the data which are used for calibration of the models involved are included in this category.

⇨ ***'Model'***[3] concerns the 'model instruments' which are employed for the study. This category can encompass a broad spectrum of models, ranging from mental and conceptual models to more mathematical models (statistical models, causal process models, etc.) which are often implemented as computer models. Especially for the latter class of models subcategories have been introduced, distinguishing between model structure (relations), model parameters (e.g., process parameters, initial and boundary conditions), model inputs (input data, external driving forces), as well as the technical model, which refers to the implementation in hardware and software.

⇨ ***'Expert judgement'*** refers to those specific contributions to the assessment that are not fully covered by context, models and data, and that typically have a more qualitative, reflective, and interpretative character. As such, this input could also alternatively be viewed as part of the 'mental model'.

⇨ The category of ***'outputs'*** from a study refers to the outcomes, indicators, propositions or statements which are of interest in the context of the problem at hand.

Remark: Notice that 'scenarios' in a broad sense have not been included as a separate category on the location axis. In fact they show up at different locations, e.g., as part of the context, model structure, model input scenario and expert judgement.

The various aforementioned uncertainties on the location axis can be further characterized in terms of four other uncertainty features/dimensions, which are described below.

[3] We define 'models' in a broad sense: a model is a (material) representation of an idea, object, process or mental construct. A model can exist solely in the human mind (mental, conceptual model), or be a physical representation of a larger object (physical scale model), or be a more quantitative description, using mathematical concepts and computers (mathematical and computer model).

(ii) The dimension **'level of uncertainty'** expresses how a specific uncertainty source can be classified on a gradual scale running from 'knowing for certain' to 'no know'. Use is made of three distinct classes:

- ⇨ ***'Statistical uncertainty'***: this concerns the uncertainties which can adequately be expressed in statistical terms, e.g., as a range with associated probability (examples are statistical expressions for measurement inaccuracies, uncertainties due to sampling effects, uncertainties in model-parameter estimates, etc.). In the natural sciences, scientists generally refer to this category if they speak of uncertainty, thereby often implicitly assuming that the involved model relations offer adequate descriptions of the real system under study, and that the (calibration)-data employed are representative of the situation under study. However, when this is not the case, 'deeper' forms of uncertainty are at play, which can surpass the statistical uncertainty in size and seriousness and which require adequate attention.
- ⇨ ***'Scenario uncertainty'***: this concerns uncertainties which cannot be adequately depicted in terms of chances or probabilities, but which can only be specified in terms of (a range of) possible outcomes. For these uncertainties it is impossible to specify a degree of probability or belief, since the mechanisms which lead to the outcomes are not sufficiently known. Scenario uncertainties are often construed in terms of 'what-if' statements.
- ⇨ ***'Recognized ignorance'***: this concerns those uncertainties of which we realize – some way or another – that they are present, but of which we cannot establish any useful estimate, e.g., due to limits to predictability and knowability ('chaos') or due to unknown processes.

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

We should notice that the uncertainties which manifest themselves at a specific location (e.g., uncertainties on model relations) can appear in each of the above-mentioned guises: while some aspects can adequately be expressed in statistical terms, other aspects can often only be expressed in terms of 'what-if' statements; moreover, there are typically aspects judged relevant but about which we know that we are (still) largely 'ignorant'. Judging which aspects manifests themselves in what forms is often a subjective (and uncertain) matter.

(iii) The third characteristic dimension, **'nature of uncertainty'**, expresses whether uncertainty is primarily a consequence of the incompleteness and fallibility of knowledge (***'knowledge-related'***, or 'epistemic', uncertainty) or that it is primarily due to the intrinsic indeterminate and/or variable character of the system under study (***'variability-related'***, or 'ontic', uncertainty).

> ⇨ Knowledge-related uncertainty can possibly, though not necessarily, be reduced by means of more measurements, better models and/or more knowledge.[4]
> ⇨ Variability-related uncertainty is typically not reducible by means of more research (e.g., inherent indeterminacy and/or unpredictability, randomness, chaotic behavior[5]).

Remark: In many situations uncertainty manifests itself as a mix of both forms; not in all cases the delineation between 'epistemic' and 'ontic' can be made unequivocally. Moreover, a combination of taste, tradition, specific problem features that are of interest, and the current level of knowledge and ignorance with respect to the specific subject determines to a large part where the dividing line is drawn. In practice it is therefore the active choice of the researcher which often determines the distinction between epistemic and ontic, rather than that it is an innate and fundamental property of reality itself. Notice that this choice can be decisive for the outcomes and interpretations of the uncertainty assessment. Still, using the distinction between 'epistemic' and 'ontic' uncertainty can render important information on the (im)possibility of reducing the uncertainties by, e.g., more research, better measurements, better models, etc. That is, although not being completely equivalent, this distinction reflects to a large extent the distinction between uncertainties which are 'reducible' and those which are 'not reducible' by means of further research.

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[4] However, it is also possible that this knowledge-related uncertainty is increased by doing more research and by the progress of insight.
[5] Although it is possible to know the characteristics of a system on a certain level of aggregation, e.g., knowing the probability distribution or the 'strange attractor', it is not always possible to predict the behaviour or properties of individuals/elements which form part of the system on a lower level.

(iv) The fourth dimension which is relevant for characterizing uncertainty concerns the **'qualification of the knowledge base'**. This refers to the degree of underpinning of the established results and statements. The phrase 'established results and statements' can be interpreted in a broad sense here: it can refer to the policy-advice statement as such (e.g., 'the norm will still be exceeded when the proposed policy measures have become effective', 'the total yearly emission of substance *A* is *X* kiloton') as well as to assertions about the uncertainty in this statement (e.g. 'the uncertainty in the total yearly emission of substance *A* is . . . (95% confidence interval)'). The degree of underpinning is divided into three classes: weak/fair/strong. If the underpinning is weak, this indicates that the statement of concern is surrounded by much (knowledge-related) uncertainty, and deserves further attention. This classification moreover offers suggestions about the extent to which uncertainty is reducible by providing a better underpinning.

Notice that this dimension in fact characterizes the *reliability* of the information (data, knowledge, methods, argumentations, etc.) which is used in the assessment. Criteria such as empirical, theoretical or methodological underpinning and acceptance/support within and outside the peer community can be used for assessing and expressing the level of reliability. If required, a so-called 'pedigree analysis' can be done, which results in a semi-quantitative scoring of the underpinning on the basis of a number of qualitative criteria such as the aforementioned ones (see the *Tool Catalogue for Uncertainty Assessment*).

(v) The final dimension for characterizing uncertainties denotes whether a substantial amount of **'value-ladenness'** and subjectiveness is involved in making the various – implicit and explicit – choices during the environmental assessment. This concerns, among other things, the way in which (i) the problem is framed *vis à vis* the various views and perspectives on the problem, (ii) the knowledge and information (data, models) is selected and applied, (iii) the explanations and conclusions are expressed and formulated. If the value-ladenness is high for relevant parts of the assessment, then it is imperative to analyze whether or not the results of the study are highly influenced by the choices involved, and whether this could lead to a certain arbitrariness, ambiguity or uncertainty of the policy-relevant conclusions. This could then be a reason to explicitly deal with different views and perspectives in the assessment and to discuss the scope and robustness of the conclusions in an explicit manner. In order to identify value-ladenness one could, e.g., use §§1 and 2 of the *Detailed Guidance*.

Appendix II

Some Verbal Probabilistic Expressions

Verbal uncertainty expressions, such as ‘likely’, ‘probable’, ‘possible’, ‘virtually certain’, etc., usually have no universal meaning and their use and interpretation strongly depends on the individual using these terms and on the context in which they are used.

By making consistent and clear decisions on the use and meaning of the terms, potential misunderstandings in interpretation and communication can partly be prevented. The Intergovernmental Panel on Climate Change (IPCC) has therefore proposed a number of uncertainty terms to express the confidence which scientists have in specific statements (see, e.g., the IPCC Third Assessment Report of Working Group I, *Climate Change 2001: The Scientific Basis*; cf. footnote nr. 7 of the Summary for Policy Makers):

> “In this Summary for Policymakers and in the Technical Summary, the following words have been used where appropriate to indicate judgmental estimates of confidence: *virtually certain* (greater than 99% chance that a result is true); *very likely* (90-99% chance); *likely* (66-90% chance); *medium likelihood* (33-66% chance); *unlikely* (10-33% chance); *very unlikely* (1-10% chance); *exceptionally unlikely* (less than 1% chance).”

These terms and their proposed use are indicated in table 2. One should realize that this usage is largely based on the availability of some sort of quantification in terms of chances. These ‘chances’ need not necessarily refer to a chance of occurence in reality as expressed in terms of frequencies, but they can also refer to a subjective ‘degree of belief’ associated with a specific outcome. Such probabilistic interpretations are, however, not always feasible or cannot always be made in an unequivocal and well-founded manner. Notwithstanding these objections, the presented set of rules can serve to obtain more clarity, consistency and uniformity in communicating about uncertainties.

Verbal expression	Chance (per cent)	Chance (fraction)
Virtually certain	More than 99% chance that the result is true	≥ 99 out of 100
Very likely	90–99% chance that the result is true	≥ 9 out of 10 and ≤ 99 out of 100
Likely	66–90% chance that the result is true	≥ 2 out of 3 and ≤ 9 out of 10
Medium likelihood	33–66% chance that the result is true	Between 1 and 2 out of 3
Unlikely	10–33% chance that the result is true	≤ 1 out of 3 and ≥ 1 out of 10
Very unlikely	1–10% chance that the result is true	≤ 1 out of 10 and ≥ 1 out of 100
Exceptionally unlikely	Less than 1% chance the result is true ditto	≤ 1 out of 100

Table 2: IPCC WGI Proposal for Interpretation and Use of Probabilistic Terms