Studium Generale Wageningen
Science, Policy and Complex Phenomena
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Post Normal Science:
working deliberatively within imperfections

Dr. Jeroen P. van der Sluijs

Copernicus Institute for Sustainable Development and Innovation
Utrecht University

&

Centre d'Economie et d'Ethique pour l'Environnement
et le Développement,
Université de Versailles Saint-Quentin-en-Yvelines, France

Haugastøl group:

Jeroen van der Sluijs; Ragnar Fjelland; Jerome Ravetz; Anne Ingeborg Myhr; Roger Strand; Silvio Funtowicz; Kamilla Kjølberg; Kjellrun Hiis Hauge; Bruna De Marchi; Andrea Saltelli

Complex - *uncertain* - risks

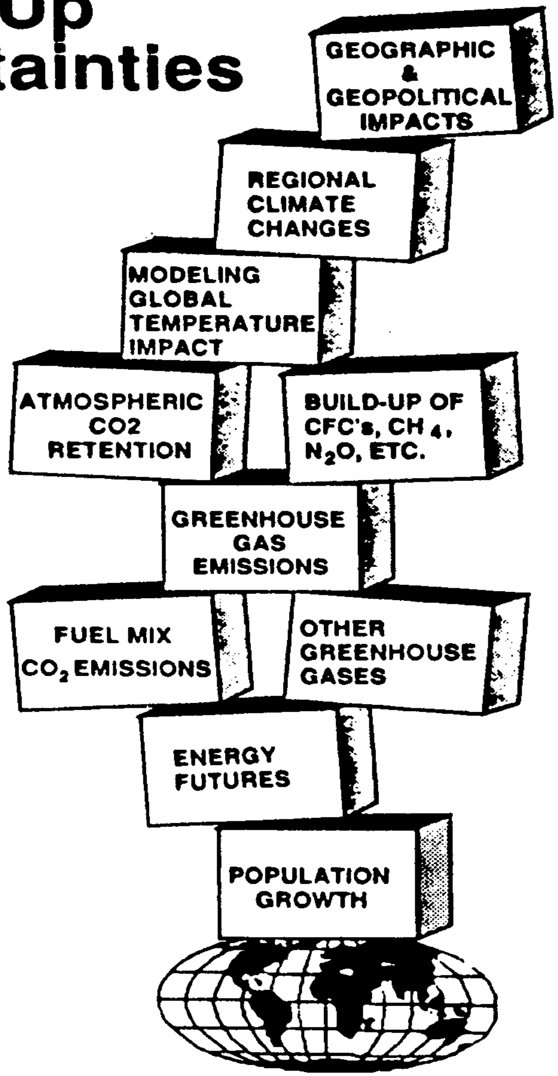
Typical characteristics (Funtowicz & Ravetz):

- Decisions will need to be made before conclusive scientific evidence is available;
- Potential impacts of ‘wrong’ decisions can be huge
- Values are in dispute
- Knowledge base is characterized by large (partly irreducible, largely unquantifiable) uncertainties, multi-causality, knowledge gaps, and imperfect understanding;
- More research ≠ less uncertainty; unforeseen complexities!
- Assessment dominated by models, scenarios, assumptions, extrapolations
- Many (hidden) value loadings reside in problem frames, indicators chosen, assumptions made

Knowledge Quality Assessment is essential

GLOBAL CLIMATE CHANGE

Piling Up Uncertainties



3 paradigms of uncertain risks

'deficit view'

- Uncertainty is provisional
- Reduce uncertainty, make ever more complex models
- *Tools:* quantification, Monte Carlo, Bayesian belief networks

'evidence evaluation view'

- Comparative evaluations of research results
- *Tools:* Scientific consensus building; multi disciplinary expert panels
- focus on robust findings

'complex systems view / *post-normal* view'

- Uncertainty is intrinsic to complex systems
- Uncertainty can be result of production of knowledge
- Acknowledge that not all uncertainties can be quantified
- Openly deal with deeper dimensions of uncertainty
  (problem framing indeterminacy, ignorance, assumptions, value loadings, institutional dimensions)
- *Tools:* Knowledge Quality Assessment
- Deliberative negotiated management of risk

Models of Science and Policy

Modern model (European Enlightenment):

Perfection and perfectibility

- Facts determine correct policy
- The true entails the good
- No limits to progress of our control over the environment
- No limits to material and moral progress of humankind
- Technocratic view
- Science informs policy by producing ***objective***, ***valid*** and ***reliable*** knowledge
- “*Speaking truth to power*”

(Funtowicz, 2006; Funtowicz & Strand, 2007)

Merton’s CUDOS norms of science

- (**C)ommunalism** - the common ownership of scientific discoveries, according to which scientists give up intellectual property rights in exchange for recognition and esteem;
- **(U)niversalism** - according to which claims to truth are evaluated in terms of universal or value-free criteria;
- **(D)isinterestedness** - according to which scientists are rewarded for acting in ways that appear to be selfless;
- **(O)rganized (S)kepticism** - all ideas must be tested and are subject to structured community scrutiny.

limitations of the modern model (I)

- *objective, valid and reliable*, but...
  - is the information really objective?
  - is it valid?
  - is it reliable?
- Conflicts of interests, what if scientists are themselves stakeholders?

(Funtowicz, 2006; Funtowicz & Strand, 2007)

limitations of the modern model (II)

Modern model assumes that:

- uncertainty can be eliminated or controlled
- there is only one correct description of the system: *system and problem are not complex*

(Funtowicz, 2006; Funtowicz & Strand, 2007)

Responses to limitations of Modern Model

- Denial
- Accommodations
- Rethinking:
  - post-normal science

(Funtowicz, 2006; Funtowicz & Strand, 2007)

Rescuing Modern Model from uncertainty:

The Precautionary Model (at least in Rio- and EU interpretations)

- Imperfection in science: *“lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (Rio Declaration 1992)*
- EU: proportionality (between costs and benefits)-> critics: not PP but extended cost-benefit analysis
- Normative principle of precautionary model is still framed and expressed in terms of quantitative science and modern rationality (CBA)
- Precautionary model meets limitations when confronted with uncertainty of the type “We do not know what kind of surprises this technology may lead to”

(Funtowicz, 2006; Funtowicz & Strand, 2007)

Risks of GMOs? Experts disagree

Report 1: “Perils amid promises of genetically modified foods”:

- **Risks:** ‘*it is (..) hazardous to biodiversity, human and animal health*’
- **Benefits:** ‘*biotechnology cannot alleviate the existing food crisis*’

Report 2 “Biotechnology and food”:

- **Risks:** ‘*complete absence of any evidence of harm to the public or the environment*’
- **Benefits**:‘*GM can be used to (..) provide a more balanced diet*’

Rescuing the modern model from indeterminacy

The Framing Model

- In absence of conclusive facts, science is one of many inputs in policy, functioning as *evidence* in the discourse.
- Conflicting certainties, multitude of alternative framings defendable
- Rescue: Dialogue, participation, inter-subjective knowledge, consensus formation, robustness, upstream engagement
- Works if framing problem is one of bias and bounded rationality
- Retains the modern ideal of certain scientific knowledge

But… it is a matter of necessary choices, not of unnecessary biases.

(Funtowicz, 2006; Funtowicz & Strand, 2007)

How to play uncertainties in environmental regulation …

Industry groups are fighting government regulation by fomenting scientific uncertainty

DOUBT Is Their Product

By David Michaels
Photographs by Mindy Jones

Few scientific challenges are more complex than understanding the health risks of a chemical or drug. Investigators cannot feed toxic compounds to people to see what doses cause cancer. Instead

vinyl chloride, chromium, benzene, benzidine, nickel, and a long list of other toxic chemicals and medications. What is more, Congress and the administration of President George W. Bush have encouraged such tactics by making it easier for

Scientific American, Jun2005, Vol. 292, Issue 6

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- Fabrication (and politicisation) of uncertainty

The example of the US Data quality act and of the OMB "Peer Review and Information Quality" which

"seemed designed to maximize the ability of corporate interests to manufacture and magnify scientific uncertainty".

Rescuing the modern model from conflict of interests

Model of science/policy demarcation

- Acknowledges expert disagreement and bias, but diagnoses and prescription differ from framing model
- Framing: make values explicit; demarcation: values are domain of politics, facts are domain of science, keep them separated.
- Ensure that political accountability rests with policy makers and is not inappropriately shifted to scientist, keep science objective and value free
- Call for independent studies, sound science, strict separation between risk assessment and risk management etc.
- But... Complexity, Indeterminacy, fundamental impossibility of value free science

(Funtowicz, 2006; Funtowicz & Strand, 2007)

Summary of responses to problems of modern model

- Imperfection
  - Policy is modified by precaution
- Misuse
  - Problems are (co-)framed by stakeholders
- Abuse
  - Scientists are protected from political interference

(Funtowicz, 2006; Funtowicz & Strand, 2007)

In case of complex problems, all modifications of modern models fail because:

- Truth cannot be known and is thus not a substantial aspect of the issue
- *“To be sure, good scientific work has a product, which should be intended by its makers to correspond to Nature as closely as possible, and also to be public knowledge. But* ***the working judgements on the product are of its quality, and not of its logical truth****.”* (Funtowicz and Ravetz 1990, p. 30)

The alternative model

Extended participation:

working deliberatively within imperfections

- Science (the activity of technical experts) is only one part of relevant **evidence**
- Critical dialogue on strength and relevance of evidence
- Interpretation of evidence and attribution of policy meaning to a given body of evidence is democratized
- Tools for Knowledge Quality Assessment empower all stakeholders to engage in this deliberative process

(Funtowicz, 2006; Funtowicz & 2007)

Knowledge versus Expertise

- Scientific *knowledge* becomes scientific *expertise* only when it is inserted into a policy making process or societal debate
- What often happens then is that the scientist is forced to express beliefs
- Belief goes beyond the limits of what science can know

Trans science (Alvin Weinberg)

- Research Questions that can be phrased scientifically but that in practice cannot be answered by science.

- Science can be useful in *framing the issue*, or *analyzing* it, a public debate among all actors is needed to *solve the issue*.

Expertise =

a skill to be deployed

rather than:

facts to be presented.

Key issues in science for policy

1. The policy maker wants relevant knowledge. But it is not easy to define what the relevant knowledge is.

2. There is a need to reduce the complexity, to confine the problem into a selection of various policy options.

3. You have to find solutions within a certain time frame. Often this is part of a conflict between policy making and science.

(key issues science for policy - continued)

4. There is a need to explore possibilities, to balance pro's and con's, and instruments are needed to do so.

5. There is a need to legitimize the decisions within an arena of competing different interest groups.

6. There is a need for robustness and consensus in the assessments

7. The assessors have to negotiate credibility with scientific peer groups, policy makers and other actors involved.

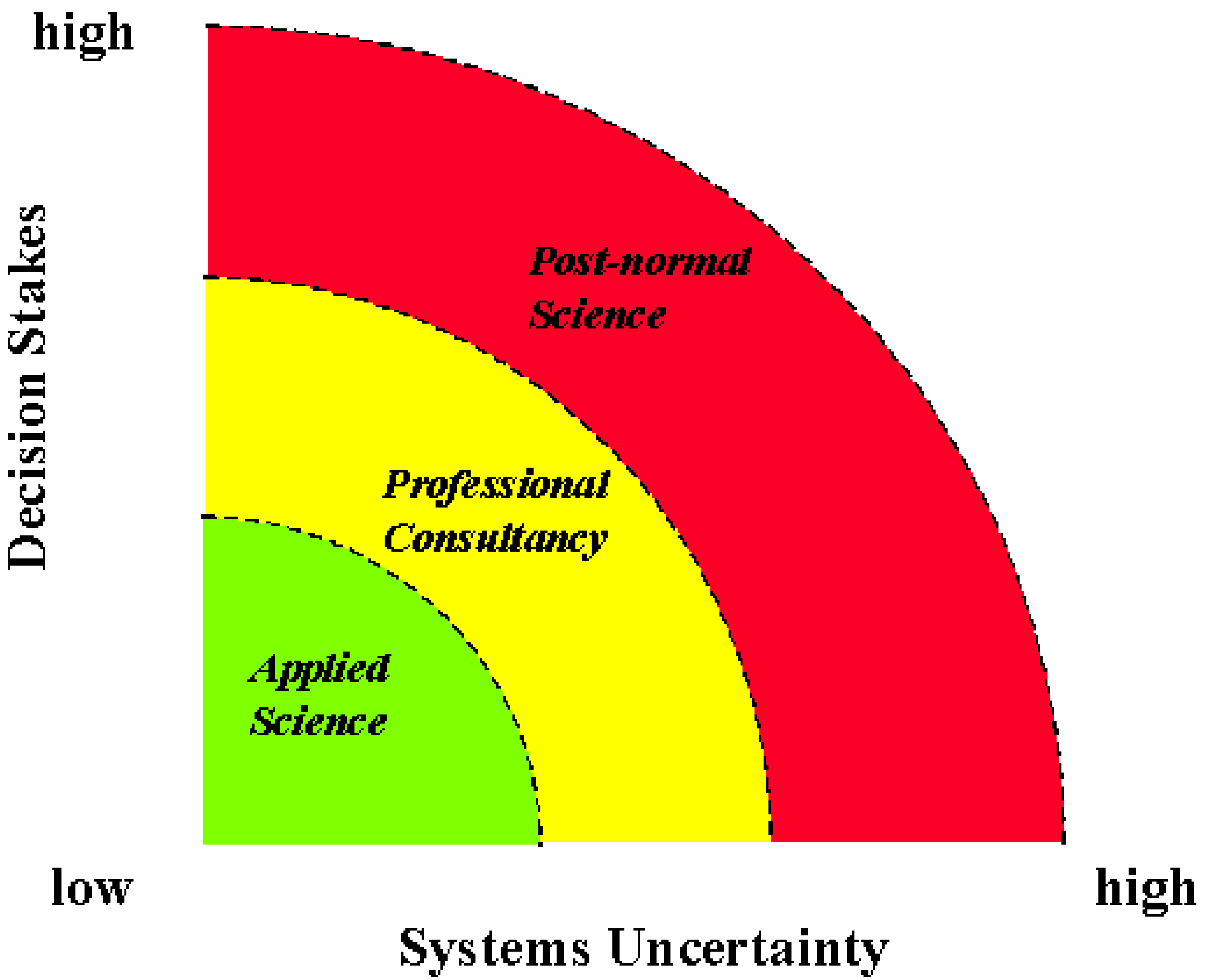
Normal science

Thomas Kuhn, Structure of Scientific Revolutions (1962)

- 'normal science' = uncritical puzzle solving within an unquestioned framework, or 'paradigm'.
- What all scientists do most of the time, and most scientists do all the time.

Normal Science - continued

- Scientists are prepared for this rigorous effort by a dogmatic scientific training with textbooks where the answers to scientific questions can be found in the back.
- This is further reinforced by naive and simplistic accounts of how scientists discover truth.
- However successful this Normal Science approach is in traditional disciplinary research, it meets its limits when society is confronted with the need to resolve transdisciplinary policy issues regarding trans-national and trans-generational environmental risk on which yet no unquestioned frameworks exist.



Funtowicz and Ravetz, Science for the Post Normal age, *Futures*, 1993

Elements of Post Normal Science

- Appropriate management of uncertainty quality and value-ladenness
- Plurality of commitments and perspectives
- Internal extension of peer community *(involvement of other disciplines)*
- External extension of peer community *(involvement of stakeholders in environmental assessment & quality control)*

PNS as criticism and alternative to the other positions

- Subjective probabilism
  - Problem: Elevates expert guess to scientific facts
- Radical social constructivism
  - Problem: Implies that “pollution is in the nose of the beholder”
- Populism/any thing goes
  - Problem: implies that “Knowledge and feelings of real people are always good and true” (marginalizes science to one of many views amongst which cannot be discriminated)

All these positions are unsatisfactory

Uncertainty in knowledge based society: the problems

1984 Keepin & Wynne:

“Despite the appearance of analytical rigour, IIASA’s widely acclaimed global energy projections are highly unstable and based on informal guesswork. This results from inadequate peer review and quality control, raising questions about political bias in scientific analysis.”

RIVM / De Kwaadsteniet (1999)

"RIVM over-exact prognoses based on virtual reality of computer models"

Newspaper headlines:

- Environmental institute lies and deceits
- Fuss in parliament after criticism on environmental numbers
- The bankruptcy of the environmental numbers
- Society has a right on fair information, RIVM does not provide it

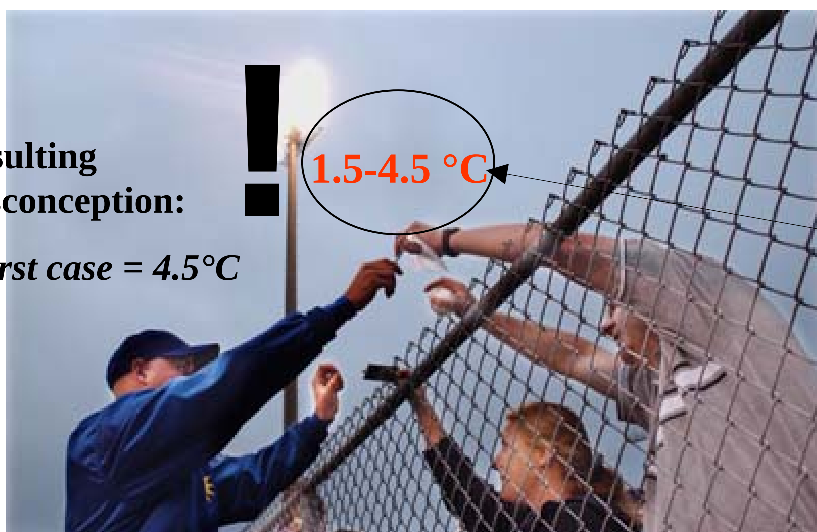
Crossing the disciplinary boundaries

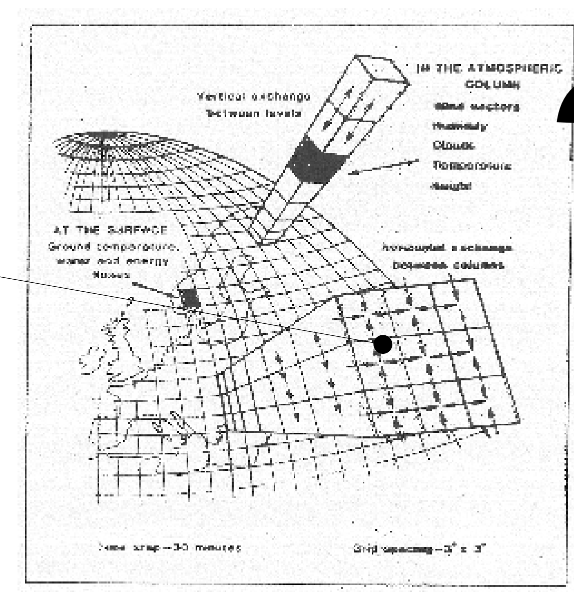
Once environmental numbers are thrown over the disciplinary fence, important caveats tend to be ignored, uncertainties compressed and numbers used at face value

e.g. **Climate Sensitivity**, see Van der Sluijs, Wynne, Shackley, 1998:

Resulting misconception:

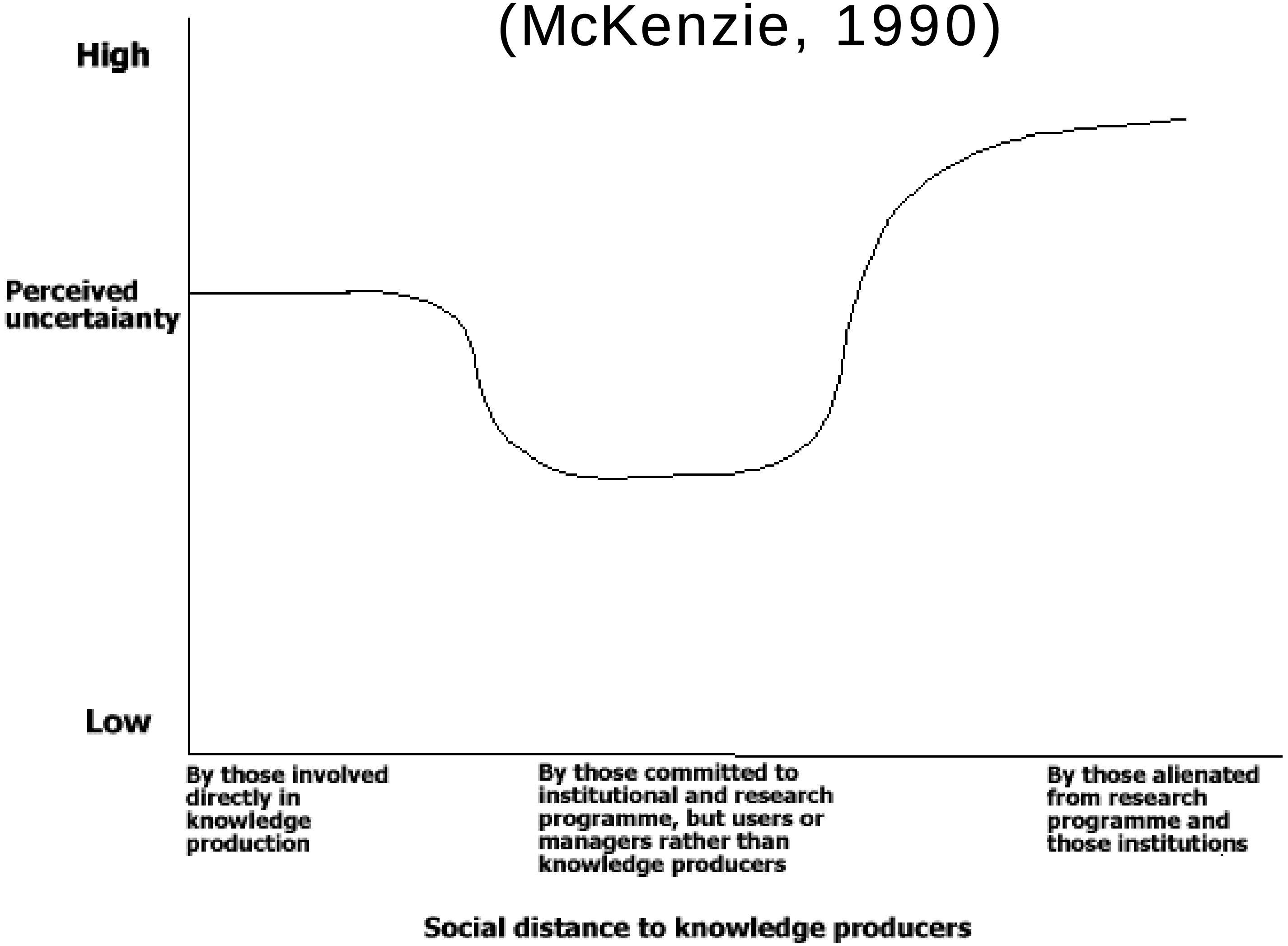
Worst case = 4.5°C





?

The certainty trough (McKenzie, 1990)



Insights on uncertainty

- More research tends to increase uncertainty
  - reveals unforeseen complexities
  - Complex systems exhibit irreducible uncertainty (intrinsic or practically)
- Omitting uncertainty management can lead to scandals, crisis and loss of trust in science and institutions
- In many complex problems unquantifiable uncertainties dominate the quantifiable uncertainty
- High quality $\neq$ low uncertainty
- Quality relates to **fitness for function** (robustness, PP)
- Shift in focus needed from reducing uncertainty towards reflective methods to explicitly cope with uncertainty and quality

Uncertainty as a “monster”

- A monster is a phenomenon that at the same moment fits into two categories that were considered to be mutually excluding

(Smits, 2002; Douglas 1966)

Cultural categories that we thought to be mutually exclusive and that now tend to get increasingly mixed up:

- knowledge – ignorance
- objective – subjective
- facts – values
- prediction – speculation
- science - policy

Responses to monsters

Different degrees of tolerance towards the abnormal:

- monster-exorcism (expulsion)
- monster-adaptation (transformation)
- monster-embracement (acceptance)
- monster-assimilation (rethinking)

monster-exorcism

- Uncertainty causes discomfort
- Reduce uncertainties!
- Strong believe in “objective science”: “the puzzle can be solved”

Example:

- *“We are confident that the uncertainties can be reduced by further research” (IPCC 1990)*

But....

- For each head science chops off of the uncertainty monster, several new monster heads tend to pop up (unforeseen complexities)
- 1994 IGBP dropped objective to reduce uncertainty: *”full predictability of the earth system is almost certainly unattainable”*

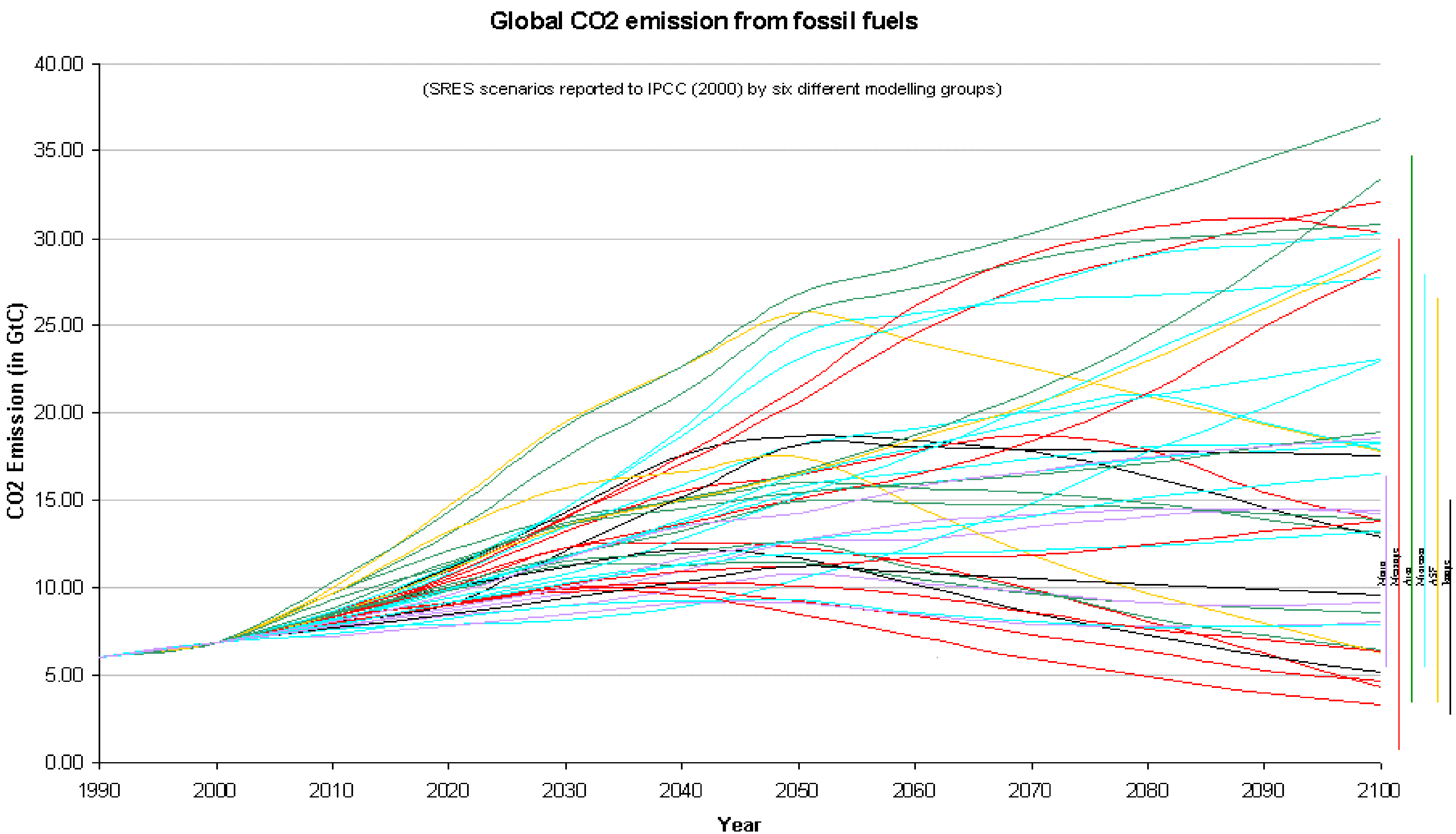
Former chairman IPCC on objective to reduce uncertainties:

- "*We cannot be certain that this can be achieved easily and we do know it will take time. Since a fundamentally chaotic climate system is predictable only to a certain degree, our research achievements will always remain uncertain. Exploring the significance and characteristics of this uncertainty is a fundamental challenge to the scientific community.*" (Bolin, 1994)

Monster adaptation

- Fit the uncertainty monster back in the categories: purification
- Quantify uncertainty,
  subjective probability & Bayesian
- Tendency to build system models based on “objective science” and externalise the subjective parts and uncertainties into scenario’s and storylines
- Boundary work

IPCC 10 years after *“we are confident that the uncertainties can be reduced...”*



(Van Vuuren et al. 2000)

Monster adaptation meets its limits

- Different models fed with the same scenarios produce very different results
- “Integrated Assessment Modeling of Global Climate Change: Transparent Rational Tool for Policy Making or Opaque Screen Hiding Value-laden Assumptions?” (Steve Schneider)

Monster Embracement

- Uncertainty is welcomed: an appreciated property of life
  - fascination about the unfathomable complexity of our living planet Gaia
  - room for spirituality and wonder at the expense of engineering worldview of managing the biosphere
- Plea for a humble science
- Holism; Inclusive Science

Or:

- Uncertainty is welcomed because it fits well in other political agenda's
- (strategic) Denial of realness of environmental risks by emphasizing all those uncertainties
- Manufacturing uncertainty

Monster Assimilation

- Rethink the categories by which the knowledge base is judged
- Create a place for monsters in the science policy interface
- Post Normal Science; Reflexive science; Complex systems research

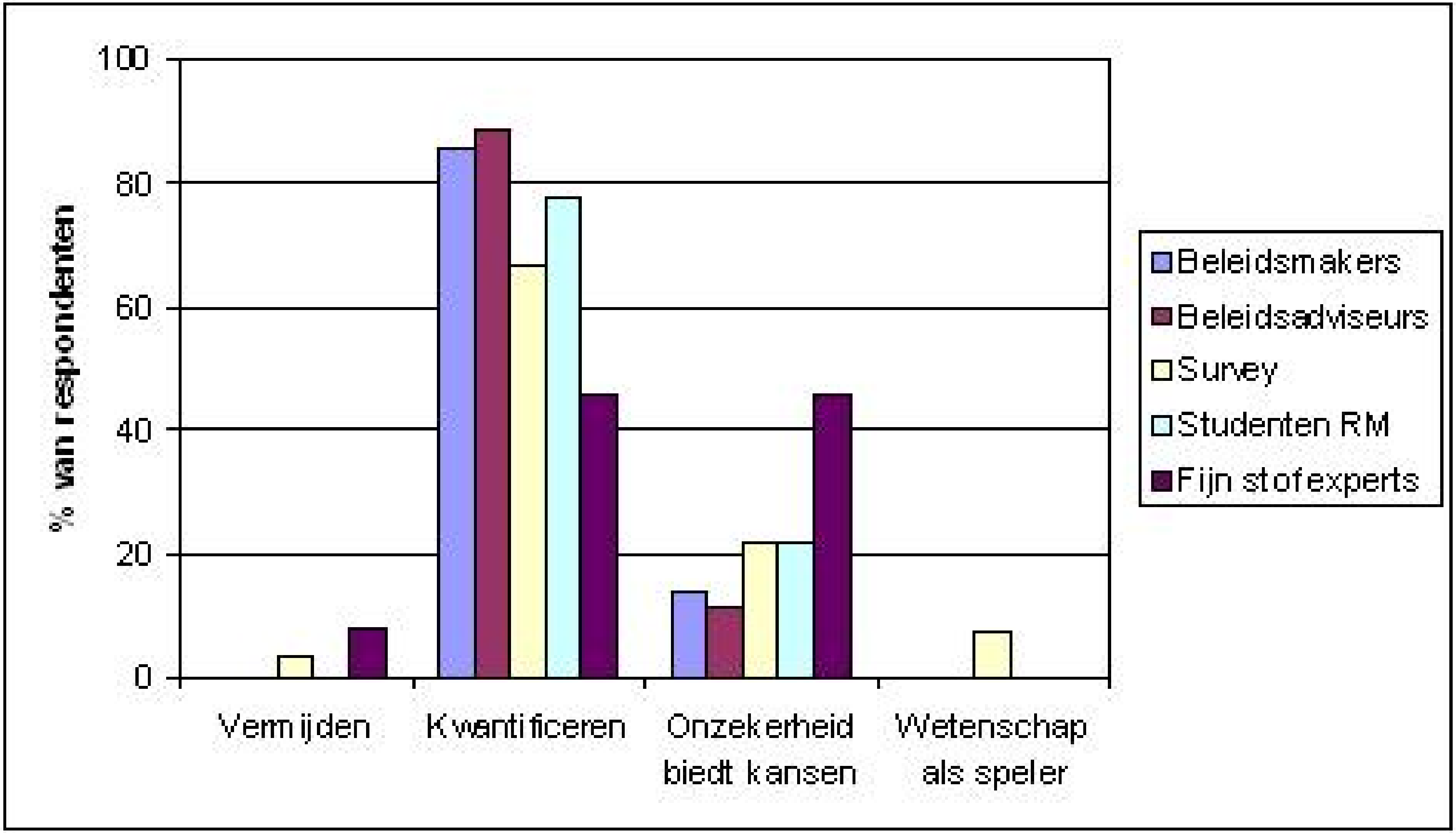
But….

- New categories tend to create new monsters
  - Every categorization is an imperfect reduction of complexity

Attitudes to uncertainty

4-point scale from positivism to constructivism:

- Uncertainty is unwelcome and needs to be avoided. The challenge to science is to get rid of uncertainty by better and more independent research.
- Uncertainty is undesirable but unavoidable. The challenge to science is to quantify uncertainty as good as possible and to separate facts and values as good as possible.
- Uncertainty creates opportunities. Uncertainty relativises the role of science. The challenge to science is to contribute to a more democratic, less technocratic societal debate.
- The distinction between science and policy is artificial and untenable. The challenge to science is be an influential player in the societal arena.



Avoid & Reduce | **Quantify all** | **Deliberate** | **play the game**

So, can the uncertainty monster be tamed?

No, only partly.

But...

- Repertoire of styles to cope with uncertainties, each having its own limitations and pitfalls
- Coping with uncertainty can and should be done more sophisticated

Locations of uncertainty

- Sociopolitical and institutional context
- System boundary & problem framing
  - System boundary
  - Problem framing
  - Scenario framing (storylines)
- Model/instrument
  - Indicators
  - Conceptual model structure / assumptions
  - Technical model structure
  - Parameters
- Inputs
  - Scenarios
  - Data

Dimensions of uncertainty

- Technical (inexactness)
- Methodological (unreliability)
- Epistemological (ignorance)
- Societal (limited social robustness)

Inexactness

Intrinsic uncertainty:

- Variability / heterogeneity

Technical limitations:

- Resolution error
- Aggregation error
- Unclear definitions

Unreliability

Methodological limitations

Limited internal strength in:

- Use of proxies
- Empirical basis
- Methodological rigour
- Validation

Limited external strength in:

- Completeness of set of relevant aspects
- Exploration of rival problem framings
- Management of dissent
- Extended peer acceptance / stakeholder involvement
- Transparency
- Accessibility

Future scope

Unreliability (continued)

Bias / Value ladenness

Bias in knowledge production

- Motivational bias (interests, incentives)
- Disciplinary bias
- Cultural bias
- Choice of (modelling) approach
- Subjective judgement

Bias in knowledge utilization

- Strategic/selective knowledge use

Ignorance

Epistemological limitations

- Limited theoretical understanding
- System indeterminacy
  - Open-endedness
  - Chaotic behavior
  - Intrinsic unknowability
- Active ignorance
  - Model fixes for reasons understood
  - Limited domains of applicability of functional relations
  - Numerical error
  - Surprise A
- Passive ignorance
  - Bugs (software error, hardware error, typos)
  - Model fixes for reasons not understood
  - Surprise B

Limited social robustness

Limited external strength in:

- Bias / Value ladenness
- Insufficient exploration of rival problem framings
- Management of dissent
- Extended peer acceptance / stakeholder involvement
- Transparency
- Access & availability
- Intelligibility

Value-ladenness

- Value orientations and biases of an analyst, an institute, a discipline or a culture can co-shape the way scientific questions are framed, data are selected, interpreted, and rejected, methodologies are devised, explanations are formulated and conclusions are formulated.
- Since theories are always underdetermined by observation, the analysts' biases will fill the epistemic gap which makes any assessment to a certain degree value-laden.
- In a context of (potential) controversy, stakeholder participation and transparency are essential in coping with value ladenness

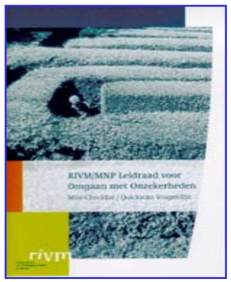
Foci and key issues in knowledge quality assessment (ref. 9)

Foci	Key issues
Problem framing	Other problem views; interwovenness with other problems; system boundaries; role of results in policy process; relation to previous assessments
Involvement of stakeholders	Identifying stakeholders; their views and roles; controversies; mode of involvement
Selection of indicators	Adequate backing for selection; alternative indicators; support for selection in science, society, and politics
Appraisal of knowledge base	Quality required; bottlenecks in available knowledge and methods; impact of bottlenecks on quality of results
Mapping and assessing relevant uncertainties	Identification and prioritisation of key uncertainties; choice of methods to assess these; assessing robustness of conclusions
Reporting uncertainty information	Context of reporting; robustness and clarity of main messages; policy implications of uncertainty; balanced and consistent representation in progressive disclosure of uncertainty information; traceability and adequate backing

RIVM-MNP Uncertainty Guidance

Reminder list
Invokes Reflection
Portal to QS

Mini-Checklist



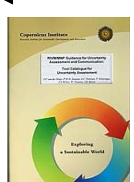
Quickscan Questionnaire

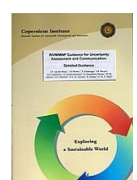
Further Guidance
Advice
Hints & Implications

Quickscan Hints & Actions List

Tool Catalogue for Uncertainty Assessment

Detailed Guidance





Advice on Quantitative + Qualitative tools for UA

Downloads: www.nusap.net

What is NUSAP?

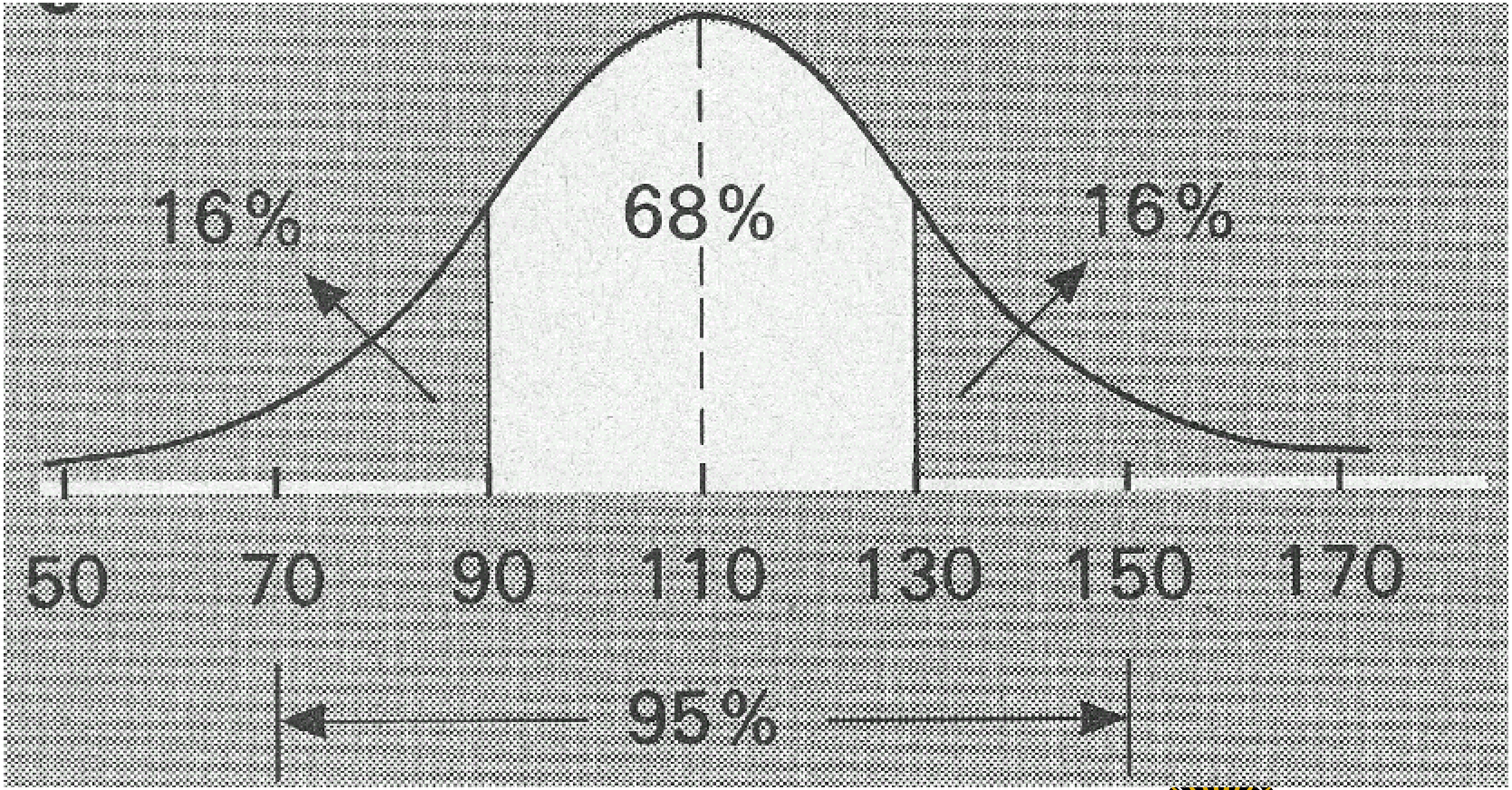
- Innovative framework for uncertainty management which enables different sorts of uncertainty in quantitative information to be analyzed and communicated in a standardized and self-explanatory way.
- Addresses **quantitative & qualitative** aspects and synthesises these
- Enables providers and users of quantities to be clear and transparent about its uncertainties and gives insight in the **strengths and weaknesses** of the underlying knowledge base.

Reliability intervals in case of normal distributions

$\pm\,\sigma = 68\ \%$

$\pm\,2\sigma = 95\ \%$

$\pm\,3\sigma = 99.7\ \%$



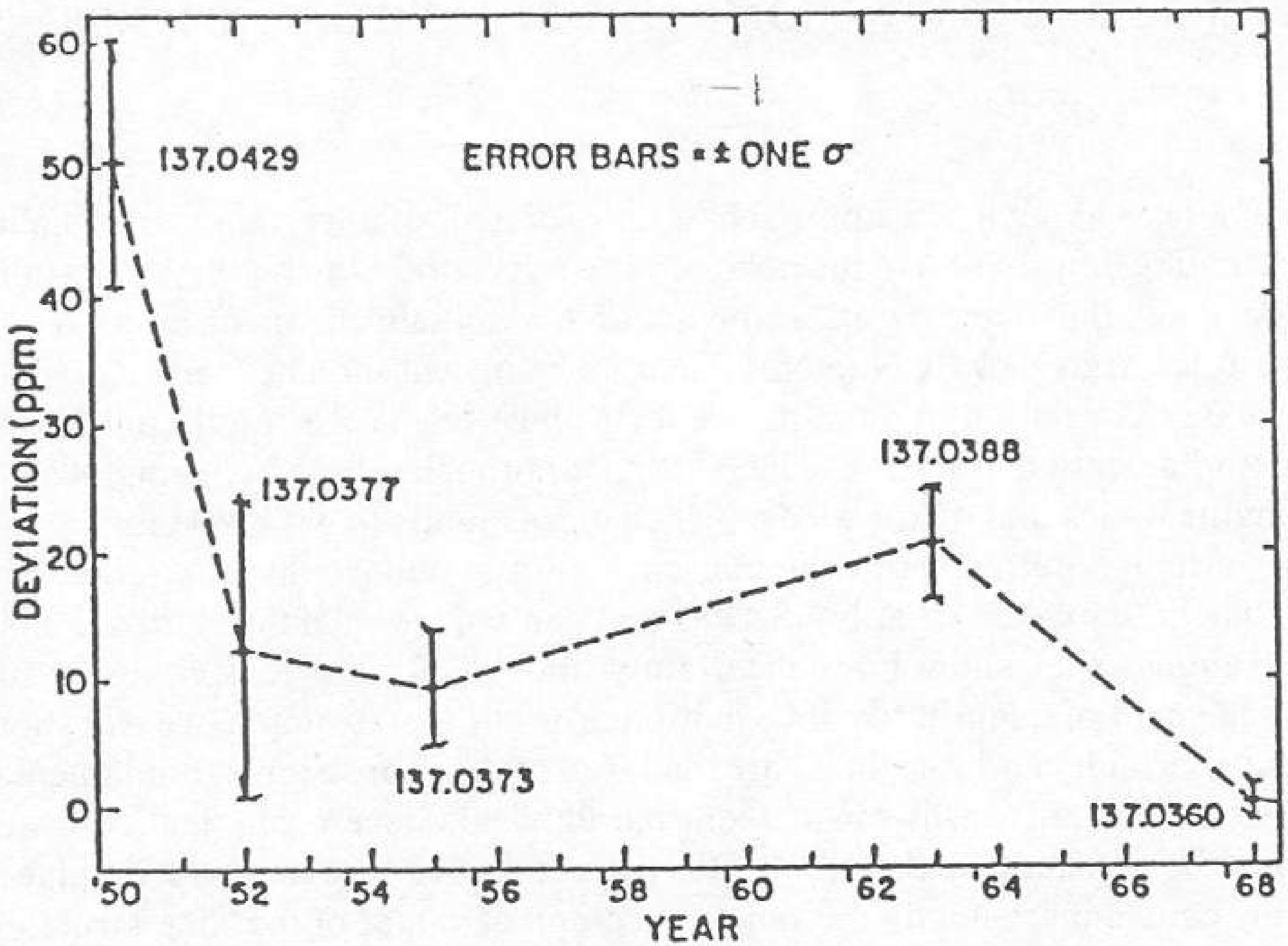
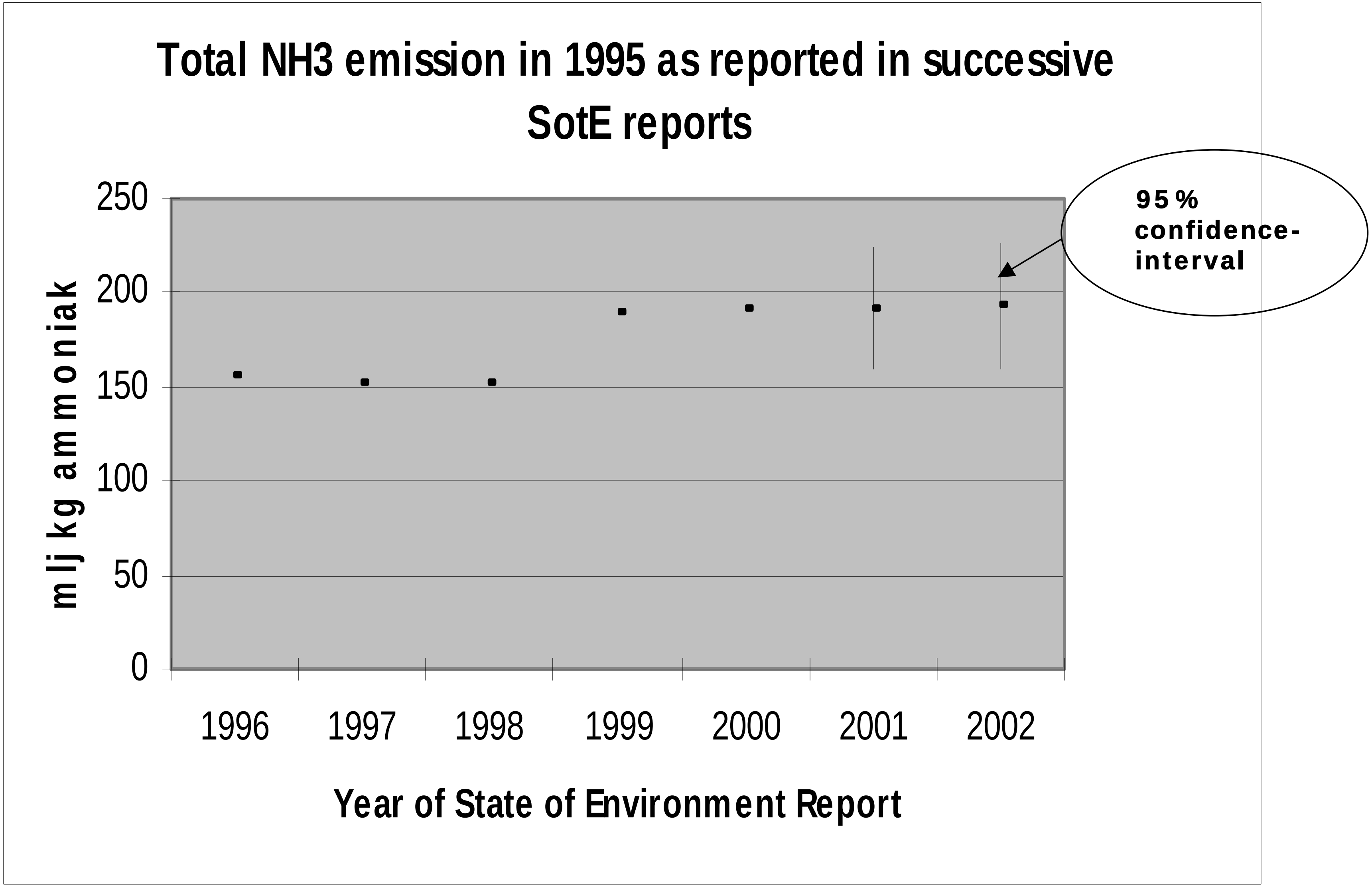


Fig. 1. Successive recommended values of the fine-structure constand α^{-1} (B. N. Taylor *et al.*, 1969, 7)



Total NH3 emission in 1995 as reported in successive SotE reports
250
200
150
100
50
0
mlj kg ammoniak
1996
1997
1998
1999
2000
2001
2002
Year of State of Environment Report
95% confidence-interval

NUSAP

Qualified Quantities

- Numeral
- Unit
- Spread
- Assessment
- Pedigree

(Funtowicz and Ravetz, 1990)

*NUSA**P**:* Pedigree

Evaluates the strength of the number by looking at:

- Background history by which the number was produced
- Underpinning and scientific status of the number

Example Pedigree matrix parameter strength

Code	Proxy	Empirical	Theoretical basis	Method	Validation
4	Exact measure	Large sample direct mmts	Well established theory	Best available practice	Compared with indep. mmts of same variable
3	Good fit or measure	Small sample direct mmts	Accepted theory partial in nature	Reliable method commonly accepted	Compared with indep. mmts of closely related variable
2	Well correlated	Modeled/derived data	Partial theory limited consensus on reliability	Acceptable method limited consensus on reliability	Compared with mmts not independent
1	Weak correlation	Educated guesses / rule of thumb est	Preliminary theory	Preliminary methods unknown reliability	Weak / indirect validation
0	Not clearly related	Crude speculation	Crude speculation	No discernible rigour	No validation

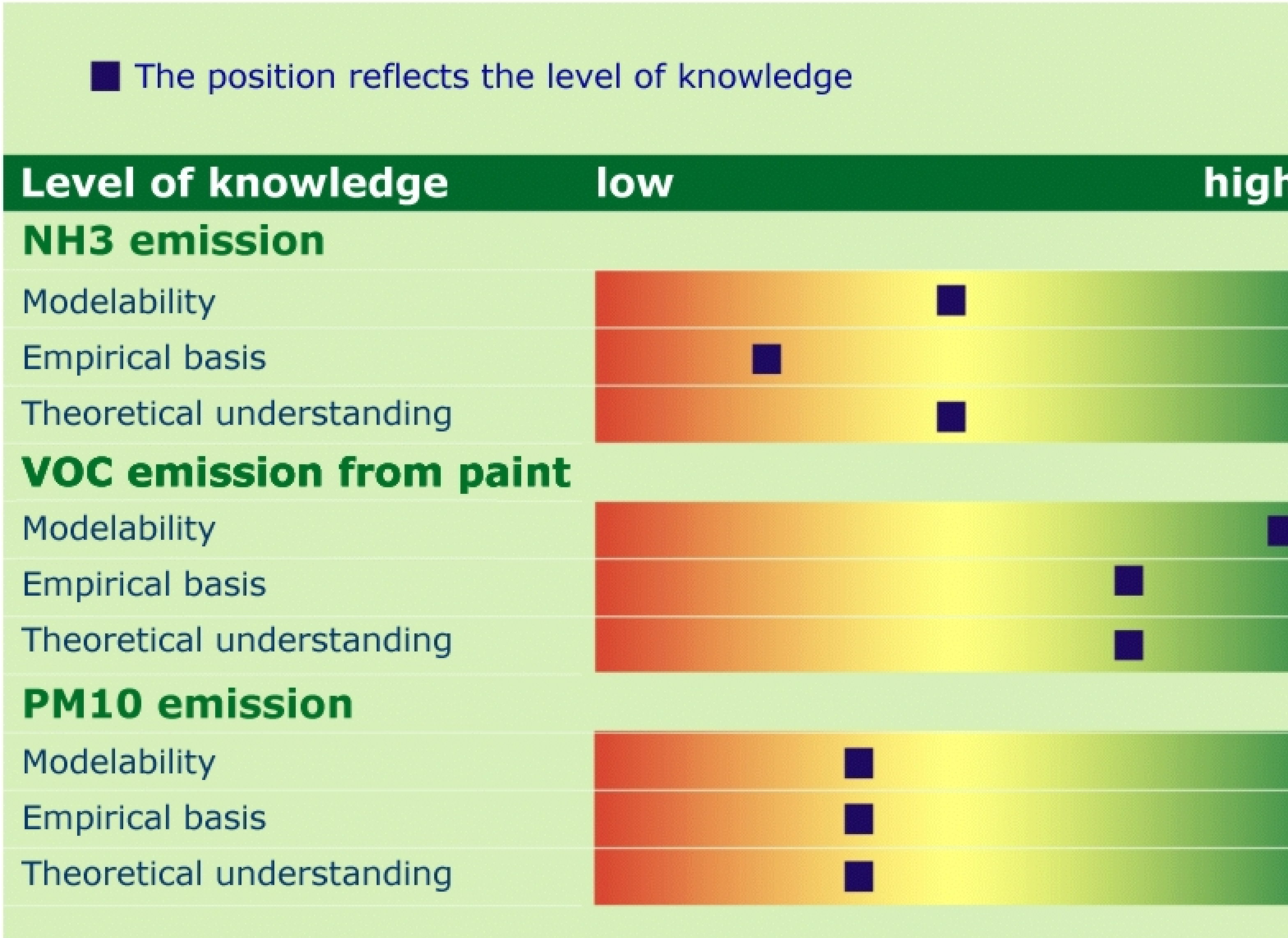
Example Pedigree results

	Proxy	Empirical	Method	Validation	Strength
NS-SHI	3	3.5	4	0	0.66
NS-B&S	3	3.5	4	0	0.66
NS-DIY	2.5	3.5	4	3	0.81
NS-CAR	3	3.5	4	3	0.84
NS-IND	3	3.5	4	0.5	0.69
Th%-SHI	2	1	2	0	0.31
Th%-B&S	2	1	2	0	0.31
Th%-DIY	1	1	2	0	0.25
Th%-CAR	2	1	2	0	0.31
Th%-IND	2	1	2	0	0.31
VOS % import	1	2	1.5	0	0.28
Attribution import	1	1	2	0	0.25

Trafic-light analogy <1.4 red; 1.4-2.6 amber; >2.6 green

This example is the case of VOC emissions from paint in the Netherlands, calculated from national sales statistics (NS) in 5 sectors (Ship, Building & Steel, Do It Yourself, Car refinishing and Industry) and assumptions on additional thinner use (Th%) and a lump sum for imported paint and an assumption for its VOC percentage. See full research report on www.nusap.net for details.

Example: Air Quality

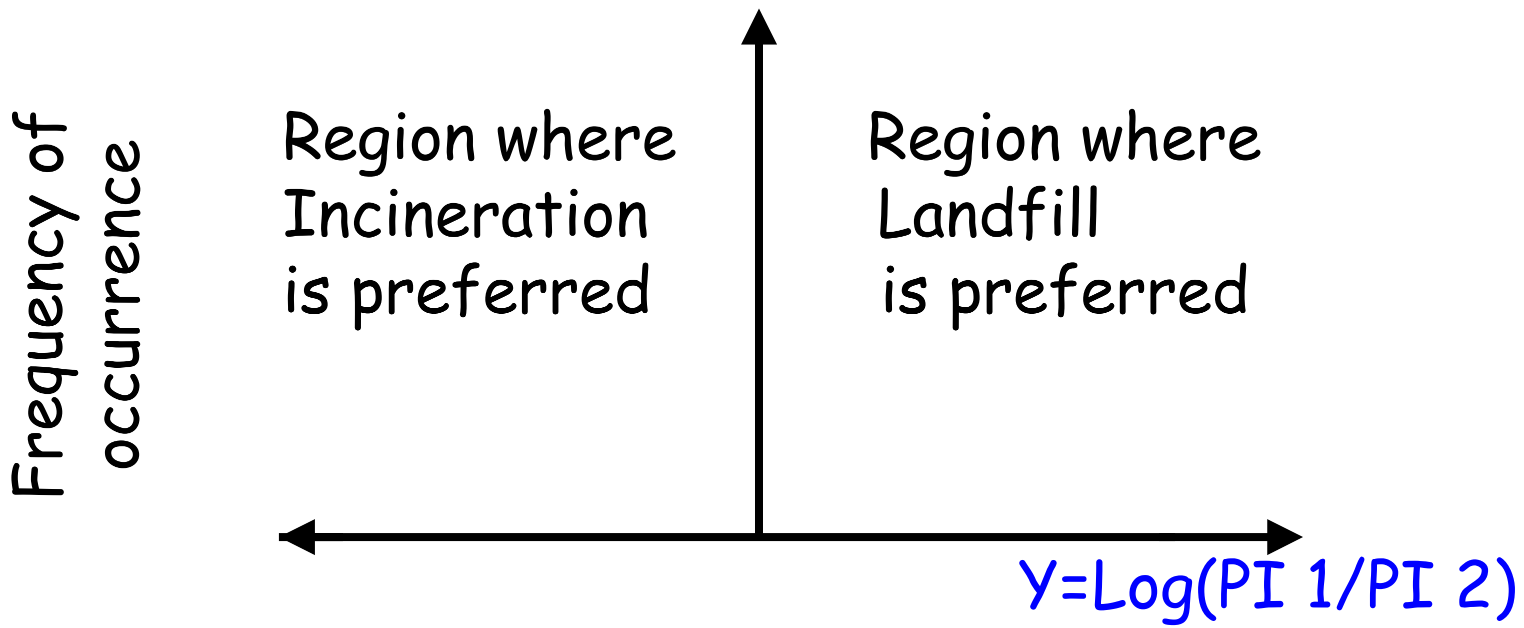


Pedigree matrix for evaluating the tenability of a conceptual model

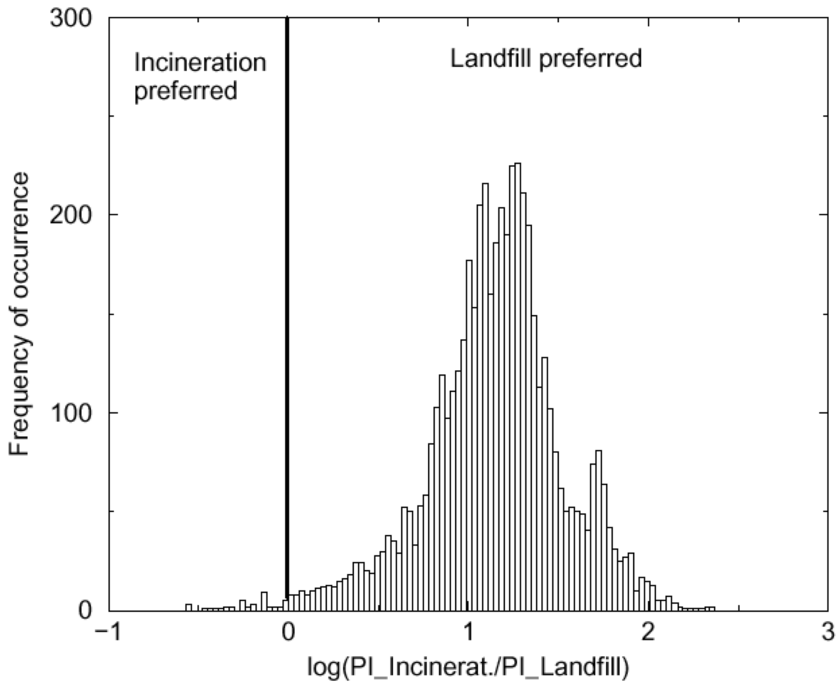
Score	Supporting empirical evidence: Proxy	Supporting empirical evidence: Quality and quantity	Theoretical understanding	Representa-tion of understood underlying mechanisms	Plausibility	Colleague consensus
4	Exact measures of the modelled quantities	Controlled experiments and large sample direct measurements	Well established theory	Model equations reflect high mechanistic process detail	Highly plausible	All but cranks
3	Good fits or measures of the modelled quantities	Historical/field data uncontrolled experiments small sample direct measurements	Accepted theory with partial nature (in view of the phenomenon it describes)	Model equations reflect acceptable mechanistic process detail	Reasonably plausible	All but rebels
2	Well correlated but not measuring the same thing	Modelled/derived data Indirect measurements	Accepted theory with partial nature and limited consensus on reliability	Aggregated parameterized meta model	Somewhat plausible	Competing schools
1	Weak correlation but commonalities in measure	Educated guesses indirect approx. rule of thumb estimate	Preliminary theory	Grey box model	Not very plausible	Embrionic field
0	Not correlated and not clearly related	Crude speculation	Crude speculation	Black box model	Not at all plausable	No opinion

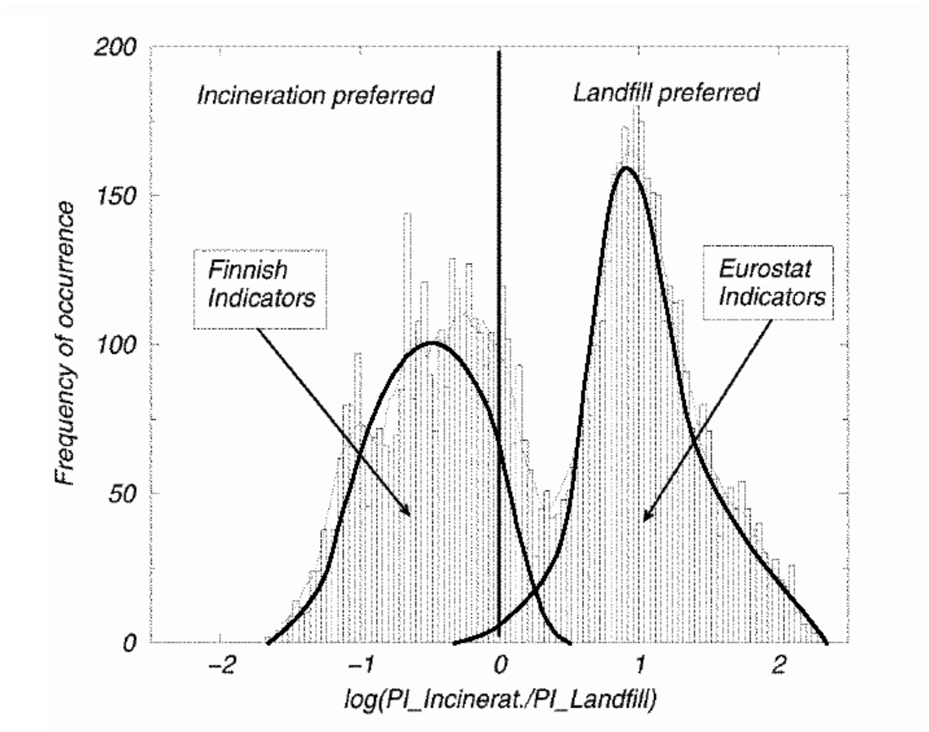
High uncertainty is not the same as low quality

Example: imagine the inference is Y = the logarithm of the ratio between the two pressure-on-decision indices PI1 and PI2



Useful inference versus falsification of the analysis



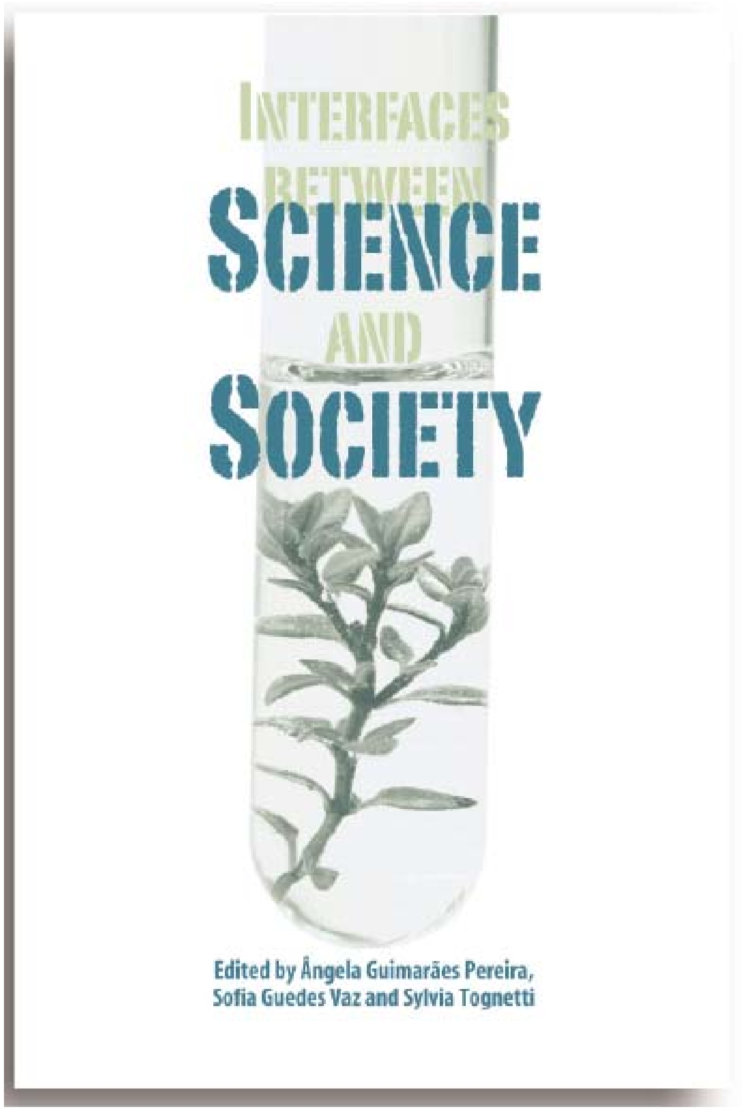


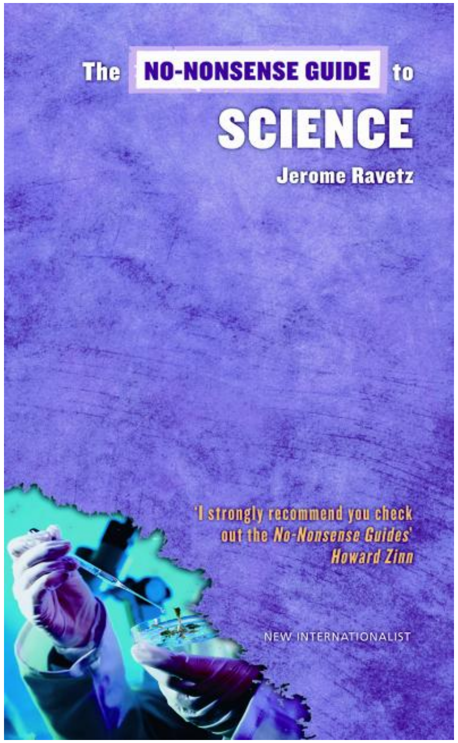
Source: Saltelli et al, 2000, 2004

Summary of Post Normal Science

- Scientists' integrity lies not in disinterestedness but in their **behaviour as stakeholders**.
- Facts still necessary, but no longer sufficient.
- Post-normal scientists should be capable of establishing **extended peer communities** and allow for '**extended facts**' from non-scientific experts.
- key task of post-normal scientists is maintenance and enhancement of **quality**, rather than the establishment of factual knowledge.
- This new role of scientists is challenging and requires different professional capabilities.
- Reflexive methods for **Knowledge Quality Assessment**: NUSAP, quality checklists etc.

Books





Websites:

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