Fagkritisk dag, Realistutvalget, 5 March 2020, Bergen

Critical reflections on scientific practice

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Senter for vitenskapsteori

Universiteit Utrecht

Coöperatieve Universiteit Amersfoort

SVT: Senter for vitenskapsteori

- Inter-faculty **interdisciplinary** research centre in UiB, established in 1987
- Vitenskapsteori: **research on research**
- **Double competence**:
  be able to **understand from the inside** what is going on in your field **AND** be **philosophically informed** about, and be able to **critically reflect on** and cope with, the **epistemic and normative presuppositions** of your own approach and your field of research
- **Critical reflection** on relation between **science and society**

Why bother about social and ethical issues?

- Do you as an academic have a special role or responsibility due to your profession?
- Can you determine the right thing to do in your study and research work?
- Are science and technology possible without ethical rules?
- Should science and technology be steered by external ethical and social norms?

Ethical conflicts within or between science and society

- **Internal:**
- 1. Conflicts of institutional norms → CUDOS/ conduct codes of good scientific practice;
- 2. Conflicts between scientific visions → epistemology & philosophy of science/ uncertainty within science

- **External:**
- 3. Conflicts between institutional norms and social norms *within the process* of doing science → conduct codes, precautionary principle
- 4. Conflicts between scientific pratice and society following from *the products* of science and technology (risks, etc) → technology assessment, technology ethics
- 5. Conflicting (and changing) norms within society about scientific products → (several forms of ethics, tecchnology assessment)

(Slide borrowed from Martijntje Smits)

CUDOS Norms (Merton 1942)

1. **Communality**
   Scientists openly share new findings with colleagues
2. **Universalism**
   Scientists evaluate research only on its merits, according to accepted standards in the field.
3. **Disinterestedness**
   Scientists motivated by desire for knowledge and discovery, and not by possibilities of personal gain
4. **Organized scepticism**
   Scientists consider all new evidence. Claims should be exposed to critical scrutiny before being accepted.

Counter-norms (Mitroff 1979, Andersson et al 2010)

1. **Secrecy** counternorm
   Scientists protect own findings to ensure priority in publishing patenting and application
2. **Particularism** counternorm
   Scientists assess knowledge based on reputation and past productivity of individual or research groups
3. **Self-interestedness** counternorm
   Scientists compete with others in the same field for funding and recognition
4. **Organised dogmatism**
   Scientists invents their career in promoting their own findings, theories and innovations

Slide borrowed from Laura Drivdal, UiB SVT, RINO project

The dilemmas of sponsored research

2013-2014 debate UIB: renewal of sponsorship deal w. Statoil

- NENT to universities: *Oil research, often sponsored by the industry, is ethically irresponsible if it contradicts UNs climate targets.*
- Referring to guidelines:
  - (1) Independence
  - (2) Sustainable development
  - (9) Precautionary principle
  - (17) Openness
  - (18) Conflict of interest

Forskningsetikk nr 3 2014:
https://www.etikkom.no/Aktuelt/Fagbladet-Forskningsetikk/arkiv/2014/2014-3/

https://www.opendemocracy.net/en/ethics-committee-to-universities-oil-research-can-be-unethical/

Slide borrowed from Laura Drivdal, UiB SVT, RINO project

Science for sale

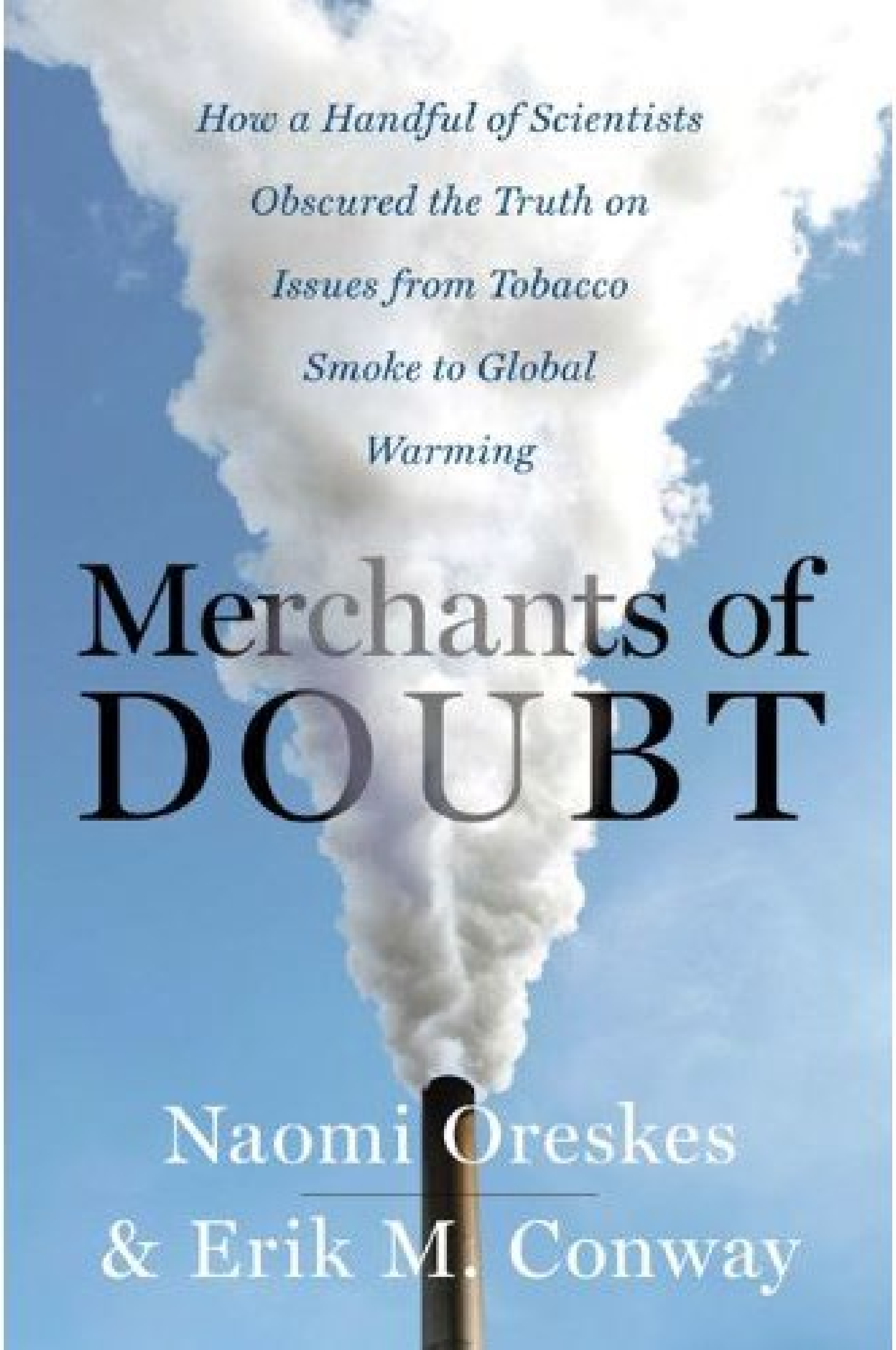
on the interaction between scientific researchers and their clients

Royal Netherlands Academy of Arts and Sciences, 2005

"because of … decreasing public funding of research**, universities and research institutes become too dependent on specific external research contracts**."

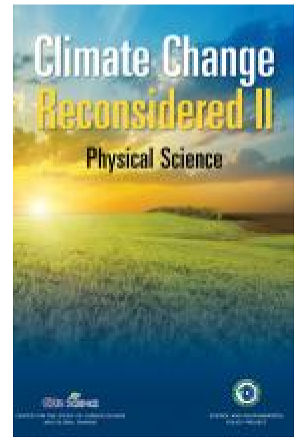
Derailments occur:
"the design of research, the collection and interpretation of data are sometimes **adjusted to provide a favourable outcome for the client** and the **publication** of research findings is sometimes **prevented, delayed or adapted to the needs of the client**. This applies to contract research funded by governments as well as interest groups and industry."

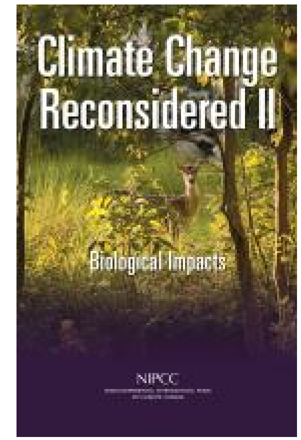
http://www.knaw.nl/Content/Internet_KNAW/publicaties/pdf/20051083.pdf



Nongovernmental International Panel on Climate Change (NIPCC)

The Heartland INSTITUTE



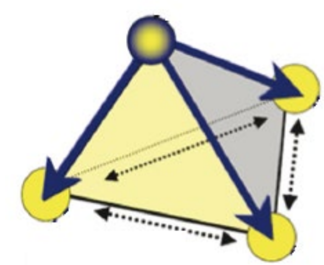


http://heartland.org/

CATO INSTITUTE

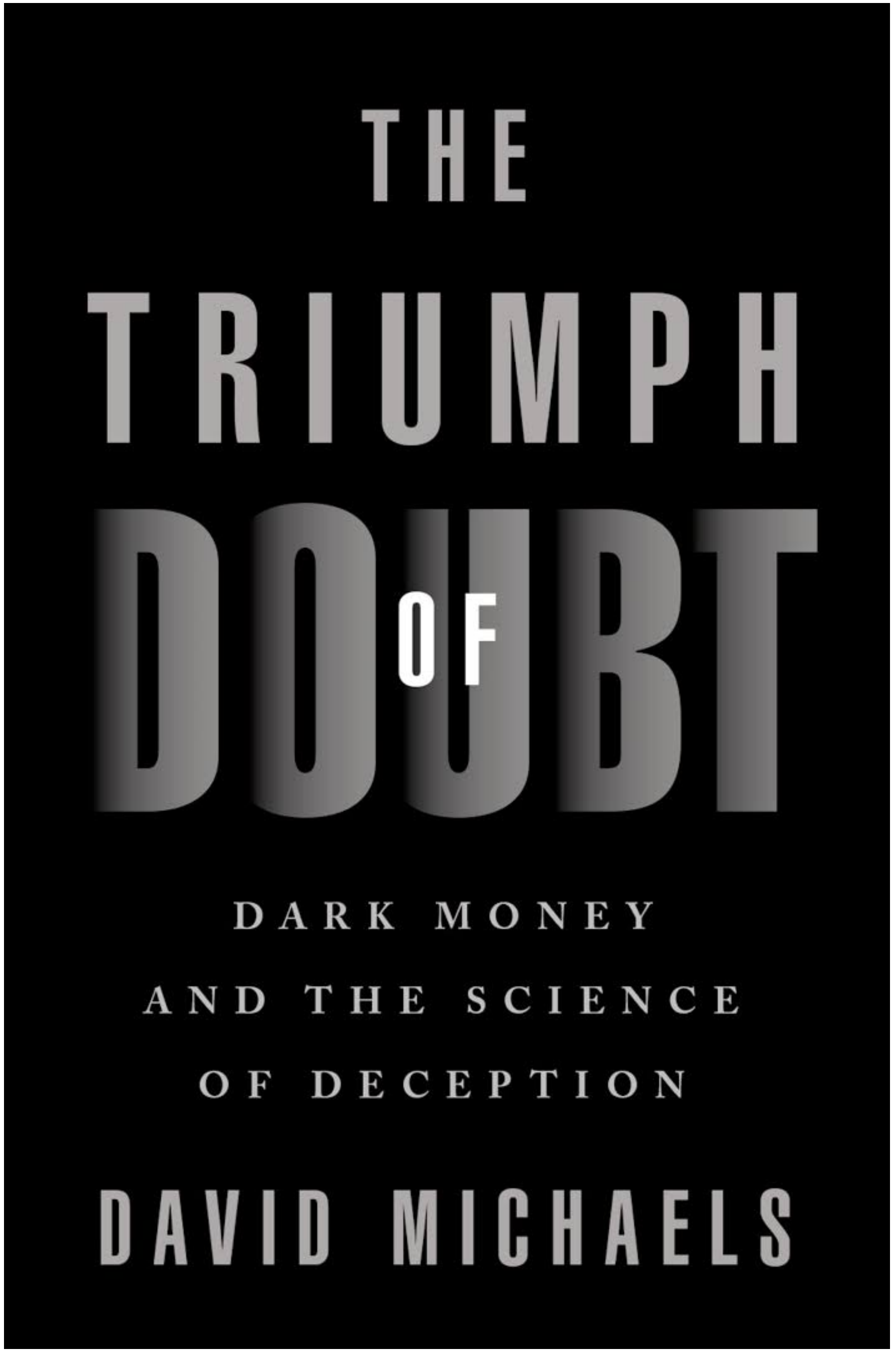
"Individual Liberty, Free Markets, and Peace"

http://www.cato.org



Interests

http://books.google.com/books?id=CrtoNFTuPwwC



Published 2020

Begins introduction and overview chapter on The Science of Deception.

Most subsequent chapters then focus on ways that corporations have with greater or lesser success managed to obscure public understanding of scientific findings regarding specific types of products or concerns.

Chemicals
Volkswagen
Opioids,
The Climate Denial Machine
Sugar
Etc

http://bostonreview.net/science-nature/david-michaels-science-sale

Some of the strategies used

- Selective funding of research adressing favourable questions;
- Keeping important (but unwelcome) aspects ouside the scope of research;
- Making (favourable) assumptions and underpinning these rethorically rather than factual;
- Deliberately faulty experimental design to obtain desired results;
- Intentional misapplication of statistics;
- Reanalysis
- Hiding unwelcom uncertainties / magnifying welcome uncertainties;
- Improper generalization;
- Removal of unwelcome results, ignoring unwelcome knowledge;
- Prohibition of disclosure of outcomes or prolongued embargo (IPR);
- Tampering of data from literature, observation or experiment;
- Knowingly wrong or biased representation of others' findings;
- Fabrication of data /fraud;
- Drawing of intentionally false concusions / firmer than justified;
- Promote wrong interpretations by the media;
- Disobligue colleagues in order to influence the scientific and societal debate;
- Feigning of expertise (acquisition, media, hearings);
- Spin doctor techniques against unwelcome knowledge;
- Gohst writing;
- Pal review (nepotism);

Academic Research in the 21st Century: Maintaining Scientific Integrity in a Climate of Perverse Incentives and Hypercompetition

Abstract: Over the last 50 years, we argue that **incentives for academic scientists have become increasingly perverse** in terms of competition for **research funding**, development of quantitative metrics to **measure performance**, and a **changing business model** for higher education itself. Furthermore, decreased discretionary funding at the federal and state level is creating a hypercompetitive environment between government agencies (e.g., EPA, NIH, CDC), for scientists in these agencies, and for academics seeking funding from all sources—the **combination** of **perverse incentives and decreased funding increases pressures that can lead to unethical behavior**. **If a critical mass of scientists become untrustworthy, a tipping point is possible** in which the **scientific enterprise** itself **becomes inherently corrupt** and public trust is lost, **risking a new dark age** with devastating consequences to humanity. Academia and federal agencies should better support science as a public good, and incentivize altruistic and ethical outcomes, while de-emphasizing output.

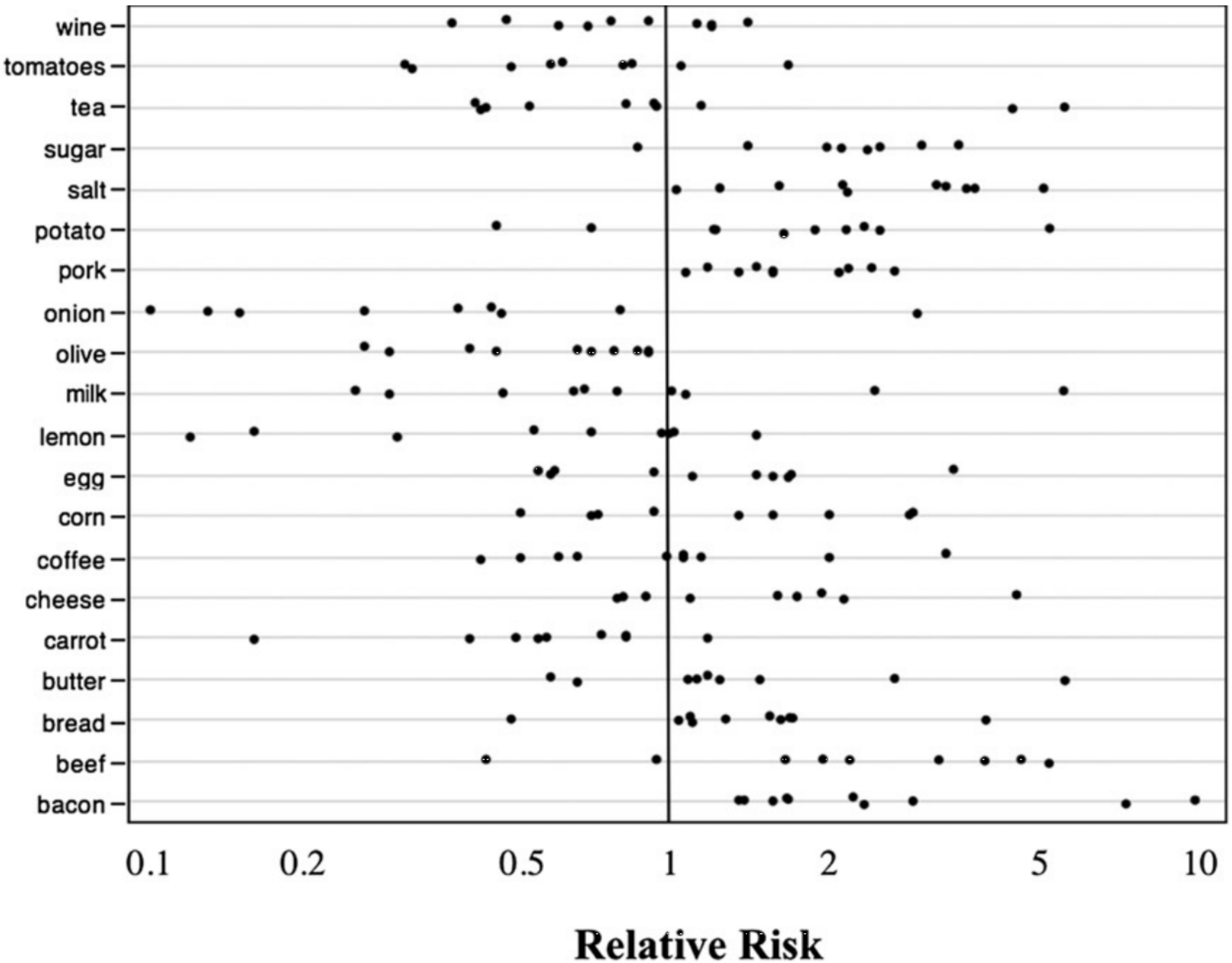
Edwards & Roy 2017
http://online.liebertpub.com/doi/10.1089/ees.2016.0223

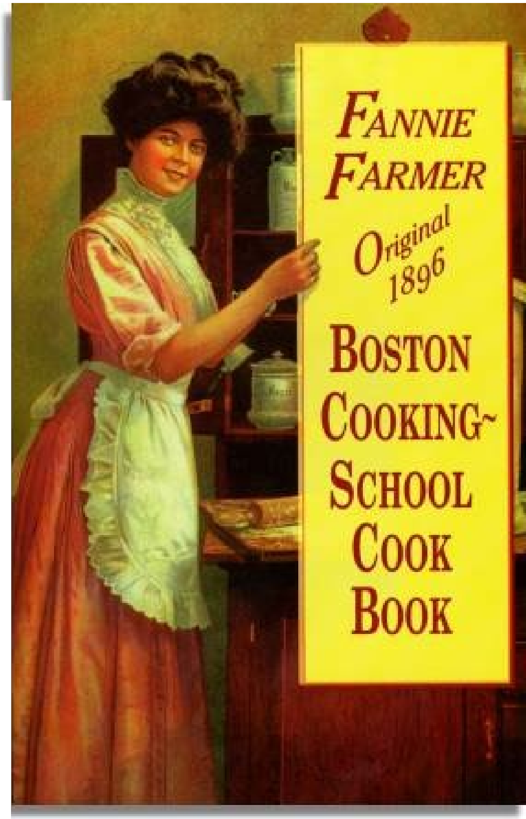
Why Most Published Research Findings Are False (Ioannidis, 2005)

There is increasing concern that most current published research findings are false. **The probability that a research claim is true may depend on study power and bias**, the number of other studies on the same question, and, importantly, the ratio of true to no relationships among the relationships probed in each scientific field. In this framework, **a research finding is less likely to be true when the studies conducted in a field are smaller; when effect sizes are smaller; when there is a greater number and lesser preselection of tested relationships; where there is greater flexibility in designs, definitions, outcomes, and analytical modes; when there is greater financial and other interest and prejudice; and when more teams are involved in a scientific field in chase of statistical significance**. Simulations show that for most study designs and settings, it is more likely for a research claim to be false than true. Moreover, for many current scientific fields, claimed research findings may often be simply accurate measures of the prevailing bias. In this essay, I discuss the implications of these problems for the conduct and interpretation of research.

http://www.plosmedicine.org/article/info:doi/10.1371/journal.pmed.0020124

Example: Is everything we eat associated with cancer? A systematic cookbook review





50 common ingredients from random recipes in a cookbook; 10 most recent articles on cancer risk

Effect estimates reported in the literature by ingredient. Only ingredients with >=10 studies are shown. Three outliers are not shown (effect estimates >10).

https://academic.oup.com/ajcn/article/97/1/127/4576988

Trans science (Alvin Weinberg)

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

Refs:

- Alvin Weinberg (1972) Science and trans-science, Minerva, 10, 1972, 209-222.
- Alvin Weinberg (1991) Origins of Science and Trans-Science, Citation Classics 34 S18,
- Harvey Brooks (1972) Science and Trans-Science - Letter to the Editor, Minerva 10, 484-486.

Trans Science – Alvin Weinberg

- "Let us consider the **biological effects of low-level radiation insults to the environment, in particular the genetic effects of low levels of radiation on mice**. Experiments performed at high radiation levels show that the dose required to double the spontaneous mutation rate in mice is 30 roentgens of X-rays. Thus, if the genetic response ,to X-radiation is linear, then a dose of 150 millirems would increase the spontaneous mutation rate in mice by 0.5%. This is a matter of importance to public policy since the various standard-setting bodies had decided that a yearly dose of about 150 millirems (actually 170 millirems) to a suitably chosen segment of the population was acceptable. Now, **to determine at the 95 per cent. confidence leve**l by a direct experiment whether 150 millirems will **increase .the mutation rate by 0.5% requires about 8,000,000,000 mice!** Of course this number falls if one reduces the confidence level; at 60 per cent. confidence level, the number is 195,000,000. Nevertheless, **the number is so staggeringly large that, as a practical matter, the question is unanswerable by direct scientific investigation**."

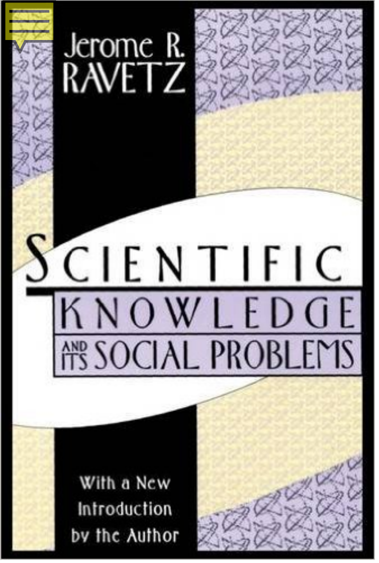
Alvin Weinberg (1972) Science and trans-science, *Minerva*, 10, 209-222.

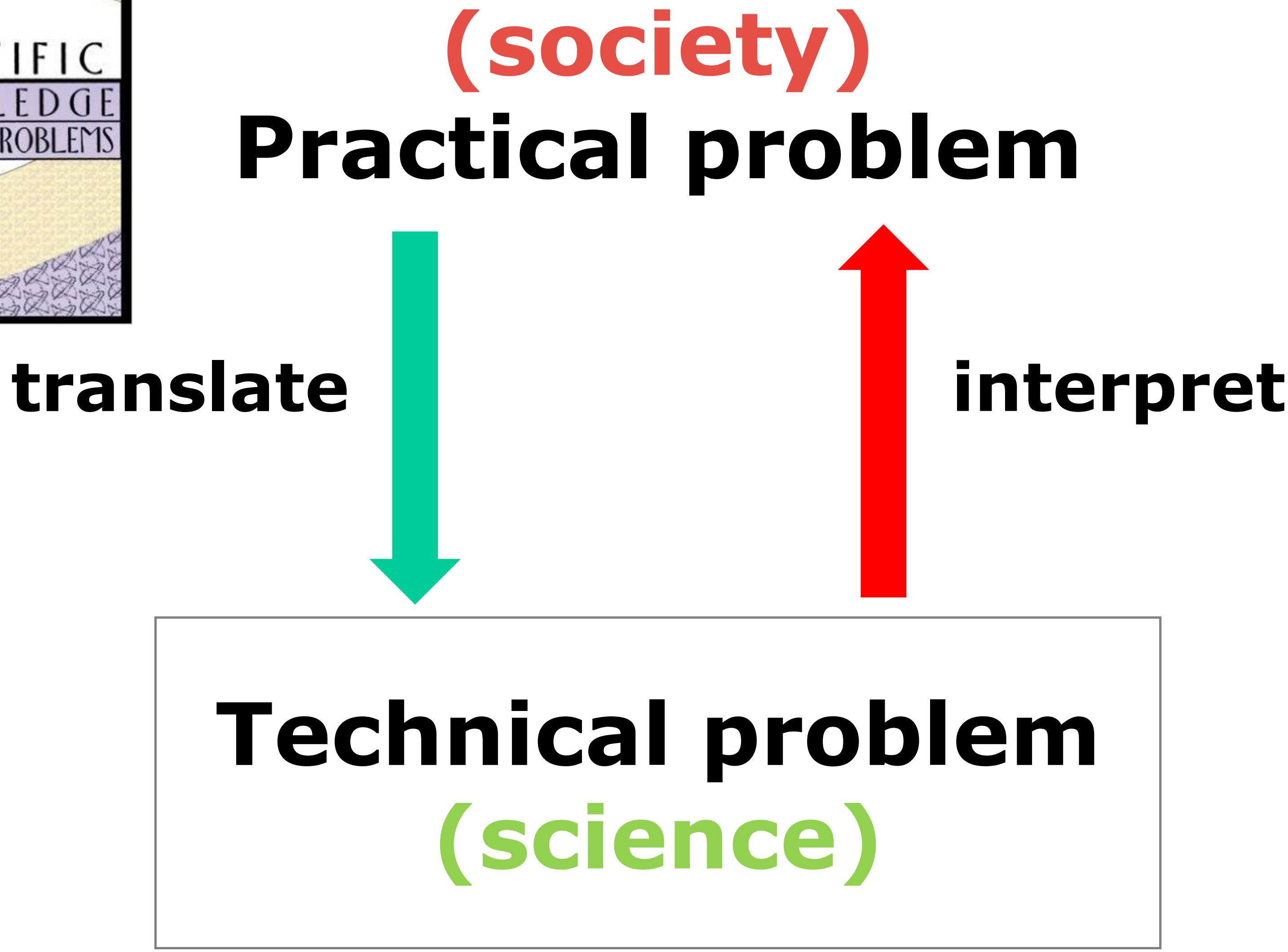
CONTENTS

http://www.andreasaltelli.eu/file/repository/Science_on_the_Verge_FINAL_.pdf

Challenges in science for policy

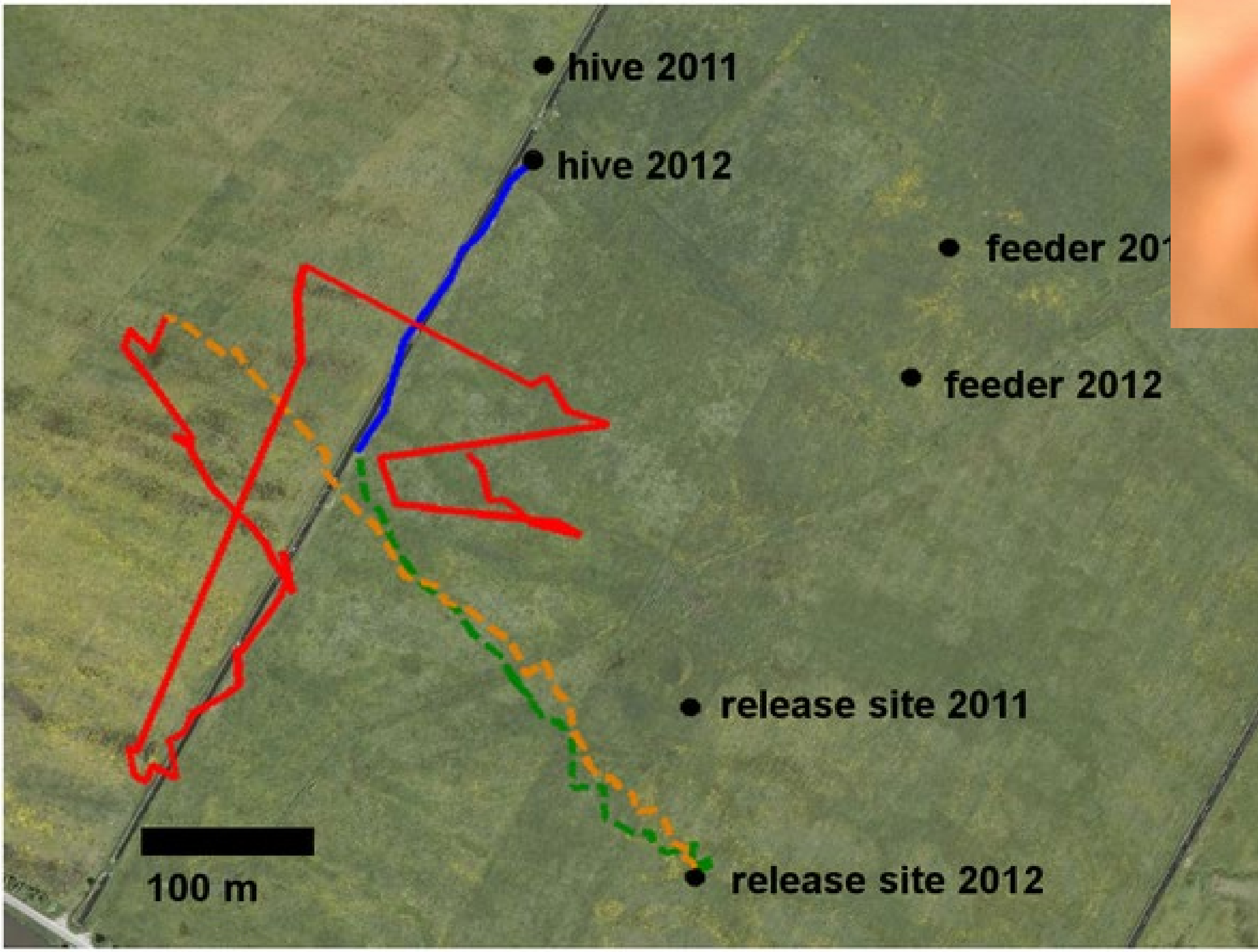
- Policy maker wants **relevant** knowledge. But: not easy to define what the relevant knowledge is.
- There is a need to **reduce the complexity**, to confine the problem into a selection of various policy options.
- You have to find solutions within a certain **time frame**. Often this is part of a conflict between policy making and science.
- There is a need to **explore possibilities**, to balance pro's and con's, and instruments are needed to do so.
- There is a need to **legitimize the decisions** within an arena of competing different interest groups.
- There is a need for **robustness and consensus** in the assessments
- Assessors have to negotiate **credibility** with scientific peer groups, policy makers and other actors involved.





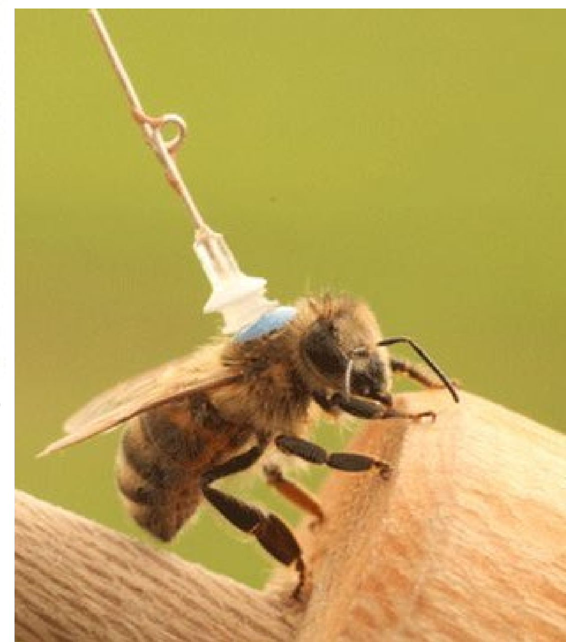
Ravetz, J., 1971, Scientific Knowledge and its Social Problems, Oxford University Press.

Radar-tracking experiment Randolf Menzel:
Bees exposed to neonicotinoids loose orientation



Yellow-Red Thiacloprid-bees

Green-Blue Control bees



Fischer J, Müller T, Spatz A-K, Greggers U, et al. (2014) Neonicotinoids Interfere with Specific Components of Navigation in Honeybees. PLoS ONE 9(3): e91364. doi:10.1371/journal.pone.0091364
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0091364

PLOS | ONE

Plurality of styles of scientific reasoning

- **Styles of reasoning** characterise the way by which academic disciplines & practices arrive at scientific propositions
- Determine what counts as rational or irrational, scientific or quasi-scientific, valid or invalid evidence, true or false.

- Examples of styles:
  - Postulation (mathematics)
  - Experimental exploration
  - Hypothetical construction of analogical models (Feynman: "*What I cannot create, I do not understand*")
  - Ordering of variety by comparison and typology
  - Statistical analysis of regularities of populations / probabilities.

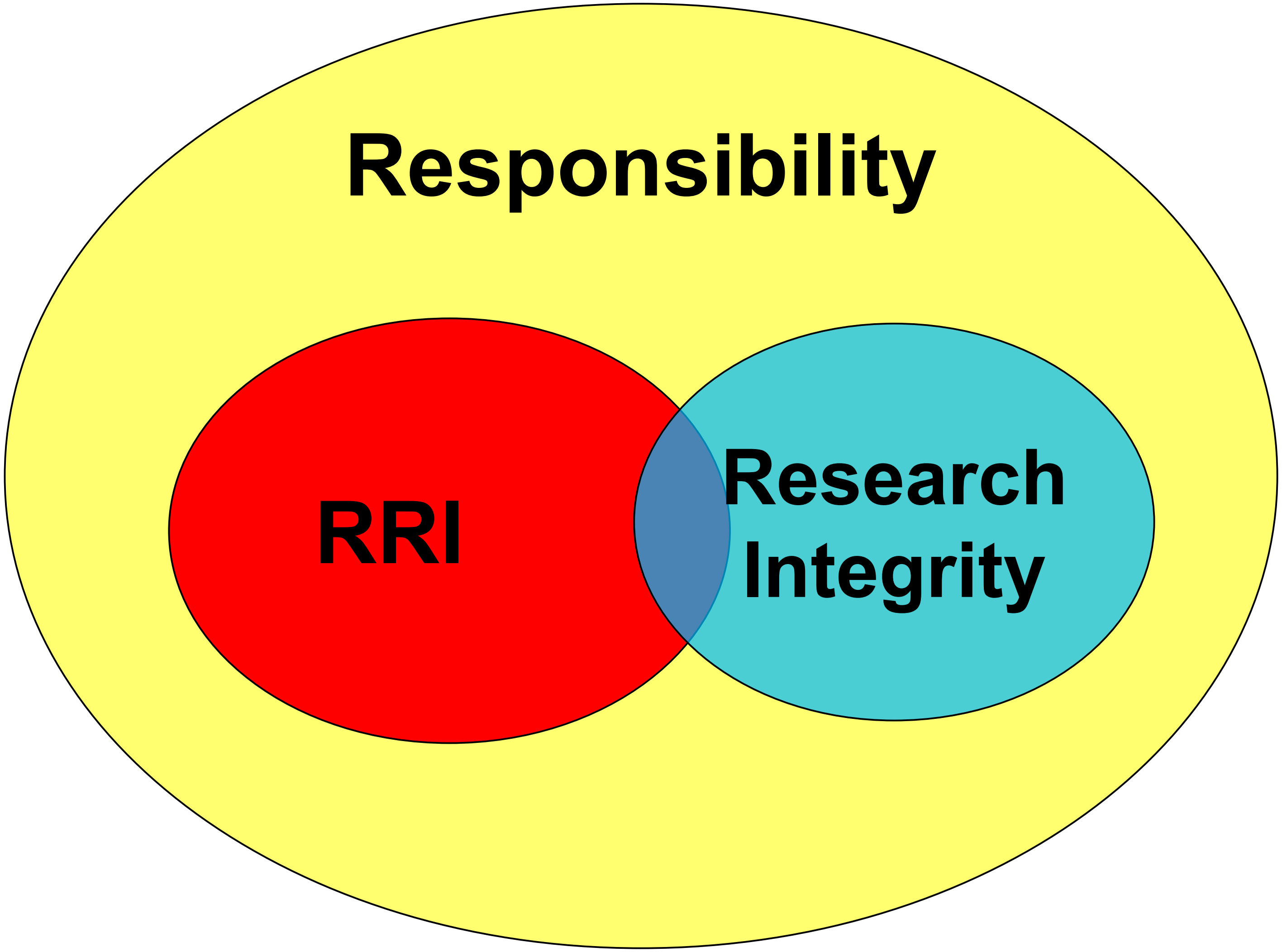
(Crombie 1992, 1994, Hacking 1982, 1985, 1992, Kusch 2010)

- *A 21st century view of science must not only embrace the wider societal context, but be prepared for the context to begin to talk back.*
- *Reliable knowledge will no longer suffice, at least in those cases, where the consensuality reached within the scientific community will fail to impress those outside.*
- *In a 21st century view of science, more will be demanded from science: a decisive shift towards a more extended notion of scientific knowledge, namely a shift towards socially robust or context-sensitive knowledge.*

(Helga Nowotny 1999)

Helga Nowotny
Former President
European Research Council

Photo http://ec.europa.eu/research/eurab/cvnowotny.html



(Slide borowed from Roger Strand UiB SVT)

RRI

- Responsible Research and Innovation (RRI) is the on-going process of **aligning research and innovation to the values, needs and expectations of society**.

Rome Declaration on Responsible Research and Innovation in Europe, 2014
https://ec.europa.eu/research/swafs/pdf/rome_declaration_RRI_final_21_November.pdf

Responsible Research and Innovation (RRI)

- *Responsible Research and Innovation is a* ***transparent, interactive process*** *by which* ***societal actors and innovators*** *become* ***mutually responsive*** *to each other with a view on the (ethical)* ***acceptability, sustainability and societal desirability*** *of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).*

R. von Schomberg (ed.): *Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields. A report from the European Commission Services*, 2012, p. 9.
https://publications.europa.eu/en/publication-detail/-/publication/60153e8a-0fe9-4911-a7f4-1b530967ef10/language-en

RRI is

- A **process** (see definitions before)

- A **practice**
  - of the highest **integrity** and **quality**

- A **reflective & critical research culture**
  - Get rid of perverse incentives

- Need for internal **reform** of science

(PNS4, 15-17 Nov 2018 Barcelona: http://symposium.uoc.edu/go/pns4
PNS5, 21-23 Sept 2020 Florence: https://pns5.biostatistica.net/)


1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
THE GLOBAL GOALS
For Sustainable Development
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

Table 1
Lines of questioning on responsible innovation.

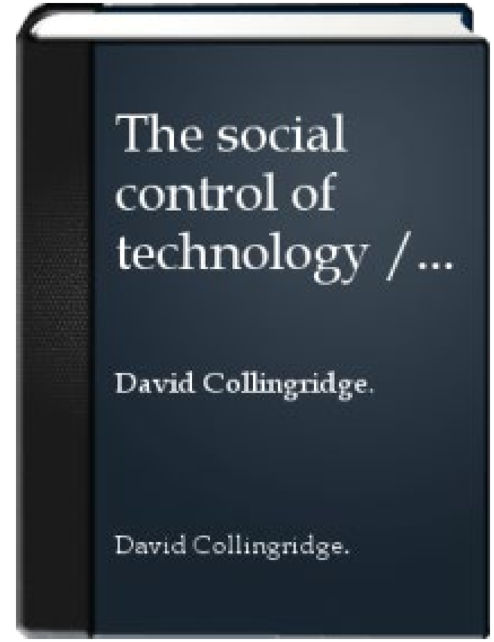
Product questions
How will the risks and benefits be distributed? What other impacts can we anticipate? How might these change in the future? What don't we know about? What might we never know about?

Process questions
How should standards be drawn up and applied? How should risks and benefits be defined and measured? Who is in control? Who is taking part? Who will take responsibility if things go wrong? How do we know we are right?

Purpose questions
Why are researchers doing it? Are these motivations transparent and in the public interest? Who will benefit? What are they going to gain? What are the alternatives?

http://dx.doi.org/10.1016/j.respol.2013.05.008

Collingridge Dilemma



1980

“The social consequences of a technology cannot be predicted early in the life of the technology.

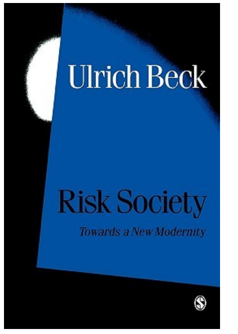
By the time undesirable consequences are discovered, however, the technology is so much part of the whole economics and social fabric that its control is extremely difficult.

This is the *dilemma of control.*”

“More and more key decisions are made in the laboratory”

Ulrich Beck,

Risk Society, 1986/1992

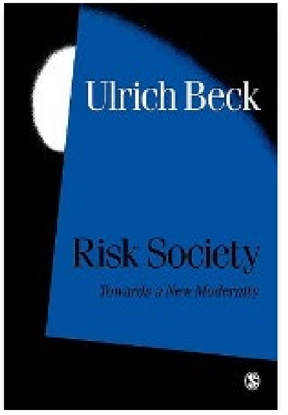


"We have learnt that it is necessary with major technologies to ensure that the debate takes place 'upstream', as new areas emerge in the scientific and technological development process”

Lord Sainsbury,

UK Science & Innovation Minister, 2004

Risk Society (Ulrich Beck, 1986/92)

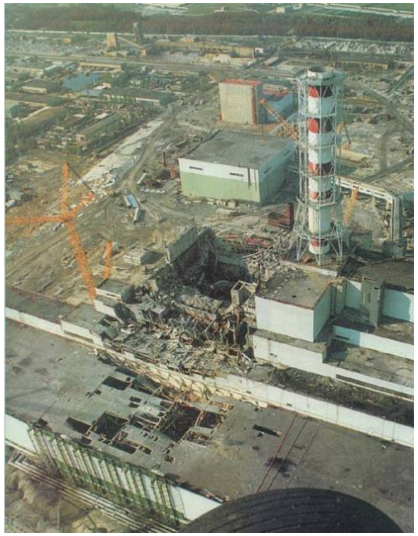


- Failure of the industrial society to manage the risks it has manufactured
- Disasters such as BSE, Tsjernobyl, etc. are presented as unique events, while in fact they are intrinsic products of the way we have organised our modern industrial society
- Focus of societal conflict shifts from ‘distrubution of goods’ to ‘distribution of bads’

Risk Society - continued

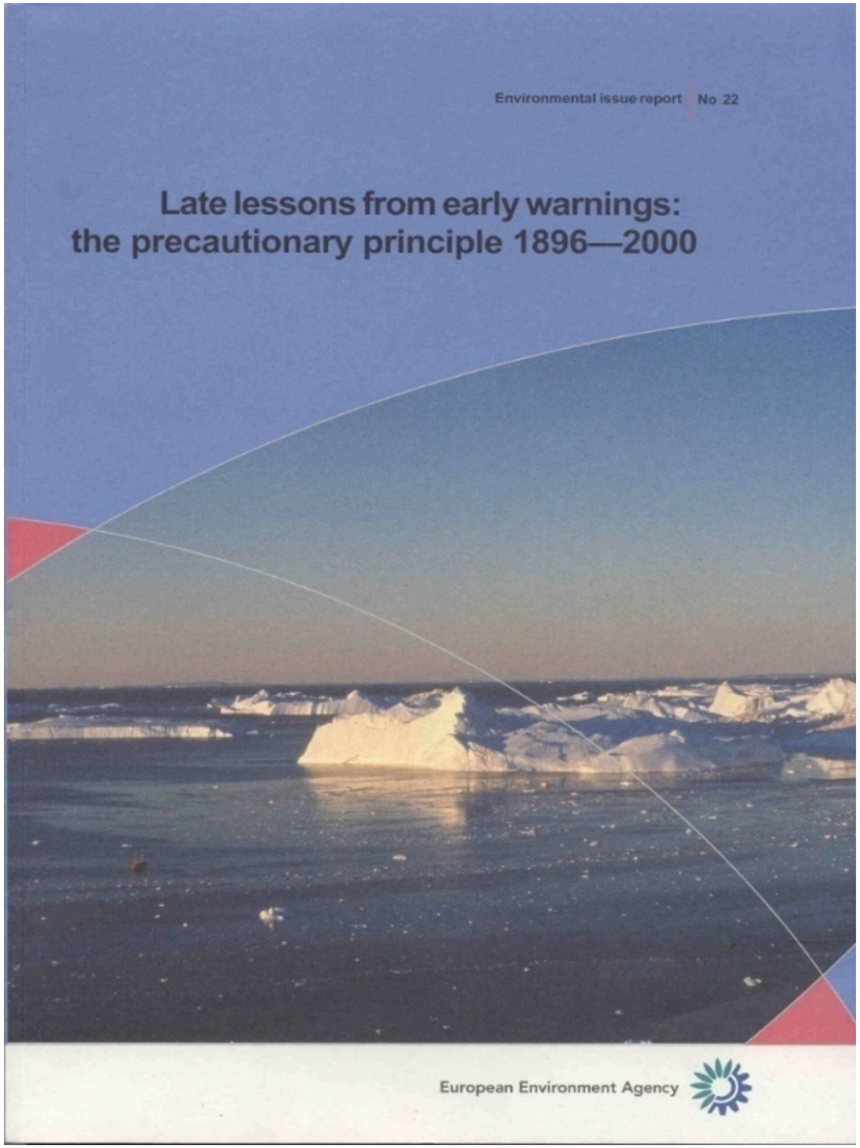
- “Unhoped failure” vs “**Normal accidents**”
- Largest risk is not physical explosiveness of technology by “societal explosiveness”: **loss of trust in institutions**
- **Symbolic policy** to create the (false) expression that risks are under control
- Who is responsible for uncontrollability of developments? **Organised irresponsibility**

Ch-Ch syndrome 1986



"***The issue of quality control in science, technology and decision-making*** *is now appreciated as urgent and threatening. The experiences of* ***Ch****ernobyl and* ***Ch****allenger, both resulting from lapses of quality control, illustrate this problem. We have described the* ***"Ch-Ch Syndrome": the catastrophic collapse of sophisticated mega-technologies resulting from political pressure, incompetence and cover-ups*** *(Ravetz et al., 1986).*"

2001 **2013**



http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0001:FIN:EN:PDF

https://www.eea.europa.eu/publications/late-lessons-2

34 case studies in the "Late Lessons" reports...

'Environmental chemicals'

- Beryllium
- PCBs
- CFCs
- TBT antifoulants
- Mercury
- Environmental Tobacco
- Perchlorethylene
- Booster biocides
- DBCP
- DDT
- Vinyl chloride
- Bisphenol A

Ecosystems

- Ecosystems resilience
- Great Lakes pollution
- Fish stock collapse
- Acid rain
- Bee decline, France
- Invasive alien species
- Floods
- Climate change

Transport fuel additives

- Benzene
- MBTE
- Lead

'Micro technologies'

- Nano
- GMOs & Agro-ecology

Animal feed additives

- BSE, 'mad cow disease'
- Beef hormones
- Antibiotics

- Asbestos

Pharmaceuticals

- Contraceptive pill
- DES

Radiations

- X-rays
- Mobile phones
- Nuclear accidents

Slide by Dr. David Gee

Late Lessons II report 2013

- Key decisions on innovation pathways made by few on behalf of many
- Lack of (institutional) mechanisms to respond to early warning signals
- Misleading market prices fail to reflect all costs and risks to society and nature

✓ Broaden application of the principles of precaution, prevention and polluter-pays

✓ Make government and business accountable

✓ Broaden evidence considered (lay/local knowledge) and public engagement

✓ Build resilience in governance systems and institutions

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.

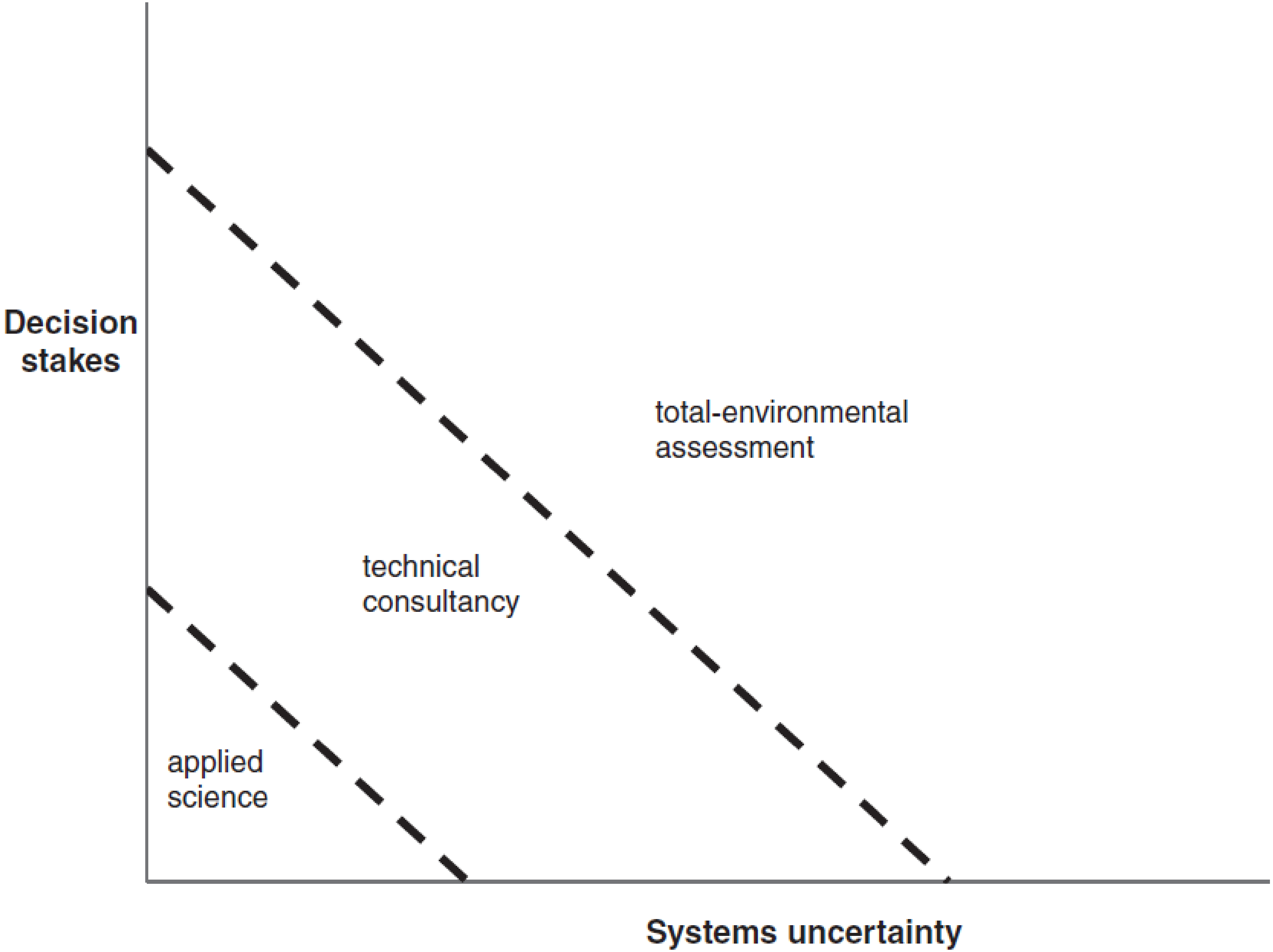
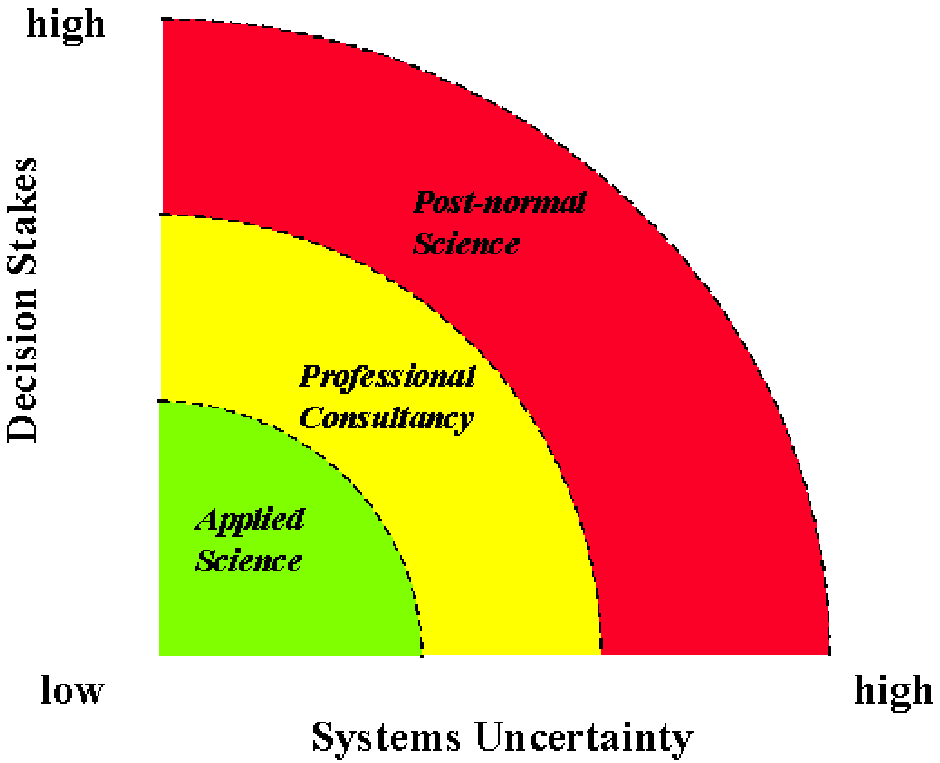


Figure 28.2 The original diagram of three types of risk assessment.
Source: redrawn after Funtowicz & Ravetz (1985).
Note: "Total-environmental assessment" would later be relabelled as "post-normal science".

Complex - *uncertain* - risks

Typical characteristics:

- Decisions urgent
- Stakes high
- Values in dispute
- Irreducible & unquantifiable uncertainty



- Assessment: models, scenarios, assumptions, extrapolations
- (hidden) value loadings in problem frames, indicators chosen, assumptions made

- **Knowledge Quality Assessment!**

(Funtowicz & Ravetz, 1993)
http://www.uu.nl/wetfilos/wetfil10/sprekers/Funtowicz_Ravetz_Futures_1993.pdf

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)*

Illustrative example

Protecting a strategic fresh-water resource under the Water Supply Act Denmark

Case:

- Important aquifer west of Copenhagen
- groundwater abstraction 12 million m^3/year
- Copenhagen County had to prepare an action plan for protection of groundwater against pollution
- Scientist were asked to assess aquifer's vulnerability to pollution in a 175 km^2 area

A practical problem:

Protecting a strategic fresh-water resource

5 scientists addressed same question:

"which parts of this area are most vulnerable to nitrate pollution and need to be protected?"

(Refsgaard, Van der Sluijs et al, 2006)

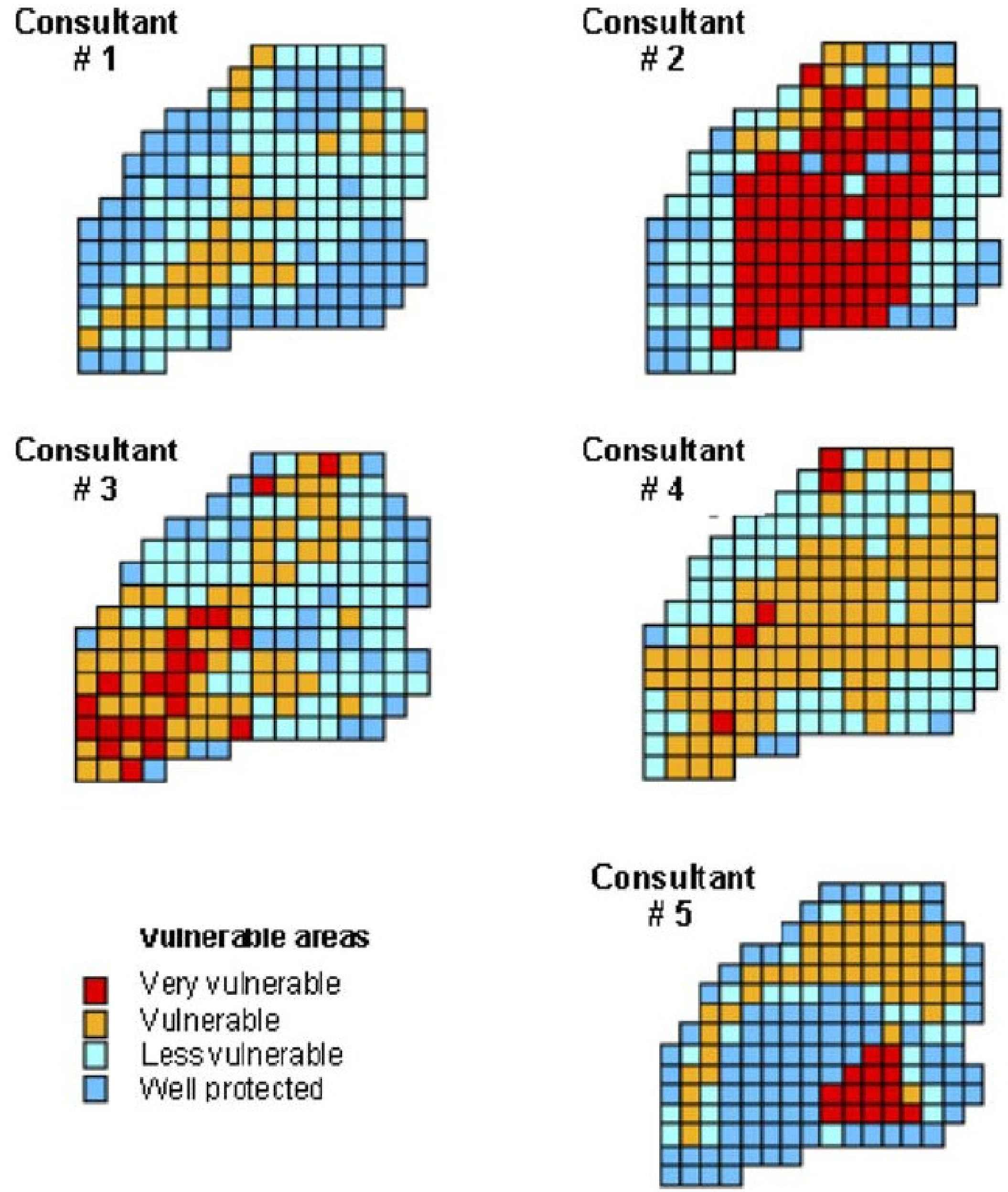


Fig. 1. Model predictions on aquifer vulnerability towards nitrate pollution for a 175 km^2 area west of Copenhagen [11].

3 framings of uncertainty

'deficit view'

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

'evidence evaluation view'

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

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

- Uncertainty is intrinsic to complex systems
- Openly deal with deeper dimensions of uncertainty
- *Tools:* Knowledge Quality Assessment
    - ***Working deliberatively within imperfections***

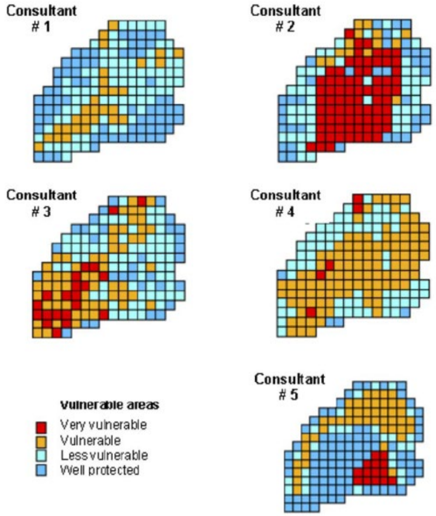


Fig. 1. Model predictions on aquifer vulnerability towards nitrate pollution for a 175 km^2 area west of Copenhagen [11].

How to act upon such uncertainty?

- **Bayesian** approach: 5 priors. Average and update likelihood of each grid-cell being red with data (but oooops, there is no data and we need decisions now)
- IPCC approach: Lock the 5 consultants up in a room and don’t release them before they have **consensus**
- **Nihilist** approach: Dump the science and decide on an other basis
- **Precautionary** robustness approach: protect all grid-cells
- **Academic bureaucrat** approach: Weigh by citation index (or H-index) of consultant.
- Select the consultant that you **trust** most
- Real life approach: Select the consultant that best fits your **policy agenda**
- Post normal: explore the relevance of our ignorance: **working deliberatively within imperfections**

Unrealistic assumptions about scientific evidence

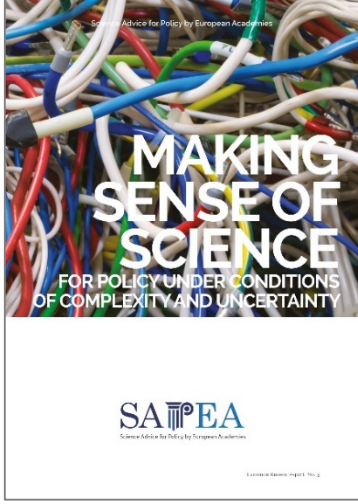
- **Illusion of certainty**: making policymakers more confident about knowing the future than is justified
- **Illusion of transferability**: making policymakers overconfident that certainty in one aspect of the problem applies to all other aspects as well;
- **Illusion of 'absolute' truth**: making policymakers overconfident with respect to the truthfulness of evidence;
- **Illusion of ubiquitous applicability**: making policymakers overconfident in generalising results from one context to another context;
- **Illusion of a linear relationship between evidence and problem-solving**: making policymakers believe that science will offer right solutions to complex problems.

Functions of scientific knowledge in policy advice

- **Enlightenment**: being informed about the state-of-the-art of factual issues (descriptions) and causal/functional relationships that form reliable knowledge
- **Orientation**: making oneself familiar with and gaining a more in-depth understanding of a challenge or a problematic situation, including visions and plans for future actions
- **Strategic planning**: providing strategies for reaching a predefined goal or objective that meet the purpose and make the side-effects of each strategy transparent to the decision-maker, including uncertainties and ambiguities (trade-offs)
- **Integration**: bringing various forms of knowledge into a coherent framework and a common understanding
- **Co-creation of knowledge**: engaging representatives of science, civil society, politics, private sector and/or the affected public(s) in designing new insights or options that facilitate the creation of innovative solutions to a given problem or challenge

http://sapea.info/masos

MASOS report
Take home insight



- **“Science advice is always affected by values, conventions and preferences.**
  …
  Rather than highlighting the role of the ‘objective’ knowledge provider, the **science-policy nexus is better served when both sides are transparent about what values and goals they apply and how knowledge claims are selected, processed and interpreted.** This creates more trust and confidence in institutions and in the processes for science advice.”

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Conclusions

The world's most pressing problems are also incredibly complex
Scientific knowledge around these areas can often be uncertain or contested

- **Science is one of many sources of knowledge that inform policy. Its unique strength is that it is based on rigorous enquiry, continuous analysis and debate, providing a set of evidence that can be respected as valid, relevant and reliable.**
- **Science advice supports effective policymaking by providing the best available knowledge, which can then be used to understand a specific problem, generate and evaluate policy options and monitor results of policy implementation.**
- **Science provides meaning to the discussion around critical topics within society.**
- **Works best when guided by co-creation of knowledge and policy options.**
- **Relationship between science advisers and policymakers relies on building mutual trust, where both scientists and policymakers are honest about their values and goals.**
- **Scientific knowledge should always inform societal debate and decision-making. Citizens often have their own experiences of the policy issue under consideration and should be included in the ongoing process of deliberation between scientists, policymakers and the public**

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PNS 5 Symposium Florence 2020

Post-Normal Science

As science's inter-penetration with technology, finance, politics and mass-media becomes ever more profound, new challenges arise. Scientific practices are becoming increasingly diverse — for example, as citizen science, DIY and makers movements gain prominence, and traditional, local and indigenous knowledge are (re)valued. Plurality in the forms of knowledge increases complexity. In this context, the protection of integrity and quality of knowledge includes critical thinking about science itself. New demarcations are needed, between science practices with qualities that are negotiated with society, and practices that are shoddy, entrepreneurial, opportunistic, reckless, vacuous, or outright dirty. Confronting issues at the science-technology-policy interface with PNS lenses yields something more rigorously managed than politics, less precise than laboratory science, more challenging than either of them, and with the potential to restore integrity to science practice and prudence in policy advice.

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