Embracing Uncertainty

How society deals with not knowing in climate science, engineering, and policy

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Agenda

1. Introduction to uncertainty
2. Uncertainty in Climate Change science
3. The forecast is always wrong
4. Decision-making under uncertainty in engineering and policy
5. Communicating climate science to the public

Objectives of this talk

- Recap uncertainty in climate science
- Recognize uncertainty as an every-day and every-where phenomenon
- Learn about examples of decision-making under uncertainty in engineering and policy
- Think about and discuss how uncertainty in climate science can effectively be communicated to the public

1. Introduction to uncertainty

Image credit: Delta Programme Commissioner, Third Annual Workshop on Decision-making Under Deep Uncertainty, 15.09.2015. Access at: https://english.deltacommissaris.nl/news/news/2015/09/18/third-annual-workshop-on-decision-making-under-deep-uncertainty

We start with some definitions of **Uncertainty** and **Risk**

- Understanding of the public: Risk is negatively connotated (vs. opportunity), uncertainty is equated to not knowing

- Frank Knight (1921): Risk is „a measurable uncertainty” (known probability distribution), uncertainty is not measurable

- Financial industry/risk management: risk is the „effect of uncertainty on objectives” (ISO 31000)

Aleatoric and epistemic uncertainty

- Aleatoric
  - Statistical uncertainty due to variations in the starting conditions of an experiment which we ***cannot*** sufficiently measure and control
- Epistemic
  - Systematic uncertainty due to neglection of certain mechanisms or lack of effort of measurement

Levels of uncertainty between determinism and total ignorance (Walker et al. 2010)

Determinism → Total ignorance

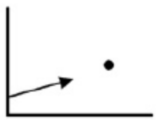
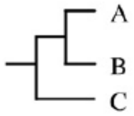
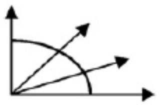
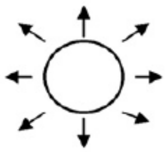
	Level 1	Level 2	Level 3	Level 4
			Deep Uncertainty	
Context	A clear enough future 	Alternate futures (with probabilities) 	A multiplicity of plausible futures 	Unknown future 
System model	A single system model	A single system model with a probabilistic parameterization	Several system models, with different structures	Unknown system model; know we don't know
System outcomes	A point estimate and confidence interval for each outcome	Several sets of point estimates and confidence intervals for the outcomes, with a probability attached to each set	A known range of outcomes	Unknown outcomes; know we don't know
Weights on outcomes	A single estimate of the weights	Several sets of weights, with a probability attached to each set	A known range of weights	Unknown weights; know we don't know

Fig. 1. The progressive transition of levels of uncertainty from determinism to total ignorance.

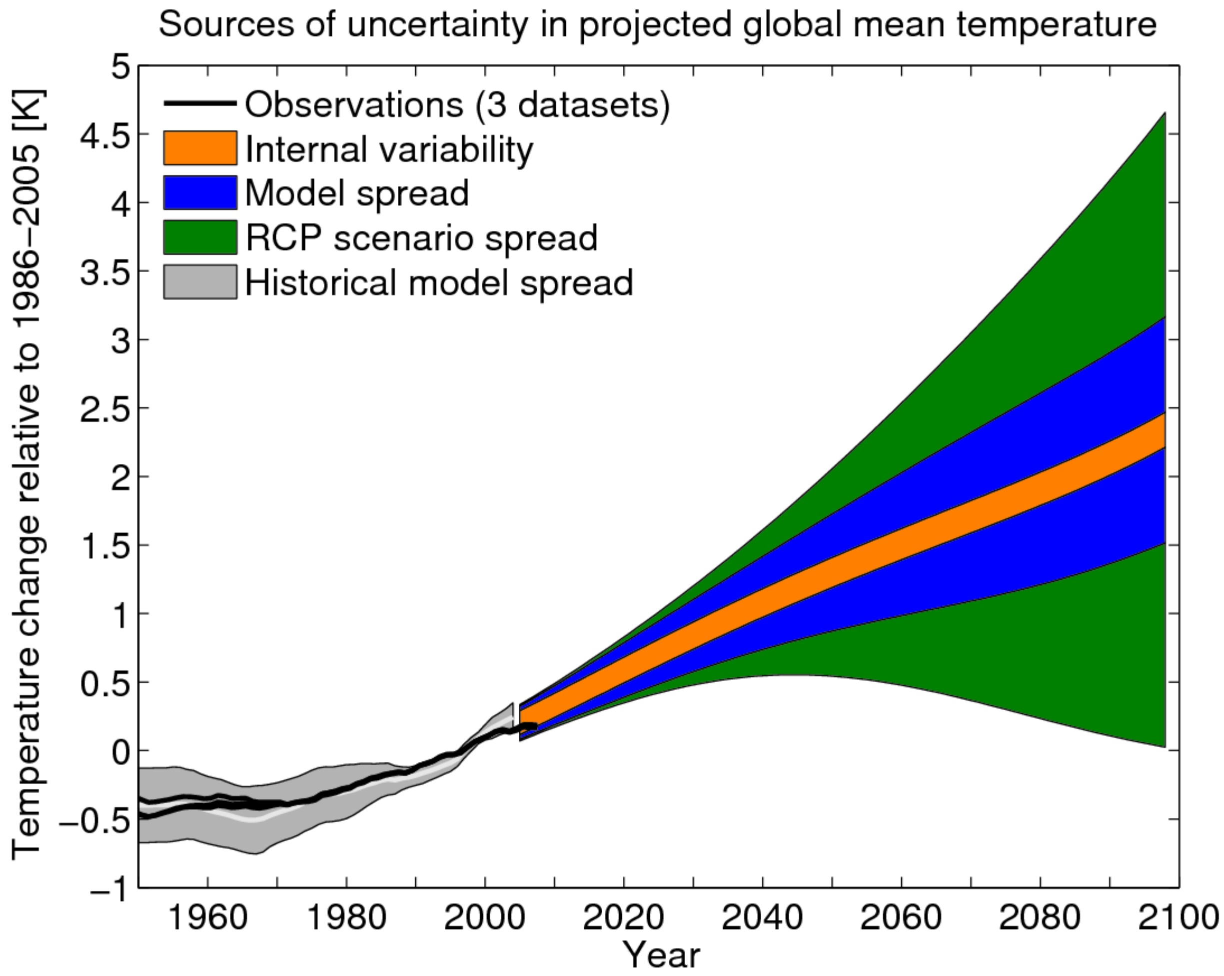
2. Uncertainty in climate science

An important distinction

Disclaimer

Uncertainty is about the **specific effects and magnitude** of climate change, **not whether climate change exists** or not

We have already heard a lot about uncertainty in the previous lectures



IPCC AR5, Fig. 11-8

An (incomplete) list of causes of uncertainty in climate models

- Climate cycles: El Niño/La Niña (2-4 years)
- Aerosol radiation: How do they influence cloud formation?
- International climate negotiations: What Nationally Determined Contributions (NDC) will countries choose?

- Too coarse of a time step
- Too coarse of a spatial resolution
- Incomplete/inaccurate representation of feedbacks
- Incomplete database of current climate variables
- Unknown unknowns
- Known unknowns: (e.g. clouds and ice)

Uncertainty in the IPCC reports

- Concepts of uncertainty have significantly evolved through Assessment Reports (AR)
- AR4:
  - Likelihood: chance of happening (quantitatively, expert judgements 1-10)
  - Confidence: degree of concensus on expert judgements (quantitatively, probability)
  - And a third qualitative approach
  - Working groups use different mix of definitions
- AR5:
  - Old concept of confidence thrown out
  - New concept of confidence: validity of a finding (qualitatively, “very low” to “very high”)
  - Likelihood: Probabilistic measures of uncertainty in a finding (quantitatively)

IPCC5 likelihood scale

Table 1. Likelihood Scale	
Term*	**Likelihood of the Outcome**
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

Side note: there is constant and current new input to the conception of uncertainty

- Critique of uncertainty concept in IPCC reports by Aven and Renn (2015)
  - Definition of a new framework for risk and uncertainty
  - Probabilities: assess the strength of knowledge on which probabilities are based on
  - Remove the likelihood indicator

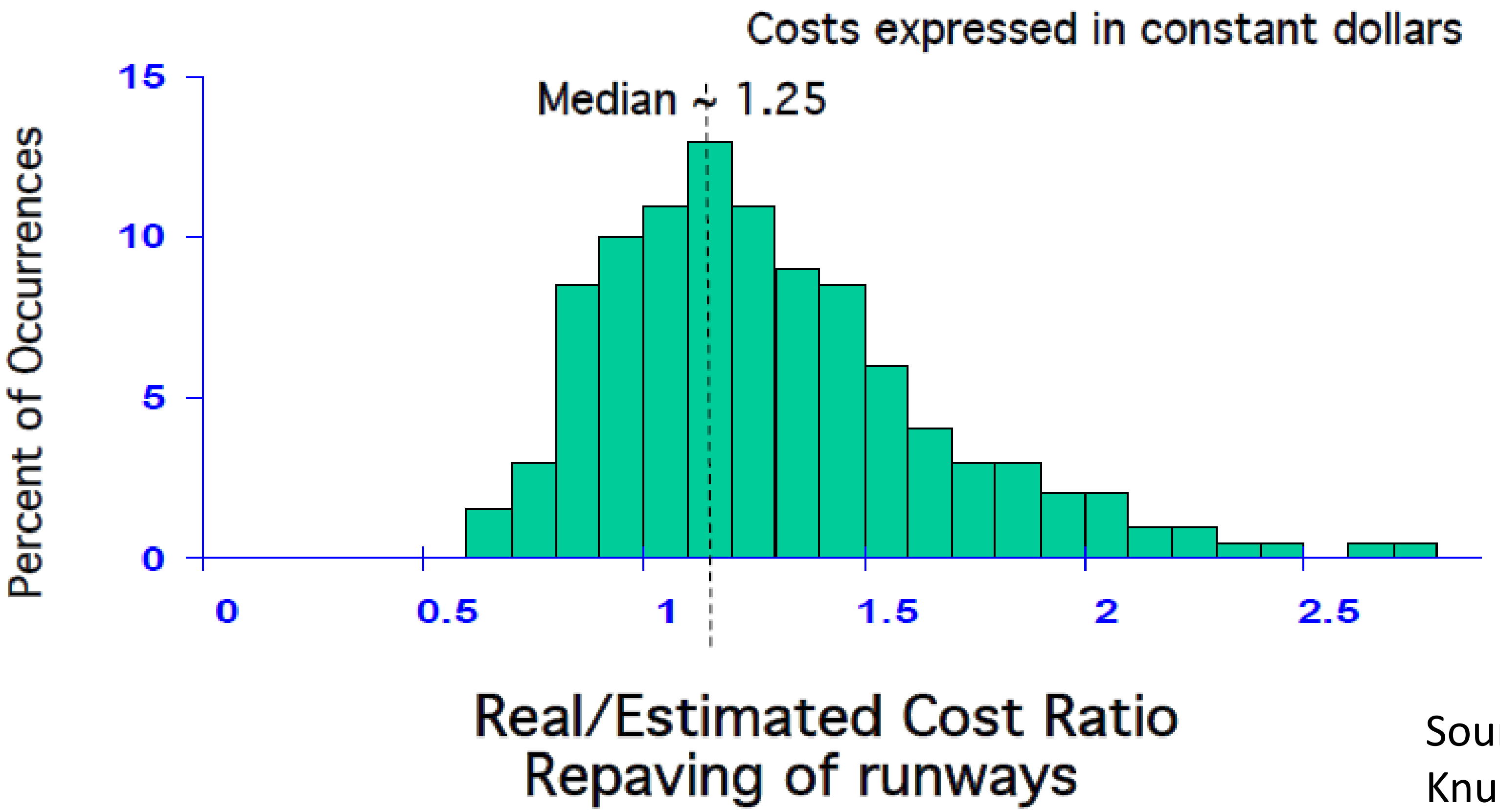
Partial summary

- Various different conceptions and classifications of uncertainty exist
- Even among experts there is no perfect agreement on terminology
- Efforts exist to consolidate methodologies at least within the climate science community

3. The forecast is always wrong

Examples of uncertainty in engineering and politics

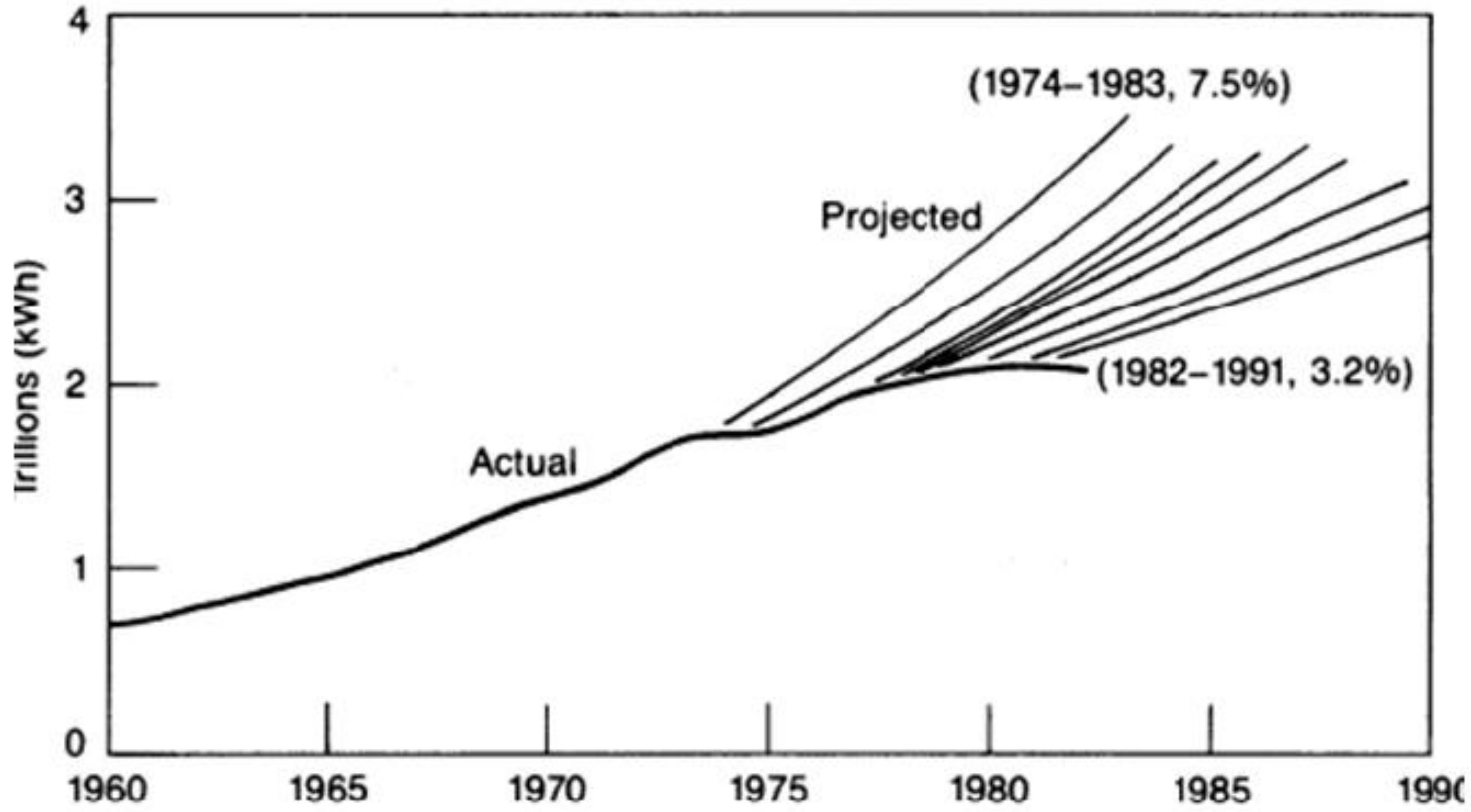
Airport runways



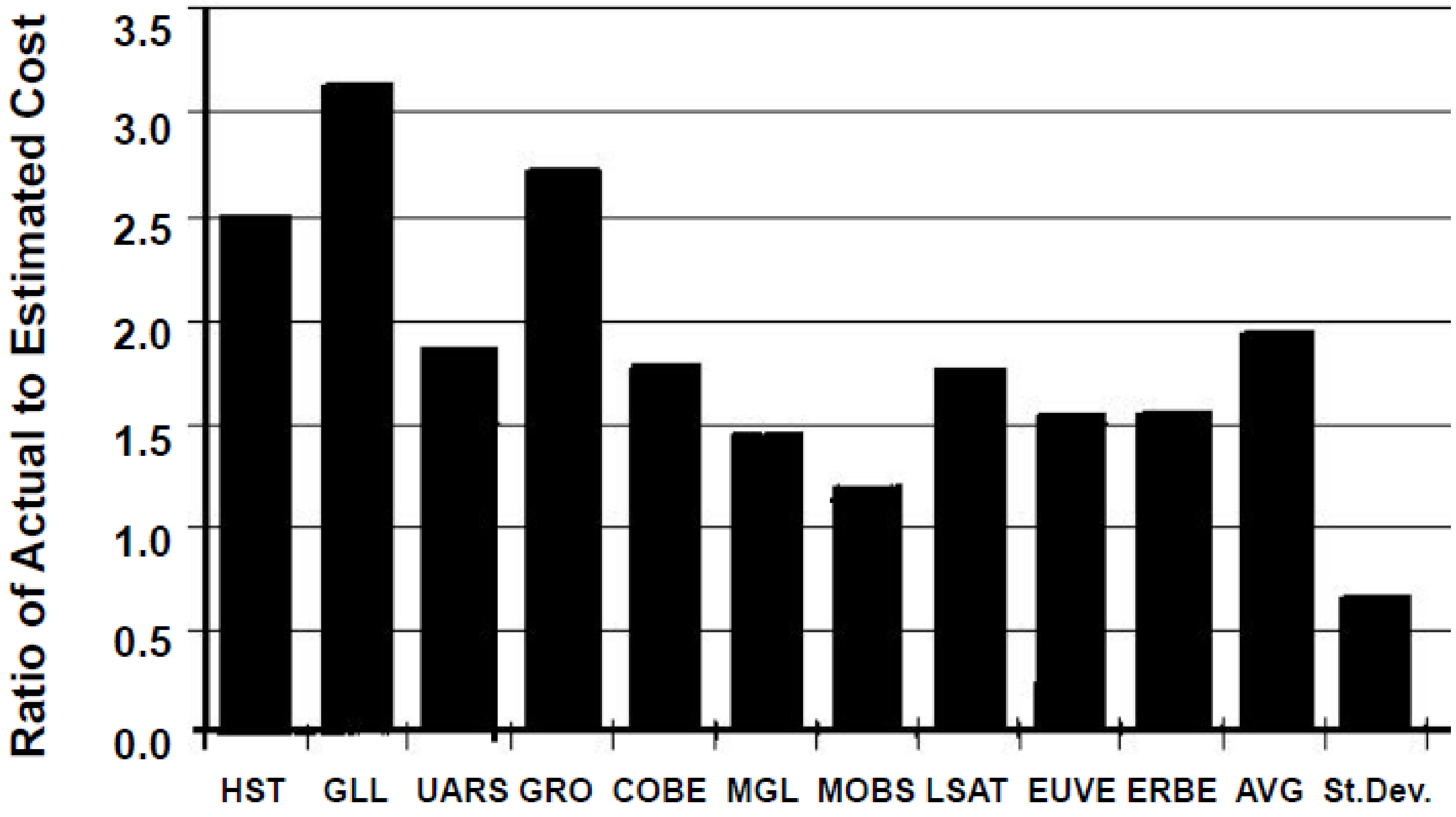
Source:
Knudsen 1976

Actual and projected power use in the US

Source: Nelson and Peck 1985, *Journal of Business & Economic Statistics*

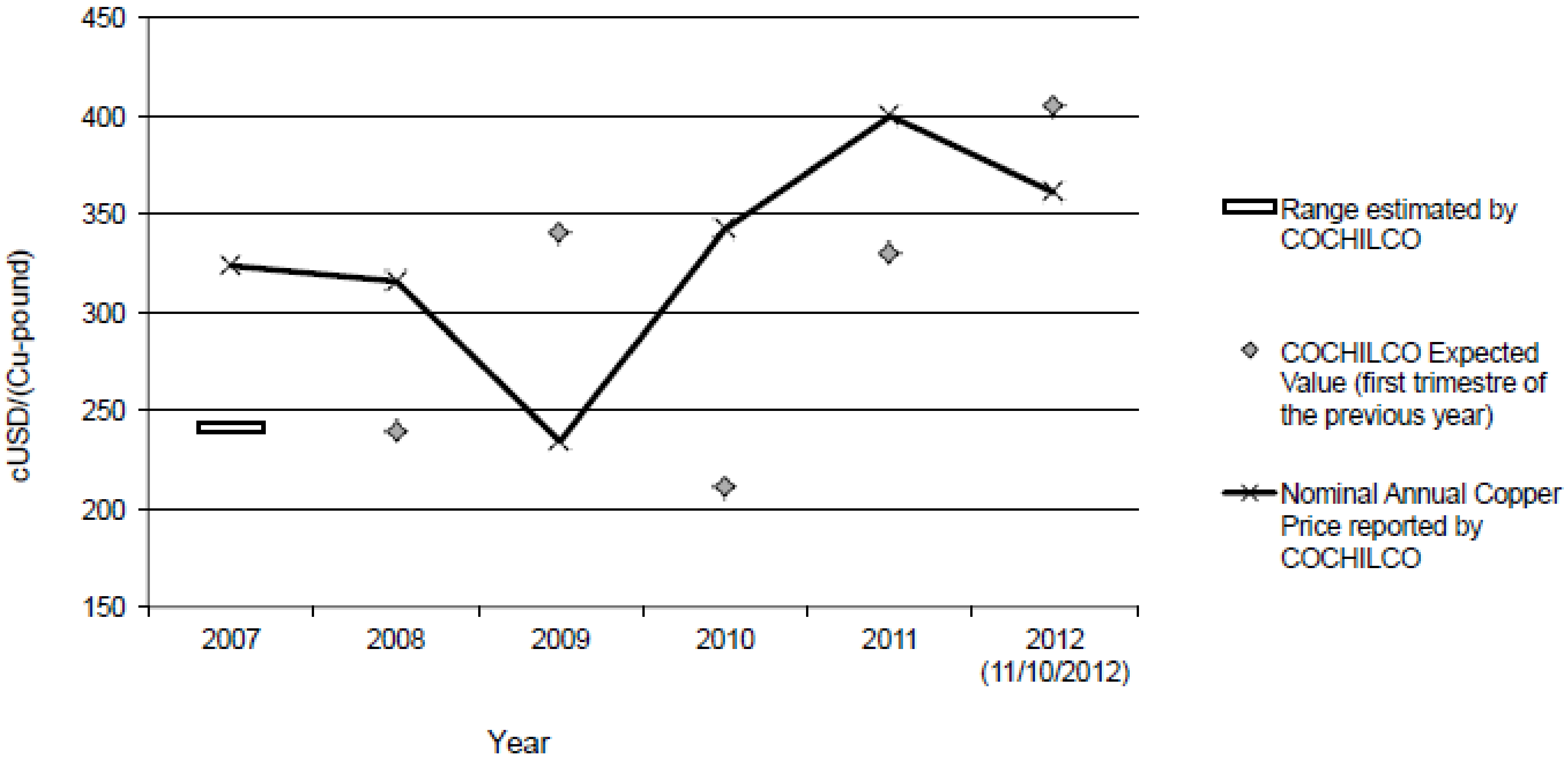


NASA projects cost growth



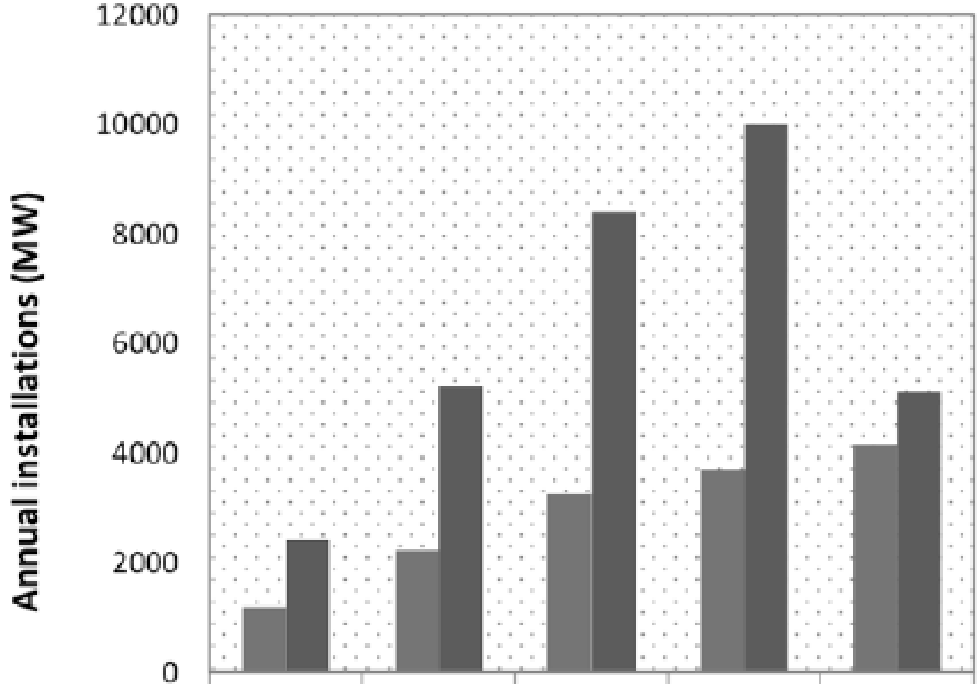
Source:
Benz 1993

World copper prices



Source: Montero, Esteban J. (2012). [*Data looked up and graph created by student for a course homework.]*

US wind energy installations



	2006	2007	2008	2009	2010
Projected (DOE)	1185	2218	3250	3700	4150
Installed	2400	5200	8400	10000	5115

20% wind energy by 2030: Increasing wind energy's contribution to U.S. electric supply, US DOE, July 2008. Per Padmabhushana Desam, 2011

Election polls: actually spot-on!

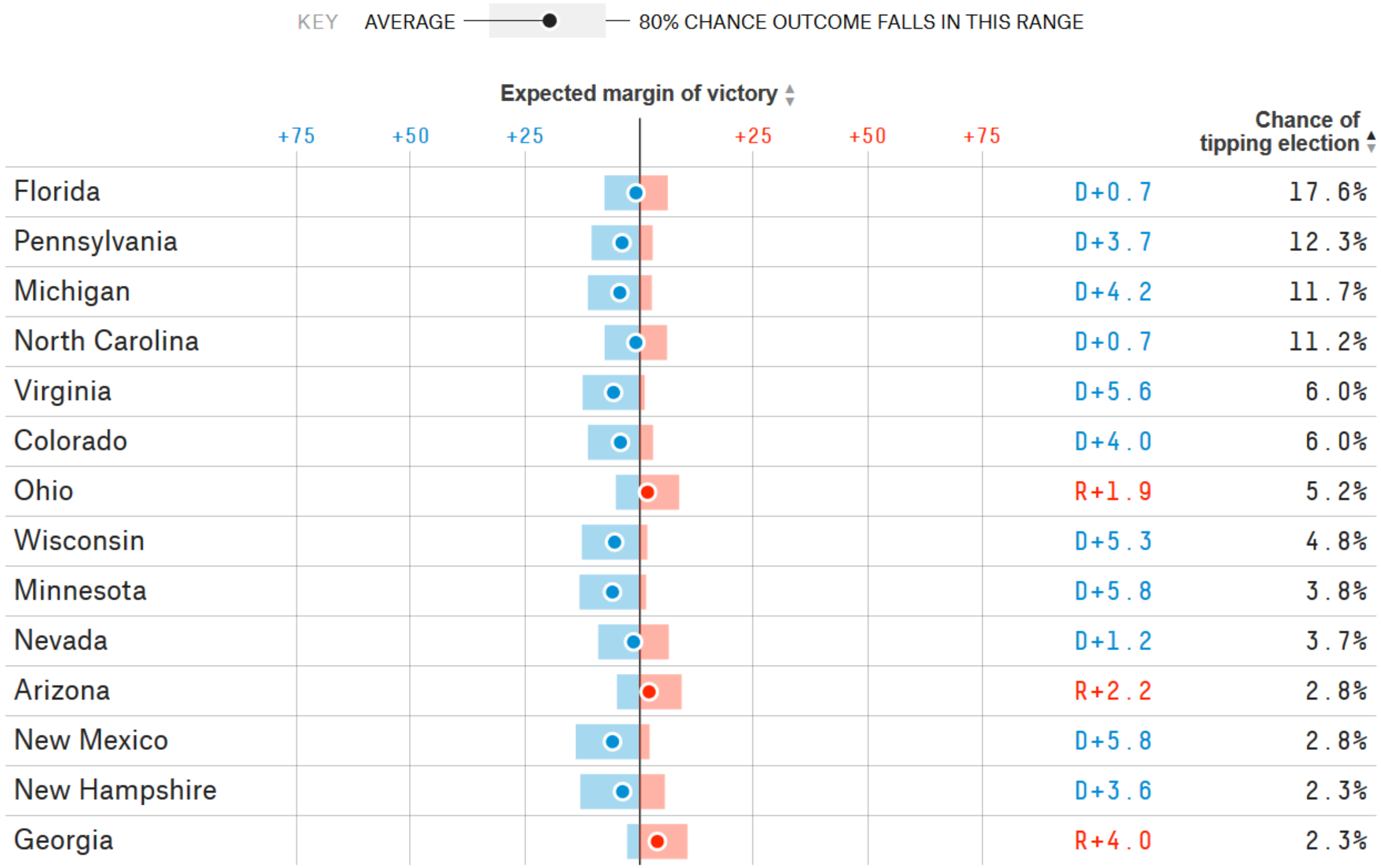


Image credit: https://projects.fivethirtyeight.com/2016-election-forecast/

4. Decision-making under uncertainty in engineering and policy

And what we can learn for climate science

Decision-making under uncertainty in engineering: Recognizing Uncertainty…

- Expected value concept
- Flaw of averages:

  the expected profitability based on the average forecast value is not equal to the average expected profitability given the range of forecasts
- Forecast as a distribution or range of scenarios

… and introducing flexibility in design

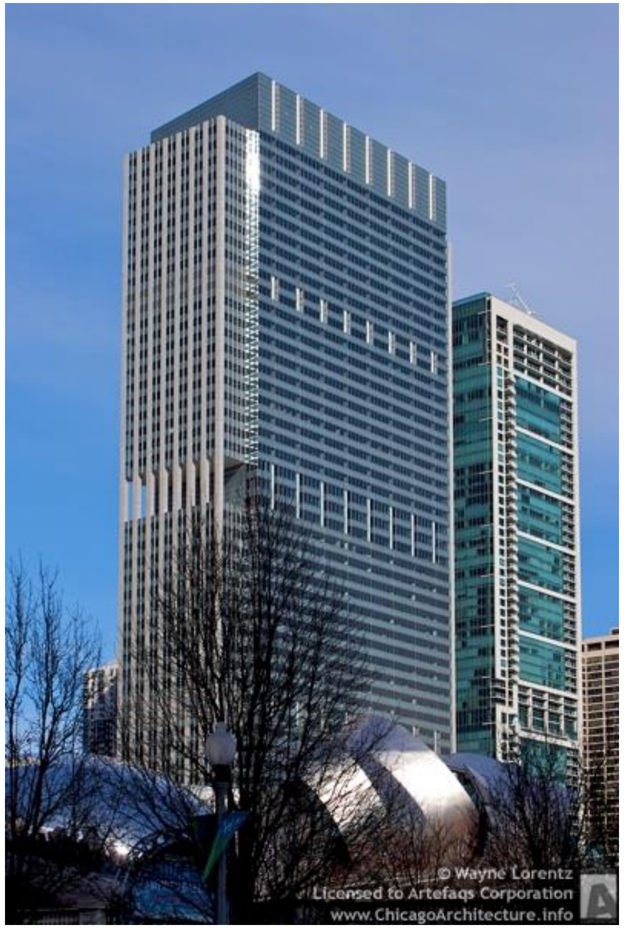


Image credit: http://www.chicagoarchitecture.info/Building/1235/300-East-Randolph.php

Decision-making under uncertainty in policy

- Adaptive Policy Making (McCray, Peterson and Oye 2010; Buurman and Babovic 2016)
  - Knowledge assessment: conducting research into cloud formation
  - Re-evaluate policy and use indicators to phase programs in or out

- Co-benefits bigger than climate benefits

Partial summary

- We experience uncertainty *every-day* and *every-where*

- We have and are developing tools to inform our decisions confronting uncertainty

5. Communicating uncertainty in climate science to the public

„The Age of Denial“

- Doubt as a tactic to undermine scientific findings such as the causal relationship between human actions and climate change

- „Post-factual world“ and „alternative facts“

Scientists, journalists and the public

- „Science journalism in an age of denial” (Deborah Blum, talk at MIT in 2016)

- How can we bridge the gap between the scientific community and the public?

Conceptual approach to the communication of uncertainty (Otto et al. 2016)

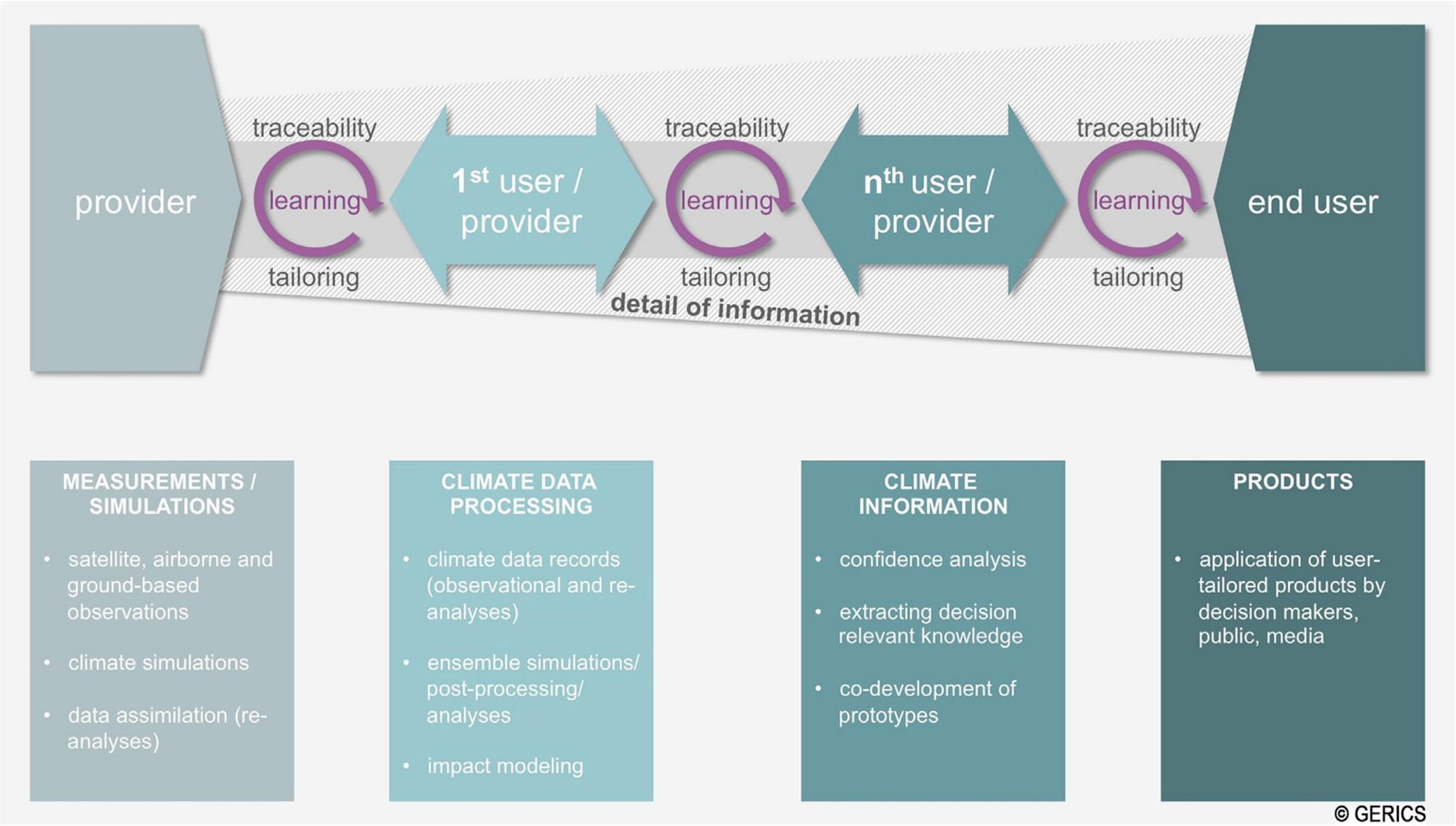


Figure from Otto et al. 2016: S267

Thank You for Listening!

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