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Addressing Deep Uncertainty in Climate Change Impacts and Adaptation Analysis for the Energy System

Alan H. Sanstad, Ph.D.
Affiliate Staff Scientist
Lawrence Berkeley National Laboratory

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What is “deep” uncertainty?

- A traditional distinction:
  - “Risk” – probabilities can be assigned
  - “Uncertainty” – they can’t
    - Note that in practice, even determining which concept is appropriate can be very challenging
    - Example: Uncertainty characterizations of the IPCC
- This terminology is not completely standard, but the underlying idea has only grown in importance over time
- While there is no single definition, in general “deep” uncertainties are particularly difficult and/or complicated instances of the second type

Deep uncertainty and climate change impact and adaptation analysis (CCI&AA)

- In general and regarding the energy system in particular, strictly speaking virtually everything in this area qualifies as deeply uncertain due to the combination of limited or absent probability information *and large ranges of possibilities* – i.e., complexity:
  - Projections of climate change (climatic and meteorological variables) – especially at regional scales
    - Projections of physical / ecosystem impacts, such as sea level and wildfires
  - Long-run evolution of energy system and its drivers – even prior to climate considerations, including
    - Energy technology evolution
    - Economic, market, and institutional changes
    - Economic growth and demographic trends

Decision-making under deep uncertainty

- Although not usually framed this way, scenario analysis is in essence a way of trying to deal with deep uncertainty
  - Given scenario choices, standard methods can be used
  - But with very few exceptions, scenario analysis as a rule takes account of a very limited degree of deep uncertainty
    - A relatively very small number of possibilities are typically addressed
- When deep uncertainty is fully confronted,
  - Traditional cost-benefit analysis is difficult to apply
  - Standard decision- making- under- uncertainty methods and stochastic analysis are difficult to apply
    - These are based on probability information and computationally challenging for large problems
  - In general, finding “optimal” solutions is not possible

Robustness

- There are alternative decision-making methodologies
- Of particular importance are different approaches to *robustness* analysis
- While there are several technical definitions of this term, it refers to identifying solutions to problems that, while not optimal, will be “satisfactory” under a wide range of conditions defined by deep uncertainty

Methods of robustness analysis

- These include
  - Max-min: Make the best possible decision assuming the worst case
    - This (and variations) has been pioneered by macroeconomists, and has been applied to climate economics (see References)
  - Complete or exhaustive accounting for *all* possibilities in the “space” defining deep uncertainty
    - This has been pioneered by Rand, and applied to energy and climate economics and policy, water planning, and other problems (see References)

Deep uncertainty and model complexity

- Computational modeling has become the dominant analytical methodology in many fields in the physical, social, and engineering sciences, including
  - General circulation – climate - modeling
  - Modeling in energy economic, policy, and planning analysis
- CCI&AA is an emerging field, but is and will continue to be primarily based on the application of such models (and others)
- In practice, deep uncertainty is usually embodied in *model* uncertainty:
  - Uncertainty about the correct fundamental principles/ structure/ features/ inputs of models of a given system (see References)

Deep uncertainty and model complexity in CCI&AA

- A fundamental challenge is that the models are very complex and getting more so
  - There are reasons for this, and highly detailed models are essential for certain purposes, but…
  - It presents considerable barriers – computational, theoretical, and empirical – to addressing deep uncertainty, including applying any form of formal robustness analysis, in energy system CCI&AA
    - Examples cited previously mostly involve small (low-dimensional) models
- Continued development of improved methods for simpler modeling in parallel to, and articulated with, ongoing CCI&AA analysis could prove very useful
  - A key research topic: What are the “returns to complexity” in modeling adaptation strategies for the energy system?

Thank you

ahsanstad@lbl.gov

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