Uncertainty in estimating the climate effects of biofuels

EPA Workshop on Biofuel Greenhouse Gas Modeling

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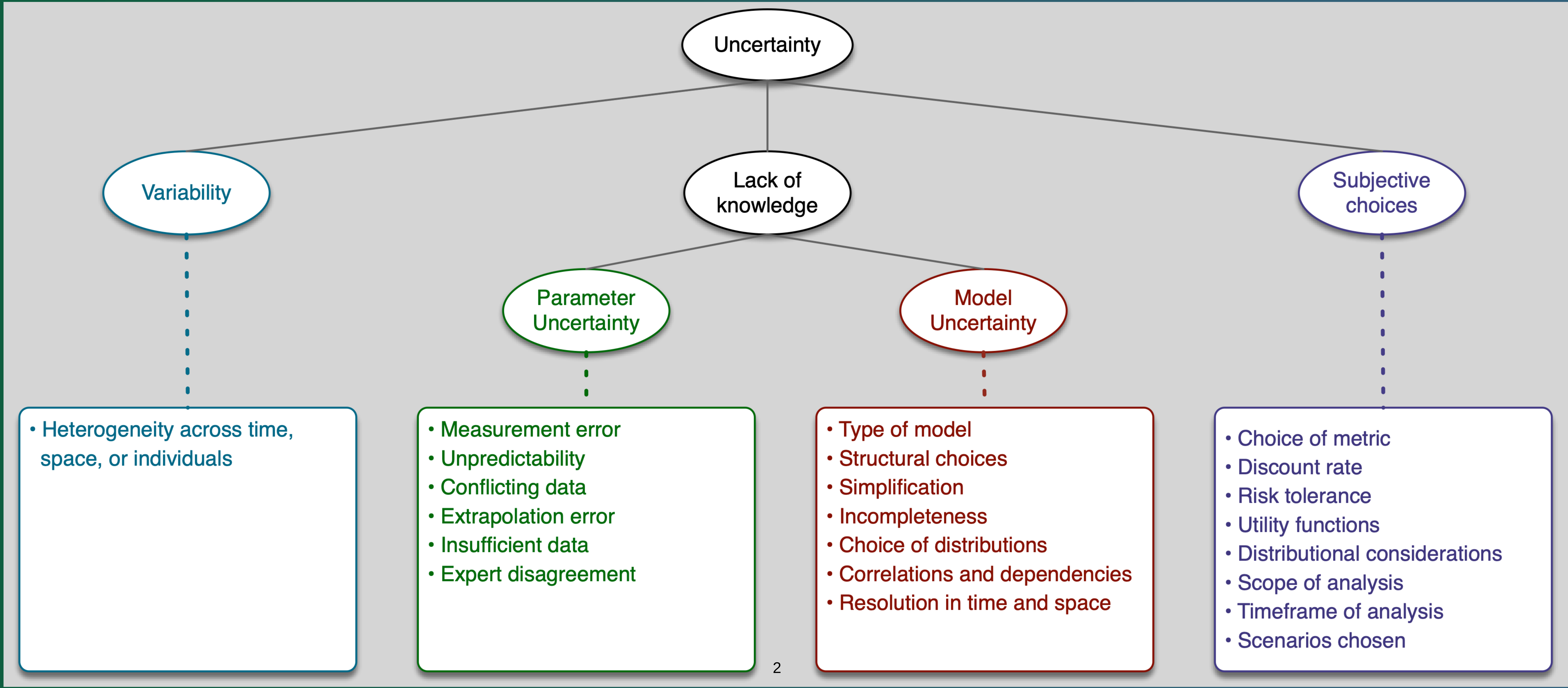
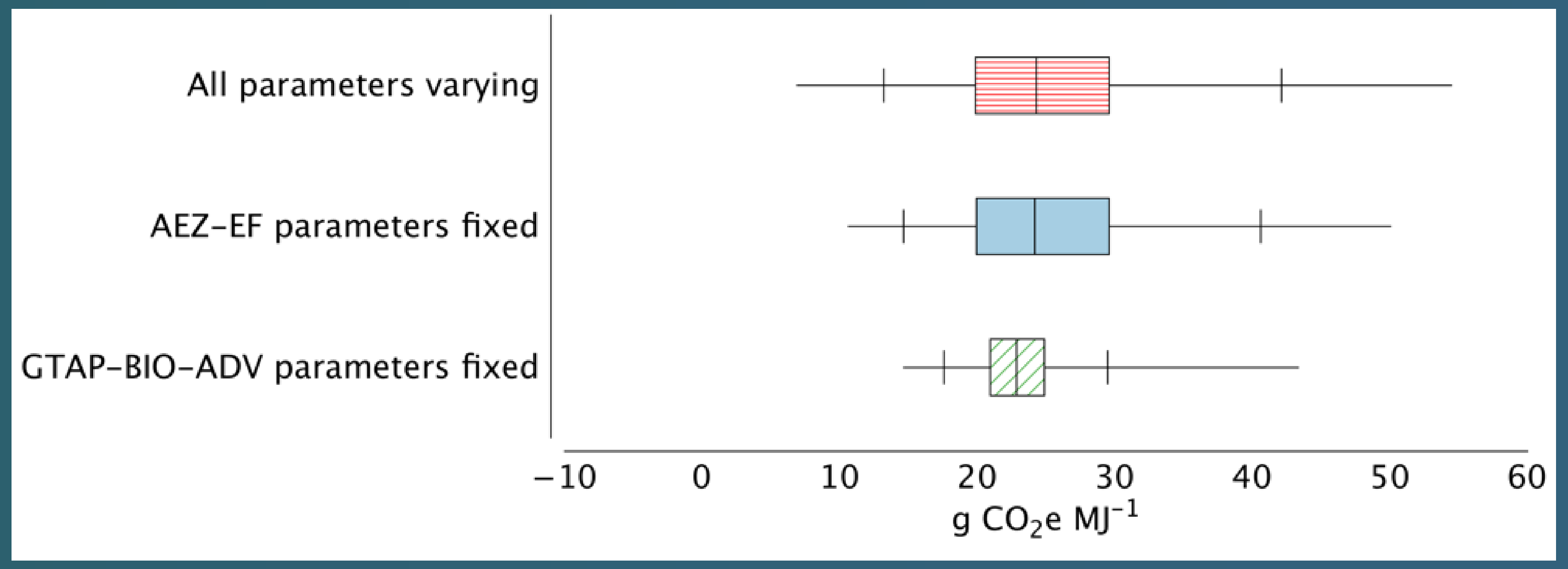
What do we mean by uncertainty?

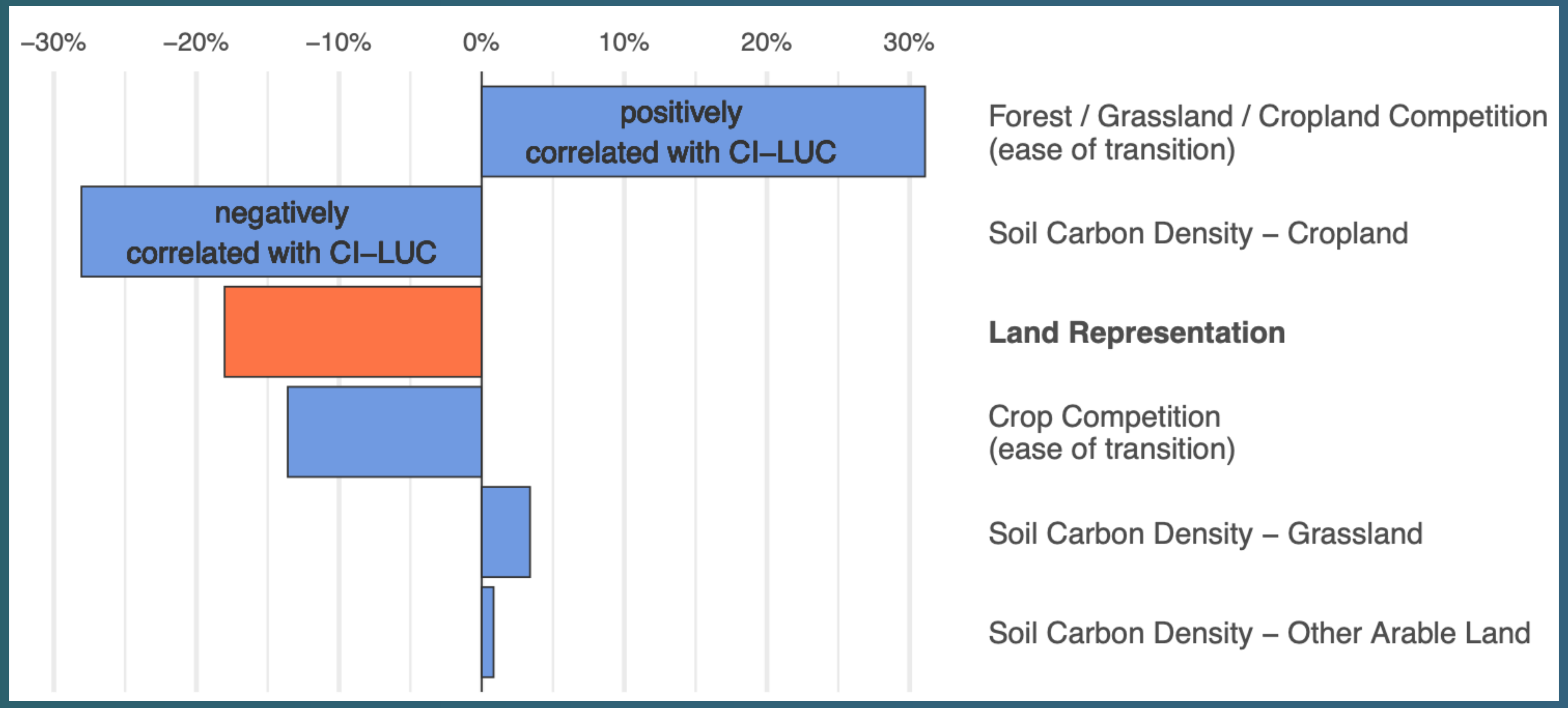


Uncertainty & sensitivity analysis

- Uncertainty quantification
  - Distribution of model results across alternative parameters & choices
  - Statistics describing distribution of model results
- Global sensitivity analysis (SA)
  - Shows relative influence of parameters & choices on model results
  - Global SA accounts for parameter interactions across their ranges
    - One-at-a-time SA fails to account for these
- Ensemble analyses (e.g., Monte Carlo simulation) can inform both of these



Plevin, R.J., et al. 2015. 'Carbon accounting and economic model uncertainty of emissions from biofuels-induced land use change', Environmental Science & Technology, 49: 2656–64.



Plevin, R.J., et al. In review. 'Choices in land representation materially affect modeled biofuel carbon intensity estimates'.

What uncertainty analysis doesn't do

- Global economic / ecosystem models are not truth machines
  - Many simplifications, deletions, and distortions
  - Can't predict non-stationary, complex, open systems

Oreskes, N. et al., 1994. 'Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences', Science, 263: 641-46.

Therefore,

- Output distribution is not a (real world) probability distribution
  - It describes behavior of the model as constructed
- A range of model results may not bound real world outcomes

Match methods to purpose

- What is the goal of our analysis and how will the result be used?
  - Choices: methods, scenarios, scope, resolution, timeframe, etc.
- Are we trying to:
  1. Estimate climate change mitigation from biofuel programs?
  2. Produce a CI value for use in a regulation?
- Models designed for (2) generally do not answer (1)
  - Different purposes require different analyses

Plevin, R.J., 2014. 'Using Attributional Life Cycle Assessment to Estimate Climate-Change Mitigation Benefits Misleads Policy Makers', Journal of Industrial Ecology, 18: 73-83.

Mitigation vs carbon intensity

To estimate climate change mitigation:

- Characterize effects on climate of an action compared to BAU
- Be comprehensive to avoid unintended consequences
- Improve model whenever data or scientific understanding allow

When estimating regulatory carbon intensity values:

- Methods may be prescribed in legislation
- Model updates causing large changes in results are politically fraught
- Avoid claims about mitigation not supported by this analysis

What is *carbon intensity*?

- CI has no well-established, concrete definition
- Every regulatory model of CI defines it differently
  - Different methods, models, boundaries, assumptions, data, timeframes

Implications:

- CI is scenario & model dependent; it’s not a concrete fuel property
- Range of CI results reflects disagreement more than uncertainty
- Results using different definitions of CI are incommensurable

Estimating climate change mitigation

- Include known climate forcings *and their uncertainties*
  - GHGs
  - GHG-precursors (e.g., CO, VOC)
  - aerosols (e.g., black carbon, organic carbon, SO_X)
  - albedo change (e.g., resulting from LUC)
- CO_2-equivalence of regional effects is not straightforward
- Better to aggregate as radiative forcing or temperature?
- Ignoring uncertain factors doesn't reduce uncertainty; it hides it

Biofuel shock results modeled in GCAM-T

Many subjective decisions are required

- Baseline scenario
- Analytic horizon or date of reckoning
- Size and shape of biofuel shock
- Climate effects to include
- Climate effects aggregation method (GWP, GTP, ΔRF, ΔT)
- Type of model (dynamic or static, myopic or foresight, partial or general equilibrium)
- Model resolution (sectors, regions, land types, technologies, time step)
- Focus of analysis (product vs policy)

Plevin, Richard J. 2016. 'Assessing the Climate Effects of Biofuels Using Integrated Assessment Models, Part I: Methodological Considerations', Journal of Industrial Ecology, 21: 1478-87.

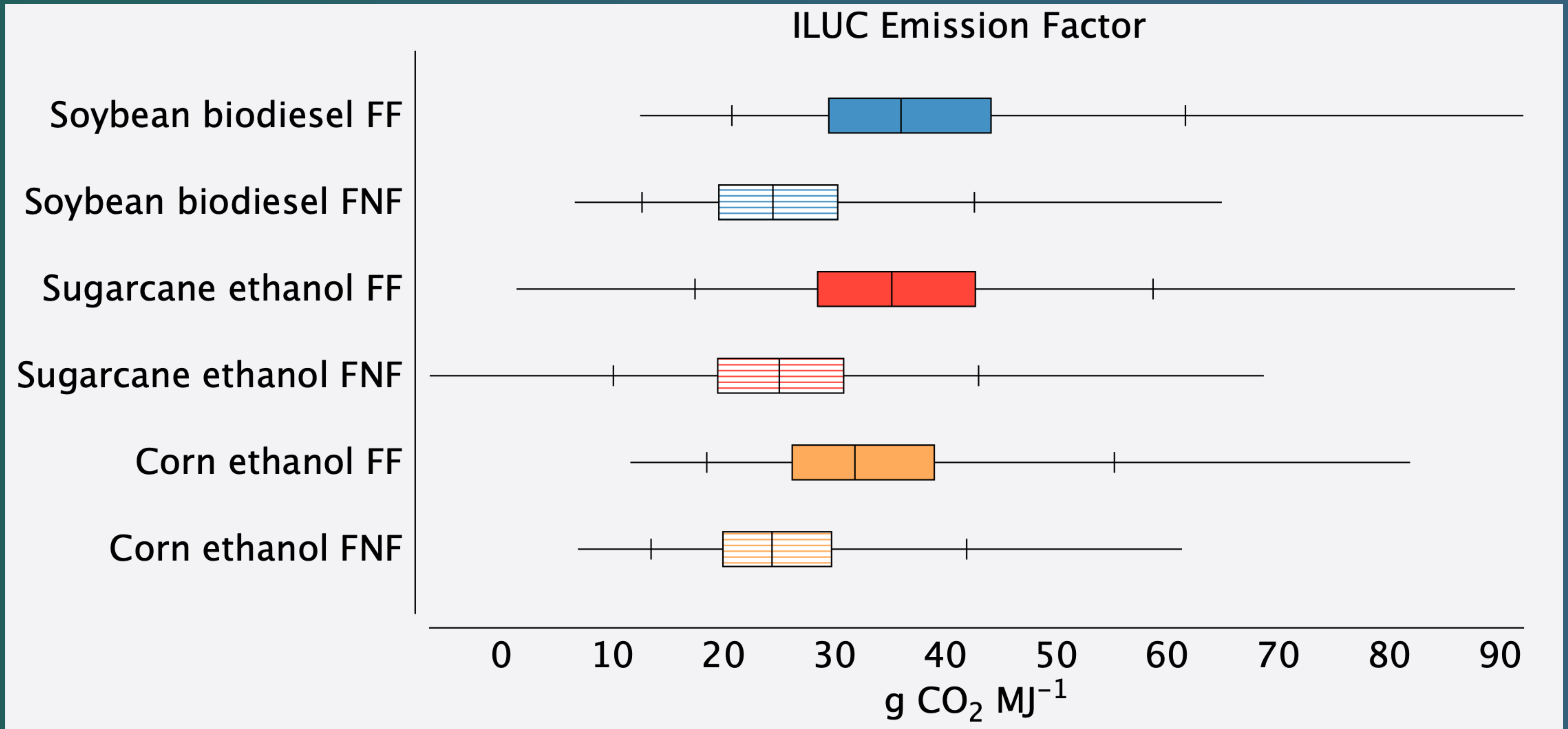
Best practices for modelers

- Sensitivity analysis is one of the "legitimate uses of a model" (Saltelli, et al. 2000)
  - Use *global* SA to capture parameter interactions
  - Use SA to interrogate your model, not "prove" it robust (Saltelli, 2010)
- Identify uncertainties strongly influencing variability in model results
- Demonstrate affects of subjective model choices on model results
- Avoid characterizing model results as predictions about real world
- Avoid unwarranted precision when presenting model results
- Document model limitations, assumptions, unquantified uncertainties

Saltelli, A., K. Chan, and E. Marian Scott. 2000. Sensitivity analysis (Wiley: Chichester ; New York).
Saltelli, Andrea, and Paola Annoni. 2010. 'How to avoid a perfunctory sensitivity analysis', Environmental Modelling & Software, 25: 1508-17.

Example 1

- ILUC analysis with GTAP-BIO and AEZ-EF models
- Monte Carlo simulation
  - 3 biofuels
  - 2 model structures (food consumption constraint)
- Results presented as distributions
- Model limitations explained

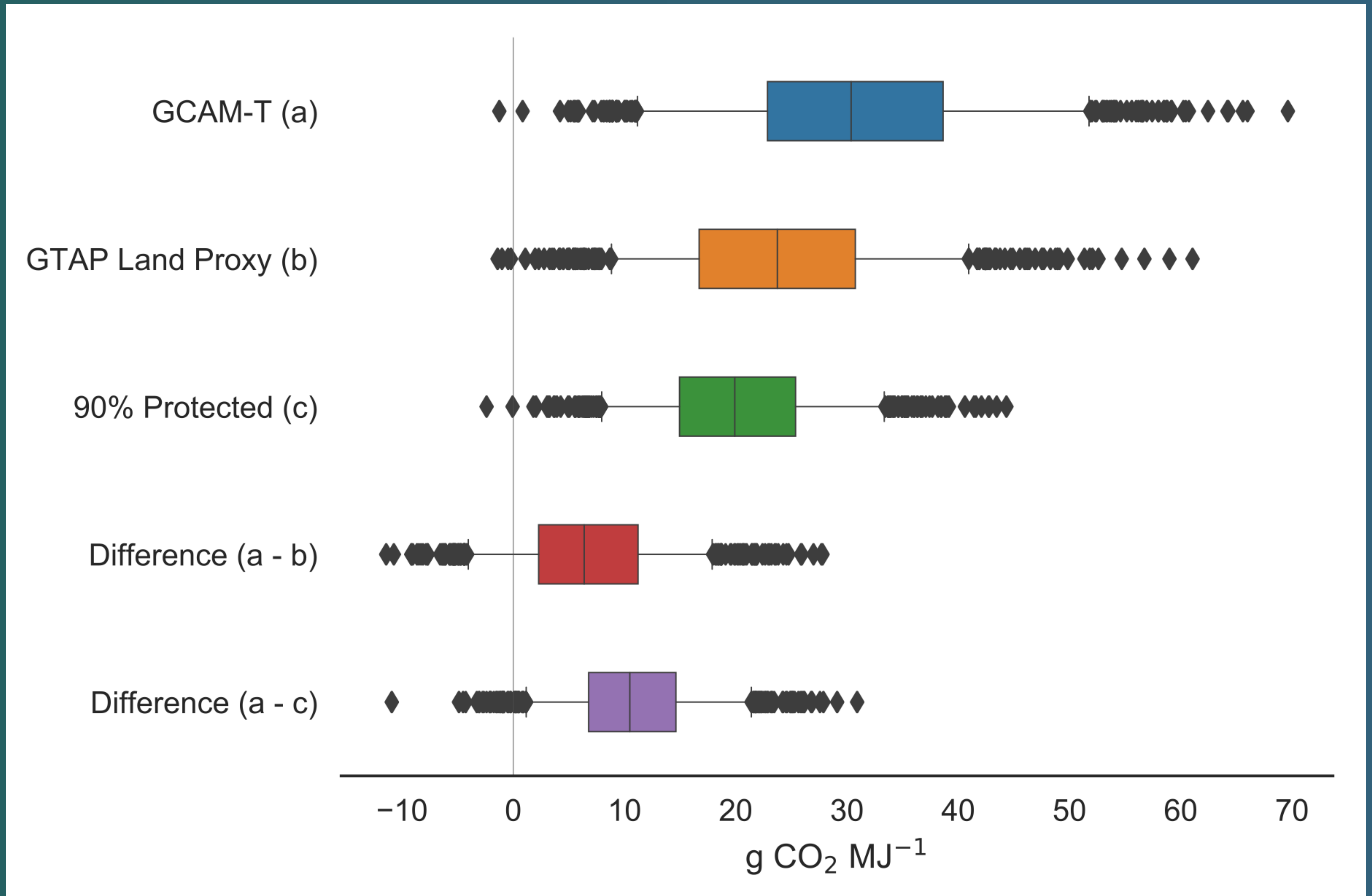


FF: food consumption fixed; FNF: food consumption not fixed

Plevin, R.J., et al. 2015. 'Carbon accounting and economic model uncertainty of emissions from biofuels-induced land use change', Environmental Science & Technology, 49: 2656–64.

Example 2

- Effect of land representation on LUC CI using GCAM
  - 3 different land representations
  - Monte Carlo simulation
- Presents distributions per model and for per-trial differences
- Avoids claims about real world outcomes



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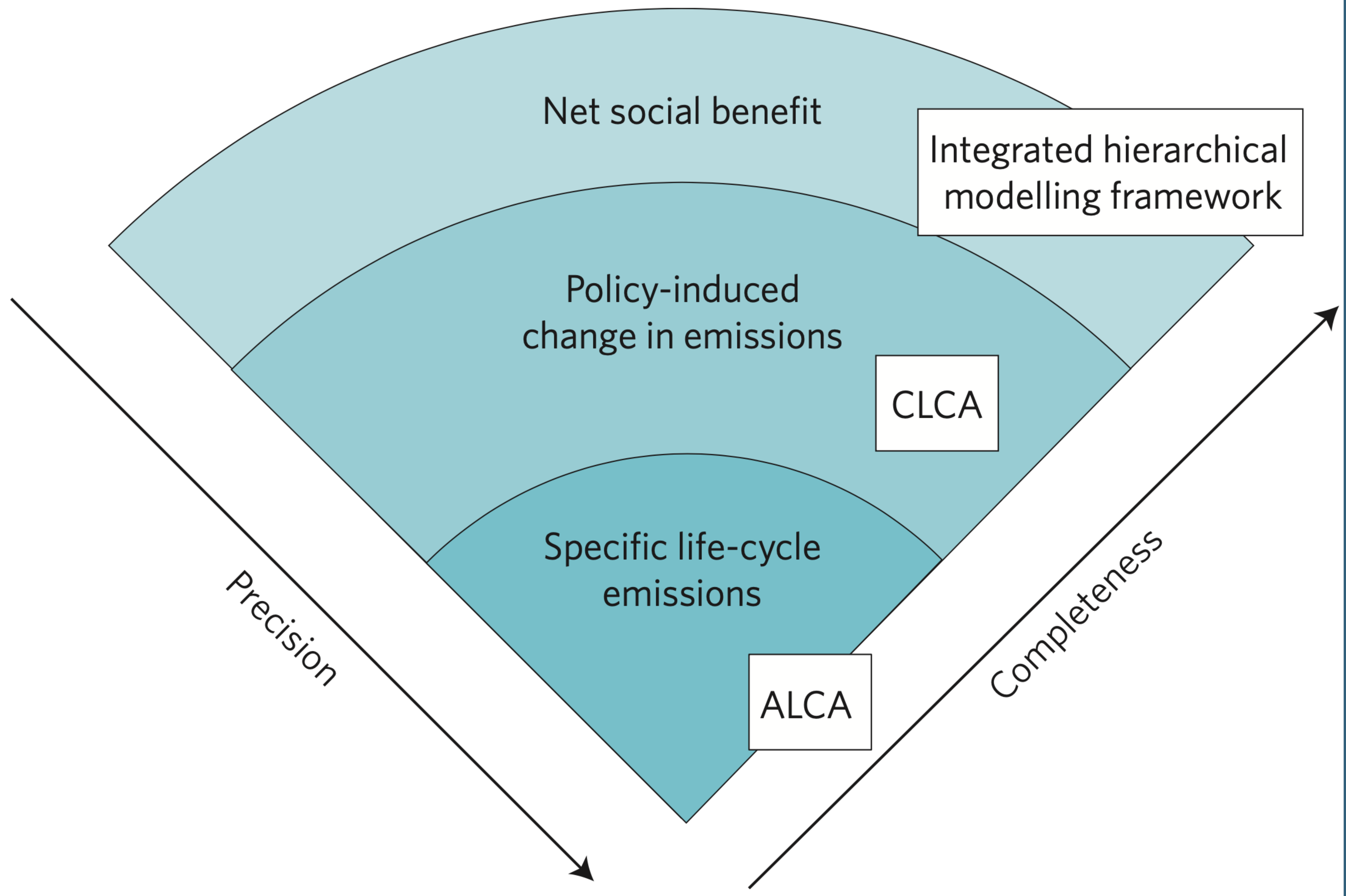
Be forthright about model limitations

- The model is not the real world
- Subjective choices often drive results
- ILUC isn't the only market-mediated effect
- Actual net petroleum displacement is key determinant of mitigation (rebound effect)
- Cannot compare *effects* of biofuel with fossil fuel CI; oil displacement is one of these effects
- Models designed for one purpose may have blind spots when used for another purpose
- Excluding uncertain features doesn't reduce uncertainty
- Uncertainty increases with scope of model



Creutzig, F., et al. 2012. 'Reconciling top-down and bottom-up modeling on future bioenergy deployment', Nature Clim. Change, 2: 320-27.