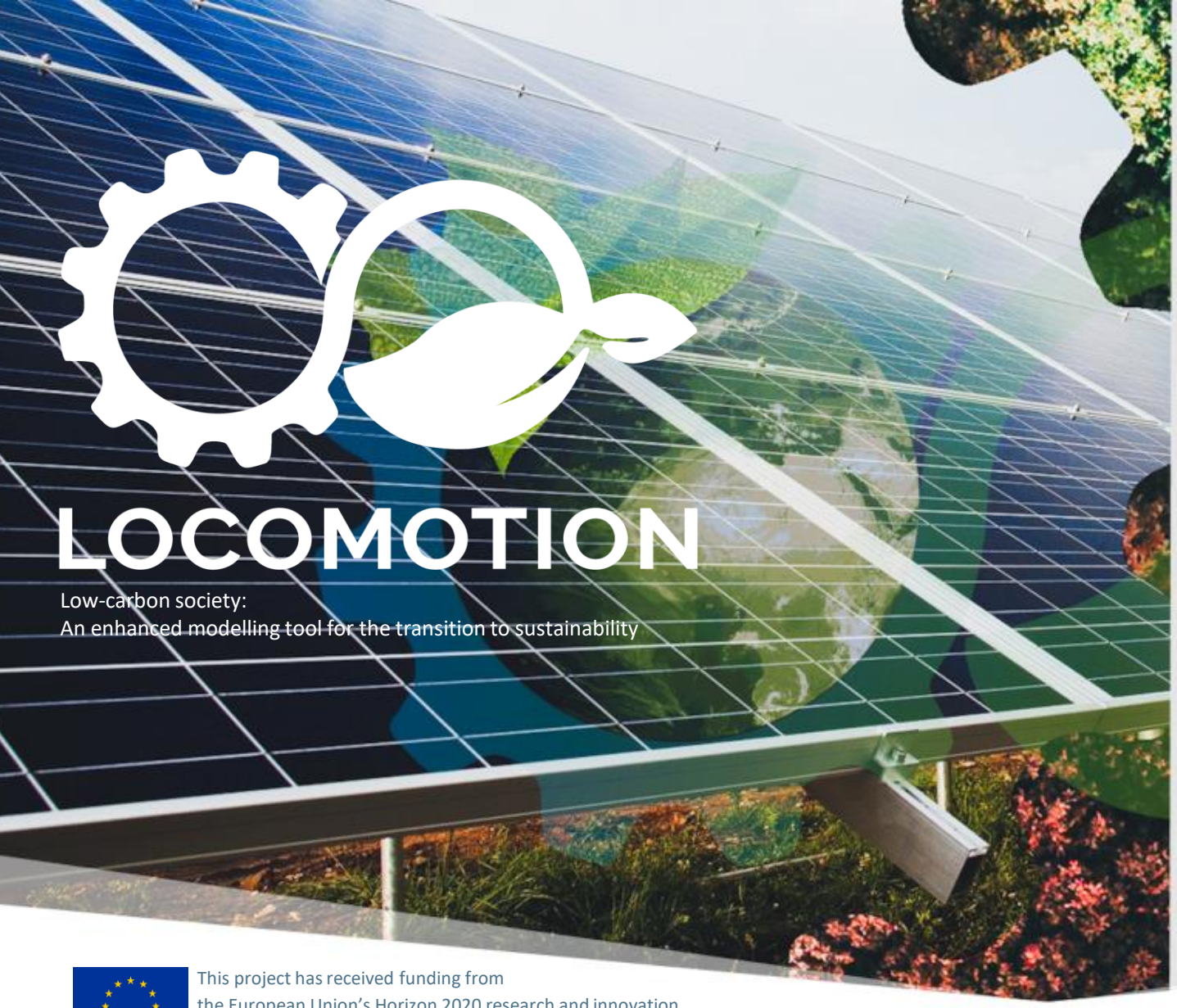

How uncertainties are tackled in multi-disciplinary science? A review to improve integrated assessments under global change.

Webinar of LOCOMOTION, Nov 25th 2020

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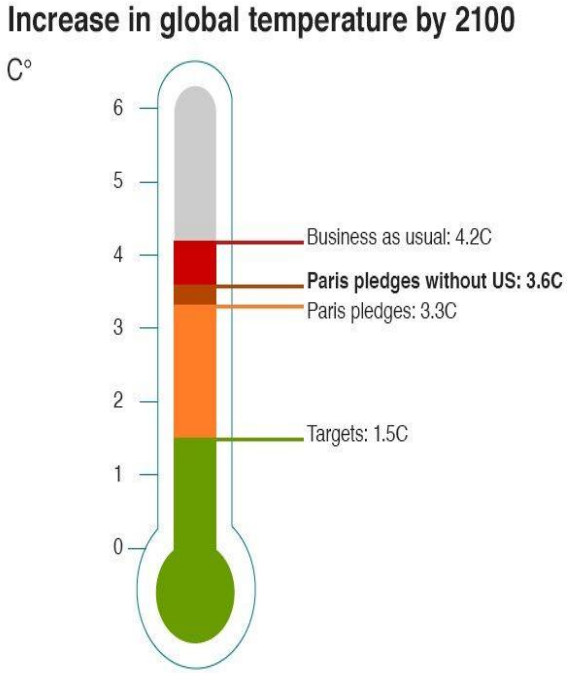
Context of the study

- **Achievement Paris agreement signed in 2016**:

"the increase in the global average temperature to well **below 2 °C** and to pursue efforts to limit to **below 1.5 °C above pre-industrial levels**".

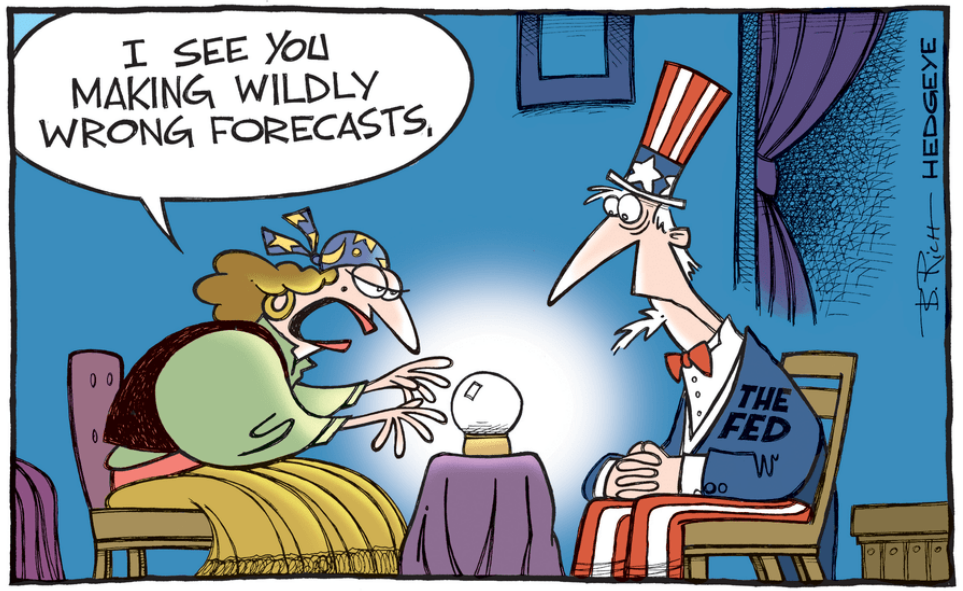
- After the Paris Agreement, **the lack of uncertainty analysis in IAs was risen** and calls for the gathering of scientists coming from all disciplines (Rogelj and Knutti 2016):

"The climate change problem remains loaded with uncertainties: **observations are incomplete** and may be biased, **models do not represent all processes**, **some processes are still poorly understood**"



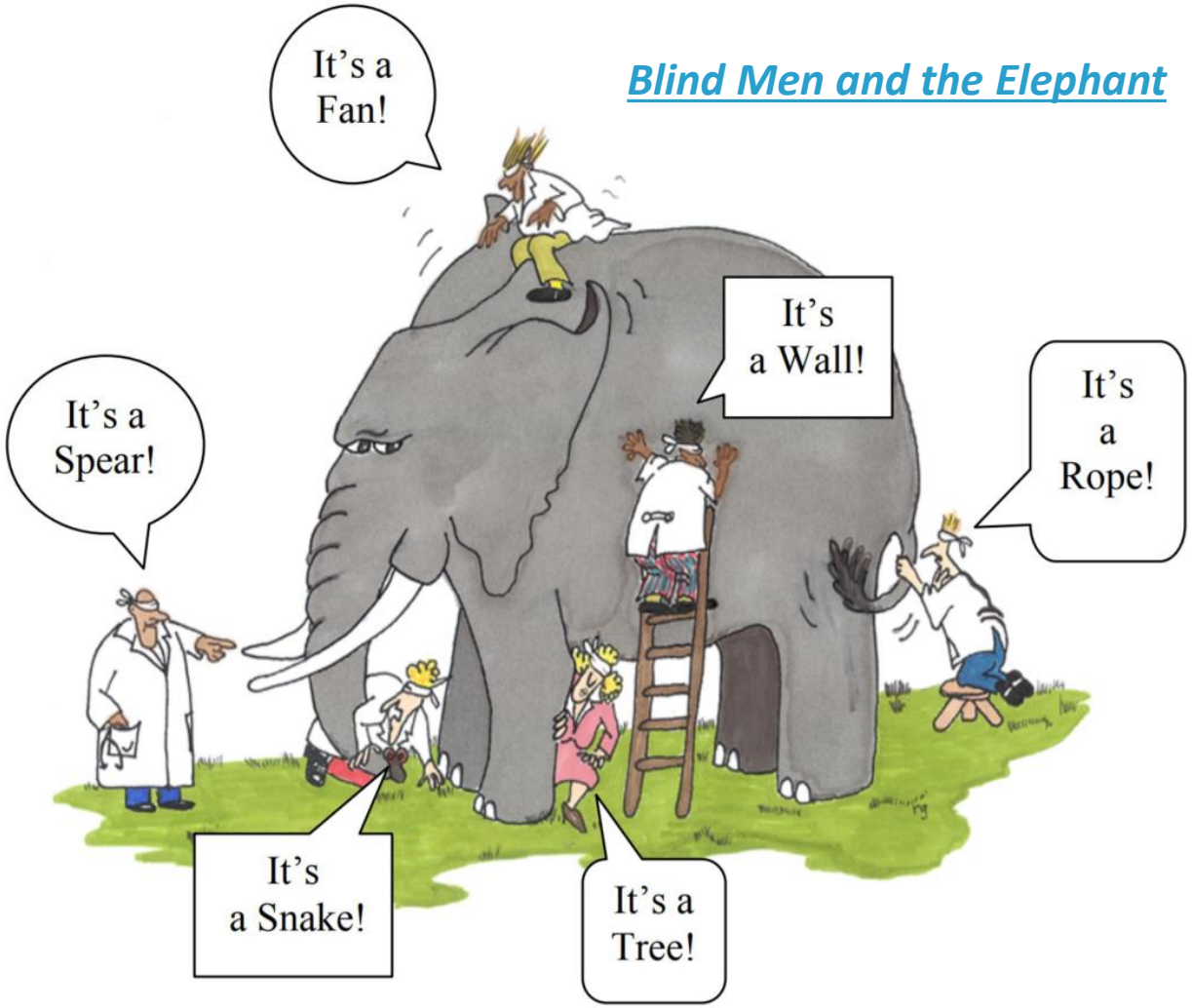
Context of the study

- The **consequences of non-communication or negligible UA** in climate and IA studies leads to a **reduction of climate mitigation investments** (Kunreuther et al. 2014).
- Therefore, it is important to,
  1. **clearly define the uncertainty in the outcomes of IAMs**, and,
  2. **communicate the relevance of this uncertainty to policymakers**.



Representation of a system (such as an Integrated assessment

Blind Men and the Elephant



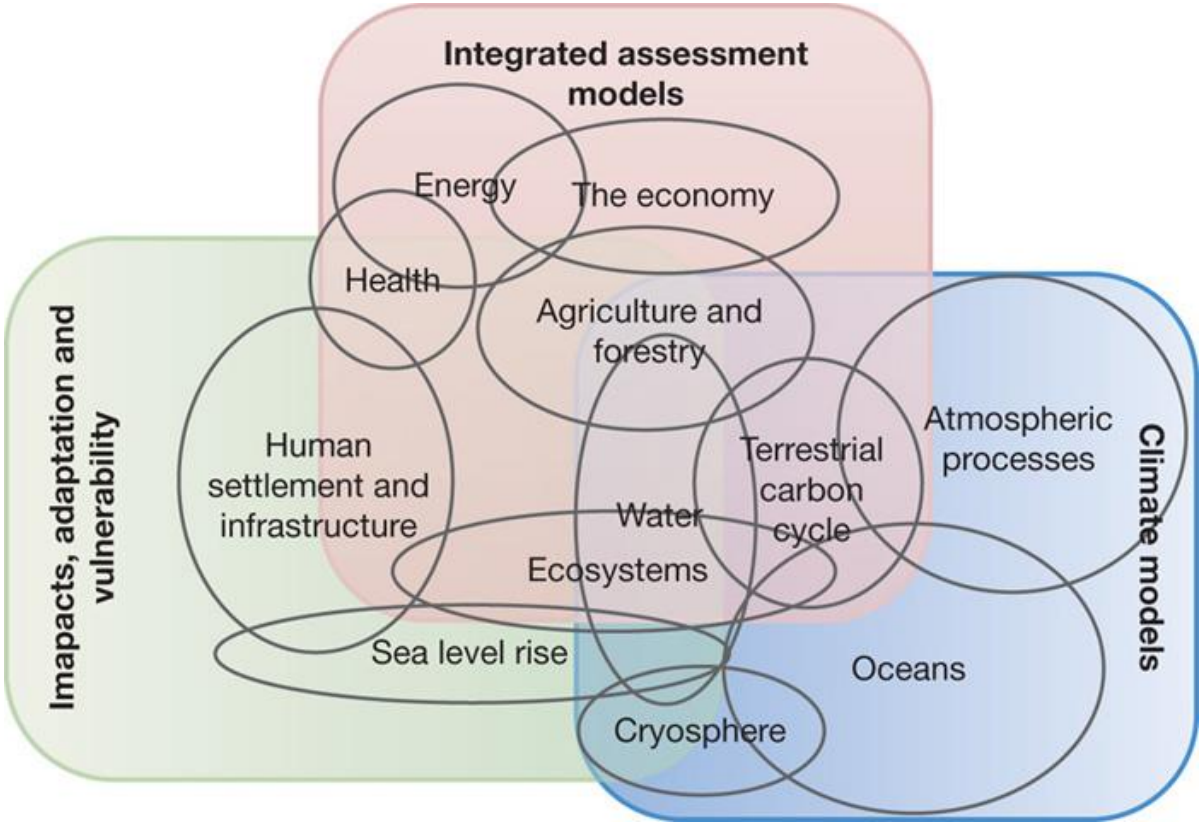
"We often think our own, partial experience represents the full truth, even though other people have different experiences and truths."

- **Everything is a system:** a product, team, market, process, habit, personal routine — even an elephant.
- **To understand (and improve) the system,** you have to understand each part, and how the parts connect. Clearly, an elephant is much more than a trunk, legs, and a trumpeting cry.
- **If you can't see or experience the full system,** you need to create models to put it all together. It's the only way to know your elephant

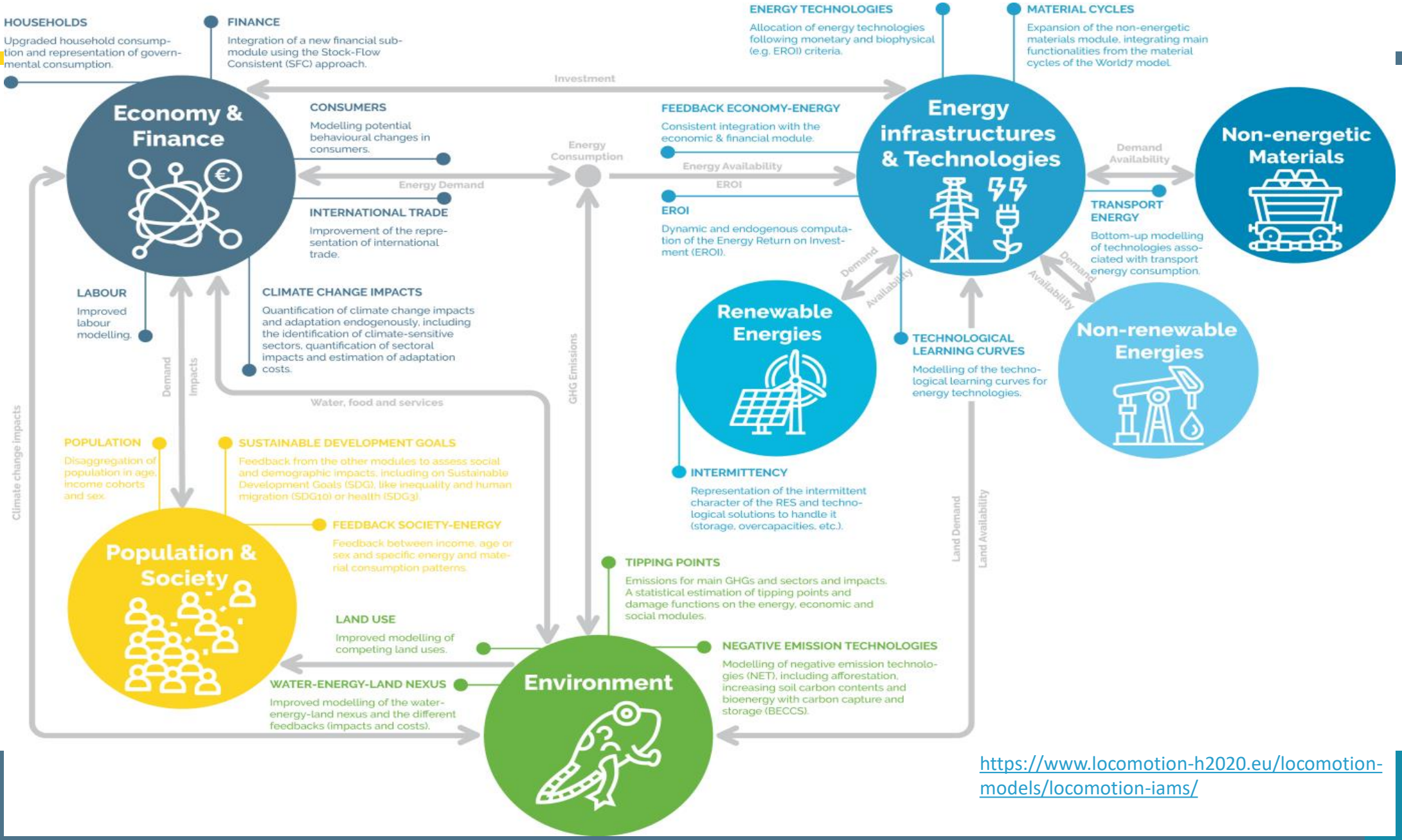
Integrated assessment models

Effective tool to gain insight into the **dynamics of coupled earth system (land use, climate etc.) and socio-economic components**.

- assess **long-term global environmental issues** and inform policy regarding **climate change mitigation and adaptation** (Havlík et al. 2015).
- Some IAMs application
  - **assess the costs of the intended climate mitigation** (Liu et al. 2018) or
  - **evaluate effects of combined implementation of low carbon technology** (afforestation, carbon capture and use of sustainable energy) on **CO_2 emissions** (Rogelj and Knutti 2016).



LOCOMOTION IAM → WILIAM model



https://www.locomotion-h2020.eu/locomotion-models/locomotion-iams/

LOCOMOTION

Context

- Many *IAMs exist today*

BUT

- Despite great achievements in describing the earth system and building IAMs
- There is still a lot of uncertainties

What means Uncertainty in sciences ?

- Uncertainty in IAMs can be due to **natural (stochastic) variability, a lack of data**, or to **poor understanding of the study system** (Van Asselt and Rotmans 2002)
- Uncertainty in IAMs can be divided in **three categories**:
  1. technical (related to computational methods and potential information technologies bugs)
  2. methodological (related to the modelling tool) and
  3. epistemological (related to parametric and structural uncertainties) (Field et al. 2012)
     1. parametric (**related to inputs and parameters of the model**) and
     2. structural (related to **model processes and equations**) uncertainty are considered in IAs.
  4. stacking of models can lead to error propagation

UA type	Example applied to hydrological models
Parametric uncertainty	Sources of data on precipitation, tempetature, radiation, CO2 concentrations, land use data etc
Structural uncertainty	representation of the process such as water balance equations/models, evapotranspiration models/processes

Uncertainty analysis in IAMs

- Difference between sensitivity analysis and UA:
  - Sensitivity Analysis: Determine the amount and kind of change produced in the model output by a change in a model parameter
  - Uncertainty Analysis: assessment/quantification of the uncertainties associated with the data, parameters and model structure

IPCC uncertainty guidance vs. IARC* adds the use of expert elicitation

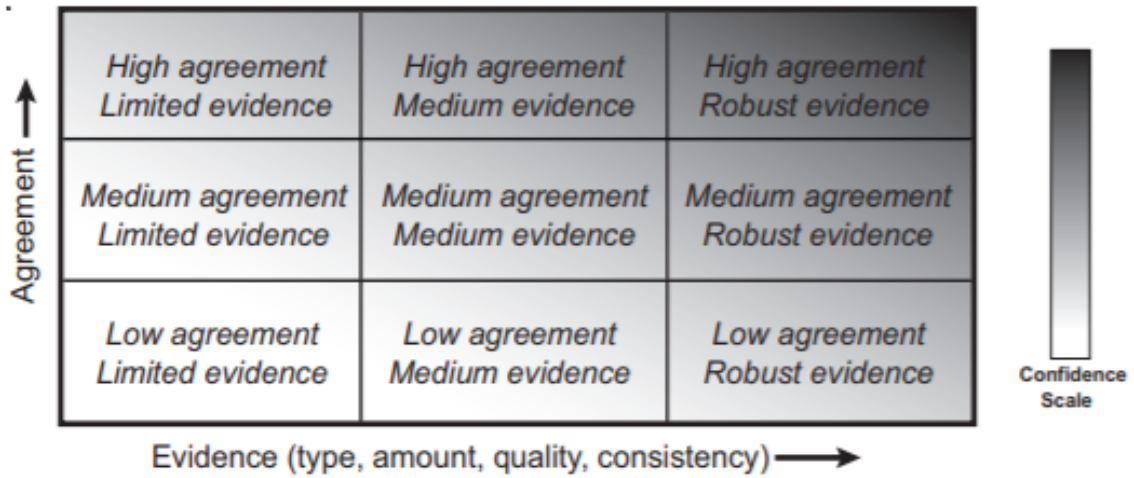


Figure 1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

IPCC, concept note. 2010

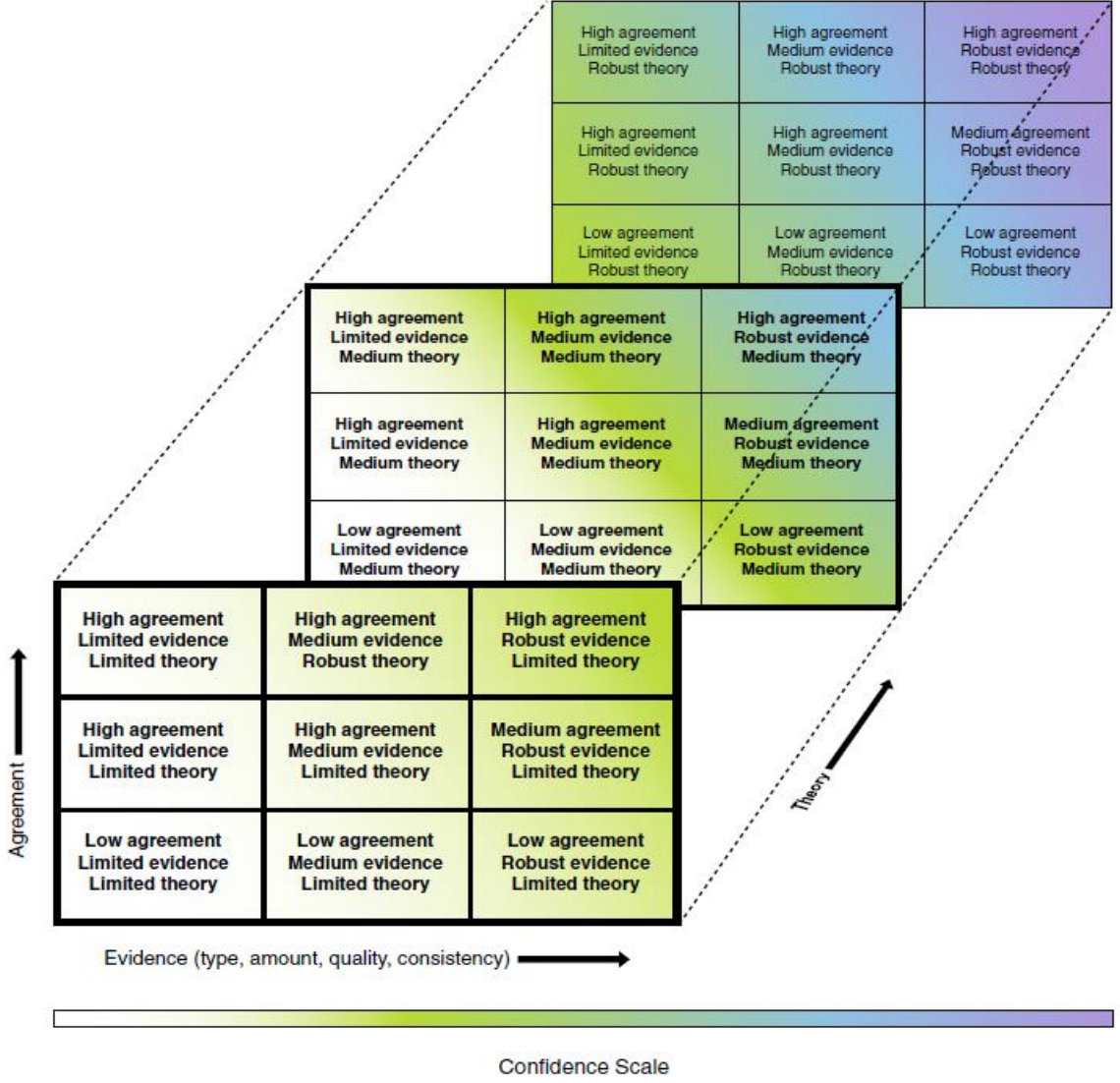


Fig. 1 A depiction of evidence, agreement, and theory and their relationship to confidence. Confidence increases with increasing strength of shading

Eby et al. 2011

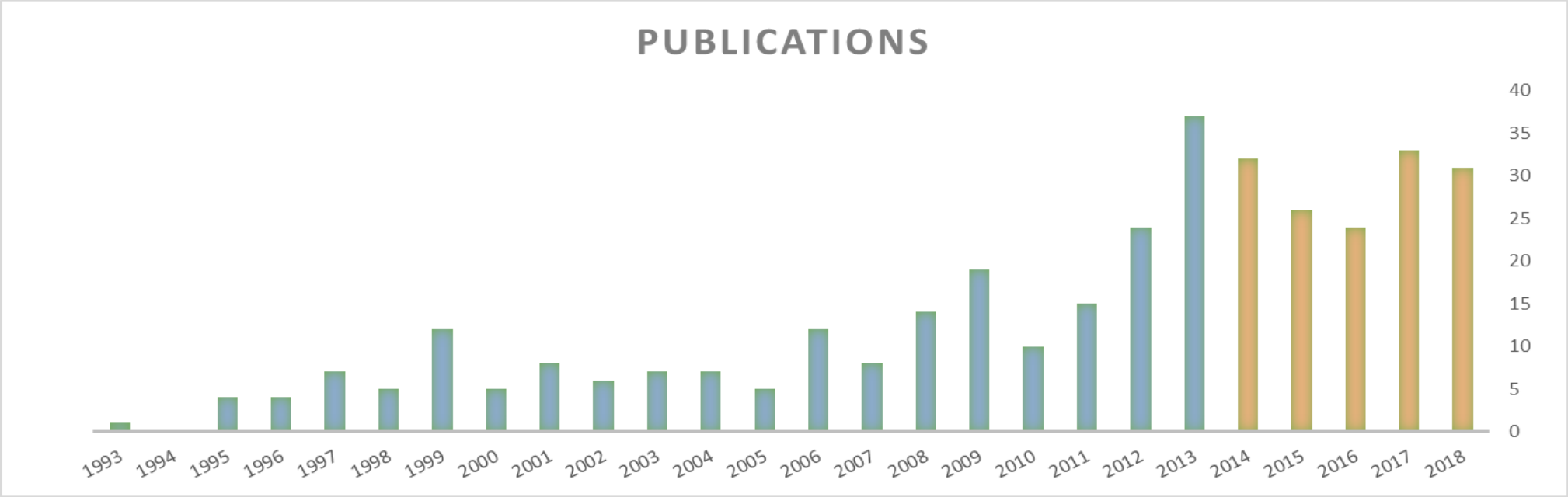
*International agency for reseach on cancer

Methods

Pastor, A. V., Vieira, D. C. S., Soudijn, F. H., & Edelenbosch, O. Y. (2020). How uncertainties are tackled in multi-disciplinary science? A review of integrated assessments under global change. *Catena*, *186*, 104305.

Methods

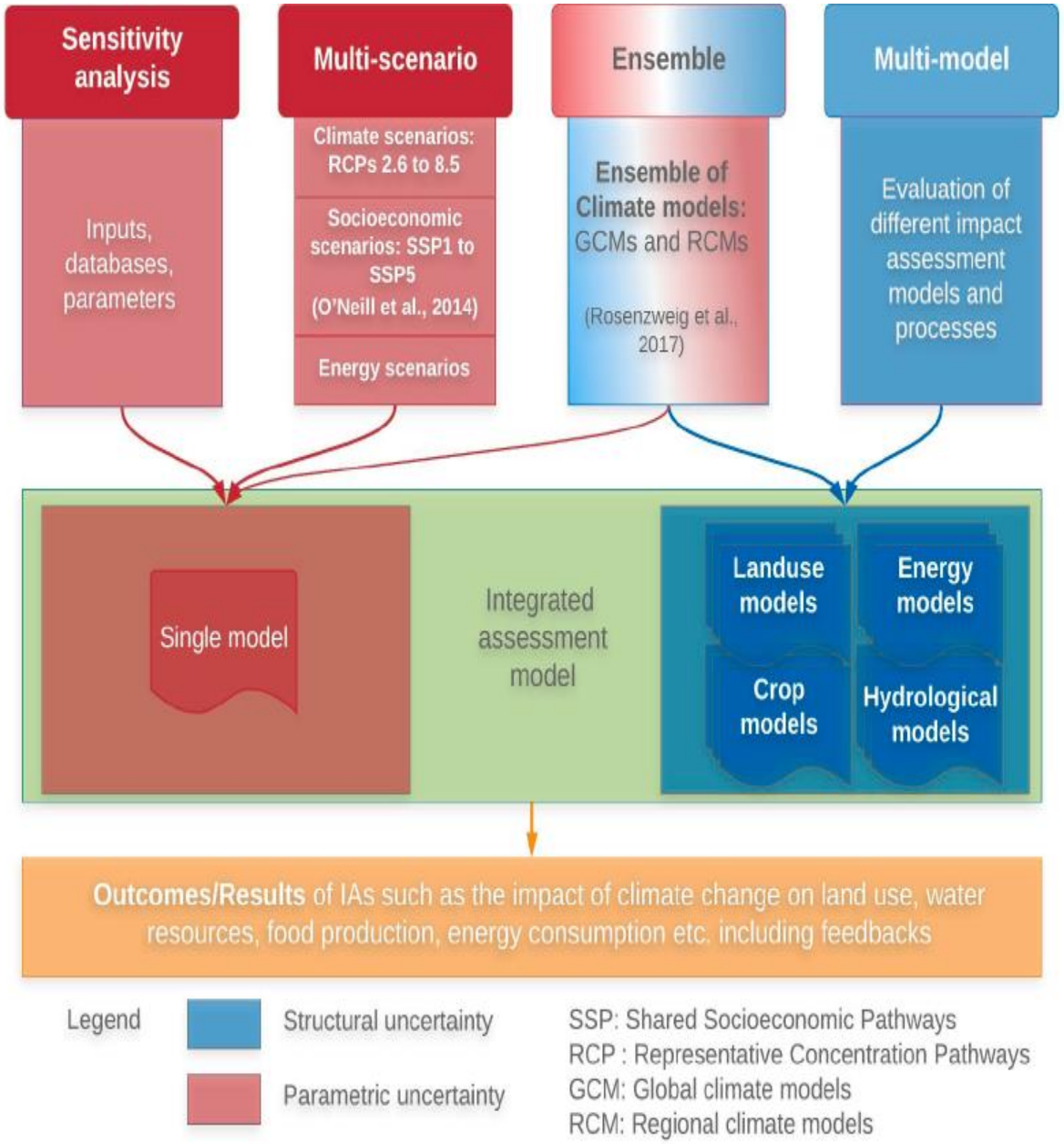
- Meta-analysis with the following keywords: **INTEGRATED ASSESSMENT, and UNCERTAINTY, and CLIMATE CHANGE, or LAND USE**
- The search initially included 357 publications (1993-2018) and was reduced to 147 by limiting the timeframe of publication to the last five years (2014-2018, Fig. 1).



Methods

- The database (67 publications) includes:
  - Study case location and scale;
  - Model type(s), input(s) and discipline(s);
  - Uncertainty analysis method(s);
  - Uncertainty analysis type(s);
  - Uncertainty communication type
- In the end, we retrieved 112 cases
- Each study was classified according to six disciplines:
  - i) climate change,
  - ii) energy,
  - iii) socio-economic,
  - iv) land use,
  - v) hydrology,
  - vi) vegetation modelling

Methods: 6 categoies of UAs



Sensitivity analysis – cases where the values of model inputs are varing using techniques such as Monte Carlo simulations, variance analysis, etc.;

Multi-scenario – cases that consider different inputs or scenarios in the same model;

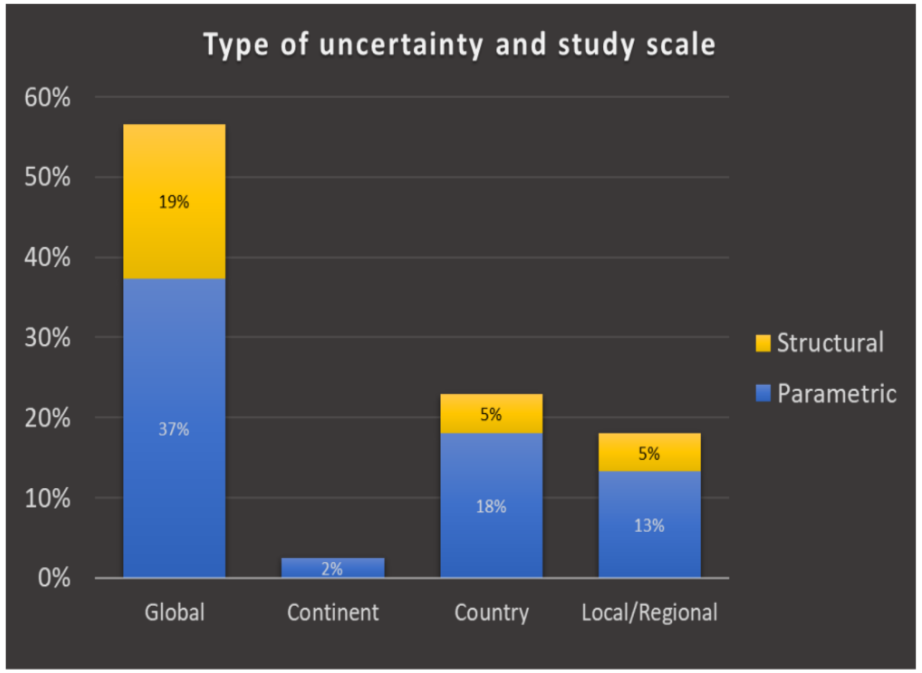
Ensemble (climate models) – cases that consider multiple climate models (GCMs or RCMs) and emission scenarios (RCPs) simulations to determine a range of inputs values for climate part of the IAM;

Multi-model – cases that include different model applications based on the same model inputs;

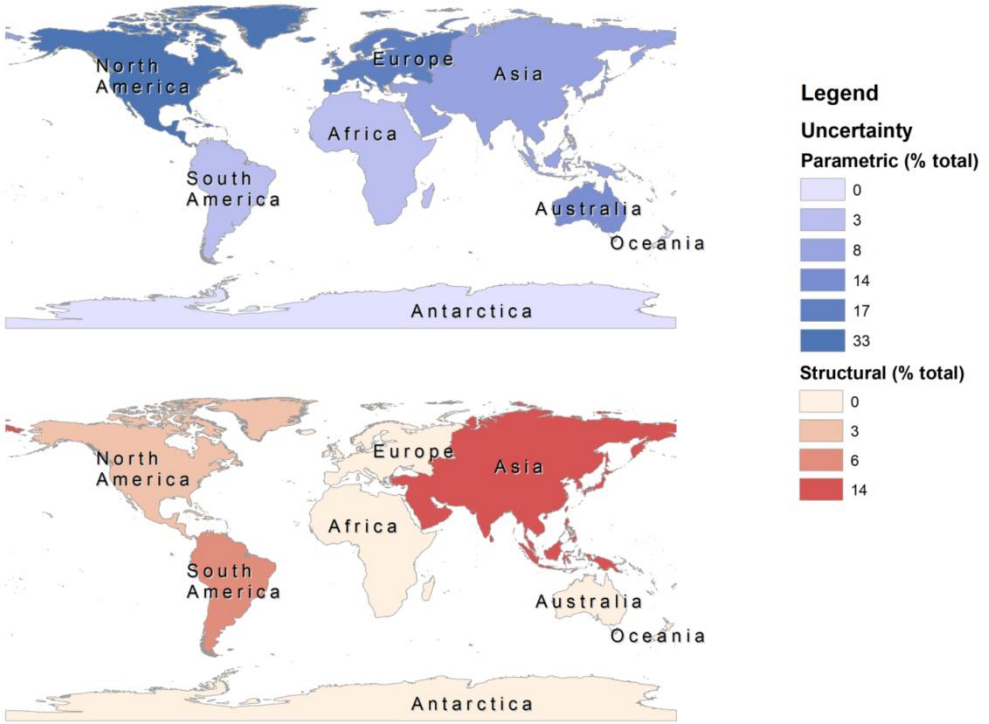
Description (qualitative) – cases in which uncertainty was not quantified, but a qualitative description of uncertainty was given.

UAs results at various scales

a)

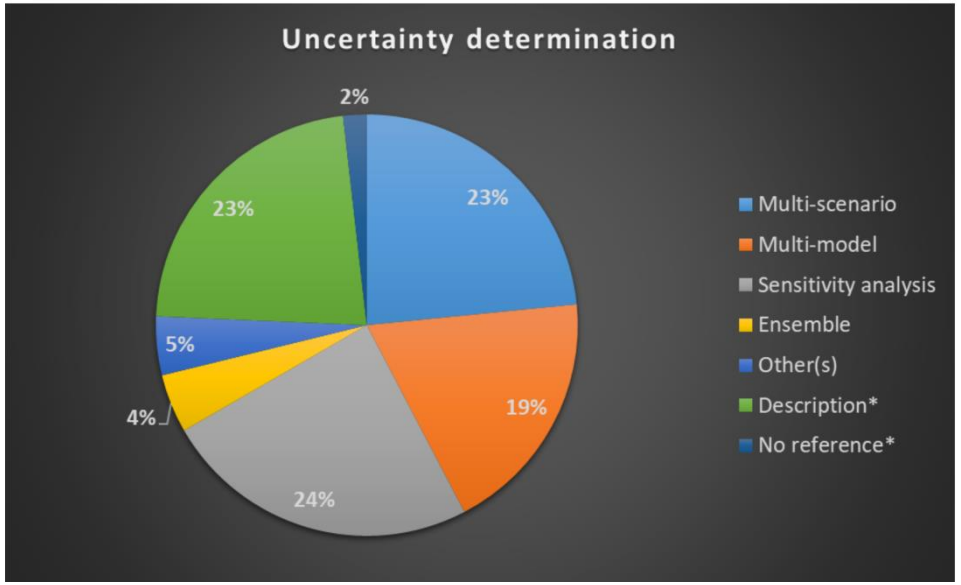


b)

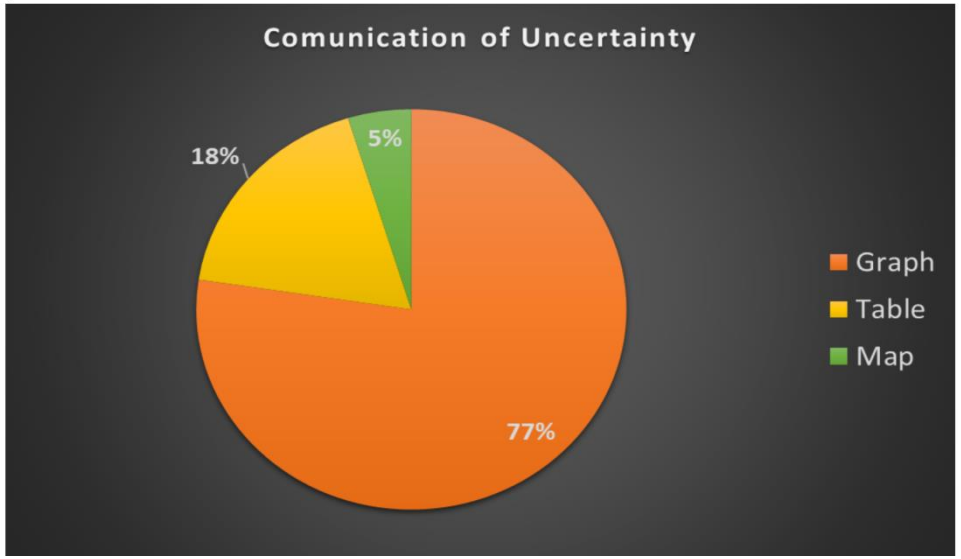


“nearly a quarter of the study cases did not quantify the uncertainty of their results and only described possible sources of error”

a)



c)



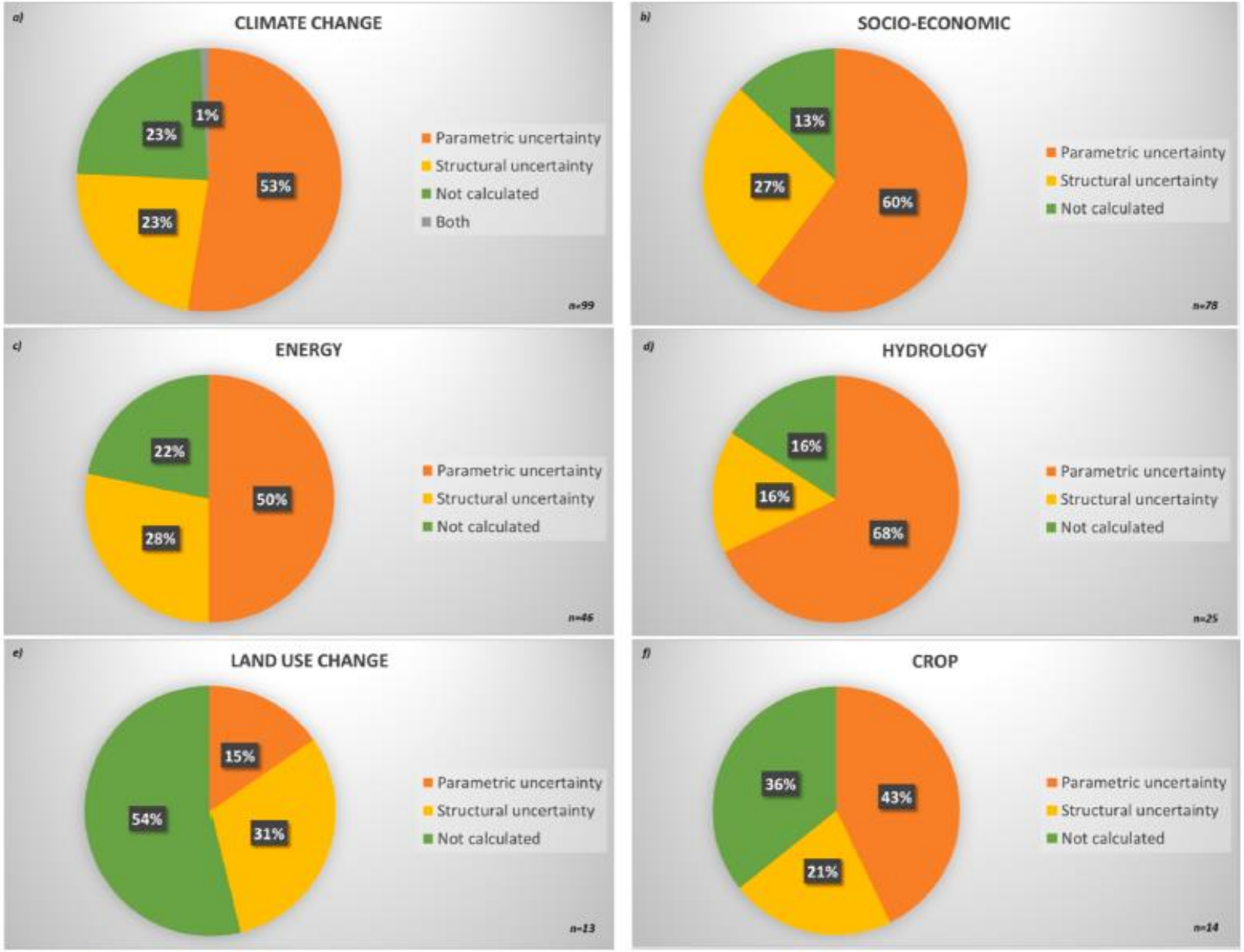


Fig. 5. Uncertainty analysis type by study areas: (a) Climate change, (b) Socio-economic, (c) Energy, (d) Hydrology, (e) Land-use change, and (f) Crop. Note: n-values are presented under each graph.

Our results

- **No uniform approach to deal with uncertainty in IAMs**
- **Lack of clarity in communicating future projections**
- **Parametric UA is used more often** than **structural UAs** in most cases.
- The highest use of **structural UA** was in the energy discipline.
- We highlight that case studies that focus on **Europe**, do not include **any structural UAs** while case studies that focus on **Asia** use **predominantly structural** UA methods.
- Uncertainty in the future development of **socioeconomic patterns** is generally studied with the use of **standardized Shared-Socioeconomic Pathways (SSPs) scenarios**.

Conclusions and recommandations

1. Analyse both parametric and structural UA in IAM !!

2. **Parametric UA**: include **more stochastic analysis and risk** analysis (+ tipping points) + Use of **fully harmonized datasets** (ISIMIP, IIASA database etc.)

e.g. the estimate of the **optimal carbon tax is higher based on a stochastic approach** due to the consideration of higher risks than with a deterministic approach (Engström and Gars (2015))

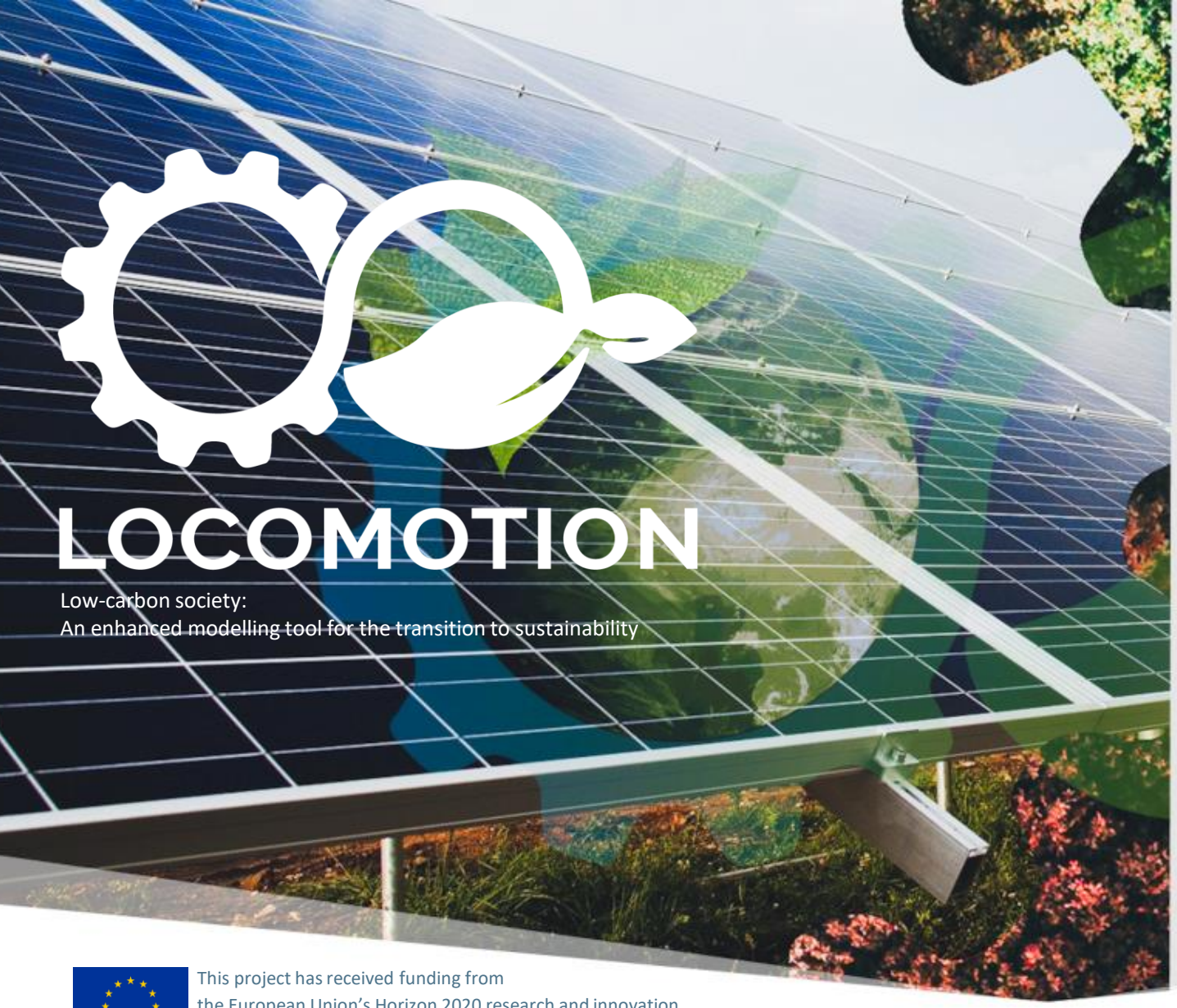
3. **Structural UA**: improve the representation of processes in model structure with **calibrating and validating models** !!

e.g. **use of multi-models**. quality of the different models can be assessed based on **expert elicitation** and pedigree analysis (Refsgaard et al. 2006)

4. Increase knowledge in all disciplines – **balanced disciplines representation** in IAM

5. Shift from the stand-alone use of integrated assessment modelling frameworks to **truly integrative processes**, in which **multiple actors and methods complement each other**" (Doukas et al. 2018)

6. By exploring and embracing uncertainty rather than ignoring it, we can contribute to **developing a more resilient society and solutions that are robust** under a wide range of potential future scenarios.



Thank you !

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