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Some Reflections on the Feasibility of Rapid Systems Transformations for Addressing Climate Change

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International Institute for Applied Systems Analysis (IIASA)

OENB, 7 June 2023

The IPCC

- International scientific body set up by WMO and UNEP
- Periodic Assessment Reports (AR6 in 2021/22)
- Hundreds of Scientists involved as Authors and Reviewers
- Does not conduct own research, but assesses the latest scientific, technical and socio-economic literature
- Elaborate Expert and Government Review
- Main findings summarized in “Summary for Policy Makers”
- Nobel Peace Price 2007 together with A. Gore

WGIII Report by numbers

278 Authors

65 Countries

41 % Developing countries
59 % Developed countries

354 Contributing authors

29 % Women / 71 % Men

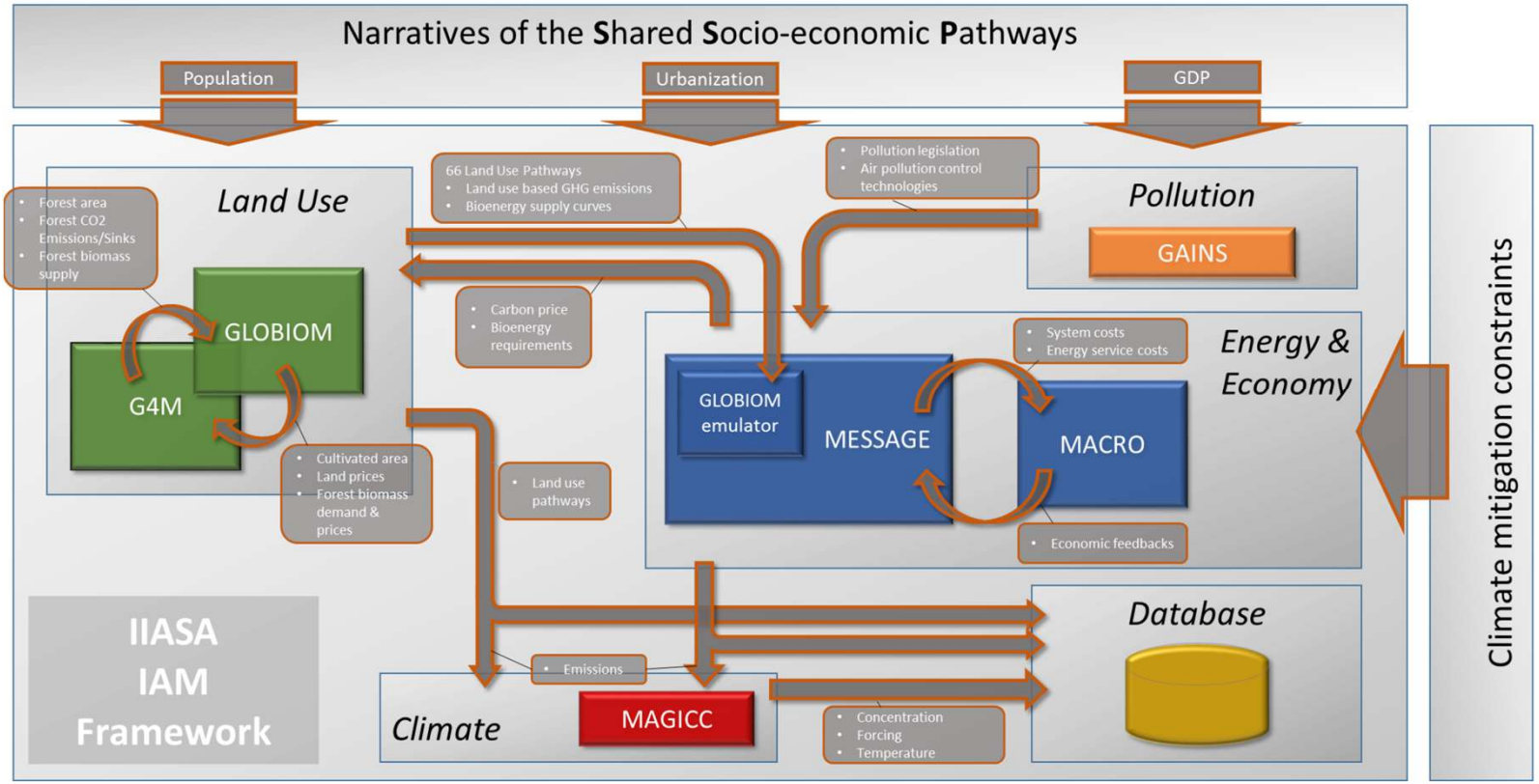
More than
18,000 scientific papers

59,212 Review comments

IPCC Plenary AR5

WGIII models: Integrated assessment models

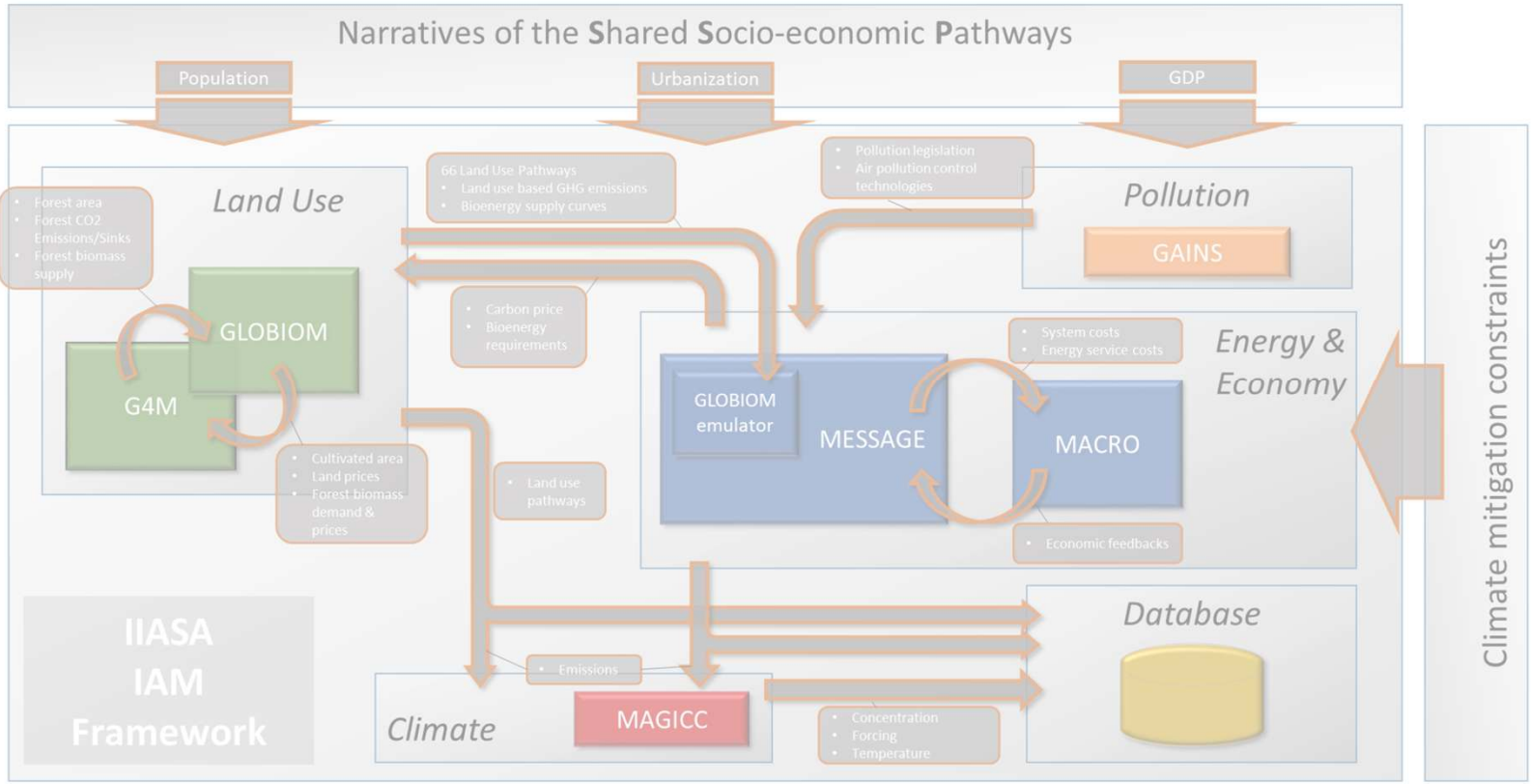
Integrated assessment models describe human interventions/systems and their implications for economic & social development and the environment



Friko et al. (2016)

WGIII models: Integrated assessment models

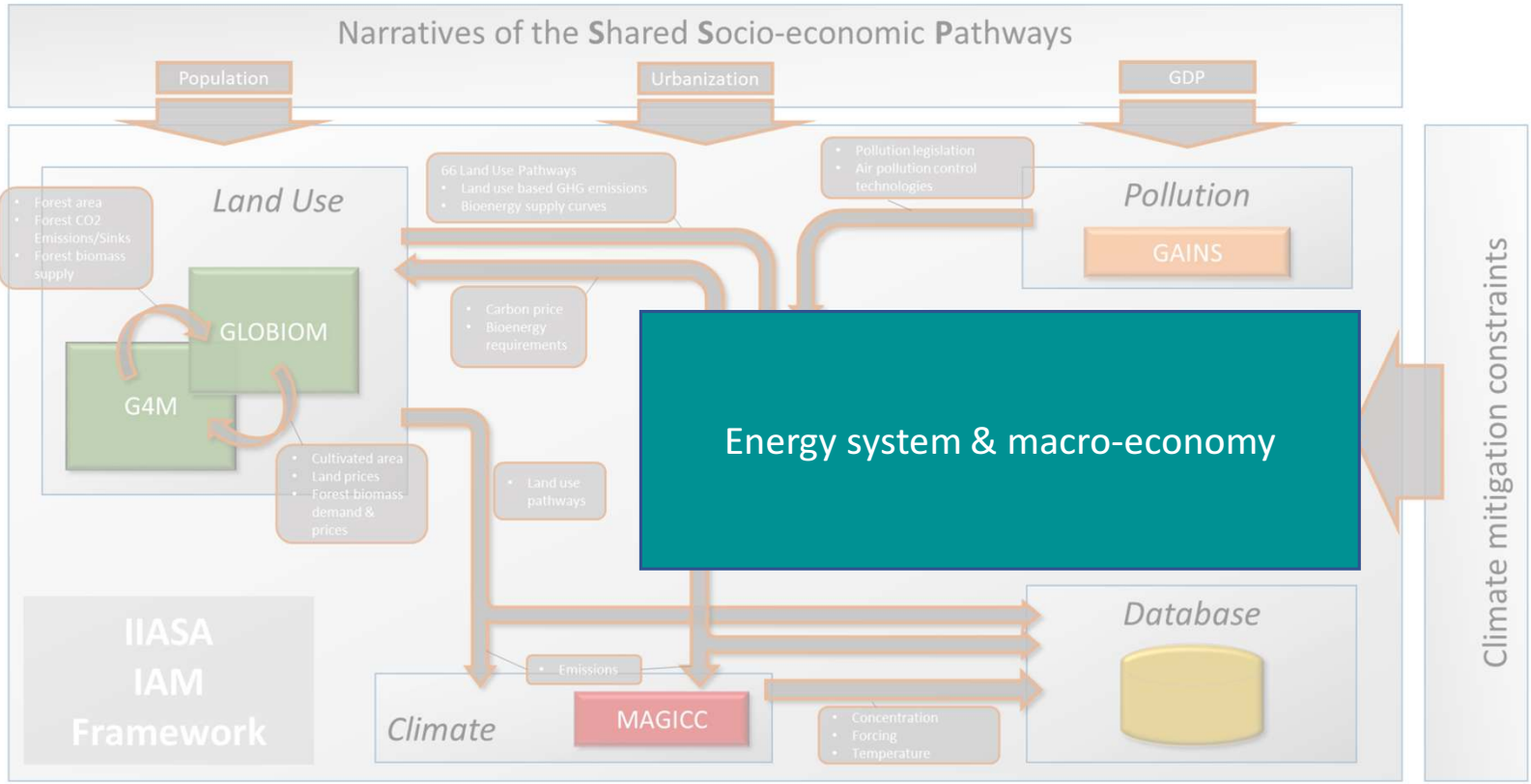
Supply and demand is represented across different service sectors



Friko et al. (2016)

WGIII models: Integrated assessment models

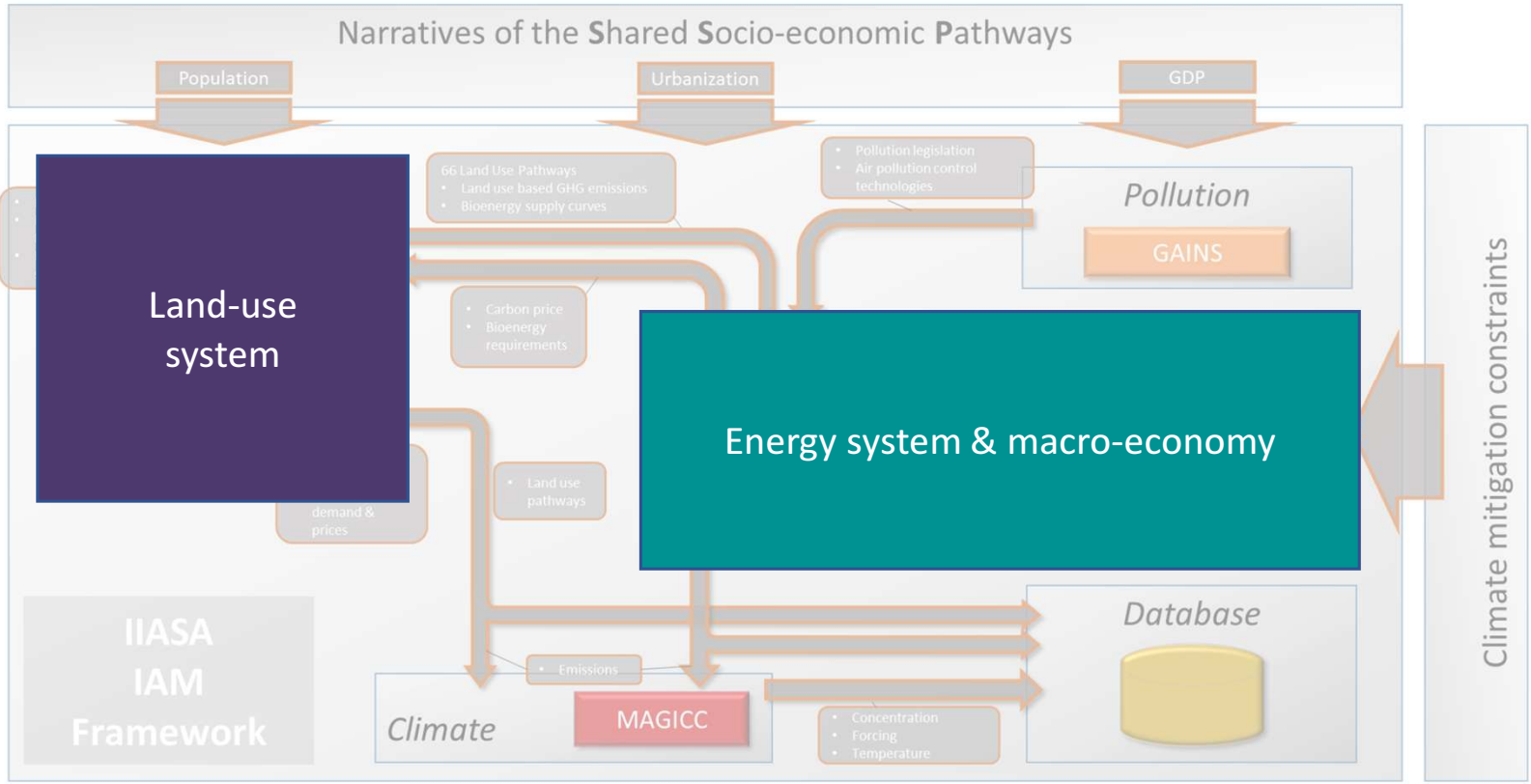
Implications of energy system choices for the economy are assessed (inl environmental externalities, such as carbon cost, etc.)



Friko et al. (2016)

WGIII models: Integrated assessment models

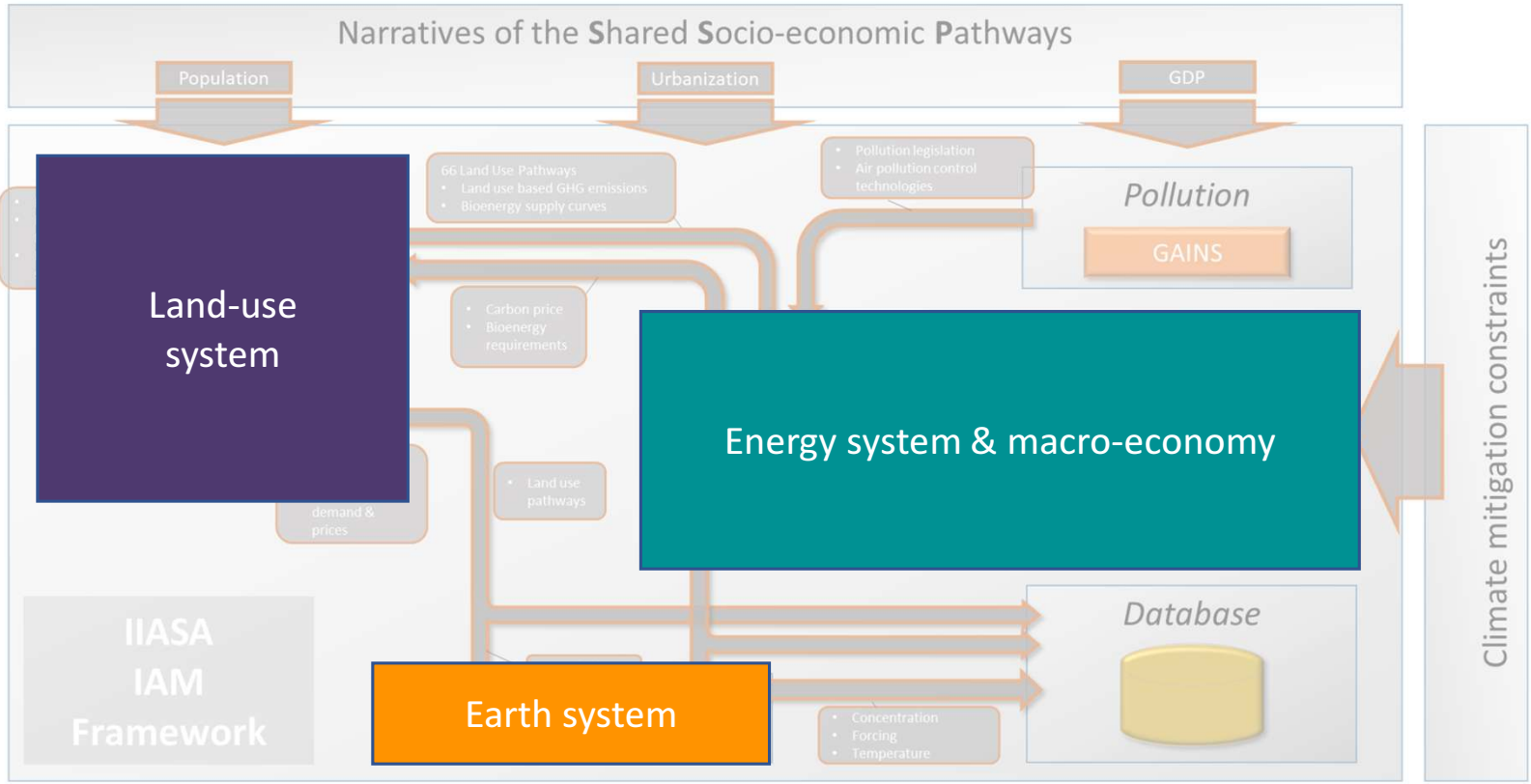
Supply and demand within the land-use system (food, wood, paper, bioenergy etc.)



Friko et al. (2016)

WGIII models: Integrated assessment models

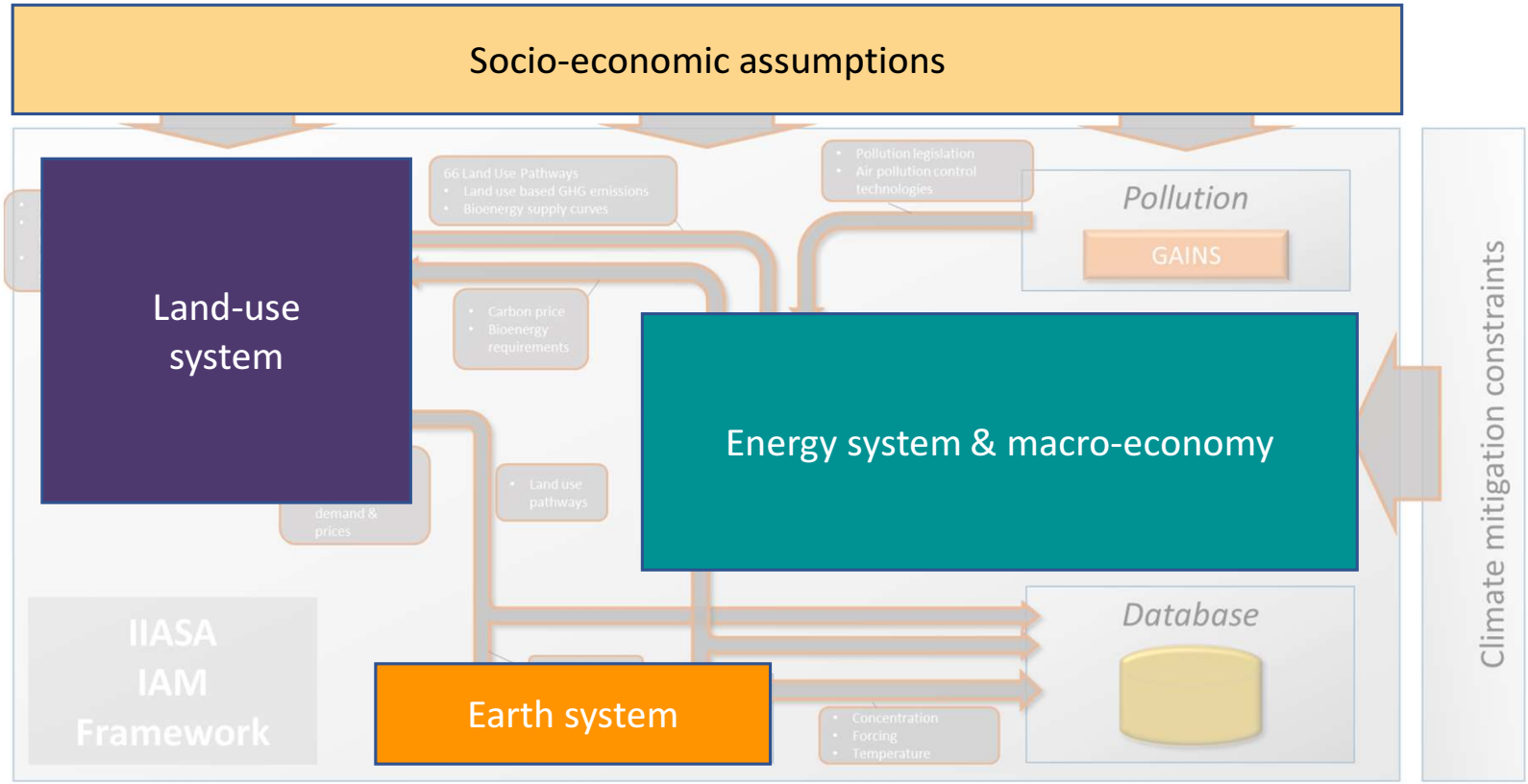
Earth system component is used for accounting for climate target such as the Paris Agreement



Friko et al. (2016)

WGIII models: Integrated assessment models

Socio-economic assumptions are the way to tell the story of future developments

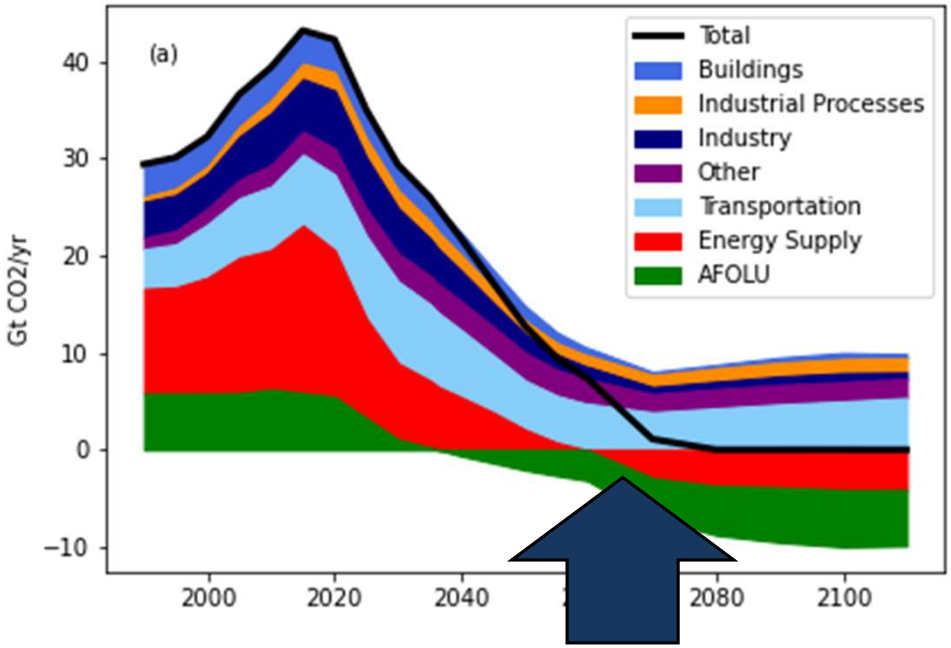


Friko et al. (2016)

What does carbon neutrality mean?

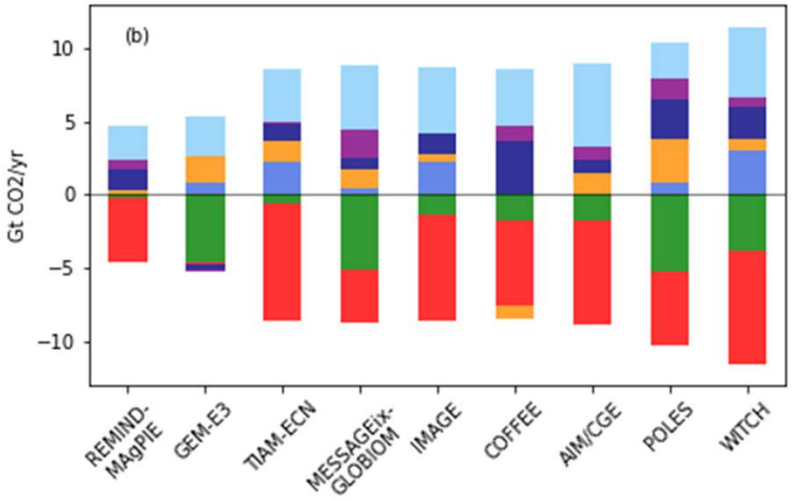
SECTORAL emissions sources and sinks

Illustrative zero emissions pathway



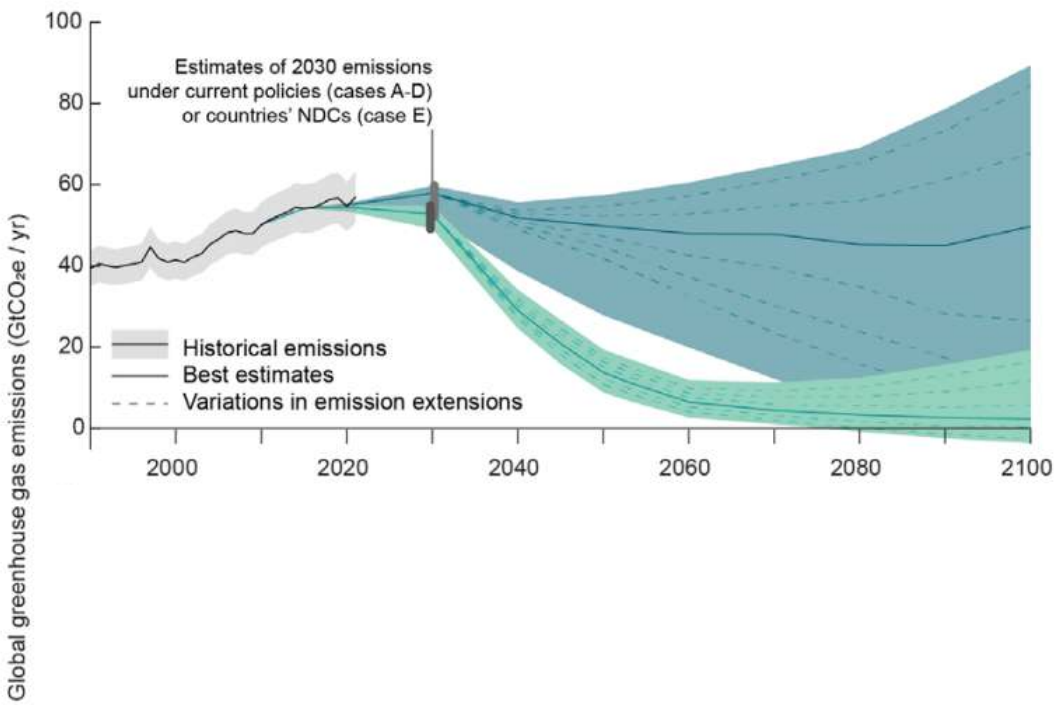
World: Net zero CO_2 emissions 2050-2070

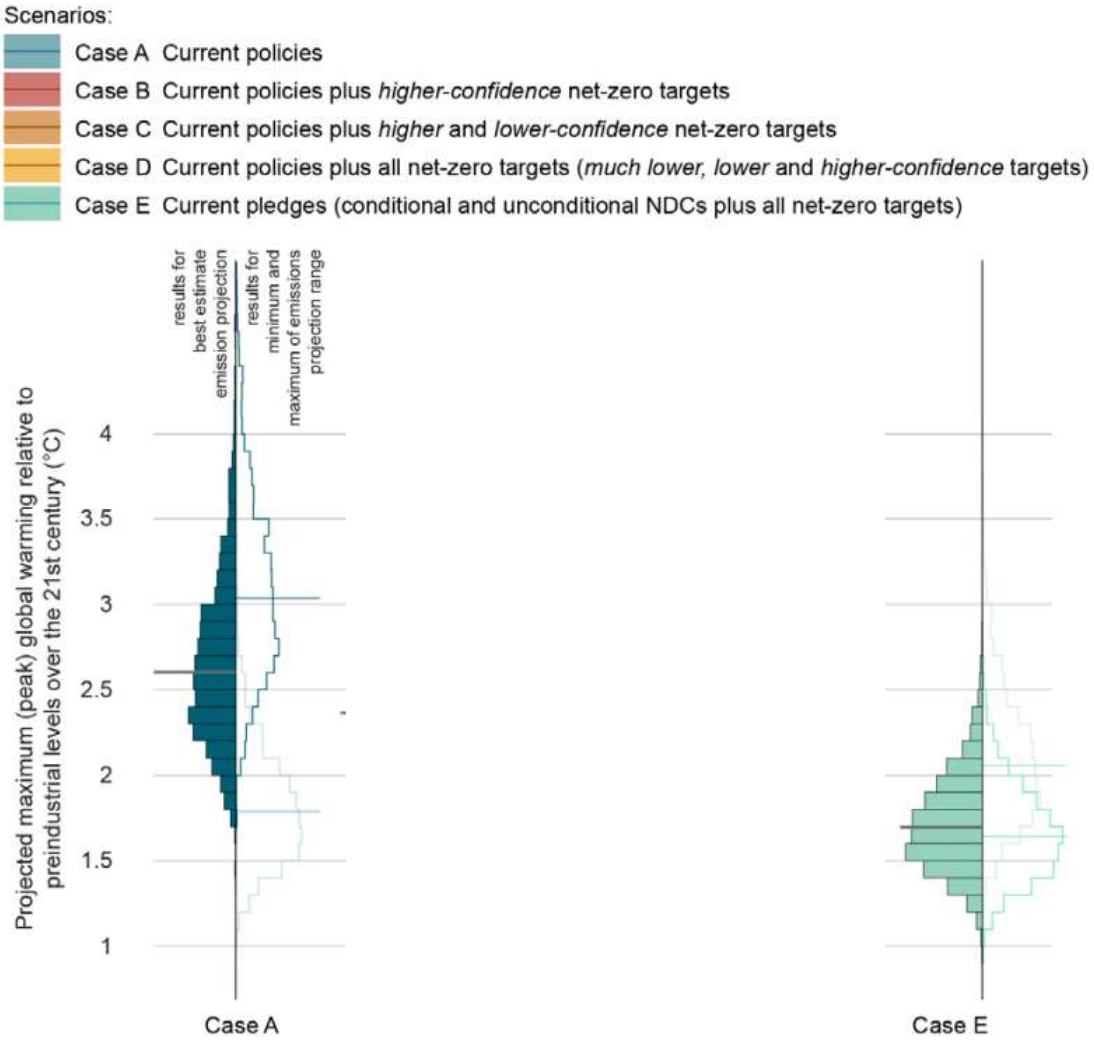
Different net zero systems across models



Riahi et al, 2022, Nature Climate Change

The credibility of country pledges



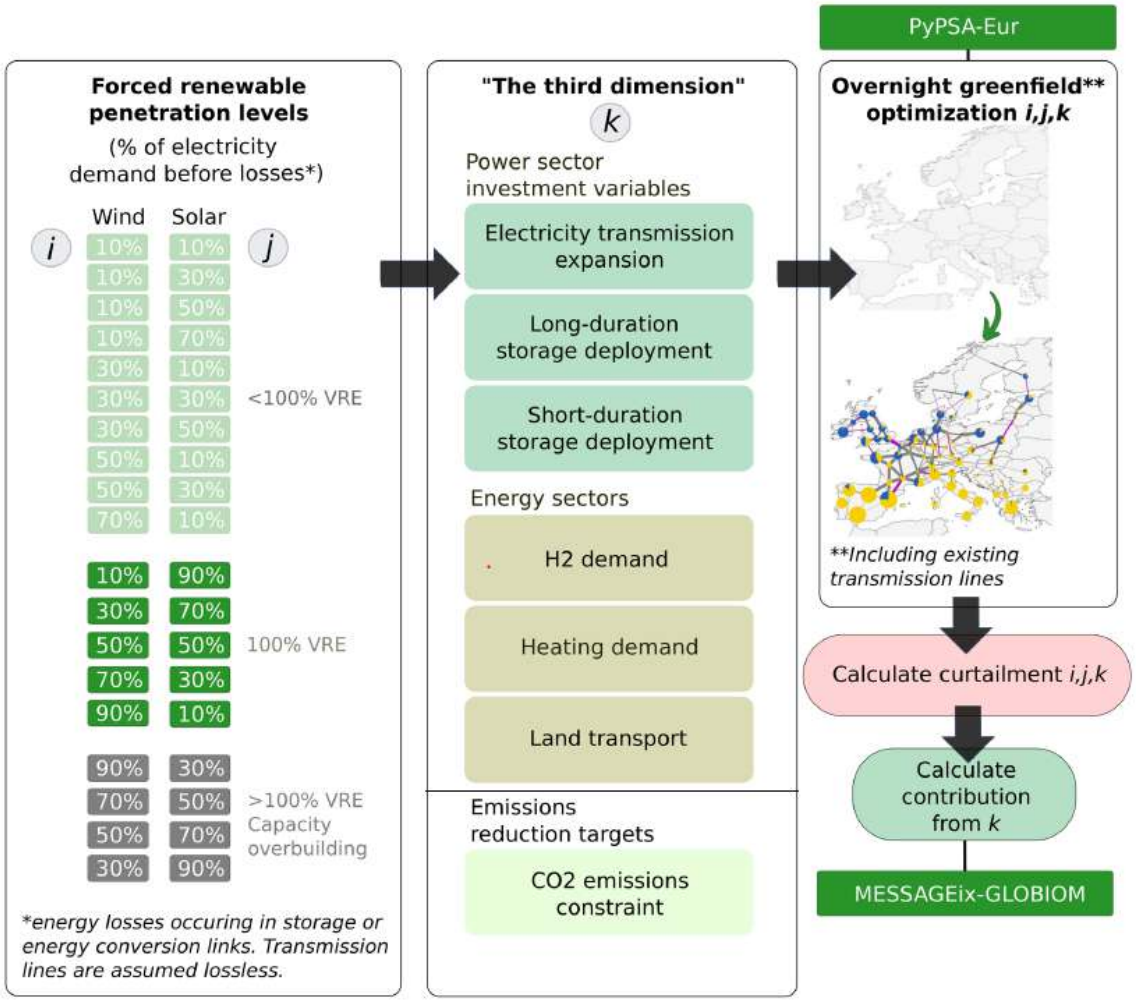


Rogelj et al, 2023

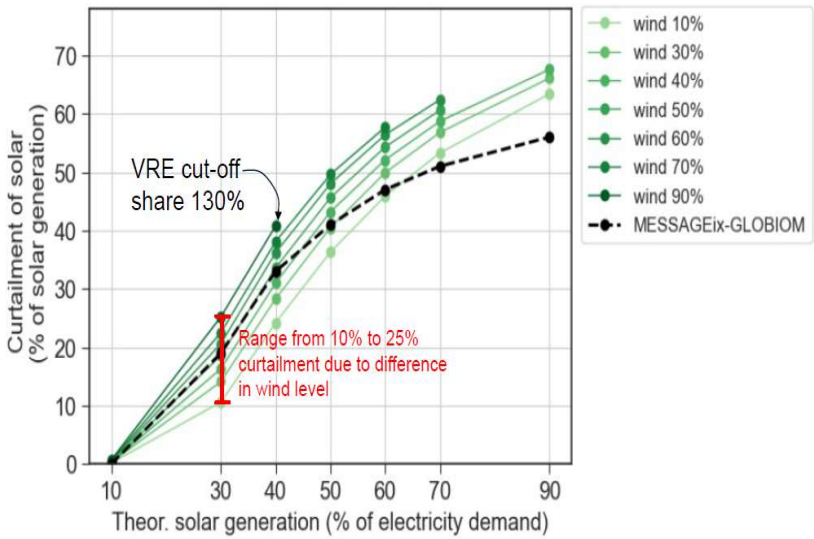
System Change (for limiting warming well below 2C)

- Limiting energy demand!
  - Energy demand in 2050 ~ about the same level as today
- Decarbonize electricity (+ storage + grid)
- Electrify demand sectors
  - (industry, buildings, mobility)
- Substitute non-electric fuels with low-carbon options
  - (power-to-x in industry, freight and aviation)
- Carbon dioxide removal from the atmosphere

Benchmarking of MESSAGEix using PyPSA-Eur



Curtailment: MESSAGEix vs PyPSA-Eur



Goetske et al., (forthcoming)

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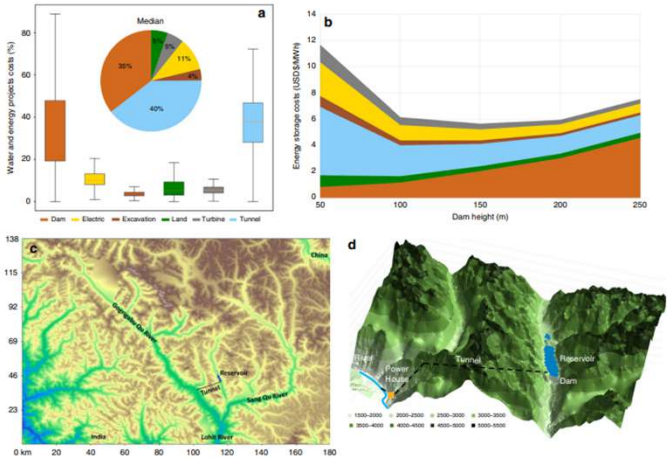
Is it feasible to reach net zero targets?

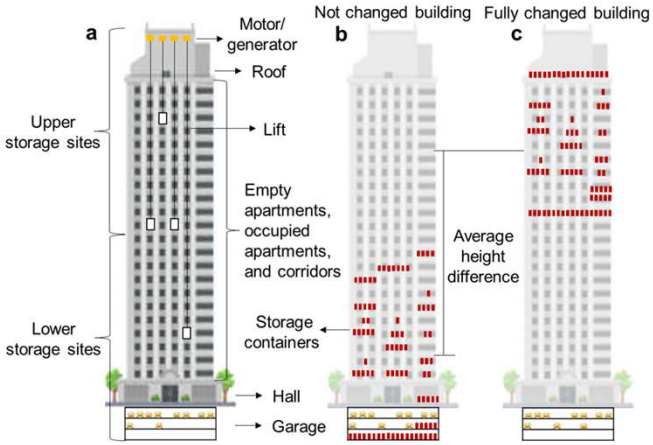
Based on IPCC AR6 and Brutschin, E., Pianta, S., Tavoni, M., Riahi, K., Bosetti, V., Marangoni, G., & Ruijven, B. J. van. (2021). A multidimensional feasibility evaluation of low-carbon scenarios. *Environmental Research Letters*, *16*(6), 064069. https://doi.org/10.1088/1748-9326/abf0ce

Various energy storage proposals exist and need to be scaled up….

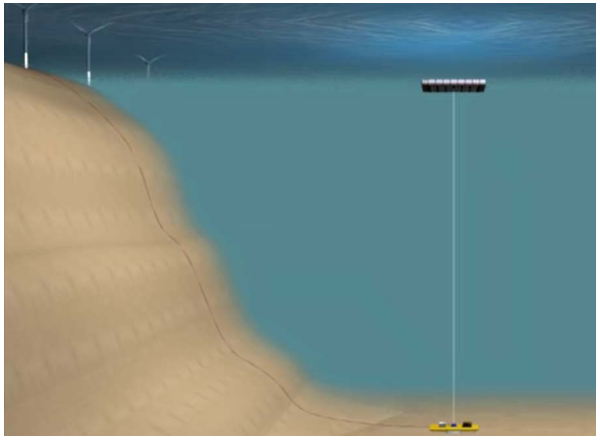
Pumped Hydro



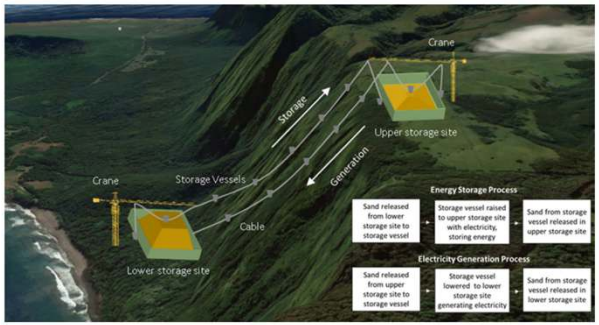
Lift Energy Storage



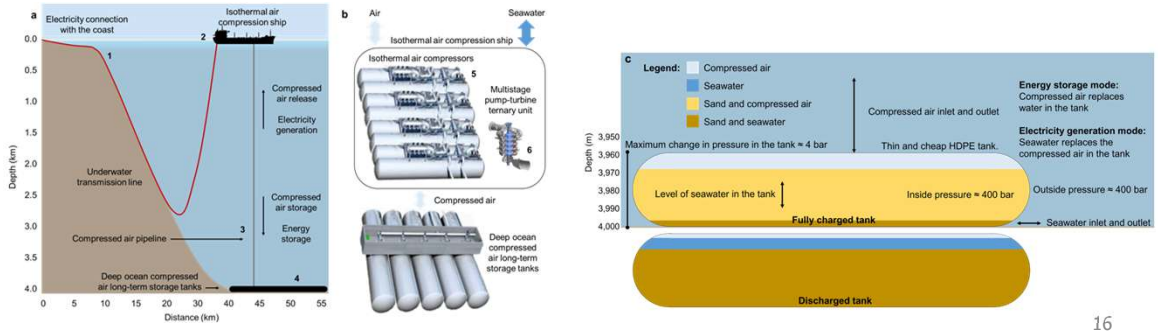
Buoyancy Energy Storage



Gravity Energy Storage



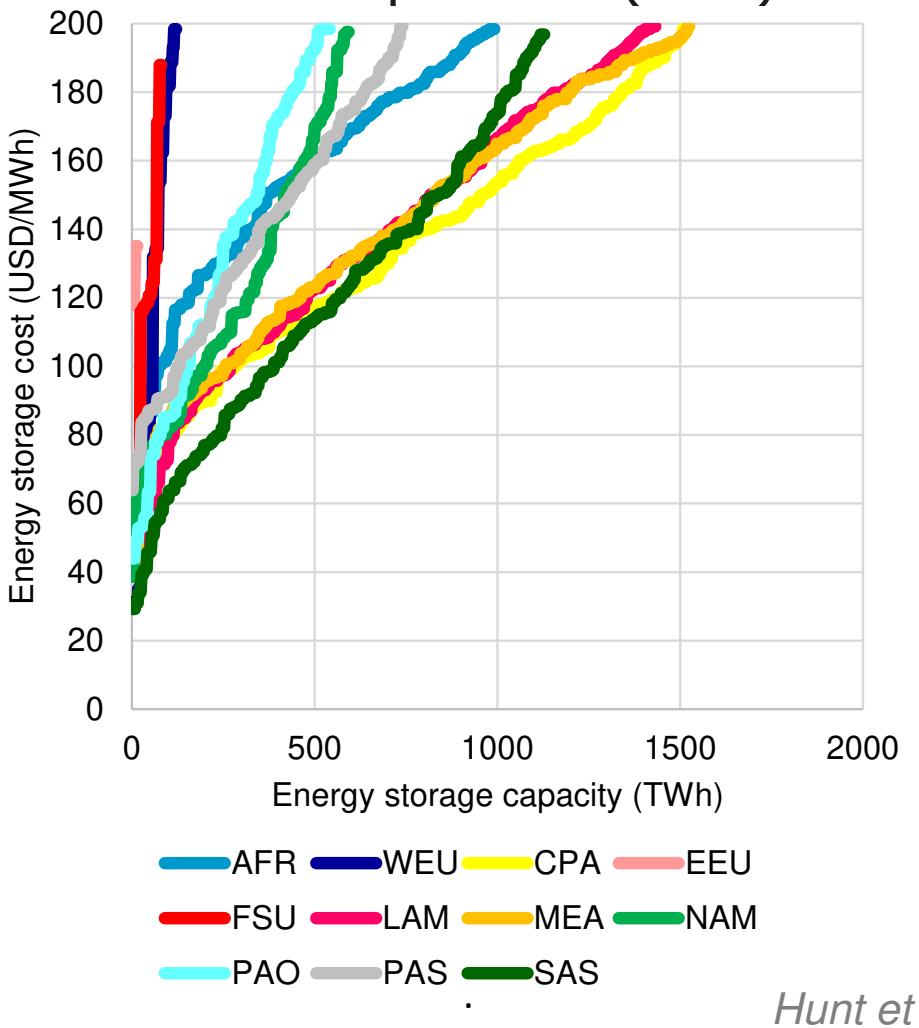
Deep Ocean: Compressed Air or Hydrogen Link:



Hunt et al, 2021, 2022, 2023, 2024

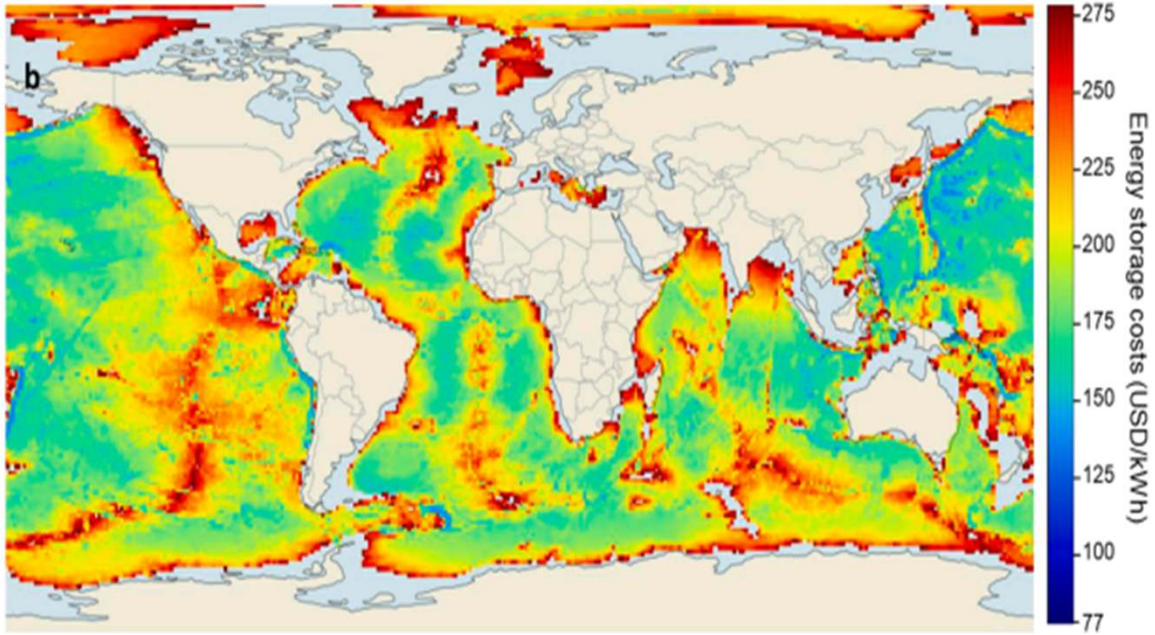
Mountain Gravity Energy Storage

Global potential (TWh)



Buoyancy Energy Storage

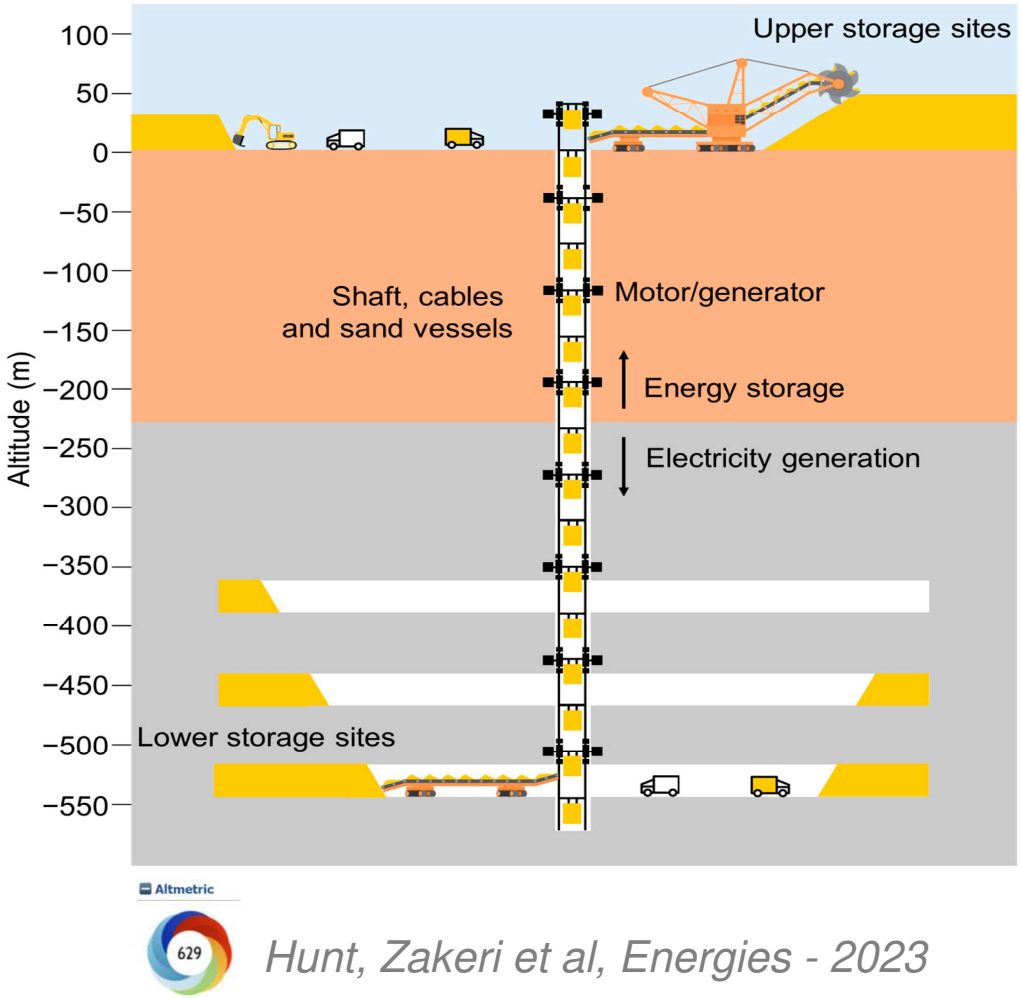
Potential >> global electricity needs



Hunt et al, 2022, 2023

Underground Gravity Energy Storage

Ideas are picked up by industry



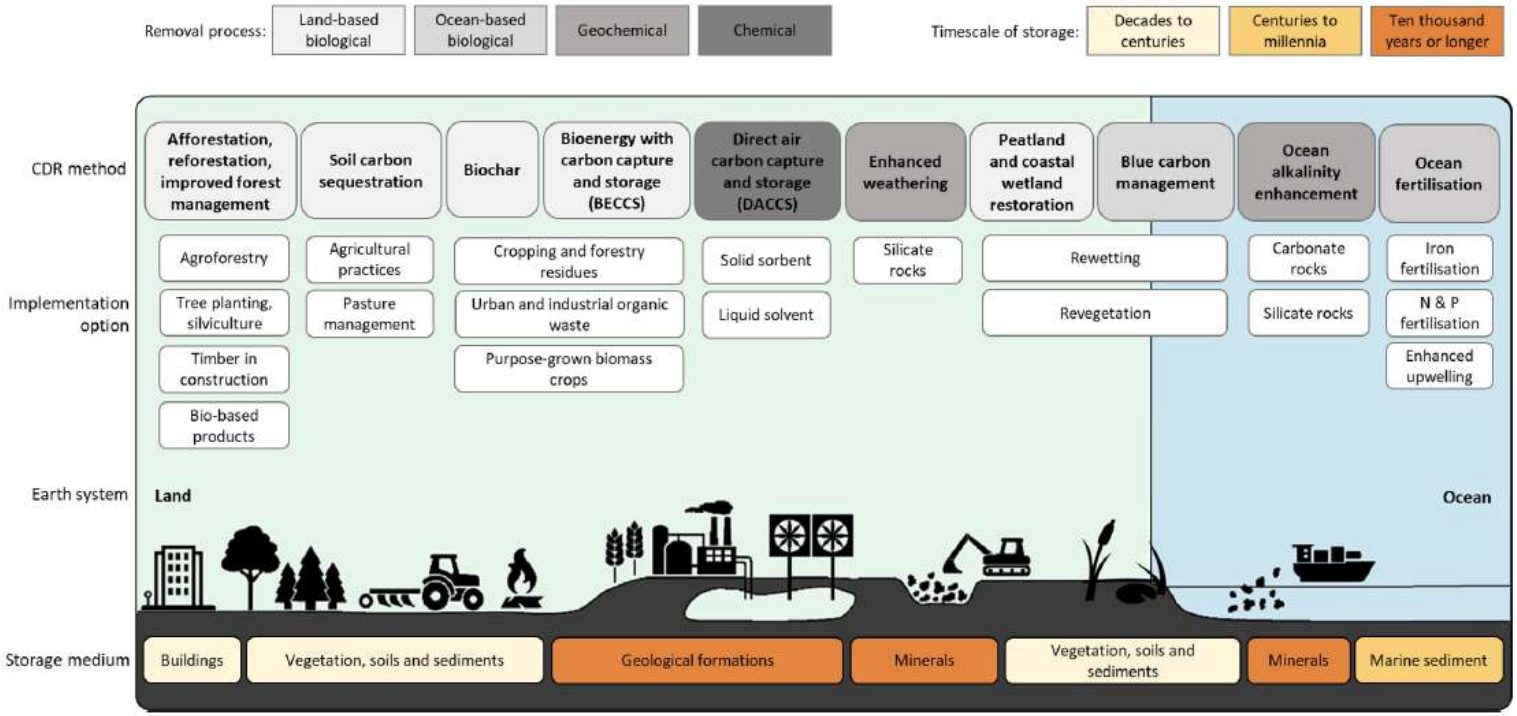
Altmetric 629

Hunt, Zakeri et al, Energies - 2023

- Green Gravity – Australia
  https://greengravity.com/technology/
- Romania to turn 17 coal mines into gravity energy storage systems
  https://balkangreenenergynews.com/romania-to-turn-17-coal-mines-into-gravity-energy-storage-systems/
- Economical Energy
  https://economical-energy.com/
- Shell is investing in the technology
  https://im-mining.com/2023/10/23/economical-energy-and-its-viper-energy-storage-tech-win-studio-x-recognition/

Cost of storage: 1 to 10 USD/kWh
Global energy storage potential 7 to 70 TWh

Carbon dioxide removal (CDR) needed to reach net zero emissions



***Source**: IPCC, 2022, Chapter 12, Cross-Chapter Box 8; based on Minx et al., 2018*

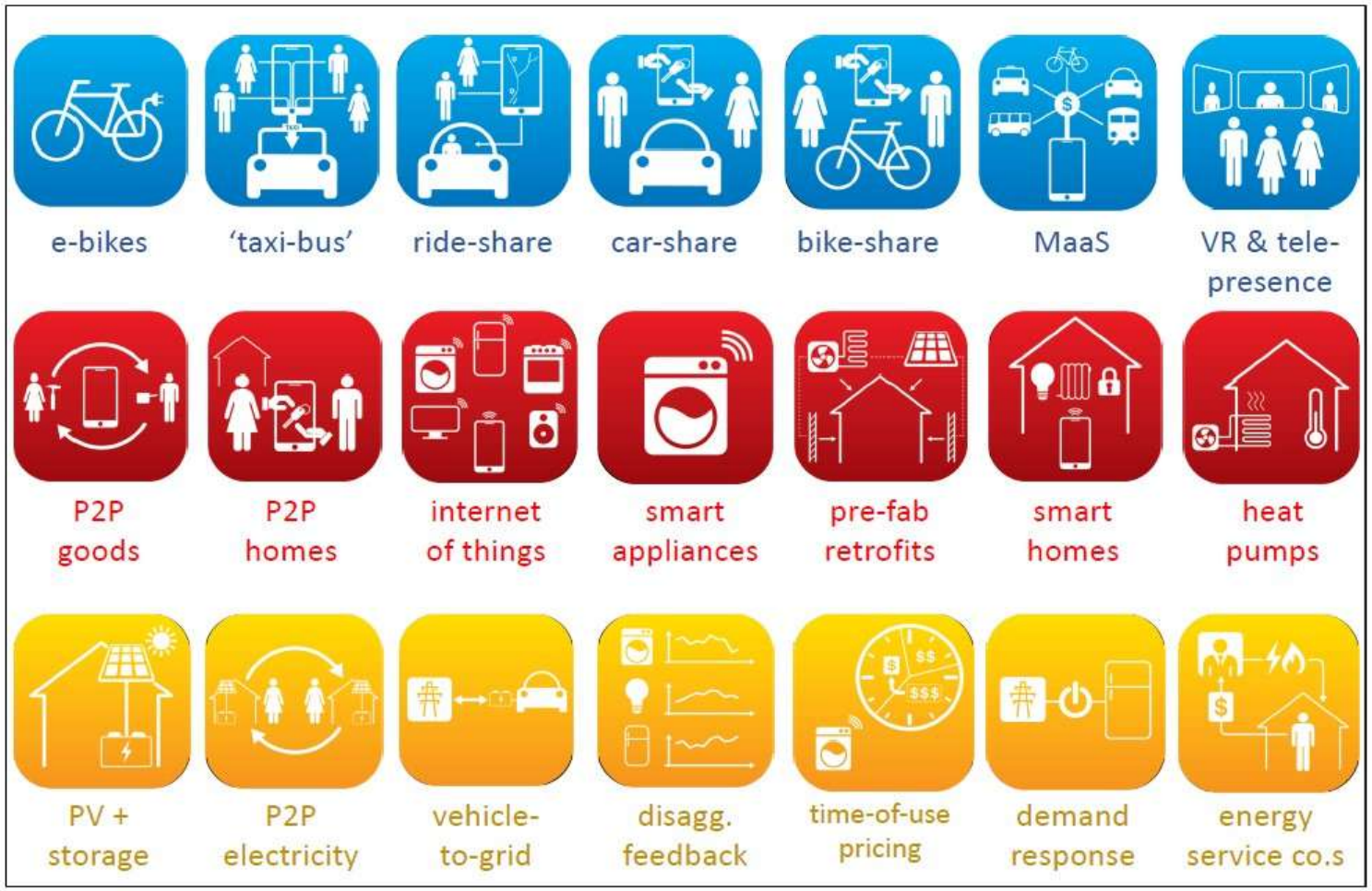
CDR characteristics:

- ✓ Needed to reach net zero
- ✓ Accelerate rate of emissions reductions (early on)
- ✓ "Repair phase" in case target stringency needs to be adjusted over time and temperatures need to reversed.

Wide portfolio

- ➢ Different public perceptions
- ➢ Trade-offs and Synergies
- ➢ Legal framing (permanence and liability)
- ➢ Policy portfolios

Disruptive End-user Innovations

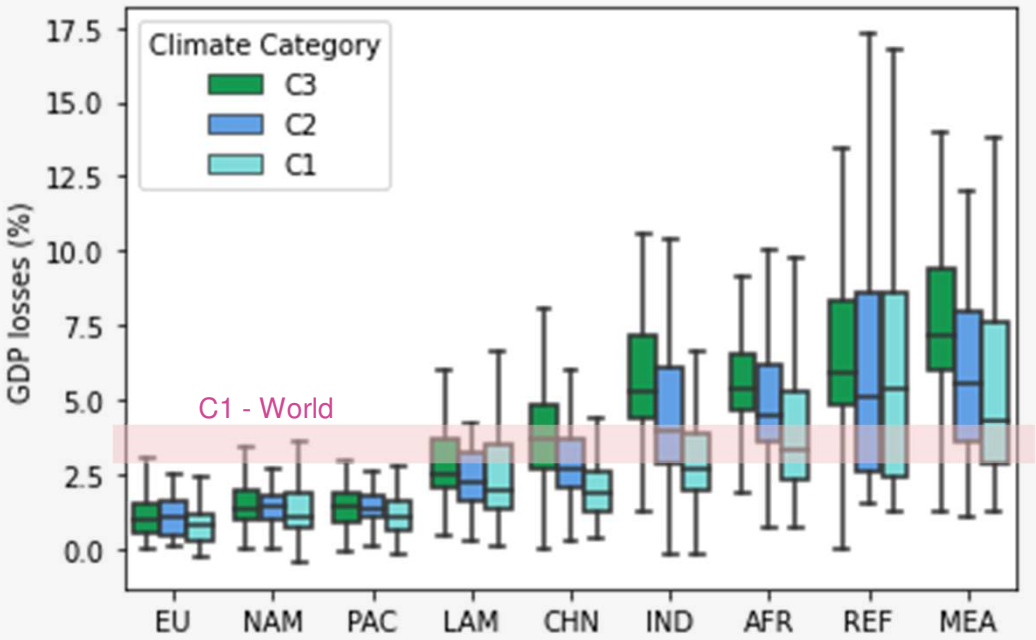


Source: Wilson et al, 2020

- ✓ Ownership to usership
- ✓ Sharing economy
- ✓ Automized to connected

Costs of mitigation are modest and on average lower than the avoided costs of impacts (of limiting warming to 2C)

Regional costs



Costs reflect cost-effective allocation of mitigation and does not consider any financial transfers or other equity considerations

- The aggregate global effects of mitigation on global GDP are small compared to global projected GDP growth:

  → 2.6 - 4.2% GDP loss by 2050 for 1.5C

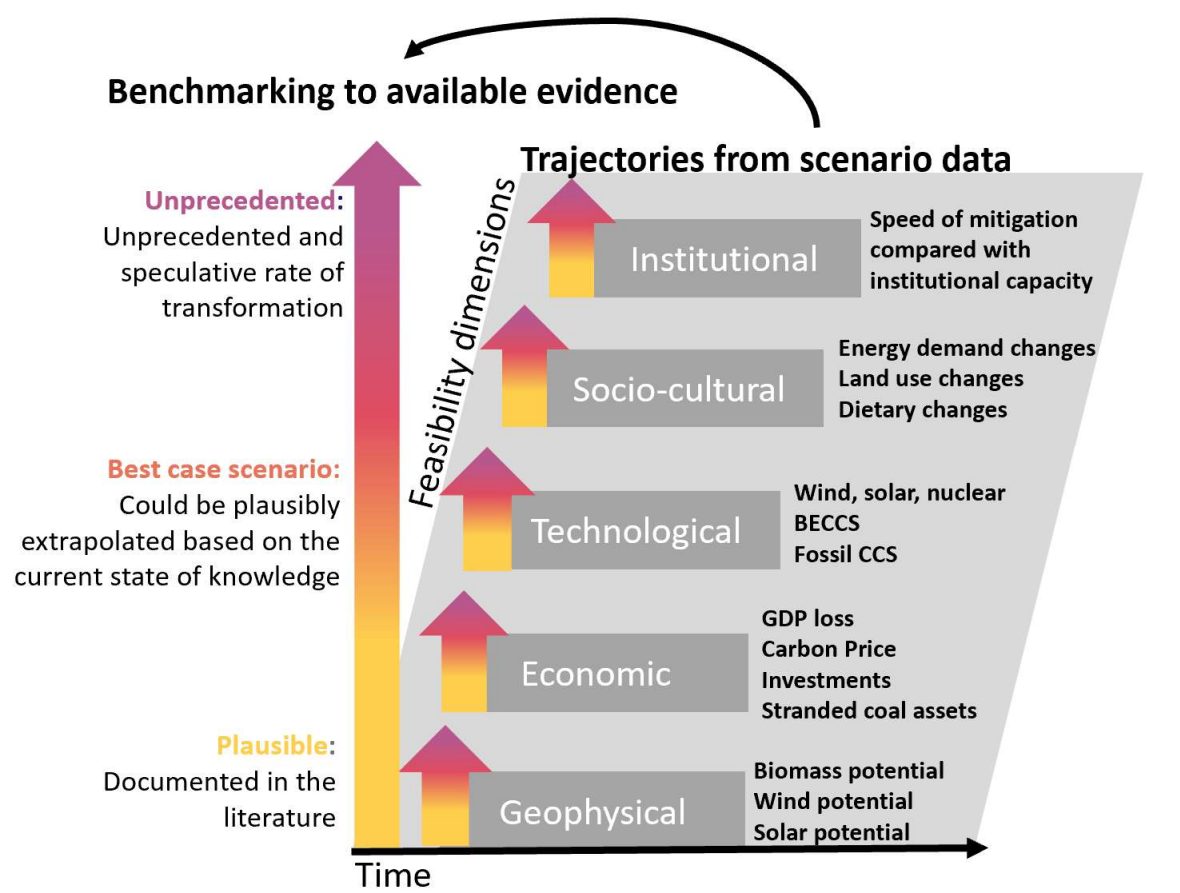
  → 1.3–2.7% GDP loss by 2050 for 2C

  Assuming coordinated global action. The corresponding average reduction in annual global GDP growth over 2020-2050 is 0.04–0.09 percentage points.

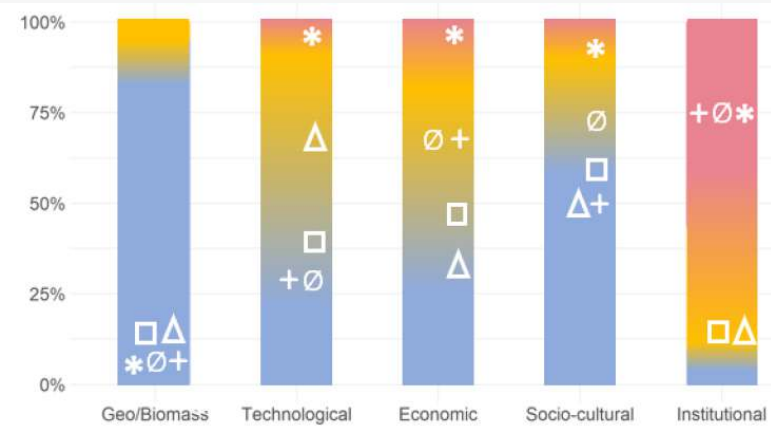
- Global GDP is projected to at least double (increase by at least 100%) over by 2050.

- Global cost of limiting warming to 2°C over the 21st century is lower than the global economic benefits of reducing warming, unless: i) climate damages are towards the low end of the range; or, ii) future damages are discounted at high rates

Key challenges comprise governance and institutional dimension in the developing world



Feasibility evaluation of 1.5C and 2C pathways



Not in the WGIII AR6 SPM due to lack of agreement

Finance Figure

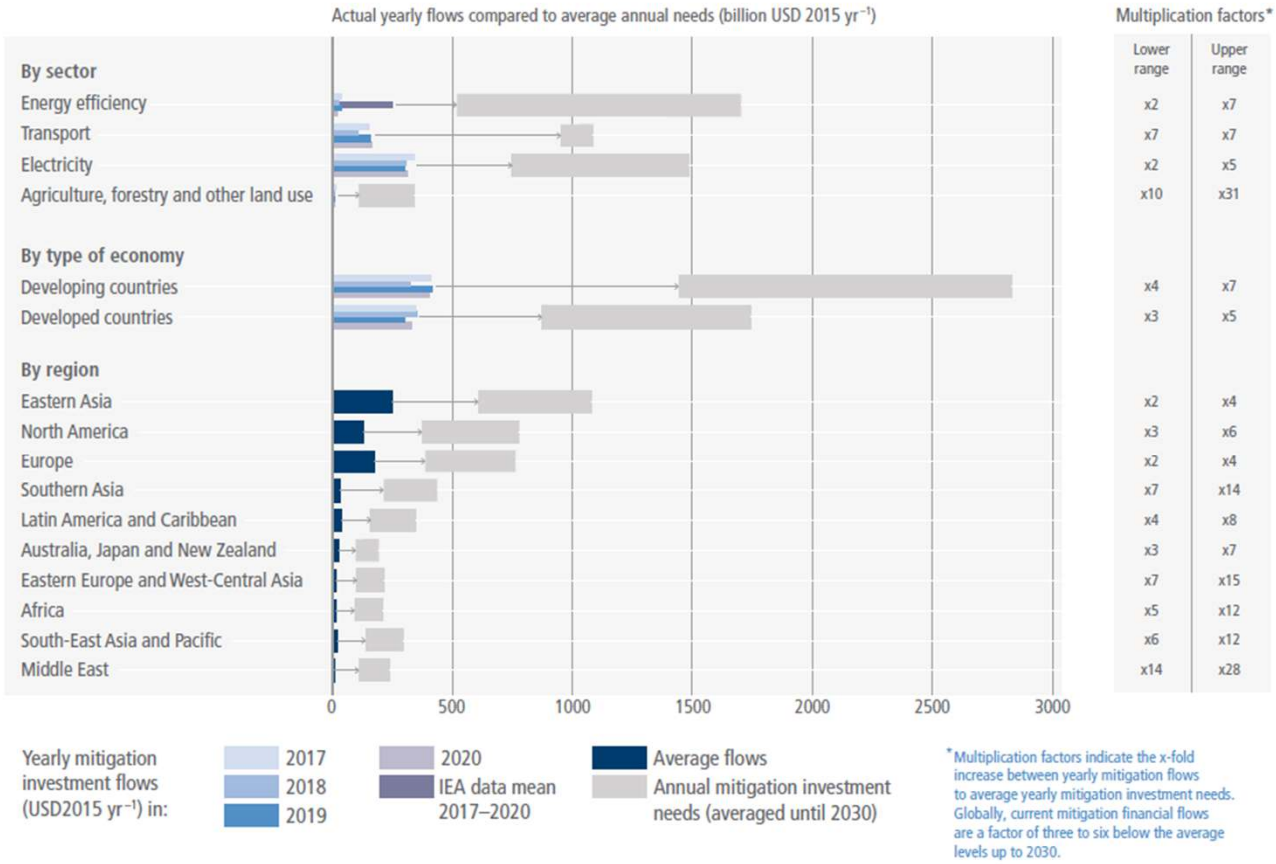
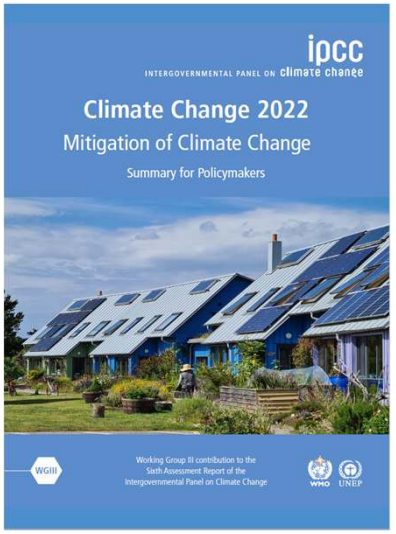
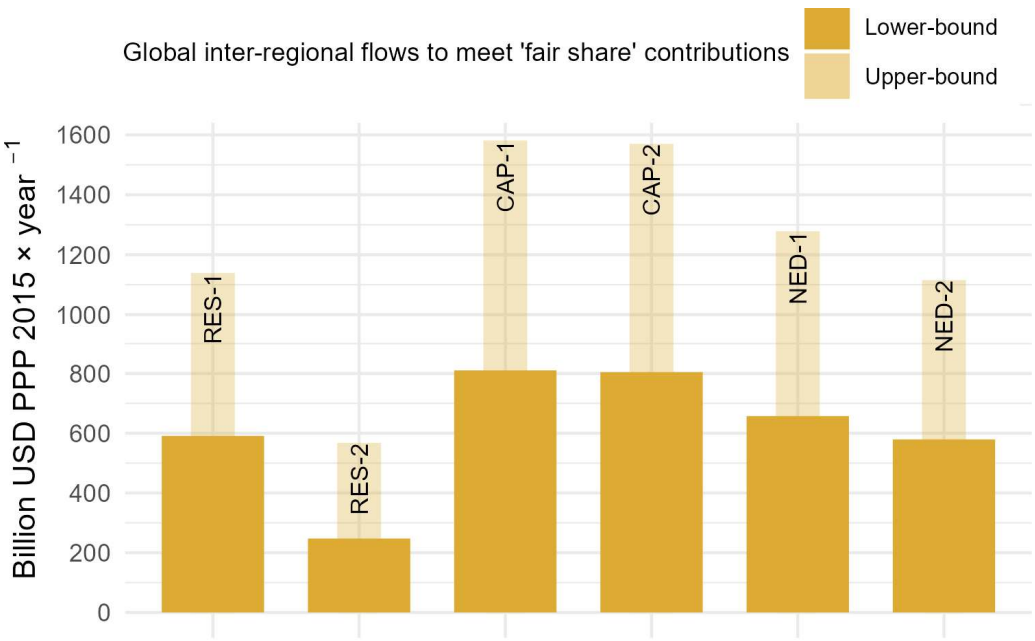


Figure 15.4 | Breakdown of recent average (downstream) mitigation investments and model-based investment requirements for 2020–2030 (USD billion) in scenarios that likely limit warming to 2°C or lower. Mitigation investment flows and model-based investment requirements by sector / segment (energy efficiency in



New fair share analysis based on AR6 pathways indicate the need of increasing finance flows



Shonali Pachauri[1], Setu Pelz[1], Christoph Bertram[2], Silvie Kreibiehl[3], Narasimha D. Rao[1,4], Keywan Riahi[1], Youba Sokona[5,6] *(Science, 2022)*

Investments in the AR6 pathways are follow a cost-effectiveness approach (consistent with Article 3 of Paris Agreement)

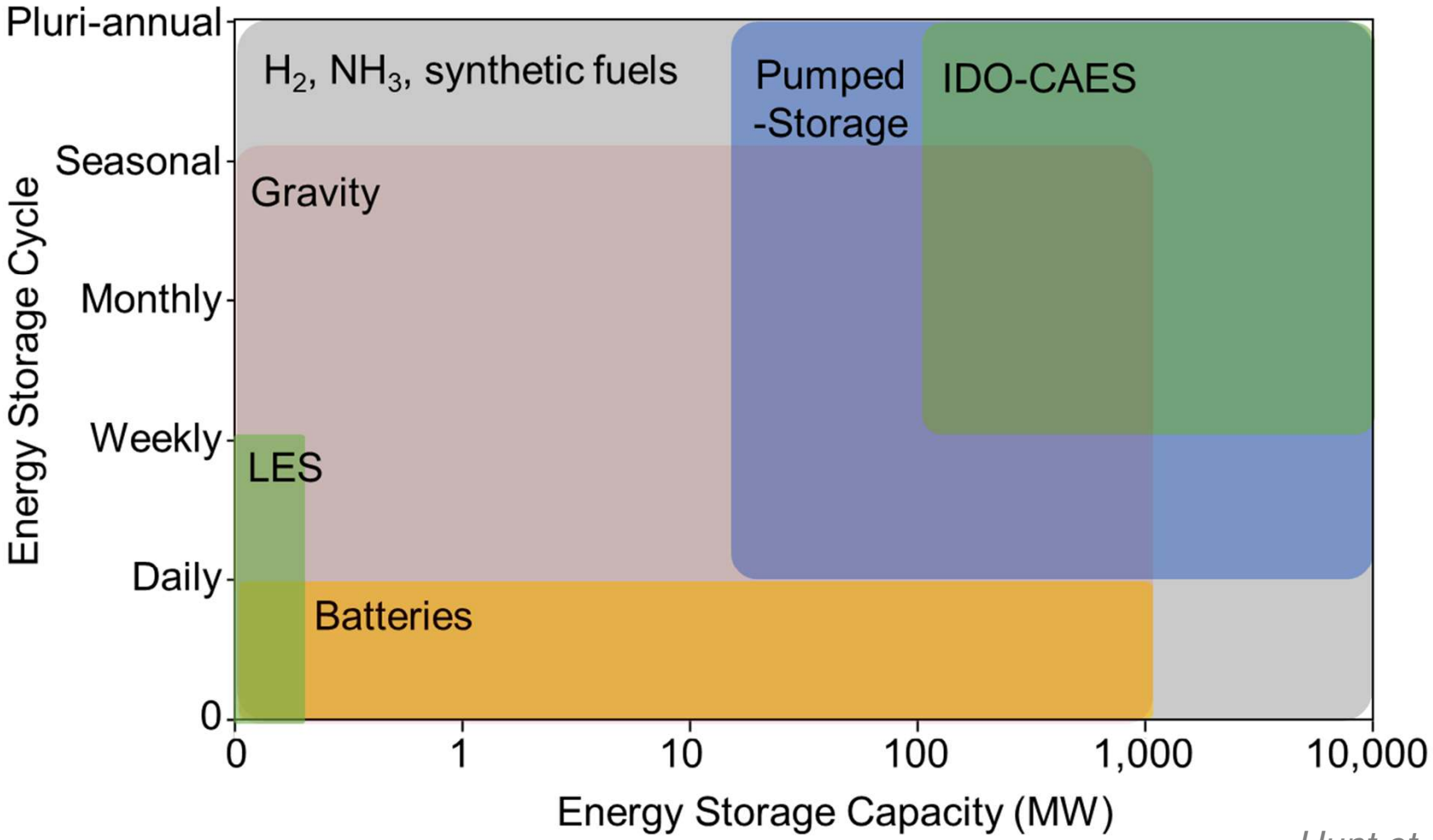
The pathways, however, do not address the issue of who is financing the regional investments

New assessment of equitable and fair finance (of the investments of the AR6 pathways) suggest a major increase of finance flows from Annex-1 to non-Annex-1 regions

Thank you.

Visit: https://iiasa.ac.at/winners-of-edits-arts-2022-competition-life-in-2050-with-much-less-energy

Energy storage cycles and storage size



Hunt et al, forthcoming