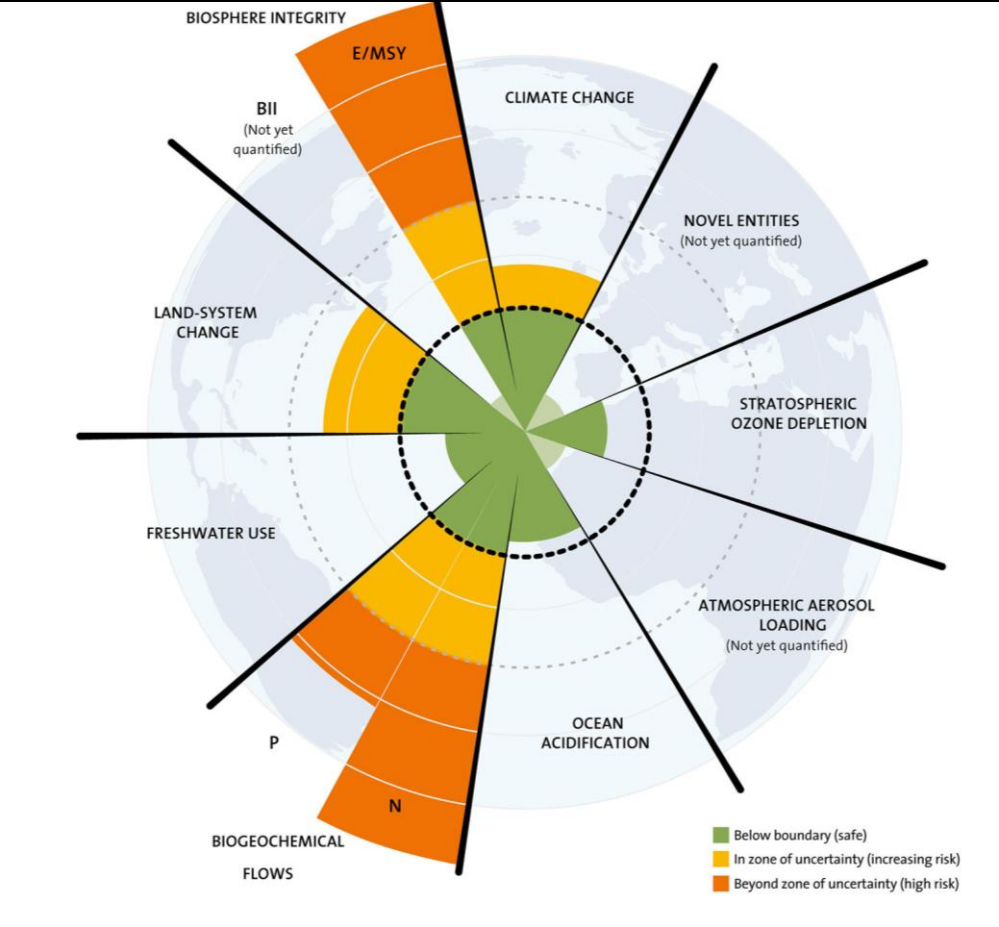


Planetary Boundaries



Source: WikimediaCommons, https://commons.wikimedia.org/wiki/File:Apollo_17_Image_Of_Earth_From_Space.jpeg

Agenda

- The method
- Some case studies
- Take aways

Planetary Boundaries

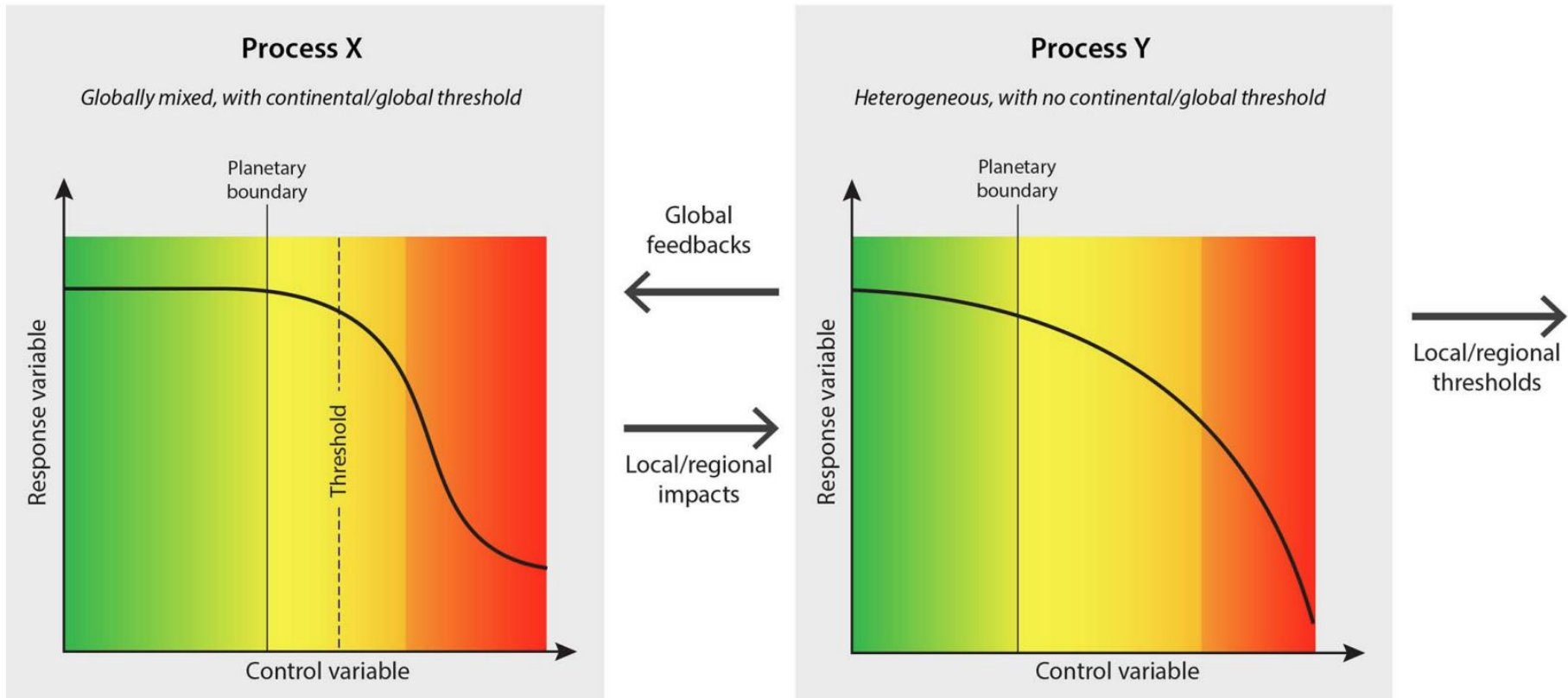
The method

- Developed in **2009** by a group of scientists around the Stockholm Resilience Center: Johan Rockström led a group of **28 internationally renowned scientists** to identify the nine processes that regulate the stability and resilience of the Earth system. ([Planetary boundaries - Stockholm Resilience Centre](#))
- Science- (and indicator)-based analysis quantifying the risk of human perturbations of the earth system (ES) on a planetary scale
- Applied on a regional-level (under development) and aggregated on a global scale
- NINE Quantitative planetary boundaries for sustained human “development”

Planetary Boundaries

The method

- PBs are NOT the critical thresholds – but defined well before them!



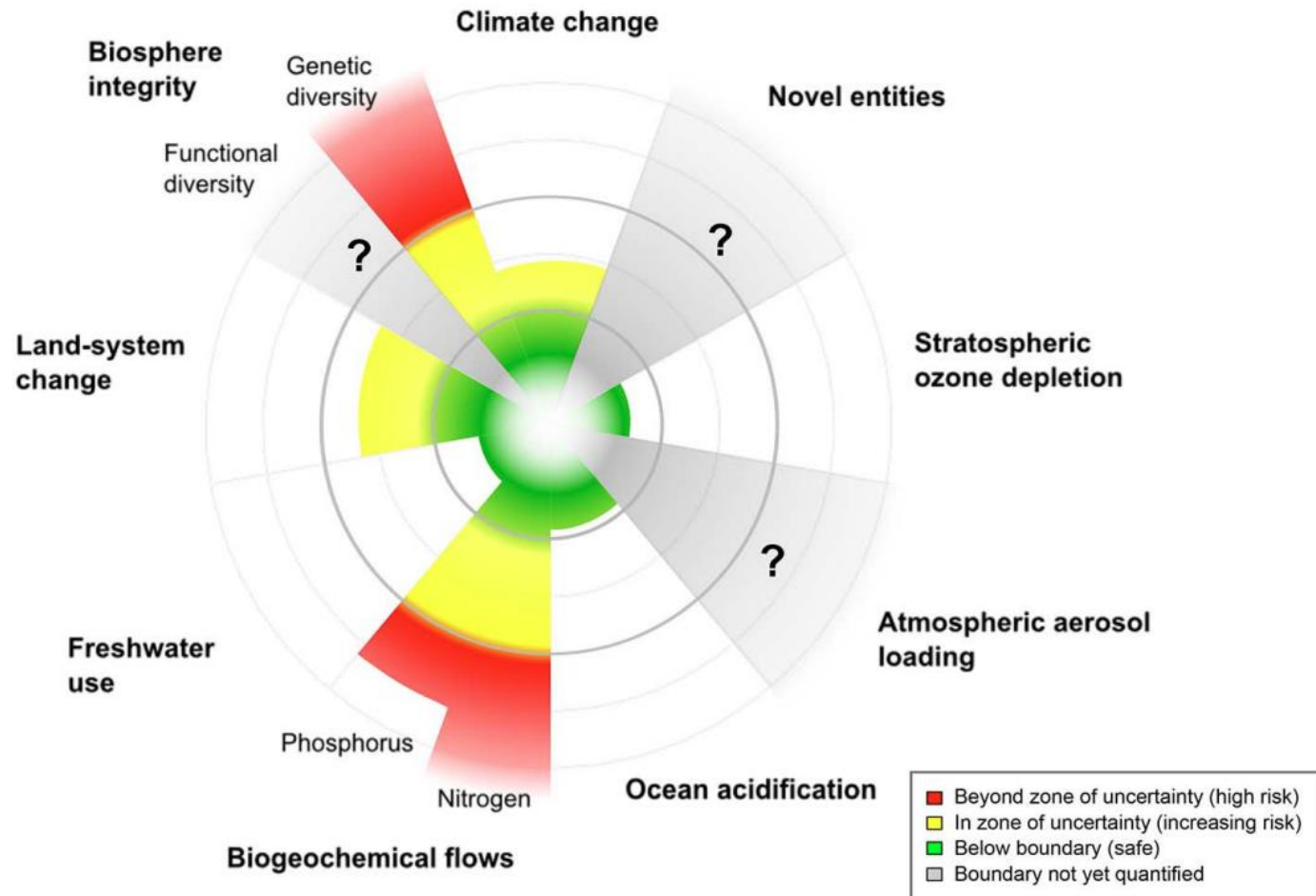
Safe operating space

Zone of uncertainty: Increasing risk of impacts

Dangerous level: High risk of serious impacts

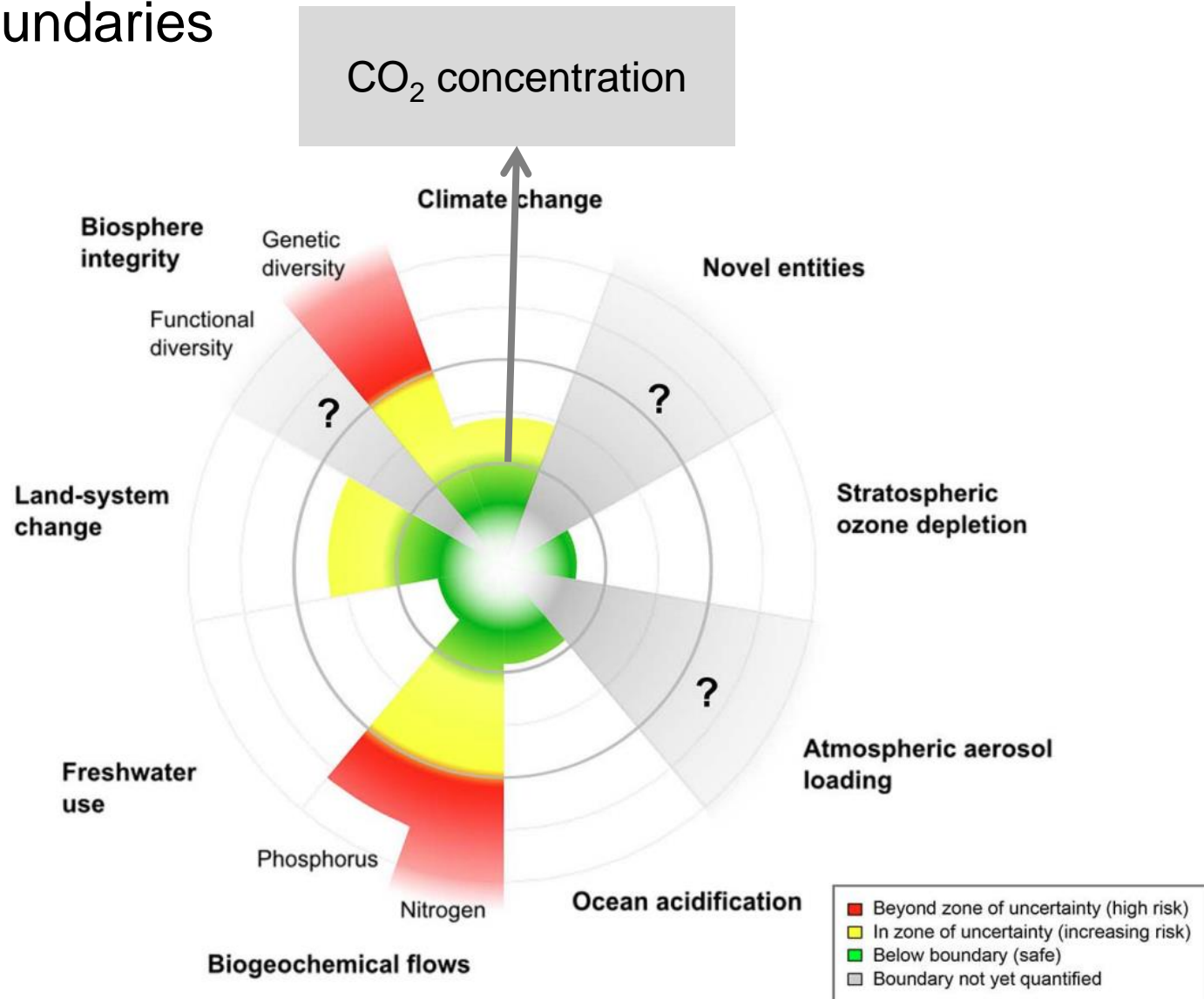
Planetary Boundaries

The method



Planetary Boundaries

The method

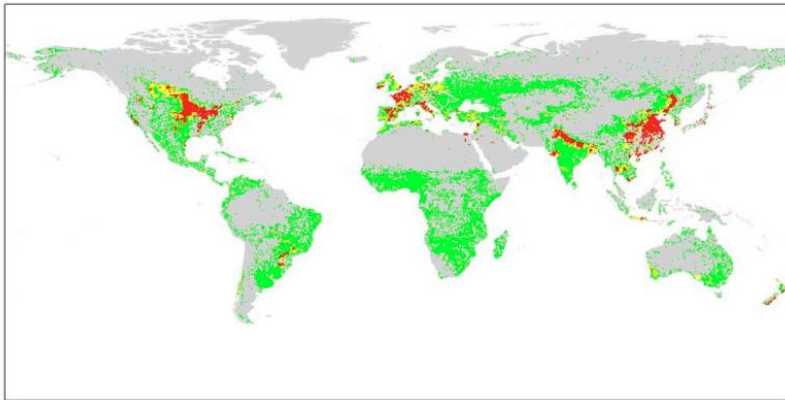


Planetary Boundaries

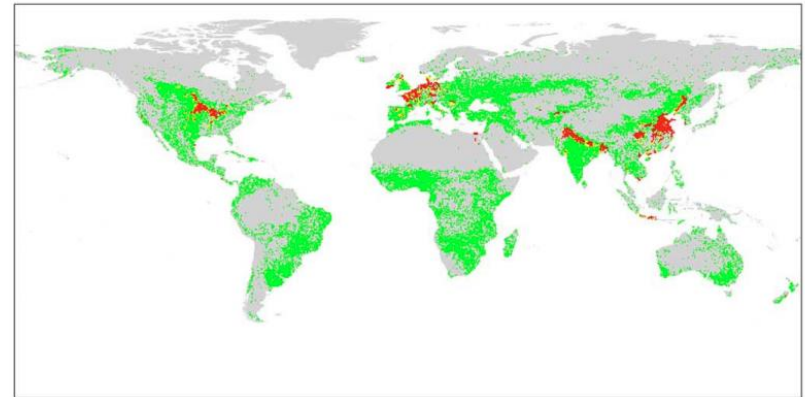
The method

Source: Steffen et al., 2015

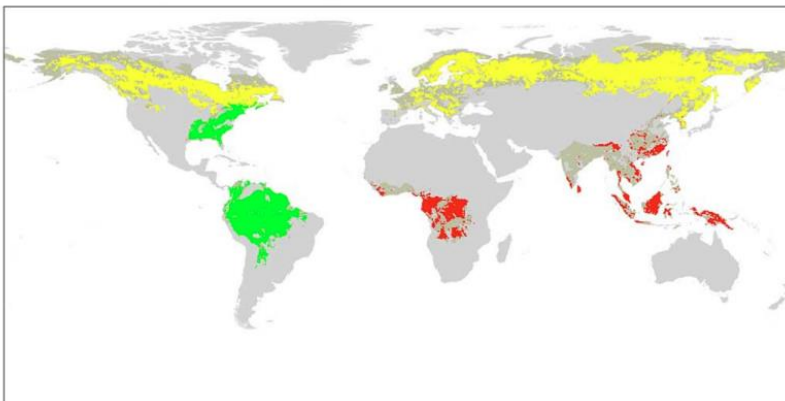
A Phosphorus



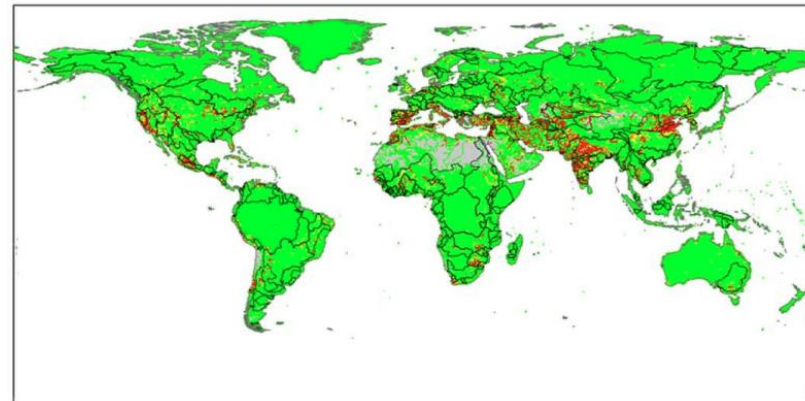
B Nitrogen



C Land-system change



D Freshwater use



■ Beyond zone of uncertainty (high risk)

■ In zone of uncertainty (increasing risk)

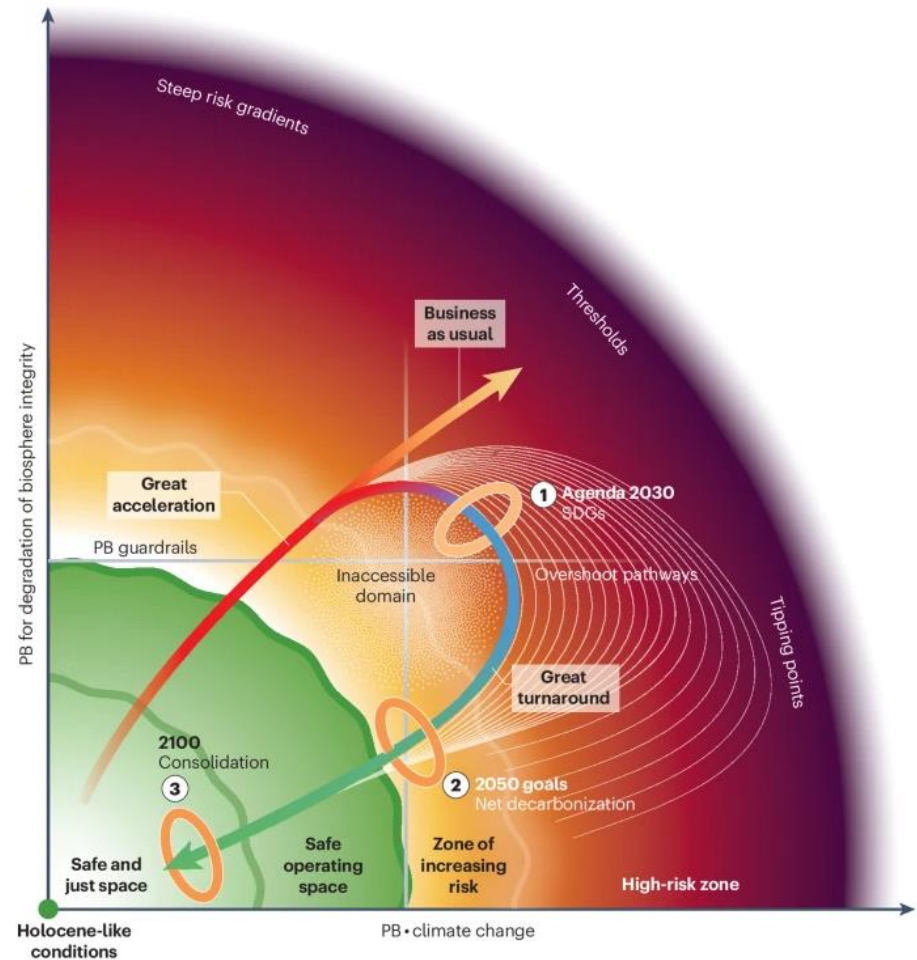
■ Below boundary (safe)

Planetary Boundaries

The goal

Guiding transformation trajectories

Fig. 4: Past and possible future Earth system trajectories.

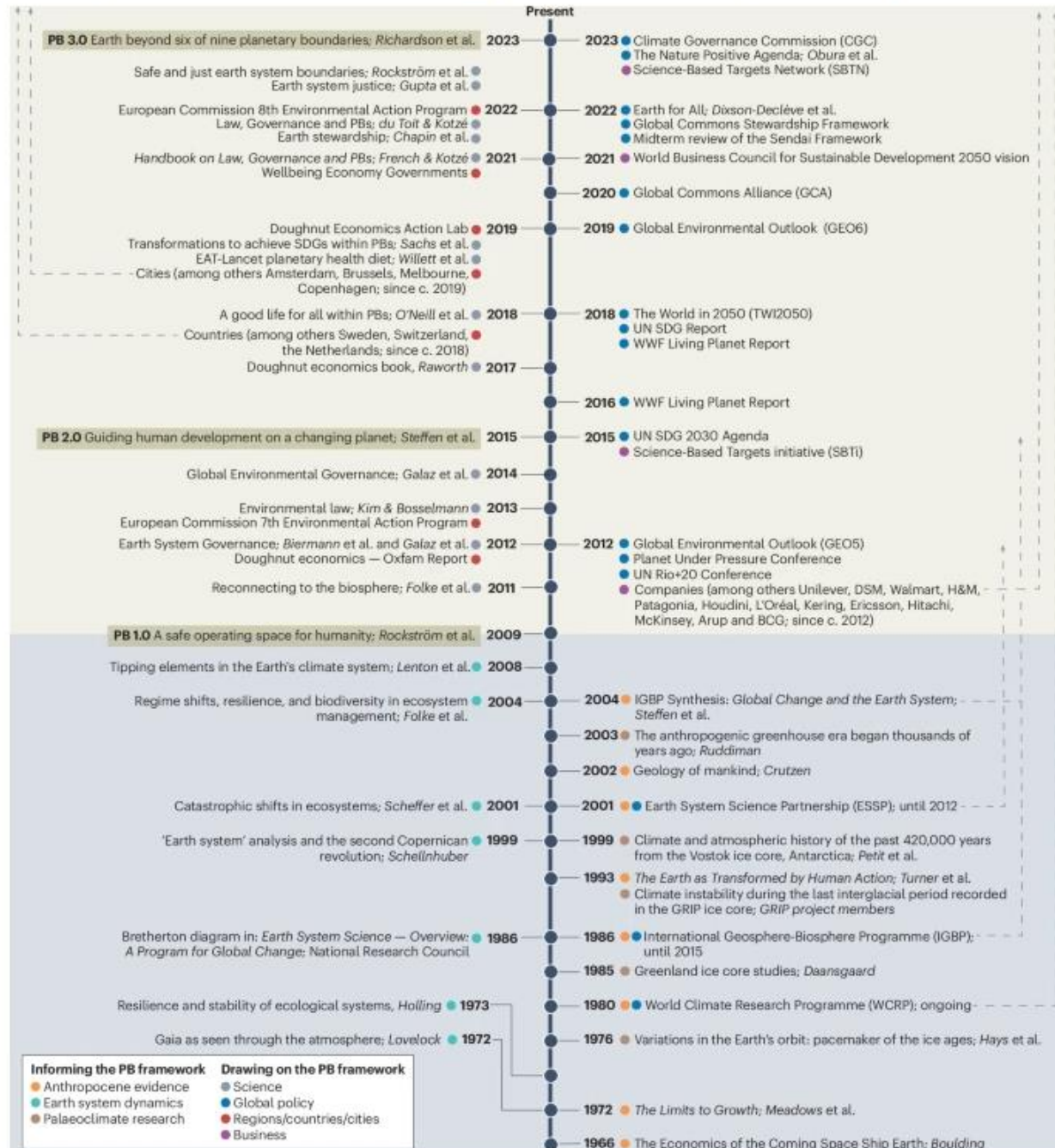


Planetary Boundaries

The goal

Society uptake

Fig. 1: Origins, evolution and societal uptake of the Planetary Boundary framework.



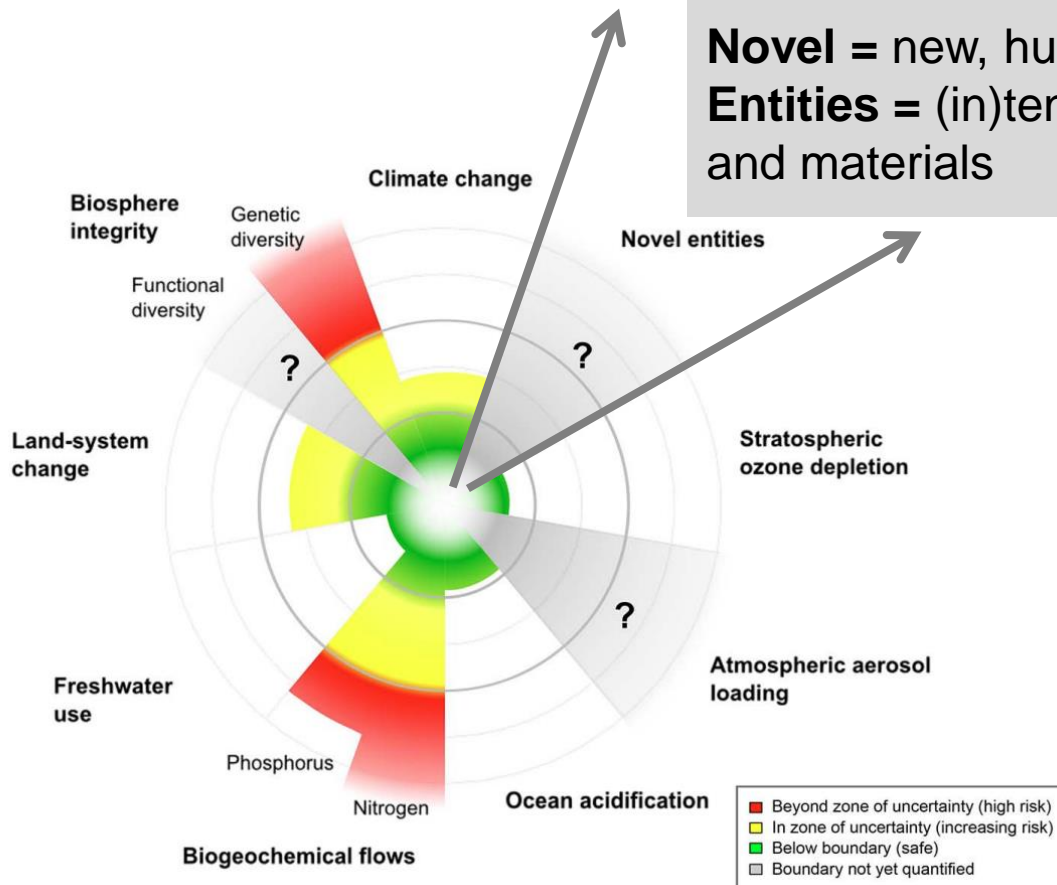
Source: Nature, [Planetary Boundaries guide humanity's future on Earth | Nature Reviews Earth & Environment](#)

Planetary Boundaries

The method

Source: Persson et al., 2022

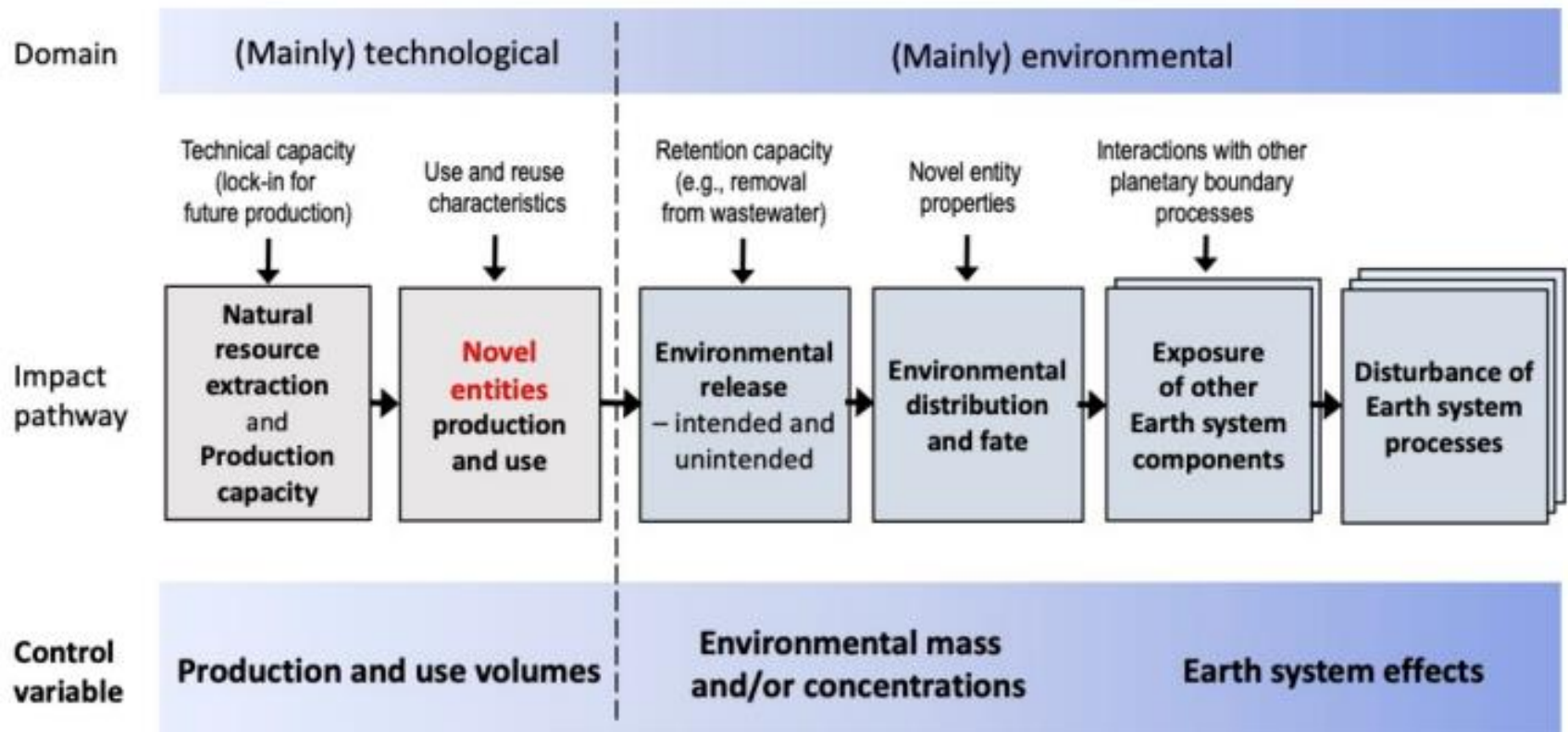
Novel = new, human created / introduced
Entities = (in)tentionally manufactured chemicals and materials



Source: Steffen et al., 2015

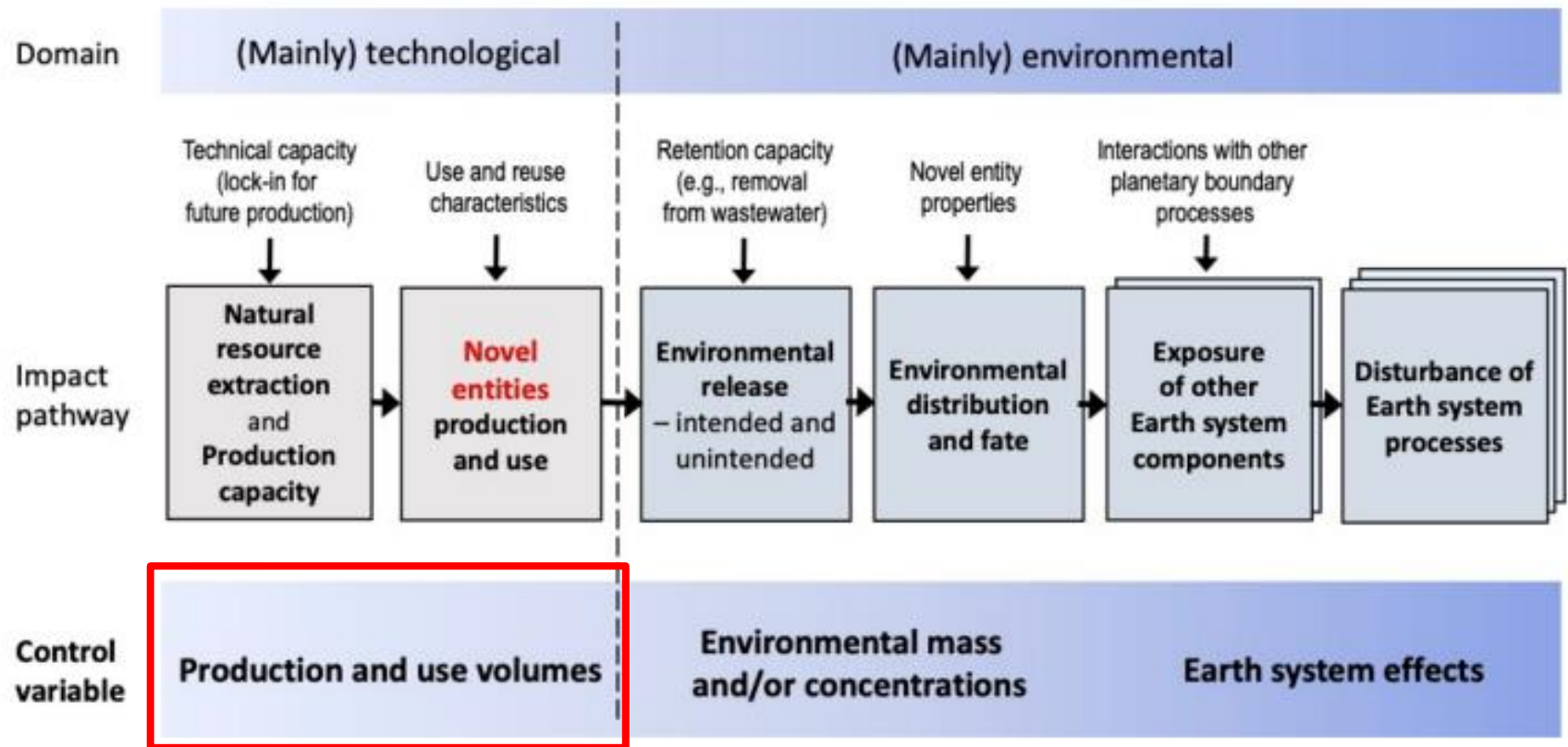
Planetary Boundaries

New entities / critical materials and LCA



Planetary Boundaries

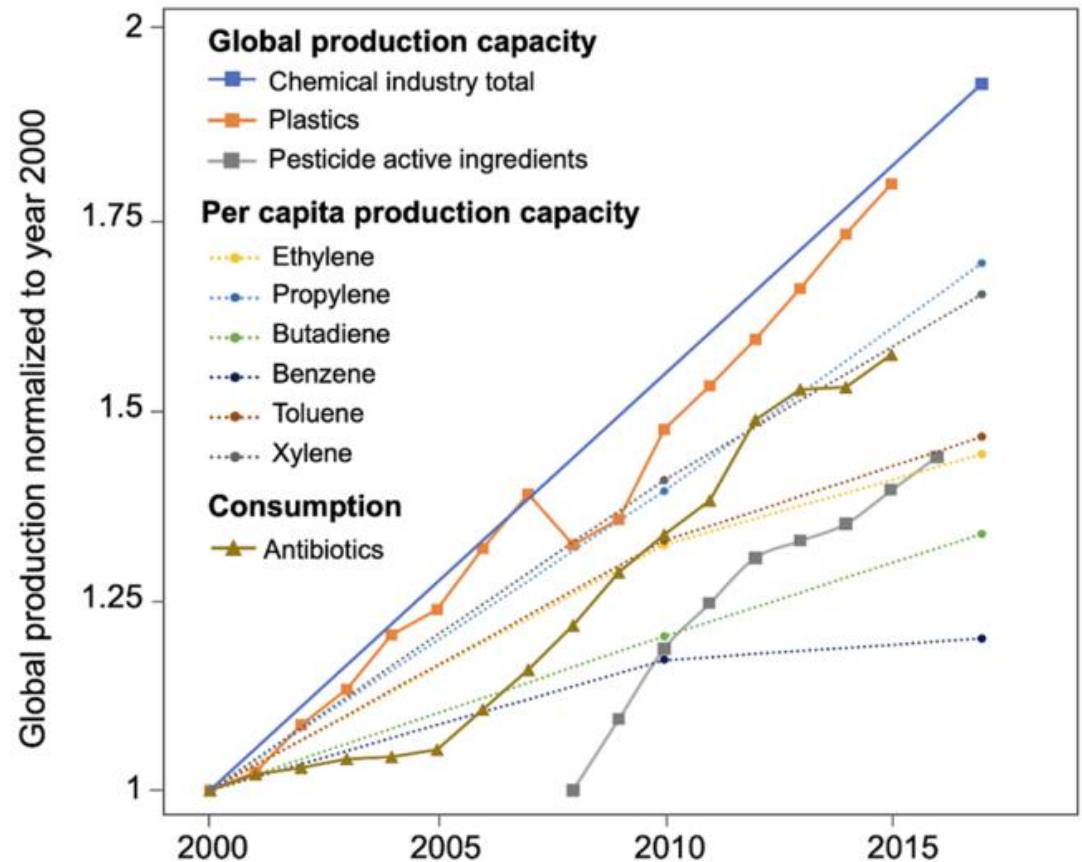
New entities / critical materials and LCA



Planetary Boundaries

New entities / critical materials and LCA

- Chemical industry is the second largest manufacturing industry worldwide
- Production has grown 50 times since 1950
- Expected to triple levels of 2010 by 2050

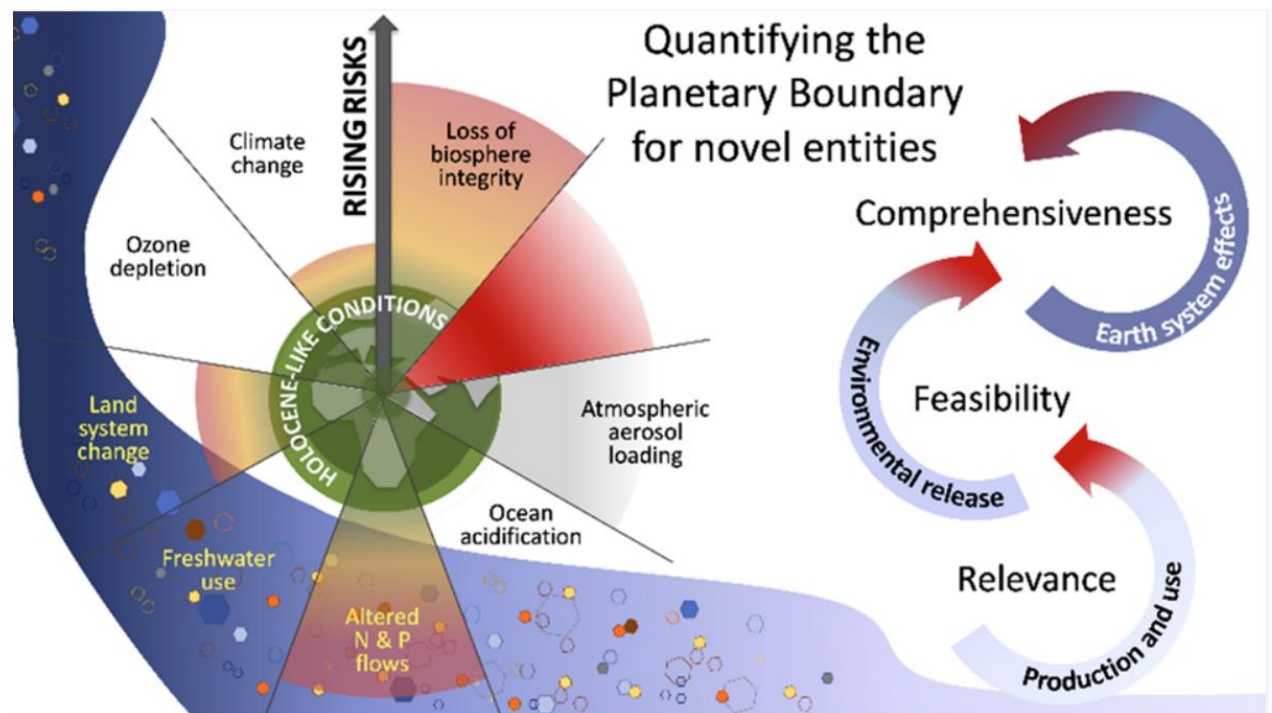


Planetary Boundaries

New entities / critical materials and LCA

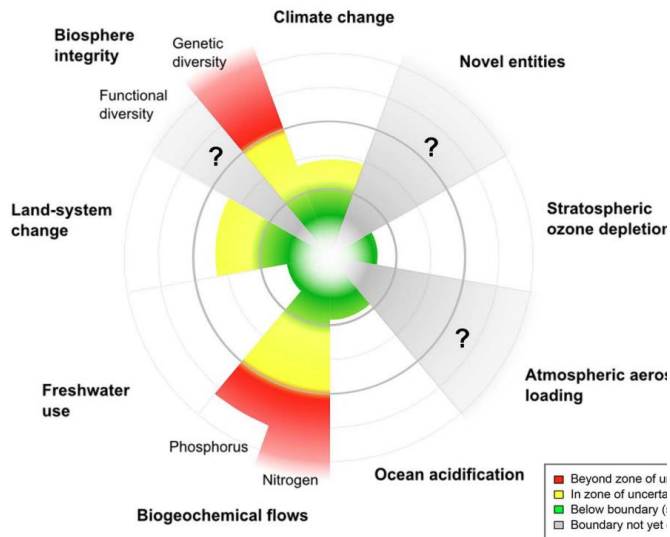
Control variables:

- trend in production volumes of chemicals
- trend in production volumes of plastics
- share of chemicals on the market that are assessed for risk or safety

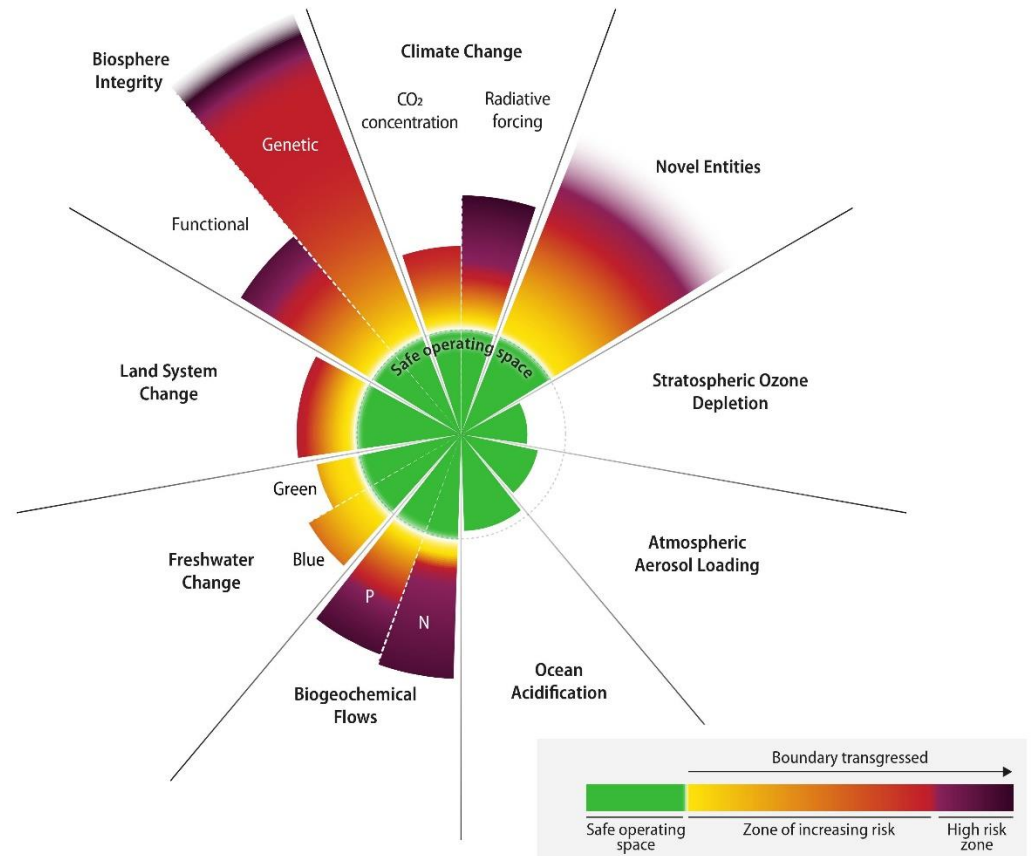


Planetary Boundaries Updated - 2022

[A full picture of planetary resilience: All boundaries mapped out, six of nine crossed — Potsdam Institute for Climate Impact Research](#)



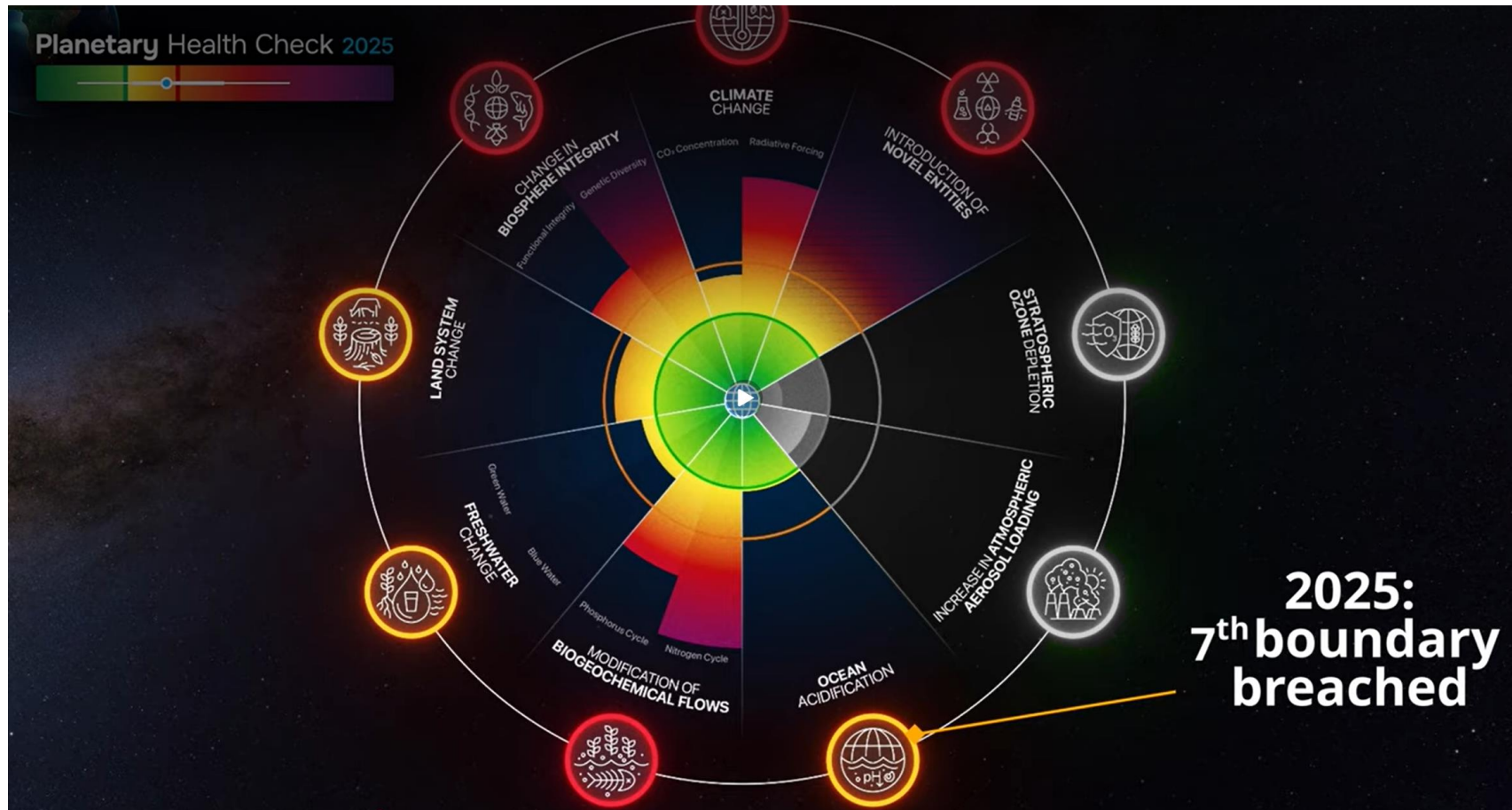
Source: Steffen et al., 2015



Source: PIK, 2023

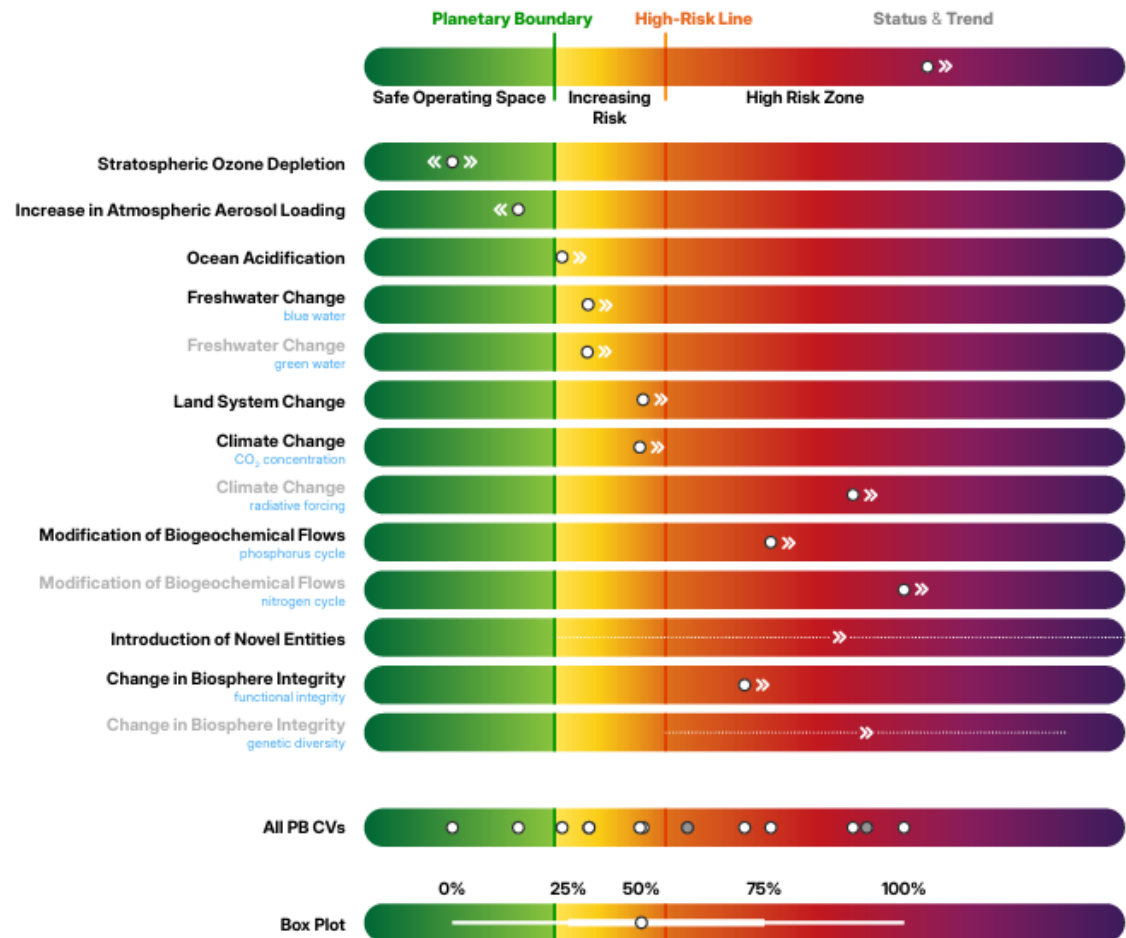
Planetary Boundaries Updated - 2022

[Official Planetary Health Check 2025 with Johan Rockström](#)



Planetary Boundaries Updated - 2025

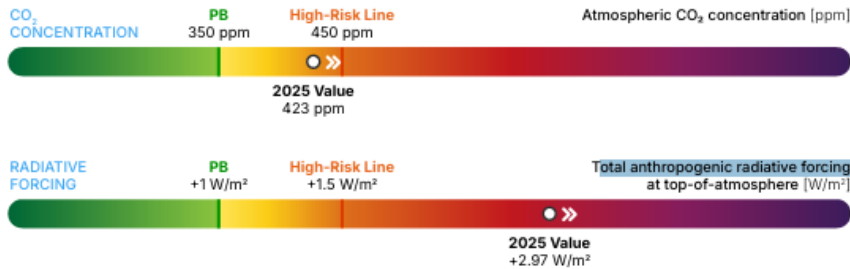
[Planetary Health Check 2025](#)



Planetary Boundaries Updated - 2025

[Planetary Health Check 2025](#)

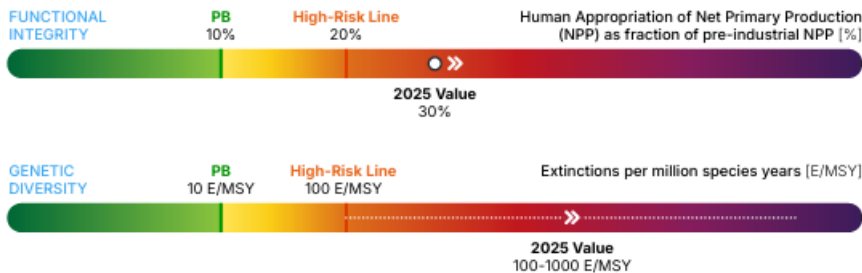
Climate Change



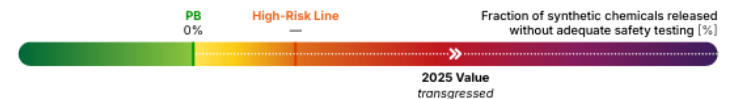
Land System Change



Change in Biosphere Integrity



Introduction of Novel Entities



Planetary Boundaries Updated - 2022

[Official Planetary Health Check 2025 with Johan Rockström](#)

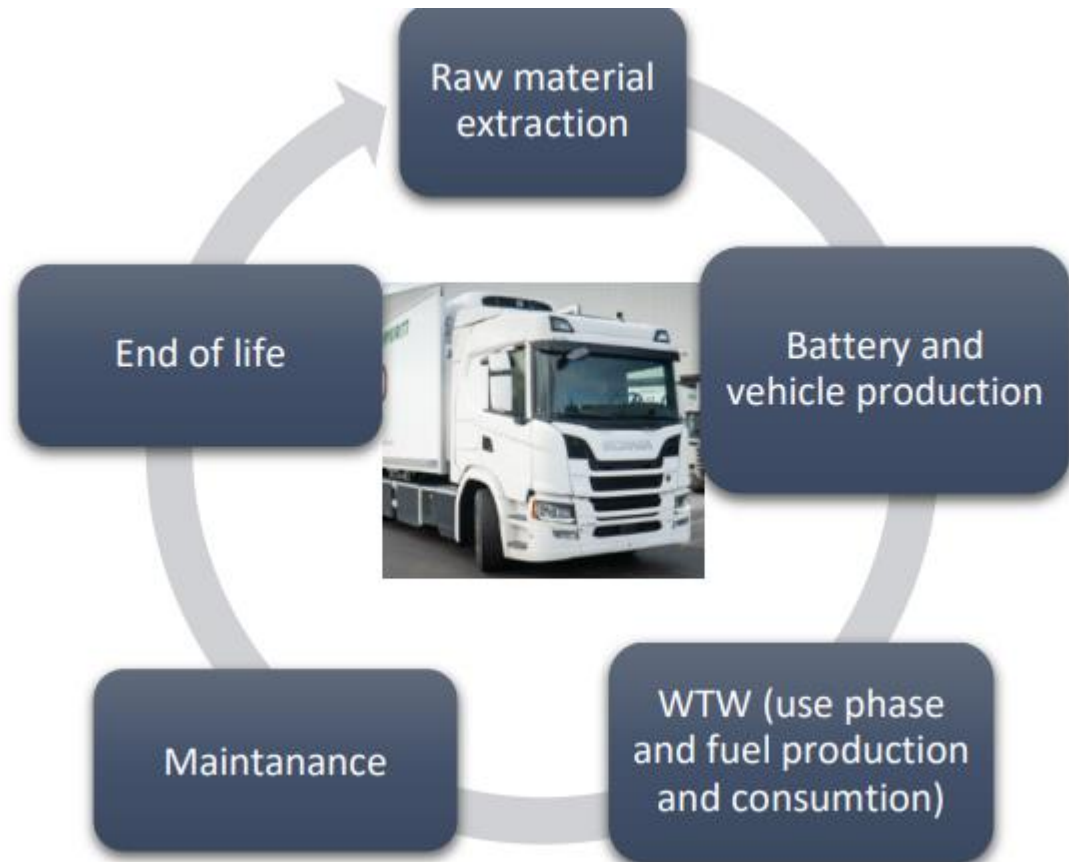


Agenda

- The method
- Some case studies
- Take aways

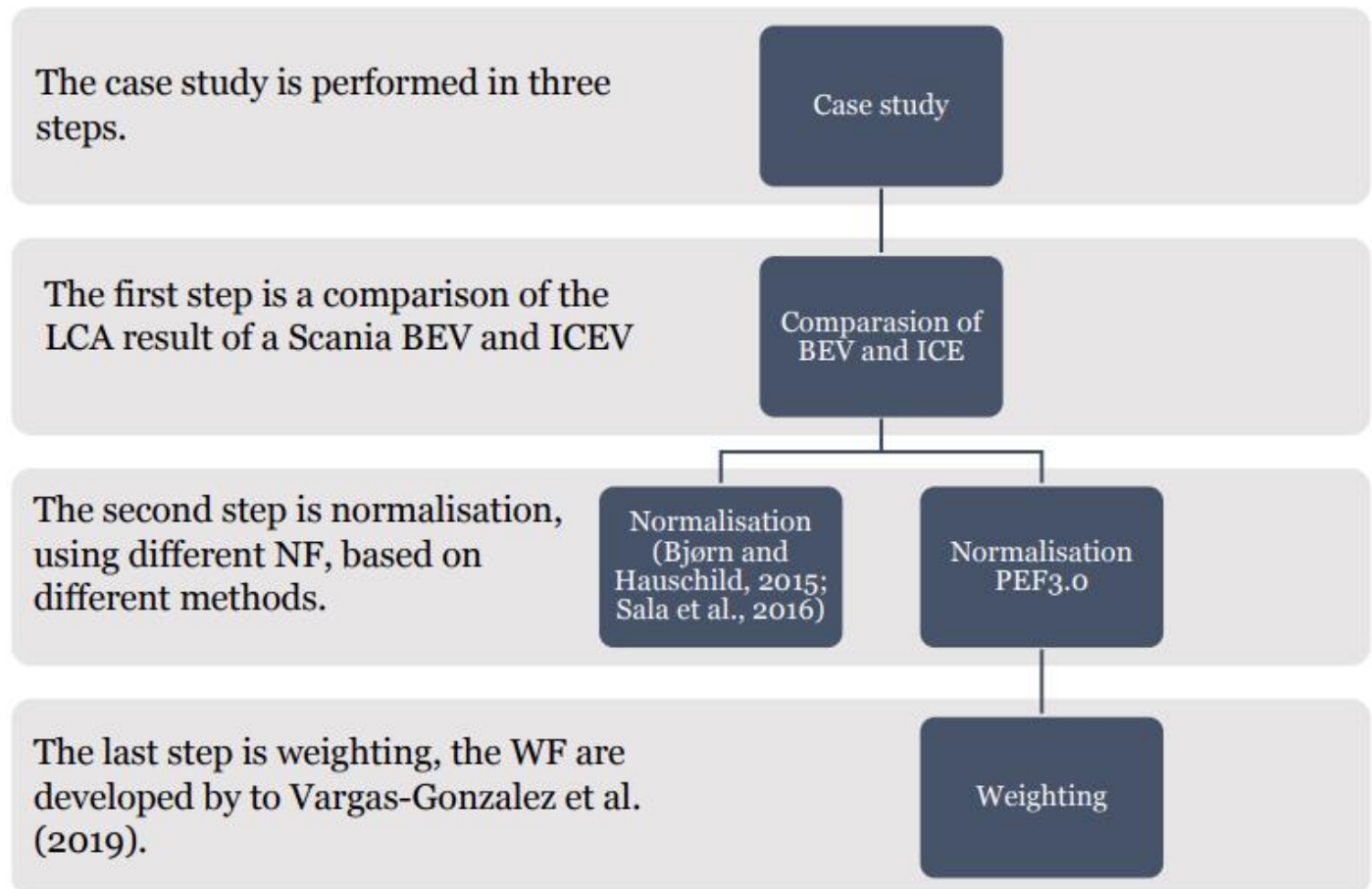
Planetary Boundaries

Case studies from the energy transition



Planetary Boundaries

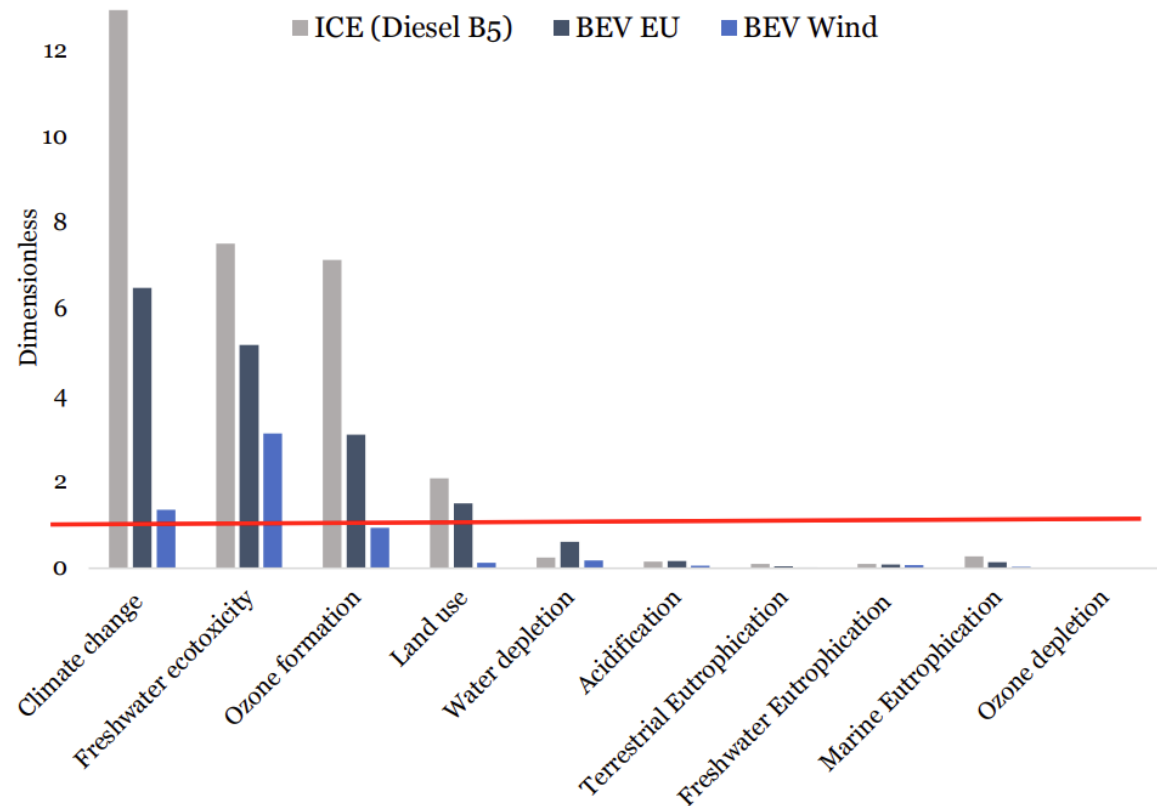
Case studies from the energy transition



Planetary Boundaries

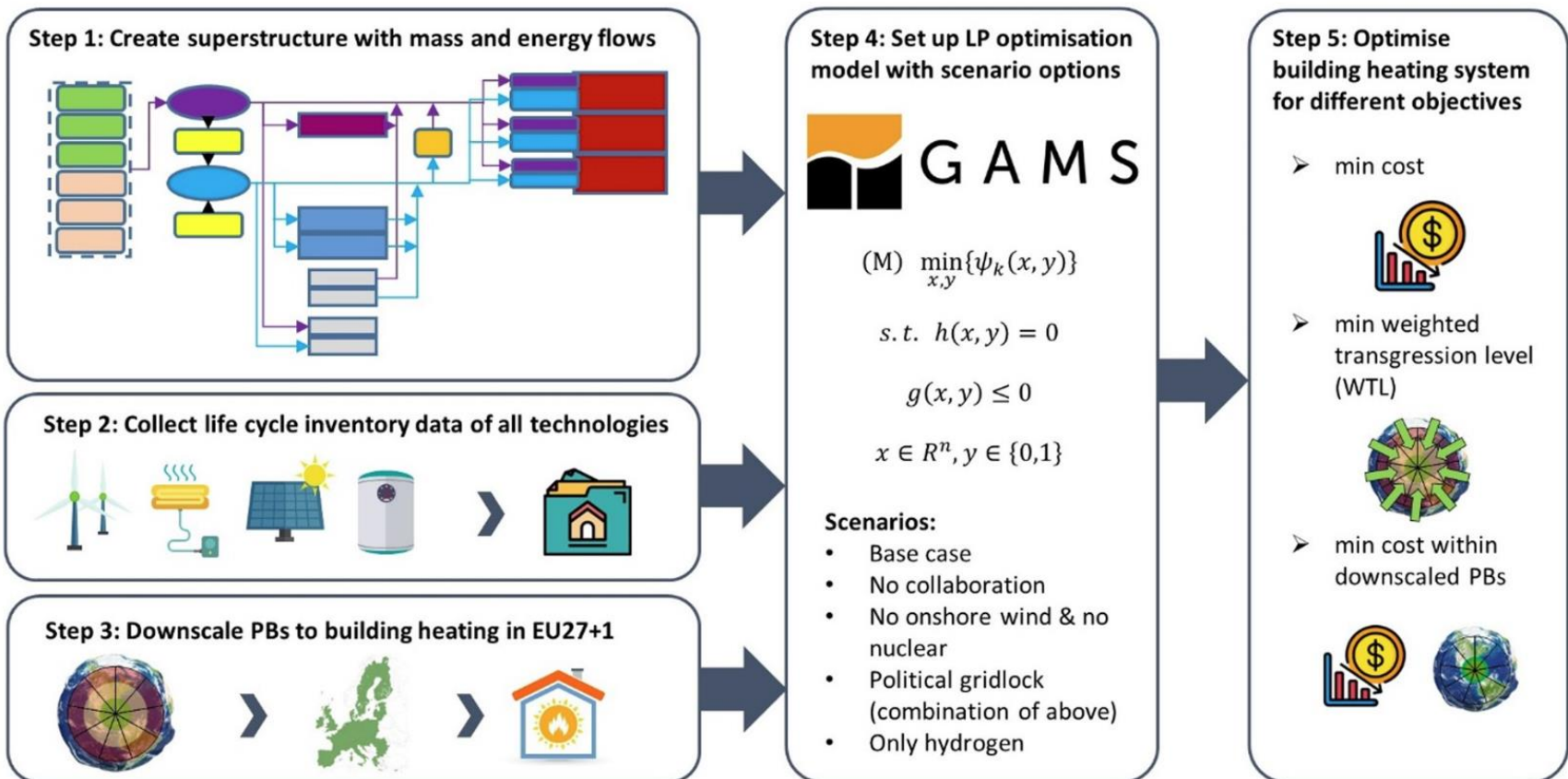
Case studies from the energy transition

Normalised results based on PB allowance
>1 exceeds the sustainable freight transport index



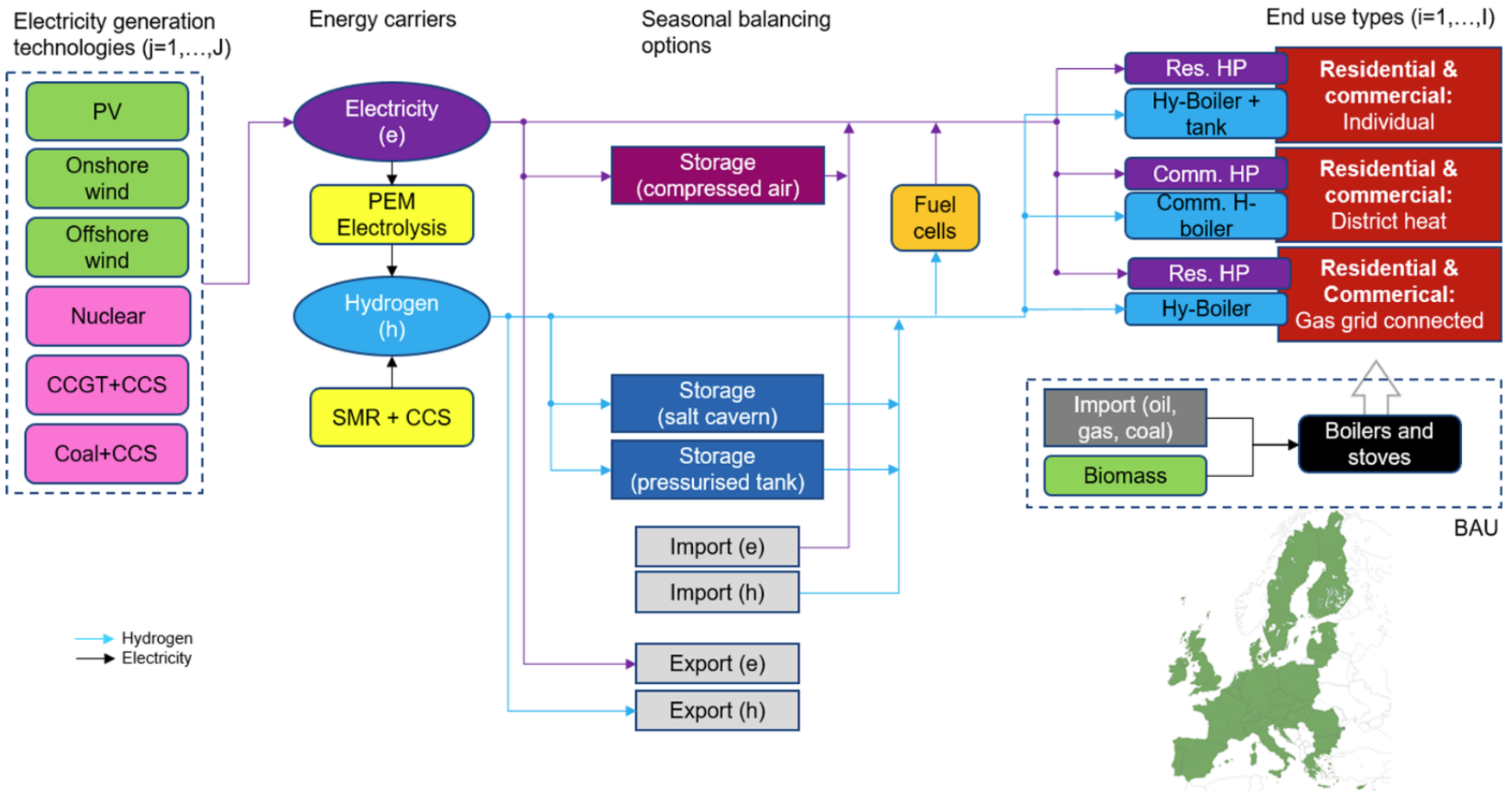
Planetary Boundaries

Case studies from the energy transition



Planetary Boundaries

Case studies from the energy transition



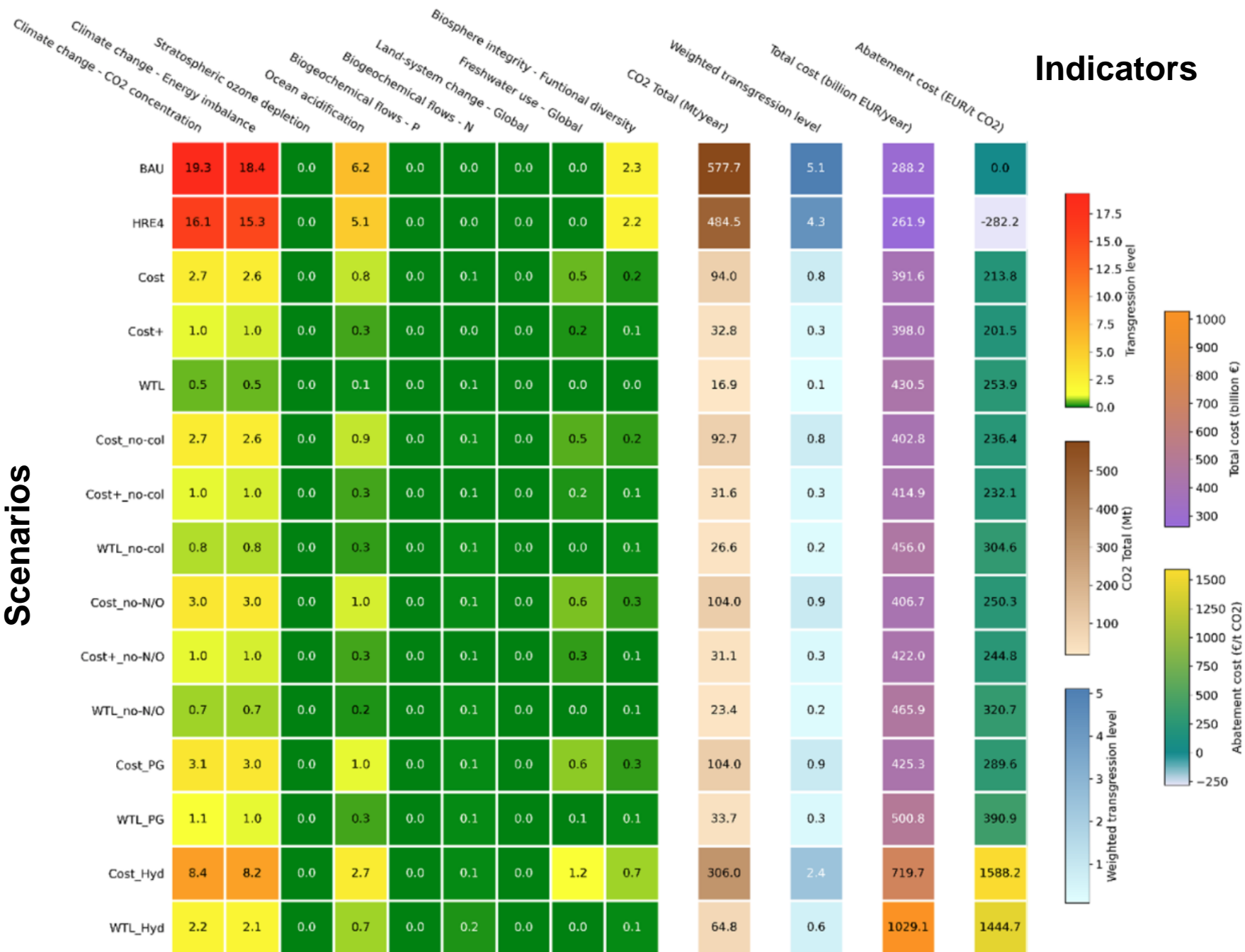
Planetary Boundaries

Case studies from the energy transition

Scenarios:

- **Cost-:** cost minimization
- **Cost+:** cost minimization and within planetary boundaries
- **No-col:** no collaboration, no trade for CO₂ or H₂ among countries in the EU
- **no-N/O:** political/popular blockade for further nuclear and onshore wind
- **PG:** political “grid-lock”
- **Hyd:** hydrogen only for heating

Scenarios



Source: Weidner & Guillen-Gosalbez, 2022

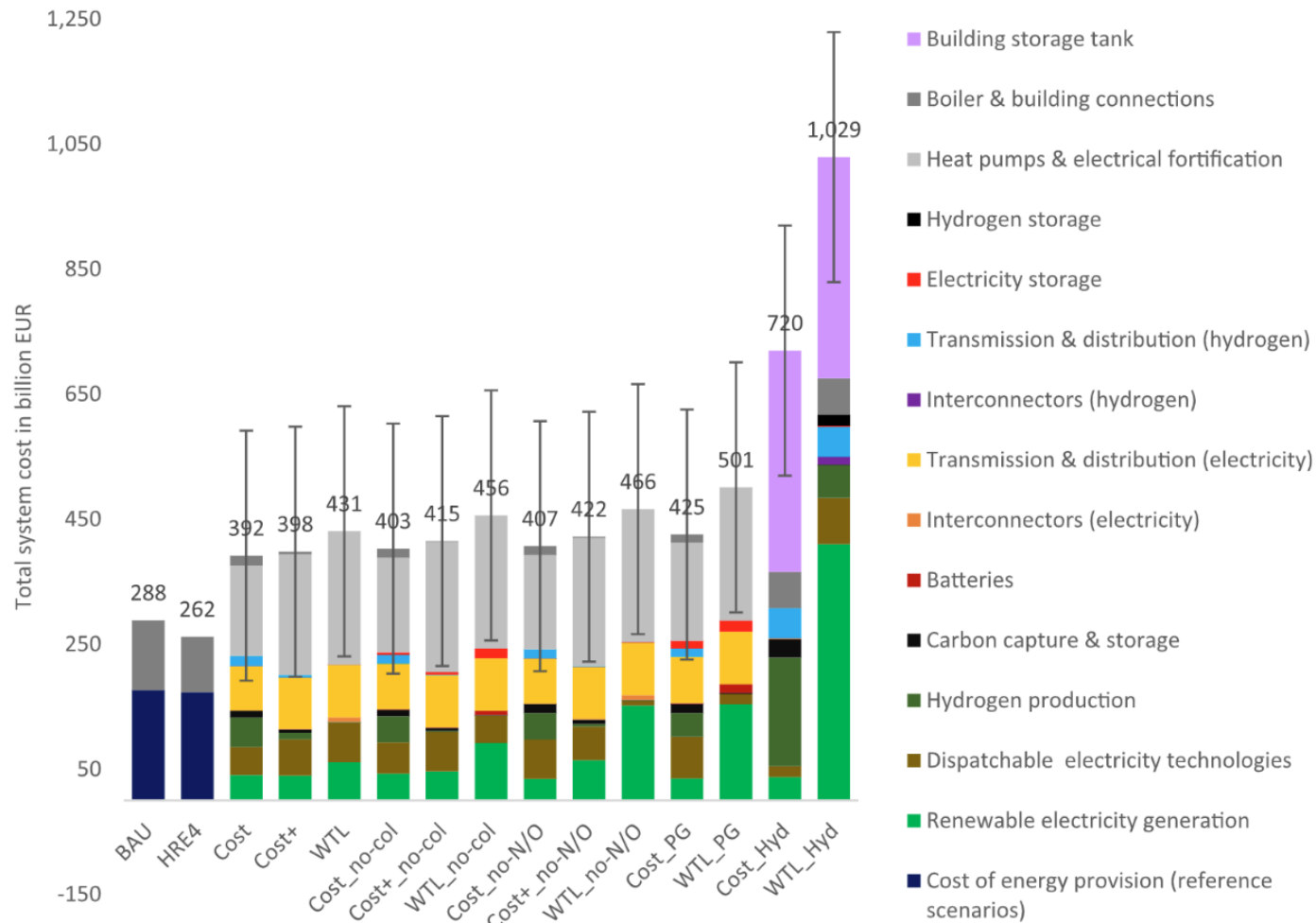


Fig. 4. Total system cost for building heating in the EU27 + 1 broken down by technologies and scenarios. Error bars describe the minimum and maximum cost depending on differing cost assumptions of all the technologies and equipment considered.

Planetary Boundaries

Case studies from the energy transition

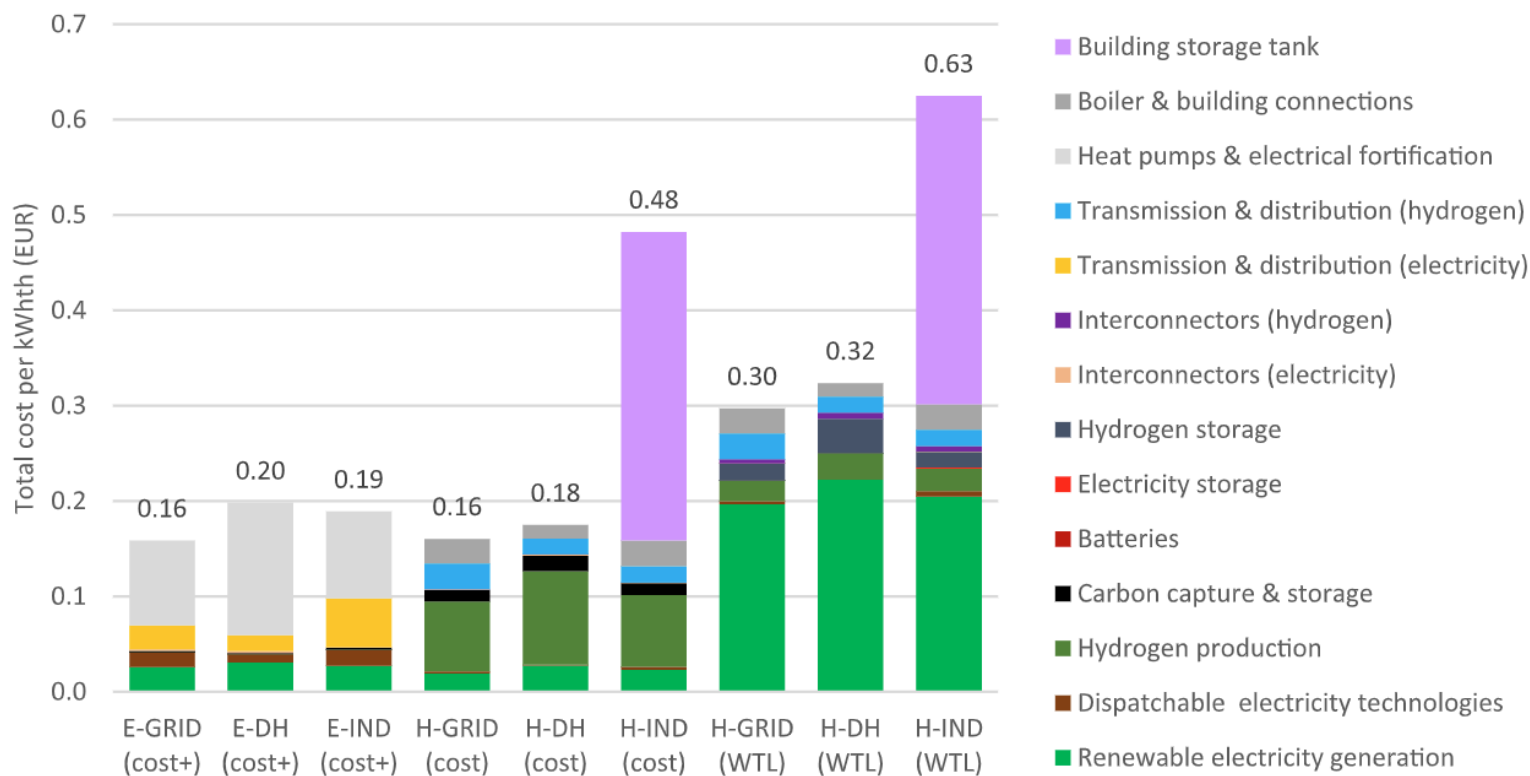


Fig. 5. Total cost per unit of heating demand met for the different end-user types; connected to the gas (GRID) or district heating (DH) grids and individual buildings (IND). Three different scenarios are shown, electrification-only (E-...) optimised by least cost, hydrogen-only (H-...) optimised by either least cost or impact (WTL). Note that the electrification-only scenario differs from the “Cost” scenario shown in previous figures as hydrogen use was set to zero (24.4%, as shown in Fig. 6 for the H2 end use share in the Cost scenario).

Agenda

- The method
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Planetary Boundaries

Take aways about the method

- Scientifically grounded, yet “under construction”
- Global and regional thresholds
- Link to LCA / critical materials
- High amount of input data
- Gives feedback on environmental sustainability

→ Strong or weak sustainability?



References

Pehrson, I. 2020. *Integrating planetary boundaries into the life cycle assessment of electric vehicles - A case study on prioritising impact categories through environmental benchmarking in normalisation and weighting methods when assessing electric heavy-duty vehicles.* M.Sc. Thesis, KTH.

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W. Steffen et al., *Planetary boundaries: Guiding human development on a changing planet* Science 347, 1259855 (2015). DOI: 10.1126/science.1259855

Weidner, Guillen-Gozalbes. *Planetary boundaries assessment of deep decarbonisation options for building heating in the European Union.* Energy Conversion and Management Volume 278, 15 February 2023, 116602

<https://doi.org/10.1016/j.enconman.2022.116602>