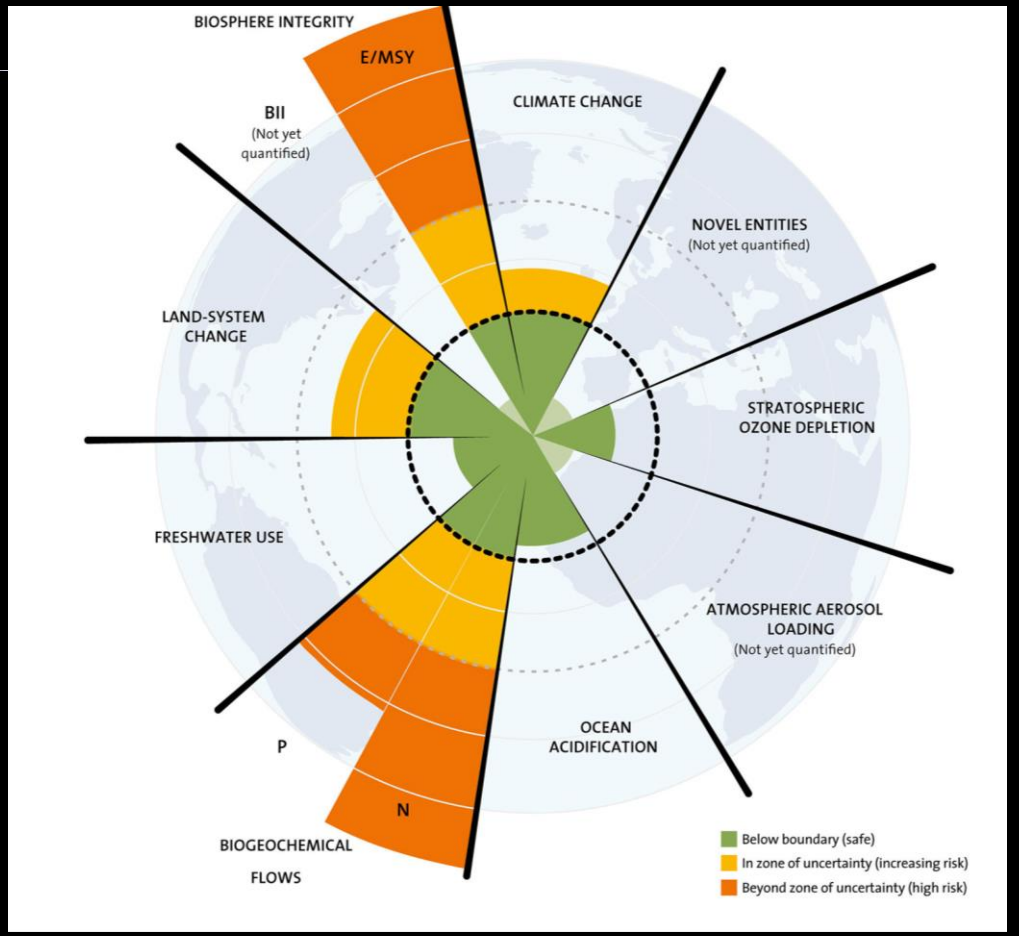
Planetary Boundaries



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

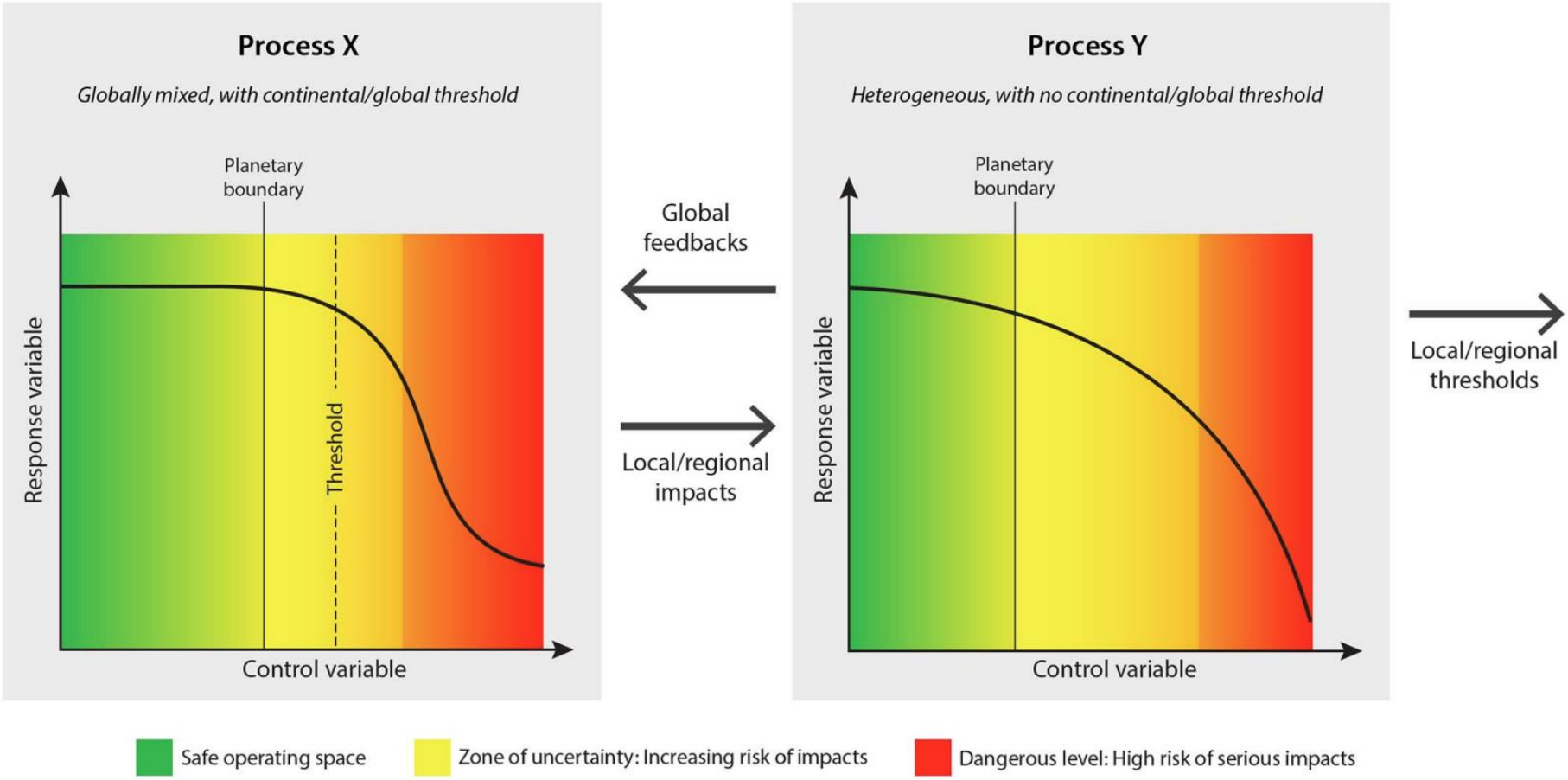
- Developed in **2009** by a group of scientists around the Stockholm Resilience Center: Johan Rockström led a group of **28 internationally renowned scientists** to identify the nine processes that regulate the stability and resilience of the Earth system. (Planetary boundaries - Stockholm Resilience 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”

Source: Steffen et al., 2015

Planetary Boundaries

The method

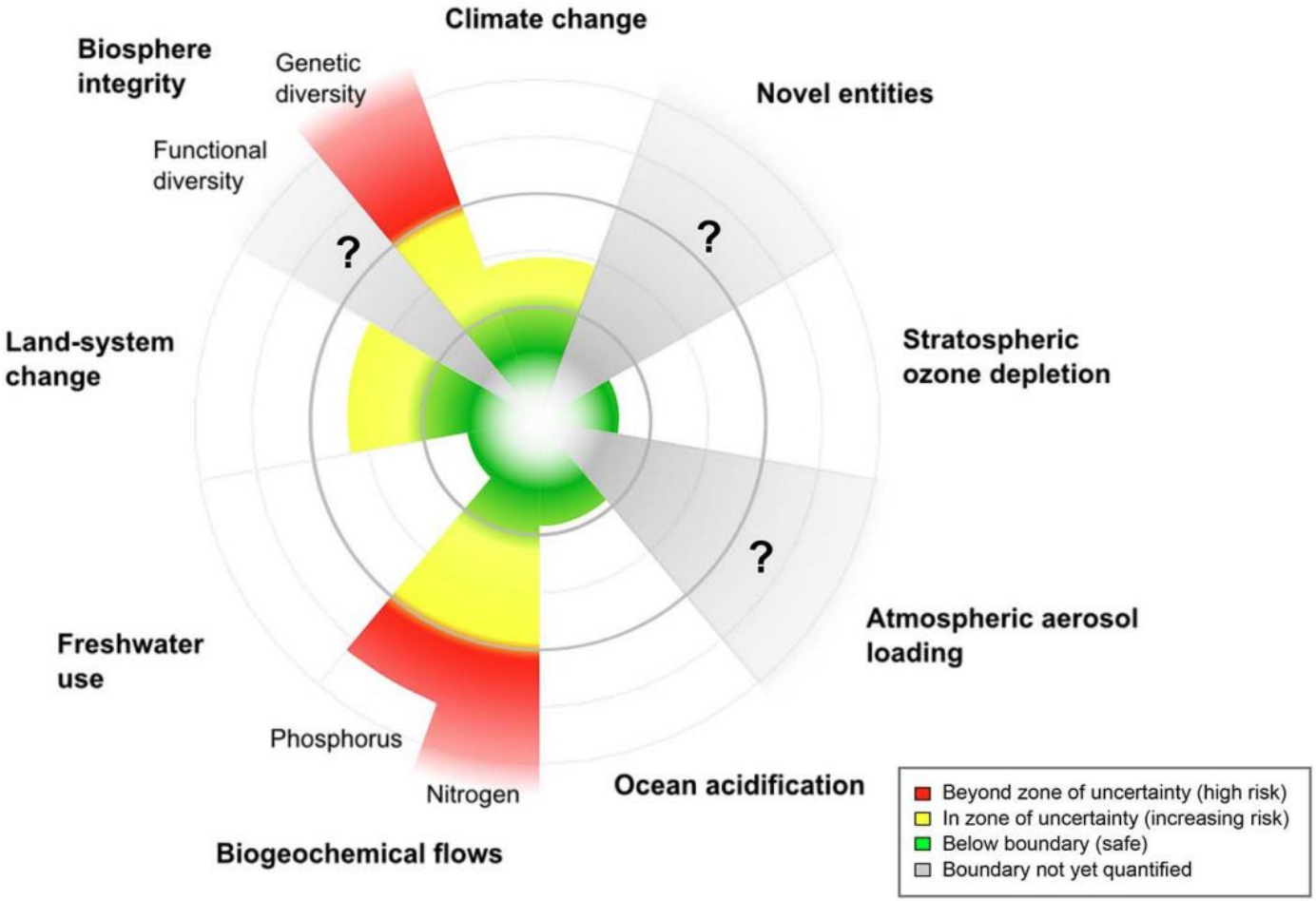
- PBs are NOT the critical thresholds – but defined well before them!



Source: Steffen et al., 2015

Planetary Boundaries

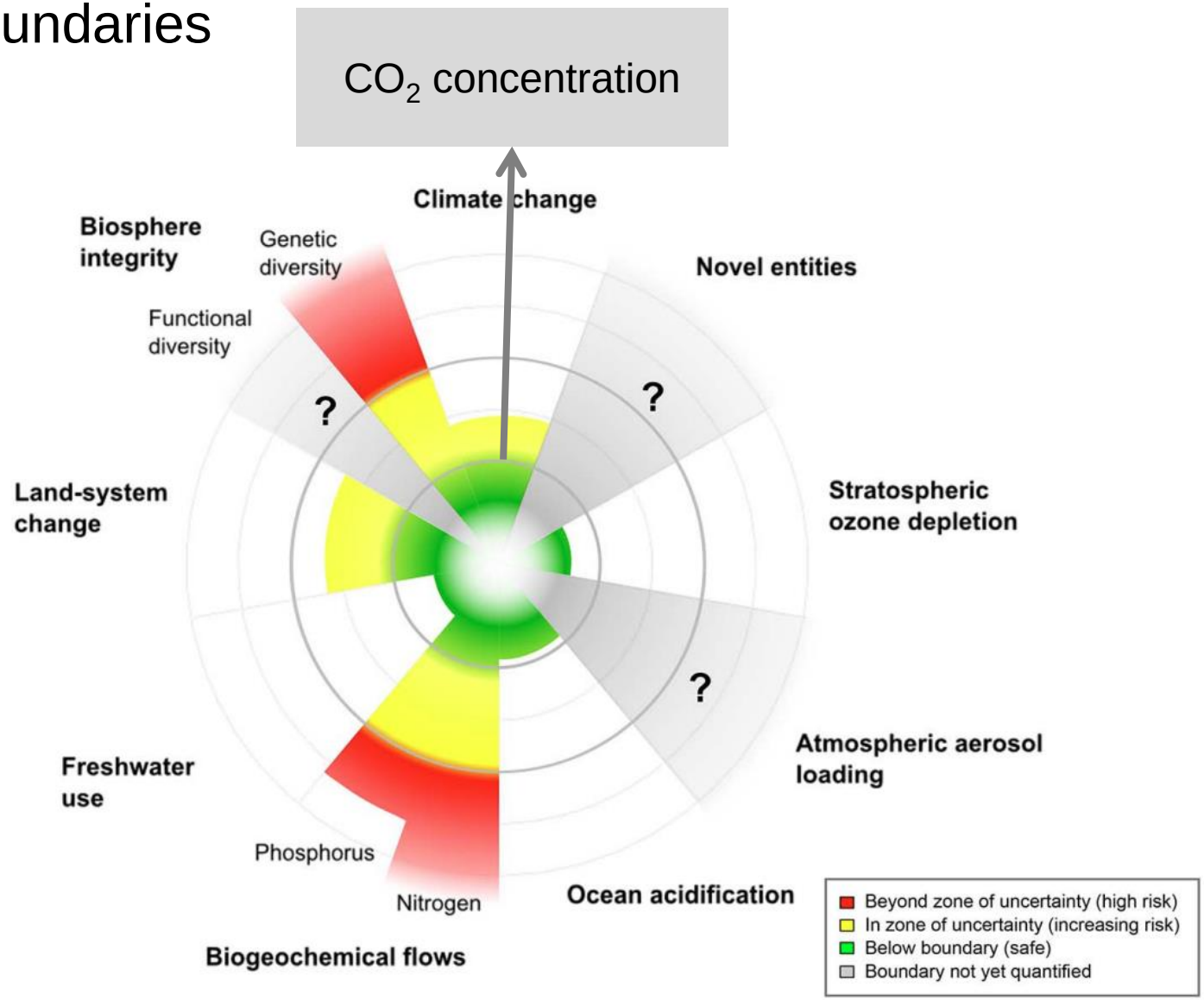
The method



Source: Steffen et al., **2015**

Planetary Boundaries

The method

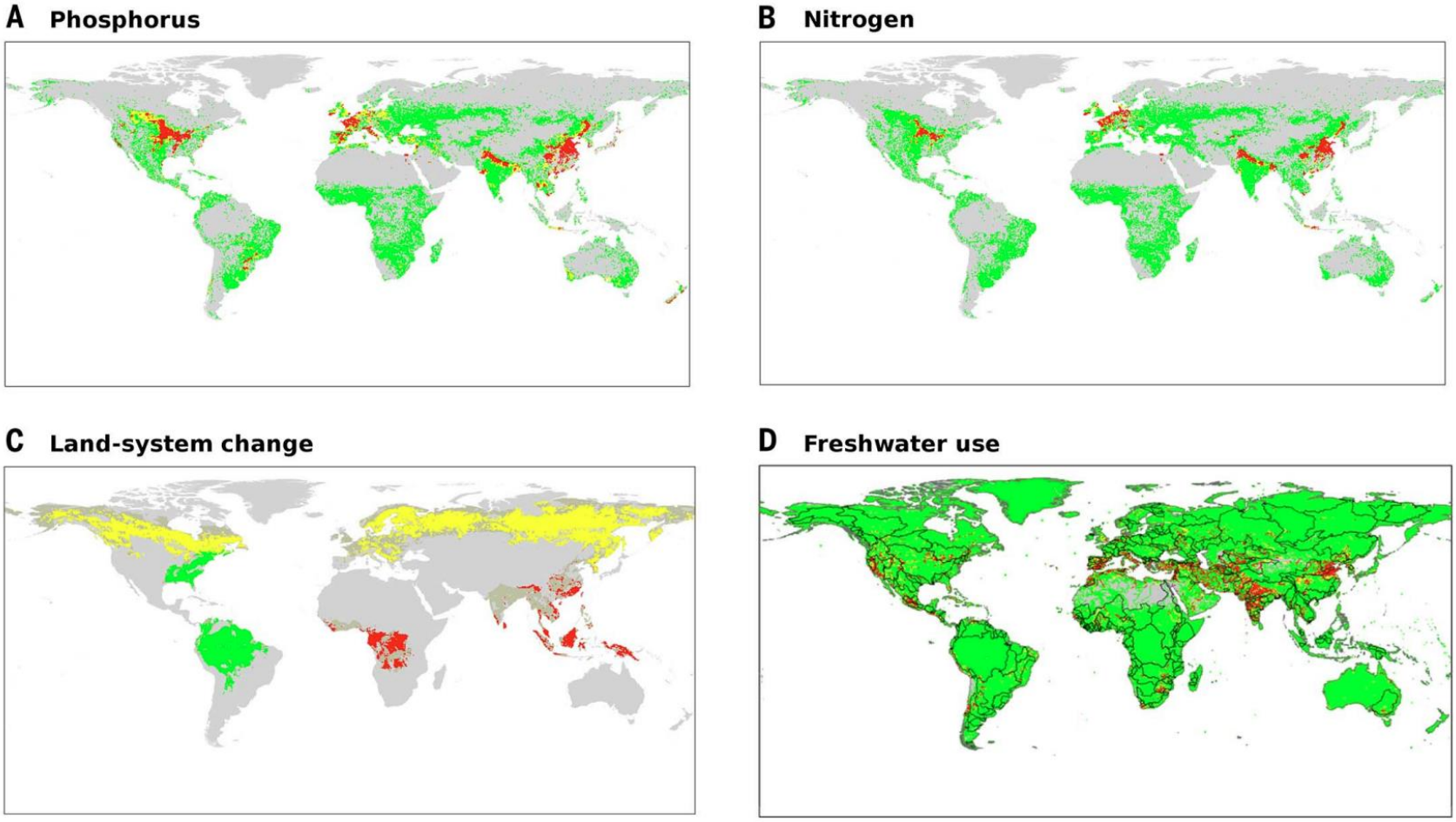


Source: Steffen et al., **2015**

Planetary Boundaries

The method

Source: Steffen et al., **2015**

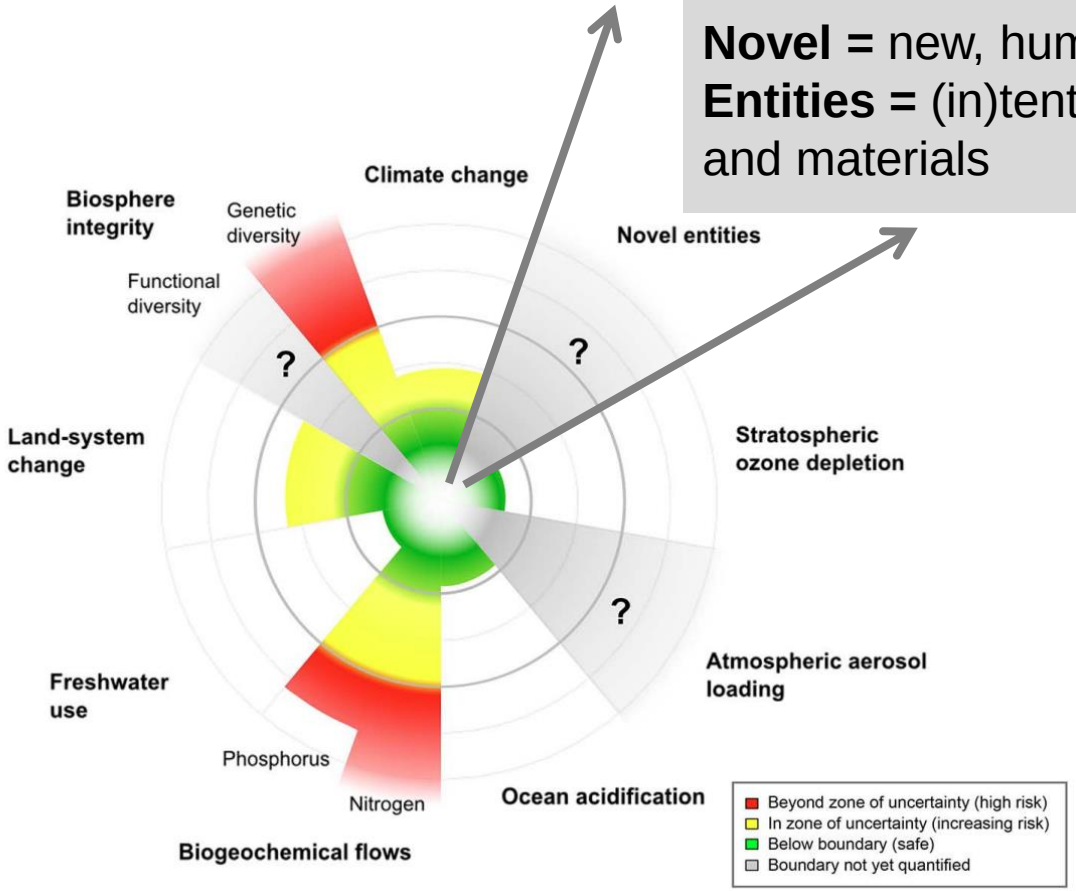


Planetary Boundaries

The method

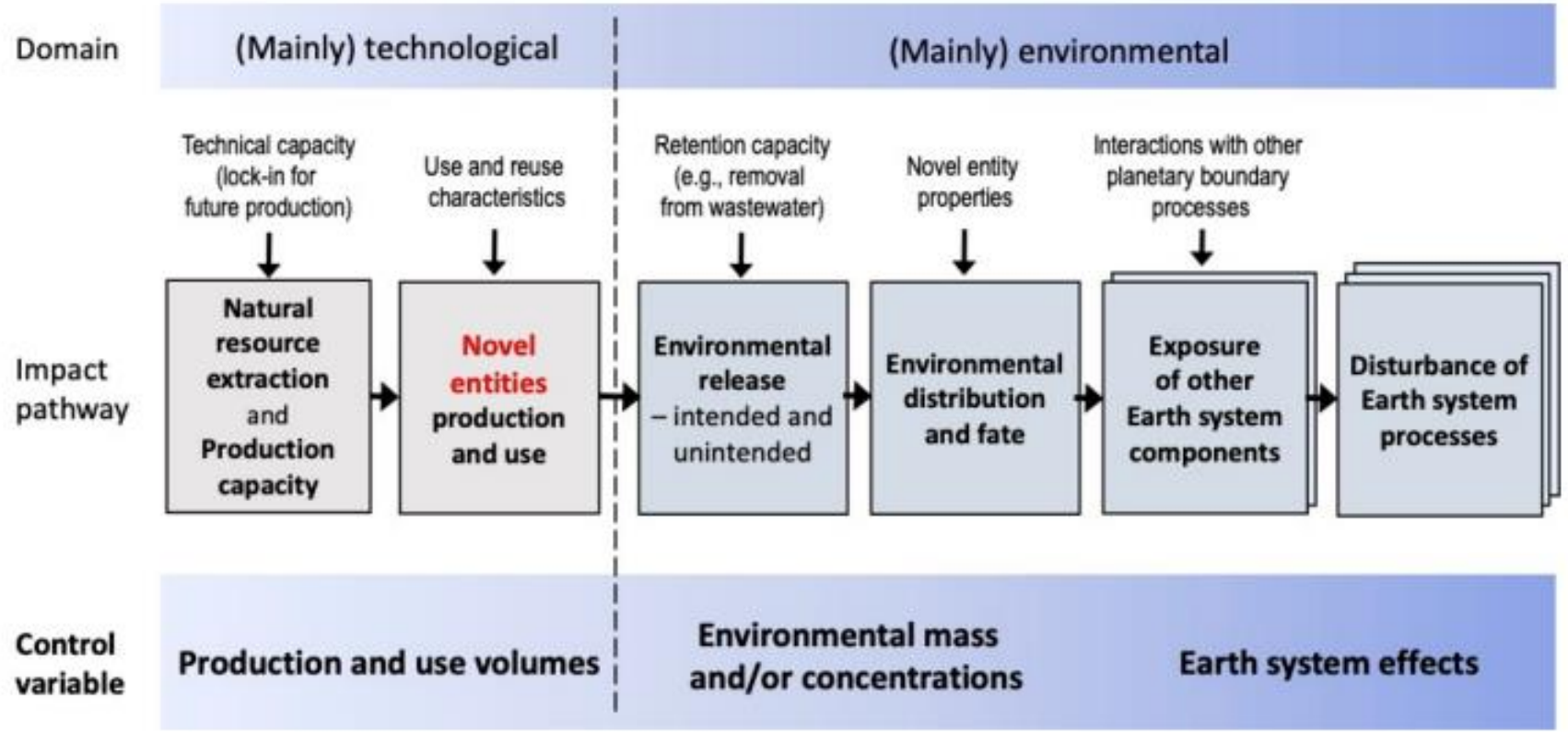
Source: Persson et al., 2022

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



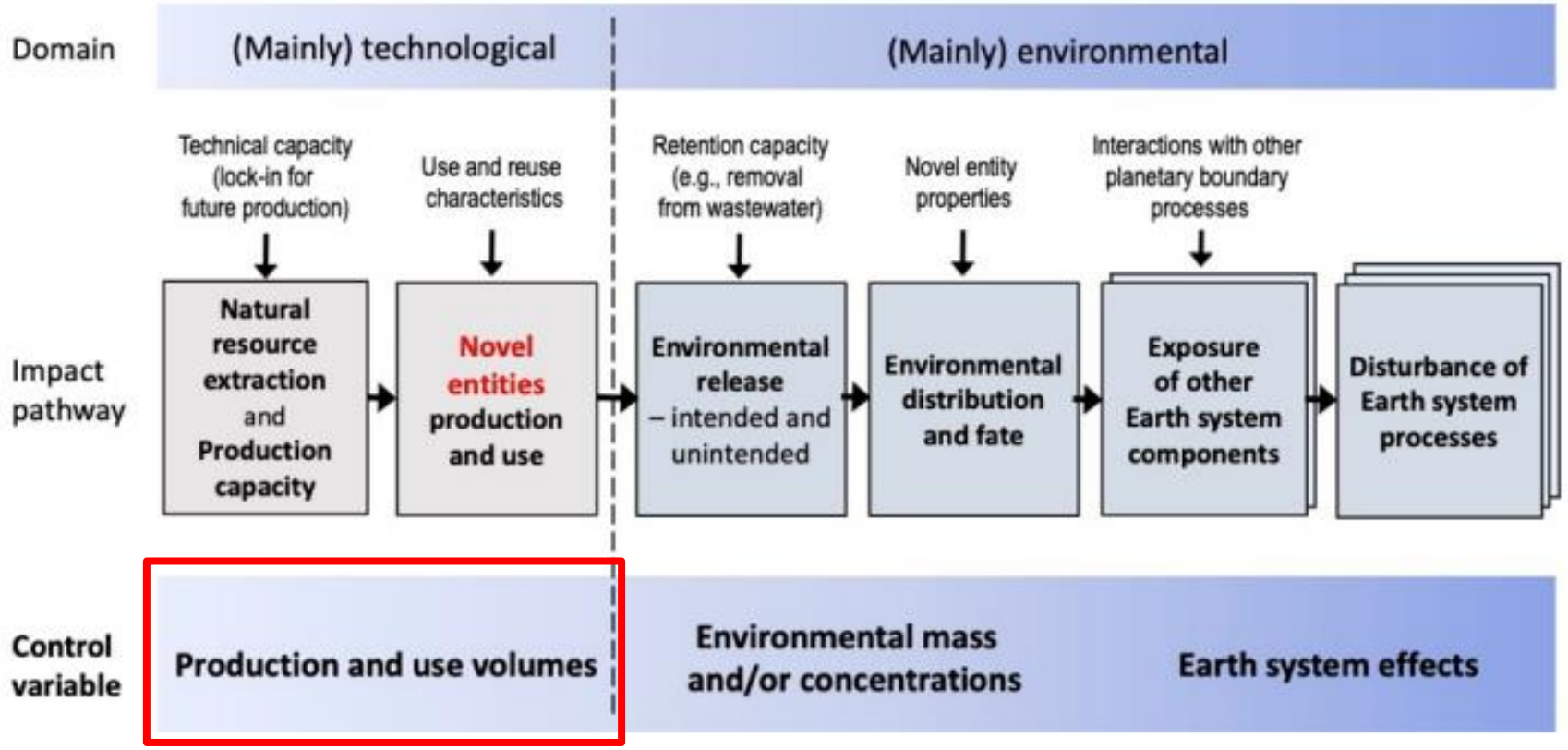
Source: Steffen et al., **2015**

Planetary Boundaries
New entities / critical materials and LCA



Source: Persson et al., 2022

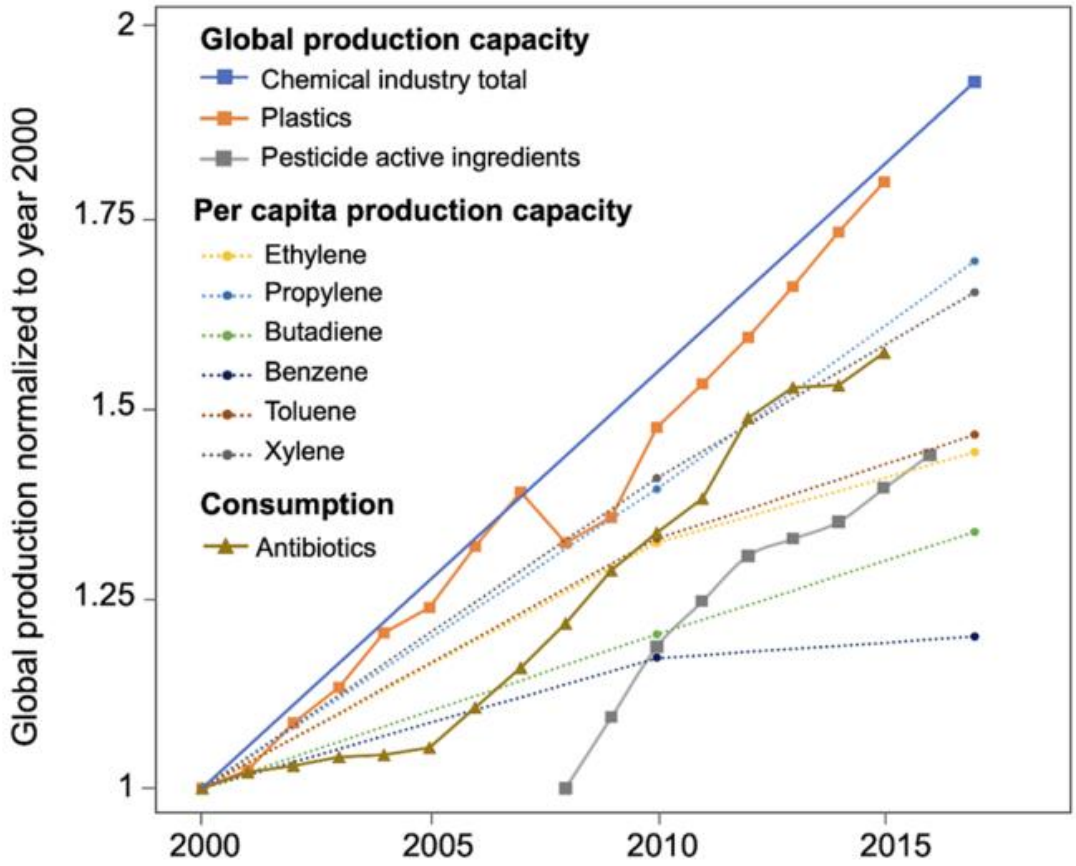
Planetary Boundaries
New entities / critical materials and LCA



Source: Persson et al., 2022

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

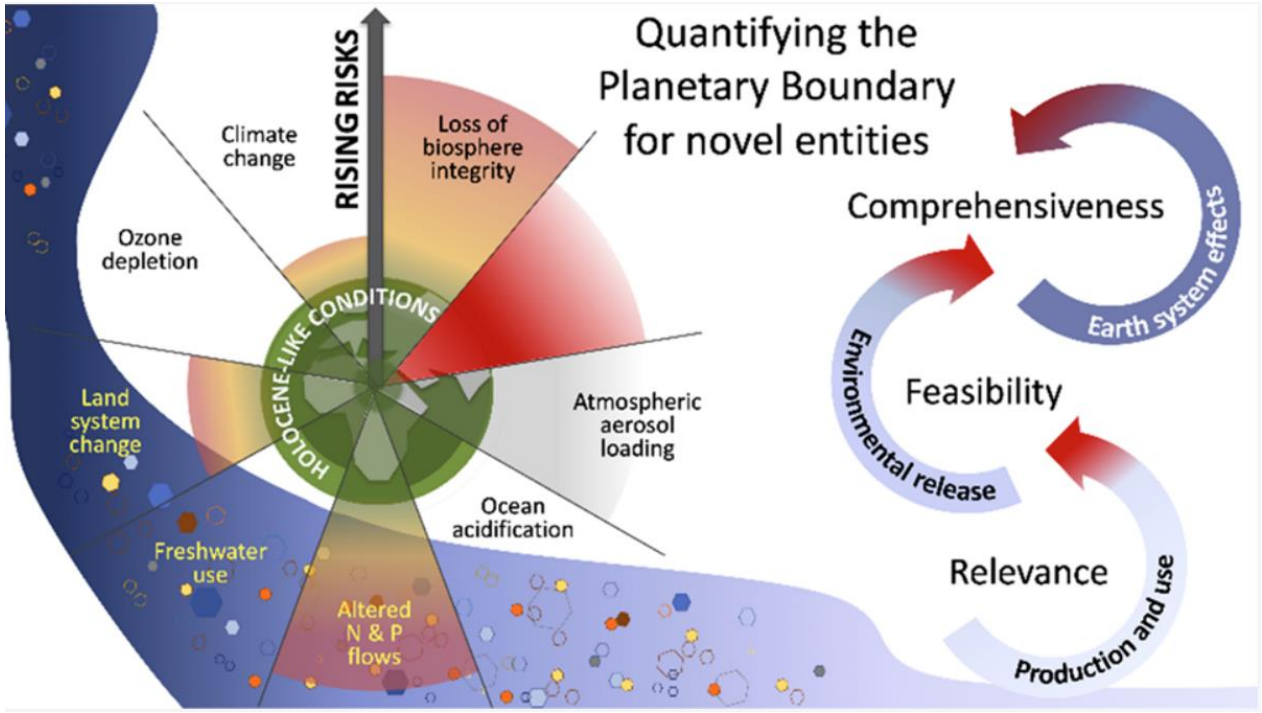


Source: Persson et al., 2022

Planetary Boundaries
New entities / critical materials and LCA

Control variables:

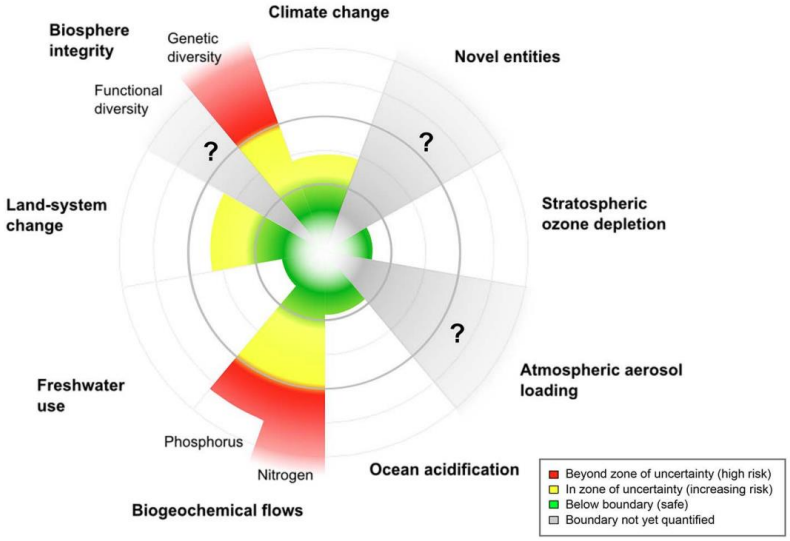
- trend in production volumes of chemicals
- trend in production volumes of plastics
- share of chemicals on the market that are assessed for risk or safety



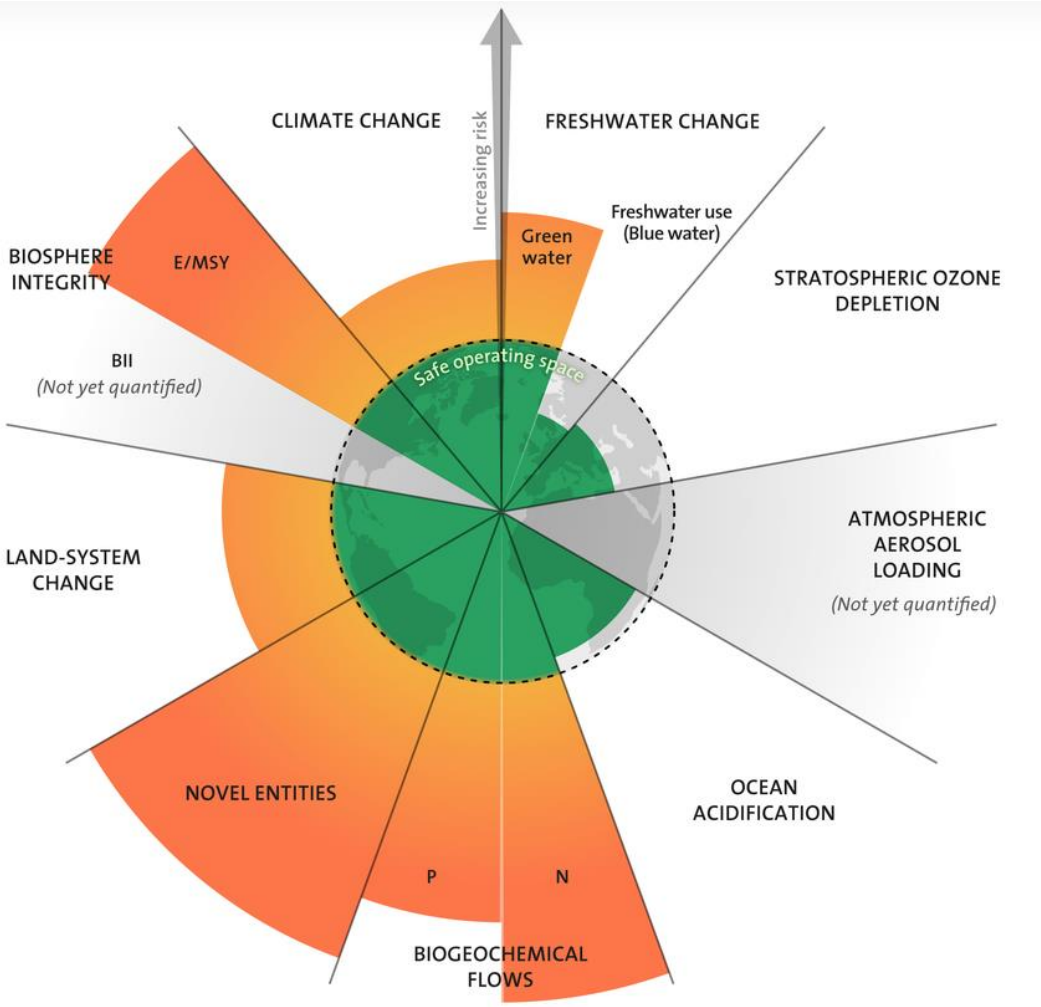
Source: Persson et al., 2022

Planetary Boundaries
Updated - 2022

https://www.pik-potsdam.de/en/news/latest-news/planetary-boundaries-update-freshwater-boundary-exceeds-safe-limits



Source: Steffen et al., **2015**

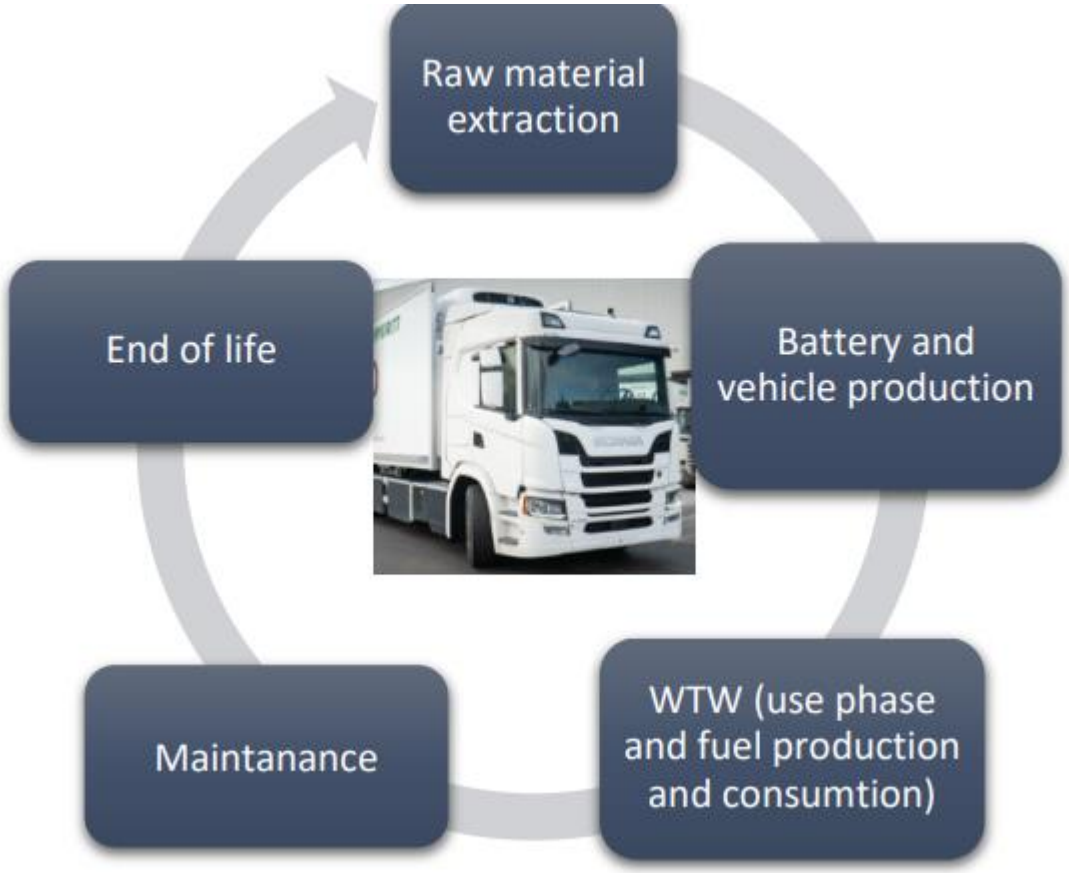


Updated Planetary Boundaries. Figure designed by Azote for Stockholm Resilience Centre, based on analysis in Wang-Erlandsson et al., 2022, Persson et al 2022 and Steffen et al 2015

Agenda

- The method
- Some case studies
- Take aways

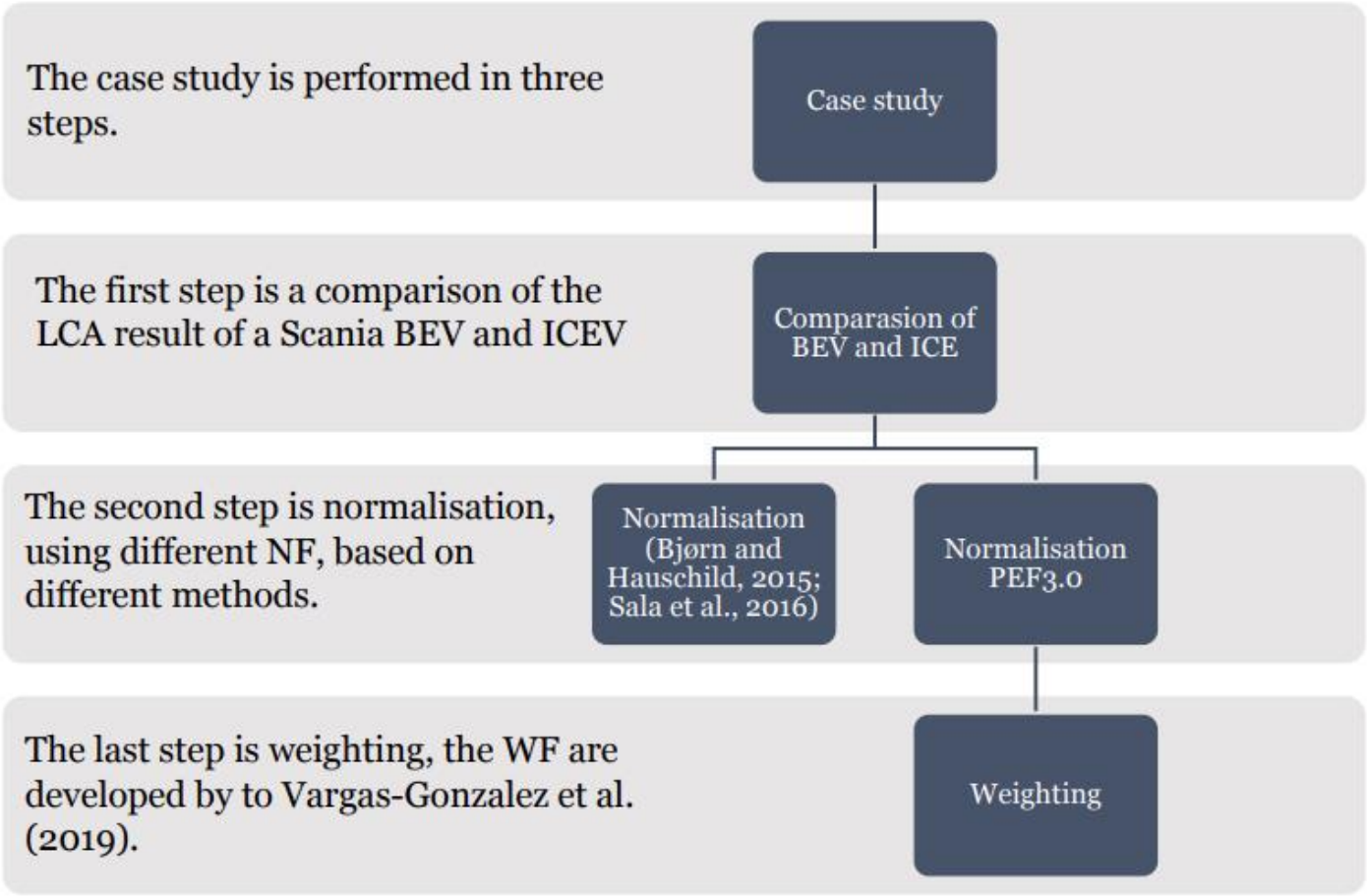
Planetary Boundaries
Case studies from the energy transition



Source: Pehrson, 2020

https://www.diva-portal.org/smash/get/diva2:1470529/FULLTEXT01.pdf

Planetary Boundaries
Case studies from the energy transition



Source: Pehrson, 2020 https://www.diva-portal.org/smash/get/diva2:1470529/FULLTEXT01.pdf

Planetary Boundaries
Case studies from the energy transition

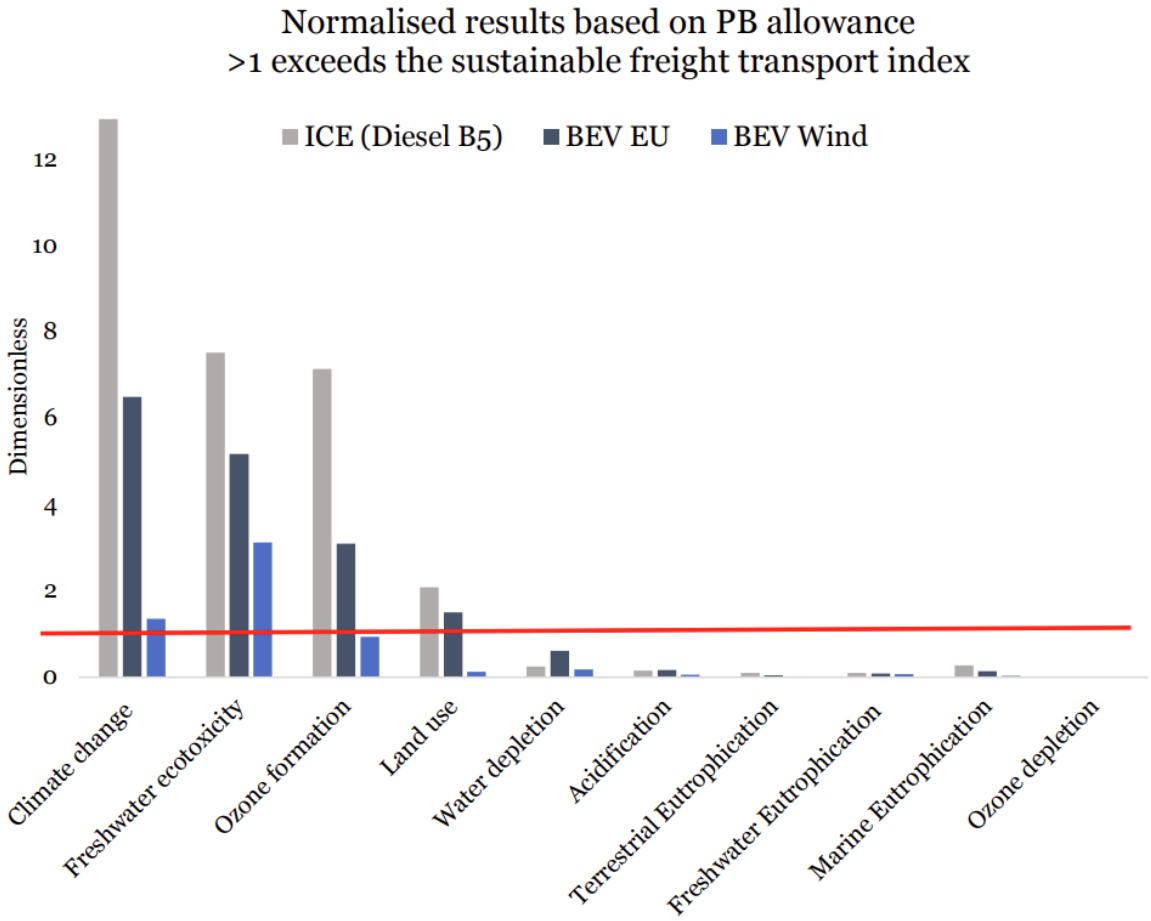
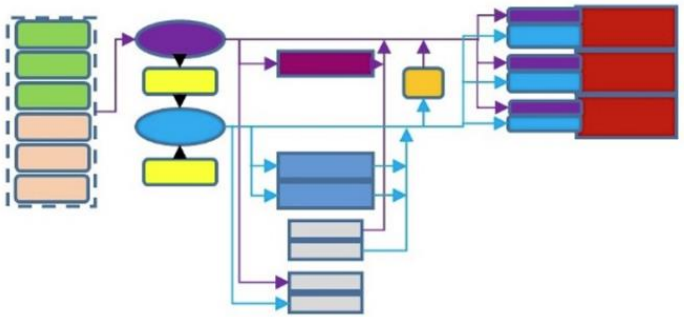


Figure 7. Normalised results of three Scania vehicles, ICE (Diesel B5), BEV EU and BEV Wind. The red line is the yearly PB allowance for the specific Scania vehicle.

Source: Pehrson, 2020

Planetary Boundaries
Case studies from the energy transition

Step 1: Create superstructure with mass and energy flows



Step 2: Collect life cycle inventory data of all technologies

Step 3: Downscale PBs to building heating in EU27+1

Step 4: Set up LP optimisation model with scenario options

GAMS

$$(\mathrm{M}) \quad \min_{x,y}\{\psi_k(x,y)\}$$

$$s.t. \quad h(x,y) = 0$$

$$g(x,y) \leq 0$$

$$x \in R^n, y \in \{0,1\}$$

Scenarios:

- Base case
- No collaboration
- No onshore wind & no nuclear
- Political gridlock (combination of above)
- Only hydrogen

Step 5: Optimise building heating system for different objectives

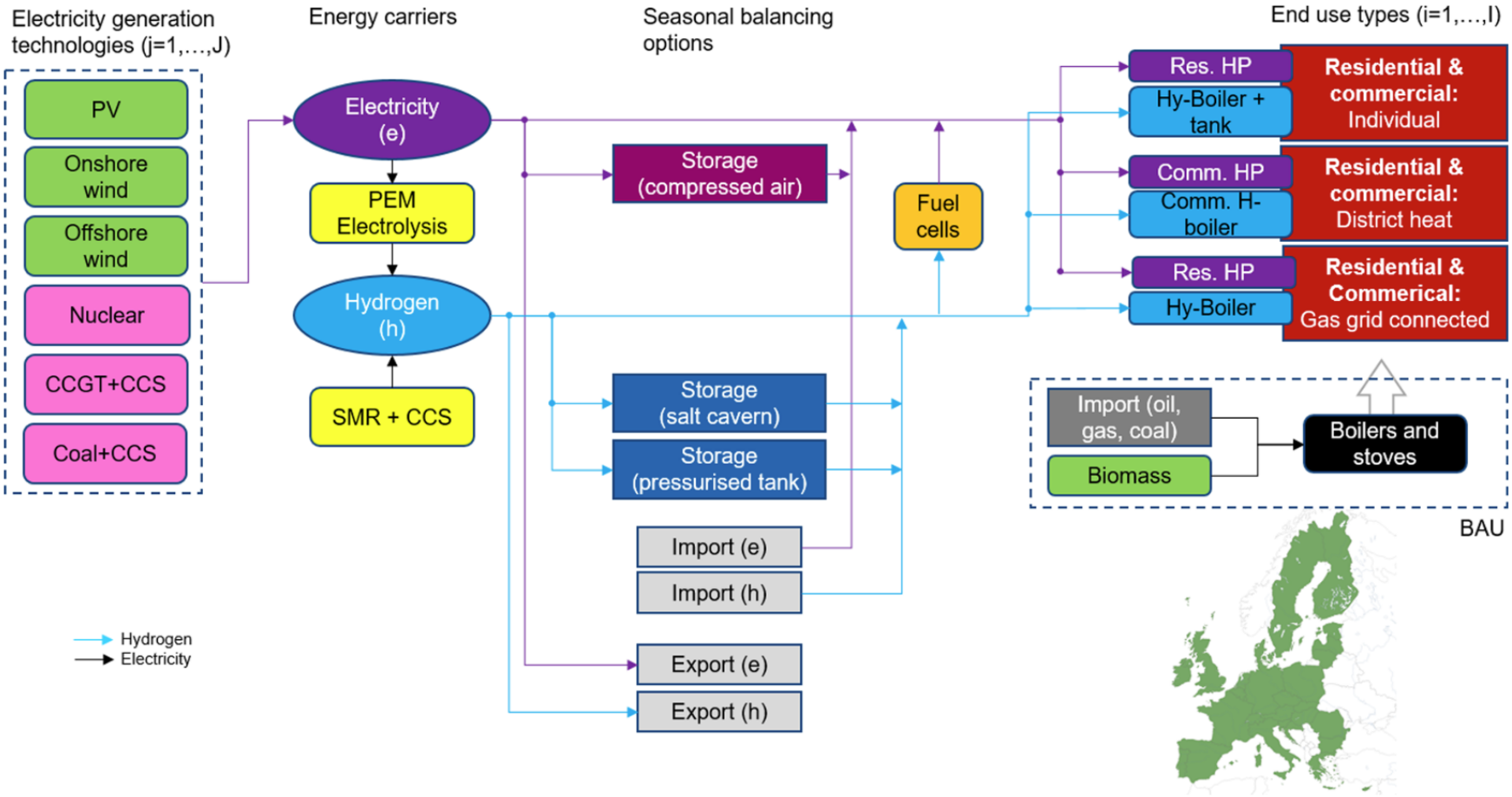
- min cost

- min weighted transgression level (WTL)

- min cost within downscaled PBs

Source: Weidner & Guillen-Gosalbez, 2022

Planetary Boundaries
Case studies from the energy transition



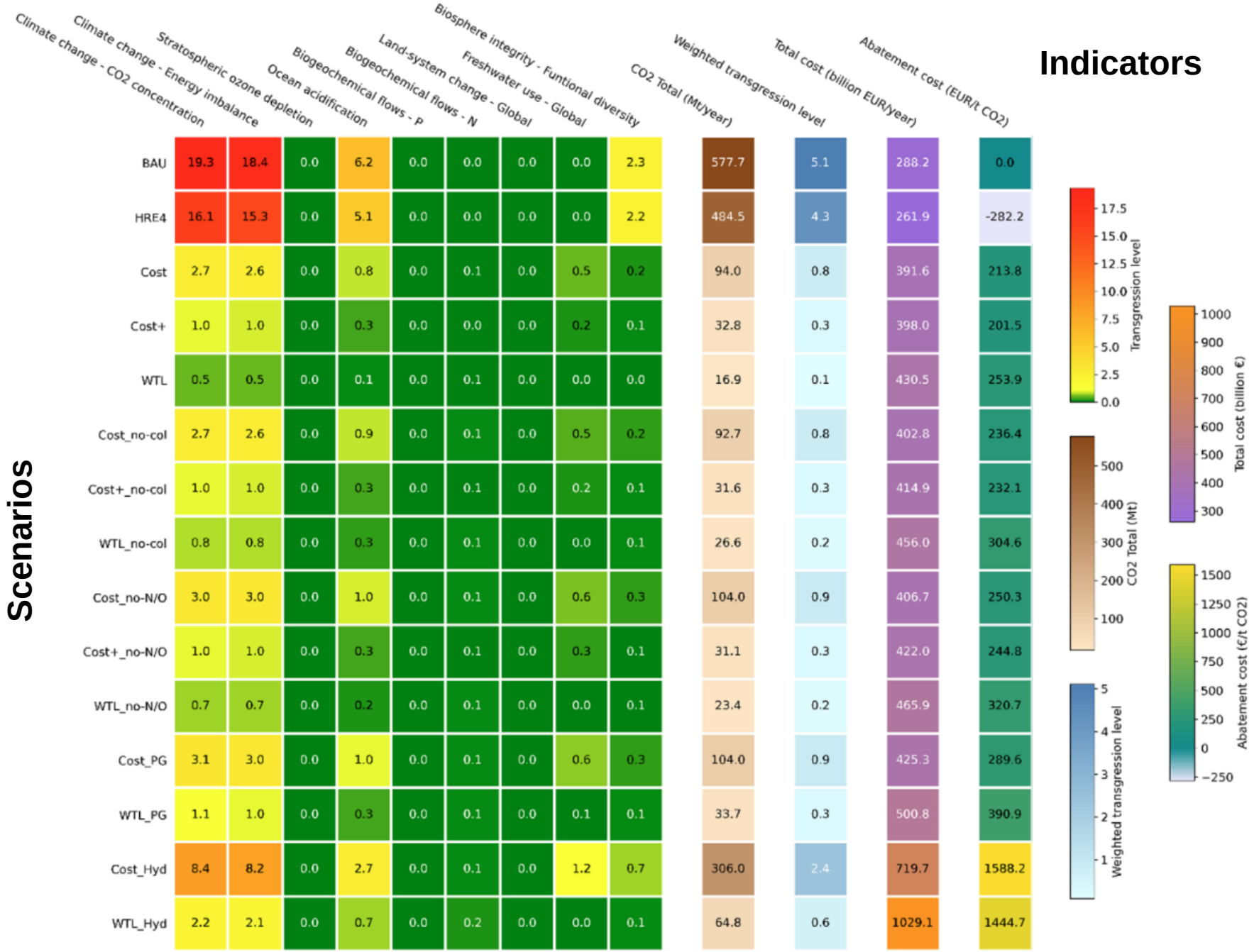
Source: Weidner & Guillen-Gosalbez, 2022

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

Source: Weidner & Guillen-Gosalbez, 2022



Source: Weidner & Guillen-Gosalbez, 2022

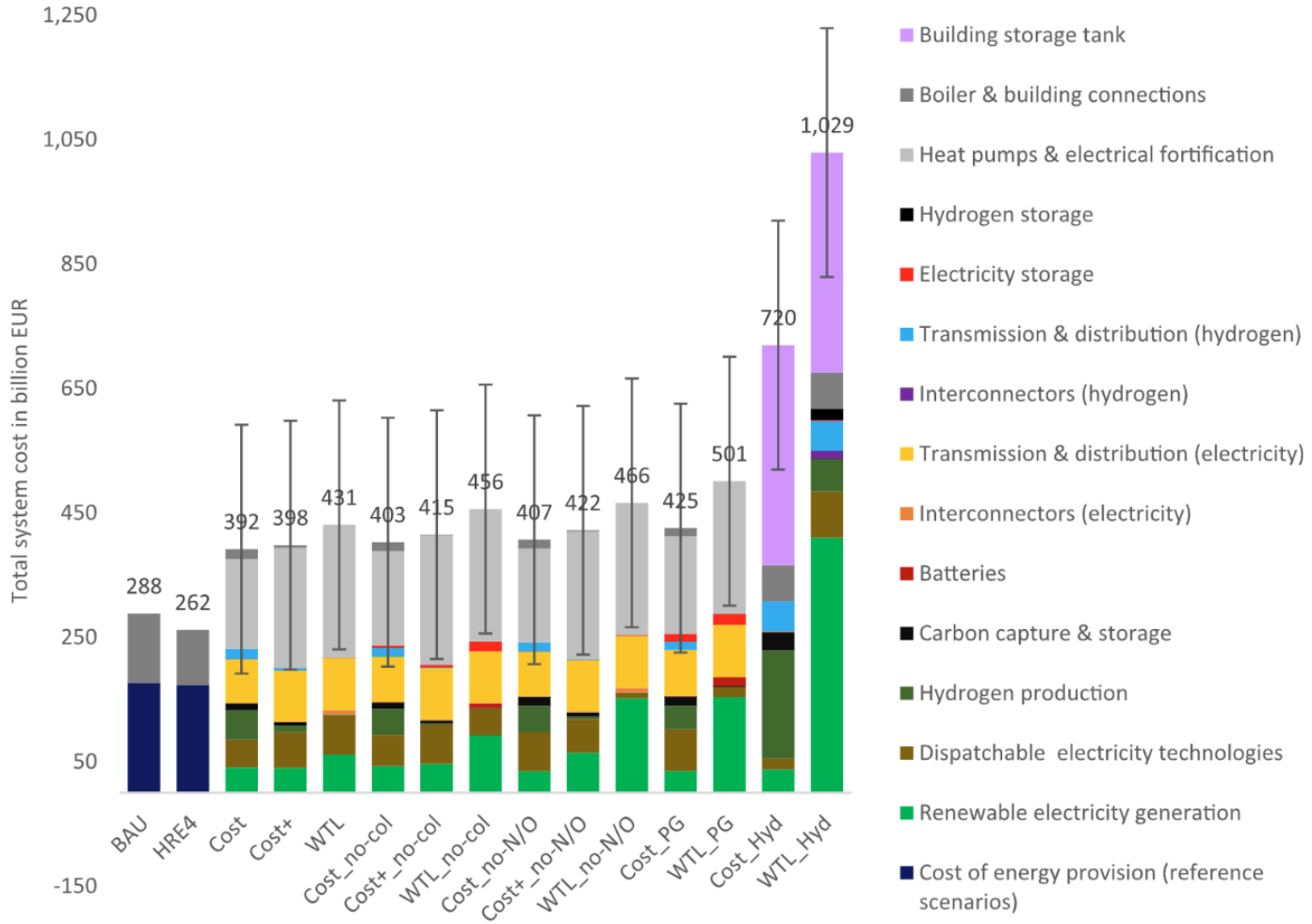


Fig. 4. Total system cost for building heating in the EU27 + 1 broken down by technologies and scenarios. Error bars describe the minimum and maximum cost depending on differing cost assumptions of all the technologies and equipment considered.

Source: Weidner & Guillen-Gosalbez, 2022

Planetary Boundaries
Case studies from the energy transition

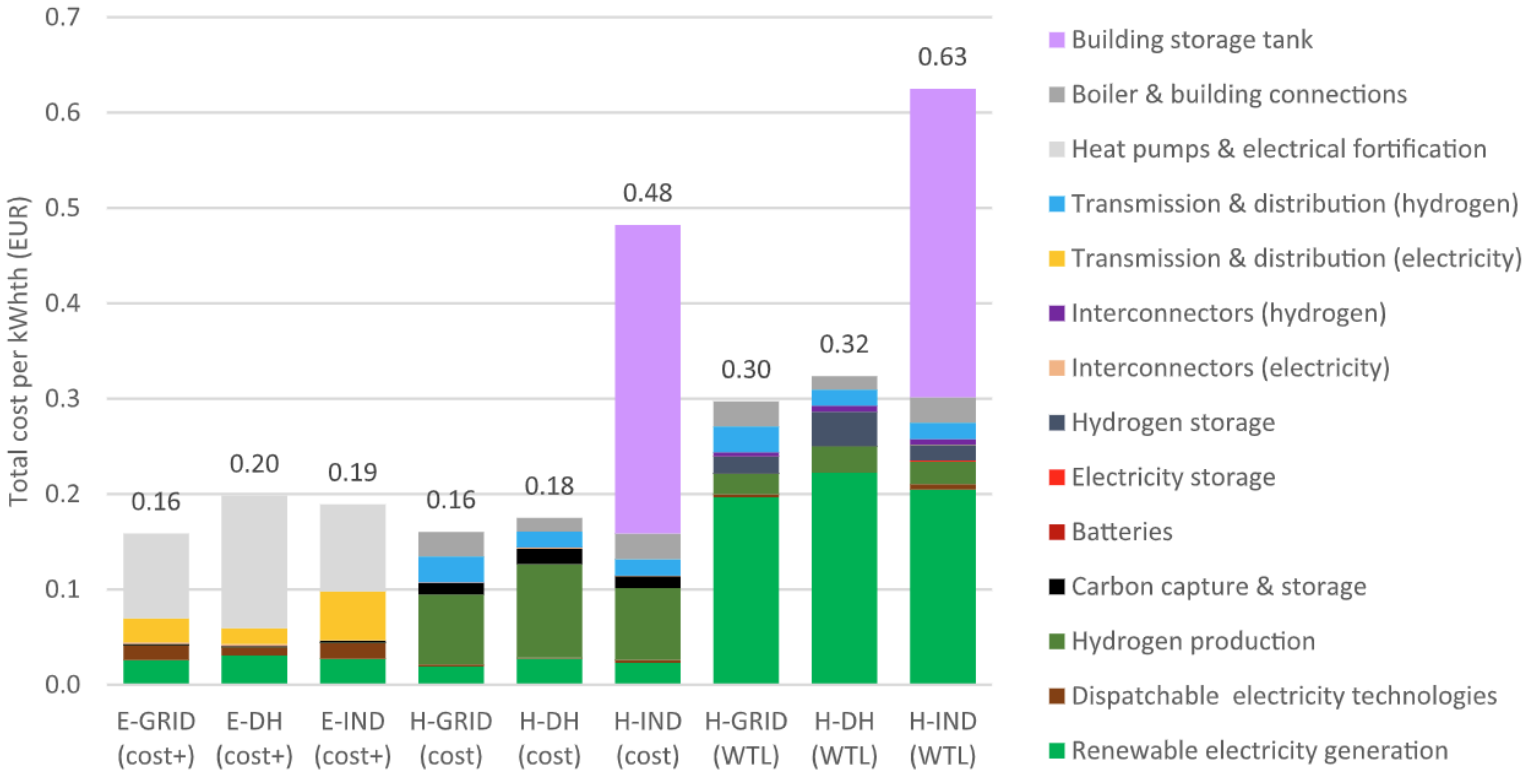


Fig. 5. Total cost per unit of heating demand met for the different end-user types; connected to the gas (GRID) or district heating (DH) grids and individual buildings (IND). Three different scenarios are shown, electrification-only (E-…) optimised by least cost, hydrogen-only (H-…) optimised by either 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).

Source: Weidner & Guillen-Gosalbez, 2022

Agenda

- The method
- Some case studies
- Take aways

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 <u>environmental</u> 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. https://www.diva-portal.org/smash/get/diva2:1470529/FULLTEXT01.pdf

Persson et al., 2022. *Outside the Safe Operating Space of the Planetary Boundary for Novel Entities.* Renewable and Sustainable Energy Transition 2 (2022) https://doi.org/10.1021/acs.est.1c04158

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 forbuilding heating in the European Union.* Energy Conversion and Management Volume 278, 15 February 2023, 116602 https://doi.org/10.1016/j.enconman.2022.116602