Absolute Sustainability in Life Cycle Assessment

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Why ”Absolute Sustainability” in LCA?

- In the SSbD context, the ”Safety” is considered being evaluated against ”Absolute criteria”
  - Properties measured on a chemical itself

- Criteria for Absolute Sustainability in the LCA step can therefore be considered desired for the sake of symmetry

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What are the challenges for Absolute Sustainability in LCA?

(non-exhaustive list)

- How to understand ”Absolute Sustainability”
  - i.e. what does it actually mean?
- Multiple impact types addressed in LCA
  - Different characteristics between impact types
    - E.g. reversibility vs irreversibility
- How to define absolute sustainability on product level?

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Framework of socio-ecological indicators (Azar et al, 1996)

In the sustainable society

- (1) concentrations of substances extracted from the Earth's crust cannot systematically increase
- (2) concentrations of substances produced by society cannot systematically increase
- (3) degradation by physical means of ecosystems cannot systematically increase
- (4) human needs are met worldwide; resources are distributed justly

Andersson, K et al, 1998. The feasibility of including sustainability in LCA for product development. *Journal of Cleaner Production*, *6*(3-4), pp.289-298.

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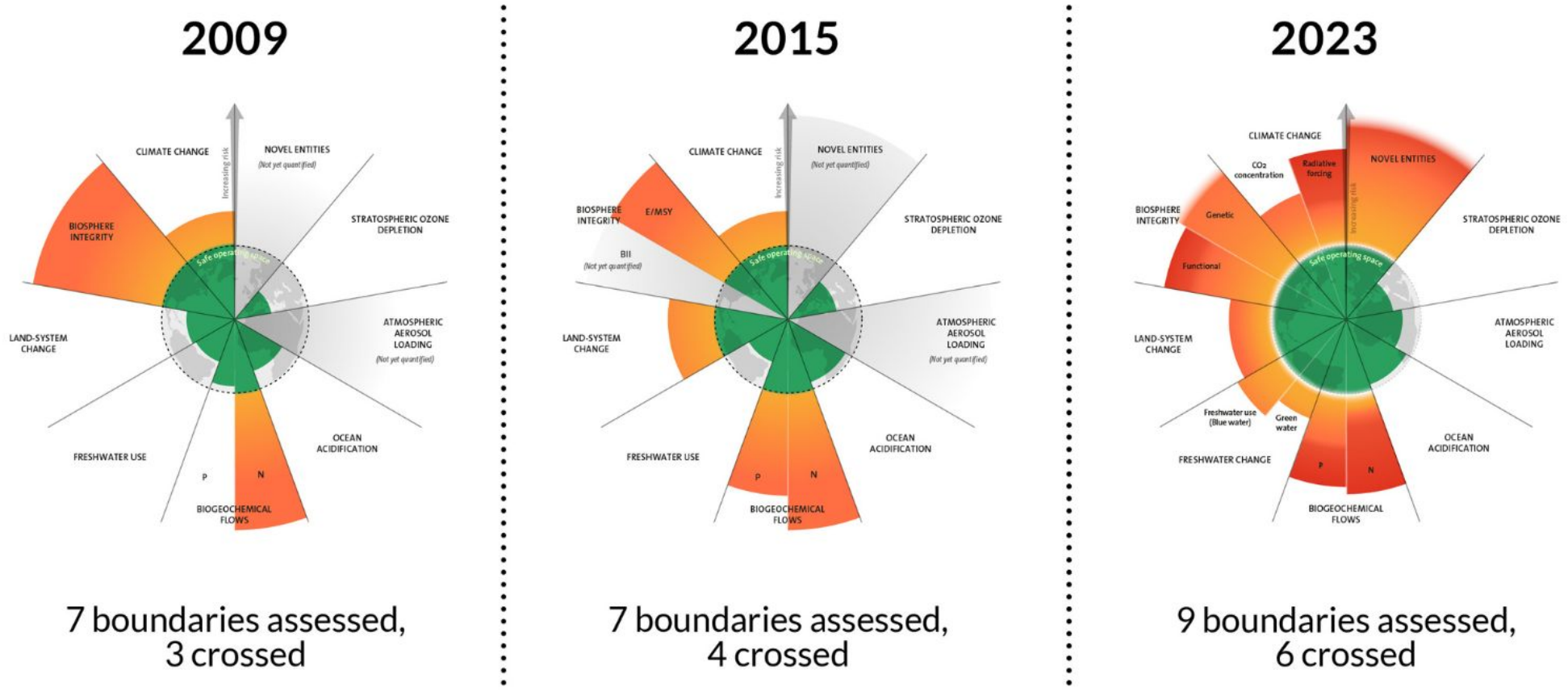

The evolution of the planetary boundaries framework. Licenced under CC BY-NC-ND 3.0 (Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009) Downloaded from https://www.stockholmresilience.org/research/planetary-boundaries.html

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Impact categories covered by PB vs LCA

Planetary Boundaries Framework of Stockholm Resilience Center (SRC)
Climate Change
Stratospheric Ozone Depletion
Atmospheric Aerosol Loading
Ocean Acidification
BioGeoChemical Flows (N,P)
Freshwater change (FW Use, Green Water)
Land System Change
Biosphere integrity
Novel entities

Impact categories in PEF /OEF of EC DG JRC
Climate change
Ozone depletion
Human toxicity, cancer
Human toxicity, non-cancer
Particulate matter
Ionizing radiation, human health
Photochemical ozone formation, human health
Acidification
Eutrophication, terrestrial
Eutrophication, freshwater
Eutrophication, marine
Ecotoxicity, freshwater
Land use
Water use
Resource use, minerals and metals
Resource use, fossils

Different choices of threshold criteria lead to different sustainability boundaries

Total Cl in the atmo-sphere	present conc (1988)	pre-industrial konc.	steady-st., emissions as 1988	certain damage level (I)	certain damage level (II)
conc (ppbv)	ca 3	ca 0.7	ca 15	ca 2	ca 1,5
emission (10^6 t ODP) (bio+ant)	ca 0.4	ca 0.1	ca 1	ca 0.3	ca 0.2
damages (example)	1-2 death /10^6 pers. per year	”0”	?	1 death / 10^6 pers. per year	no ozone hole

Example for Stratospheric ozone depletion,
Own compilation of various sources, early 1990’s

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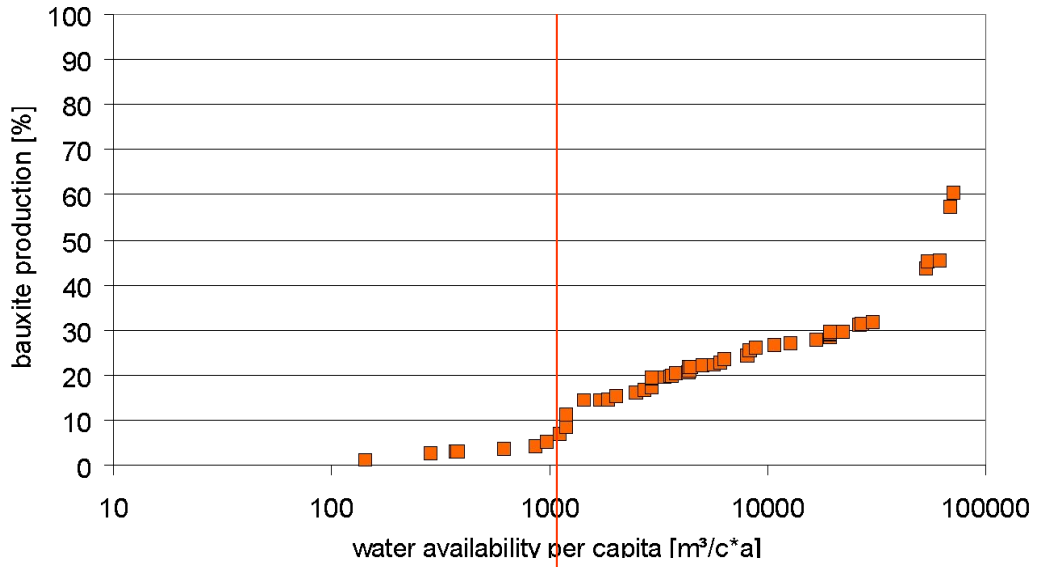
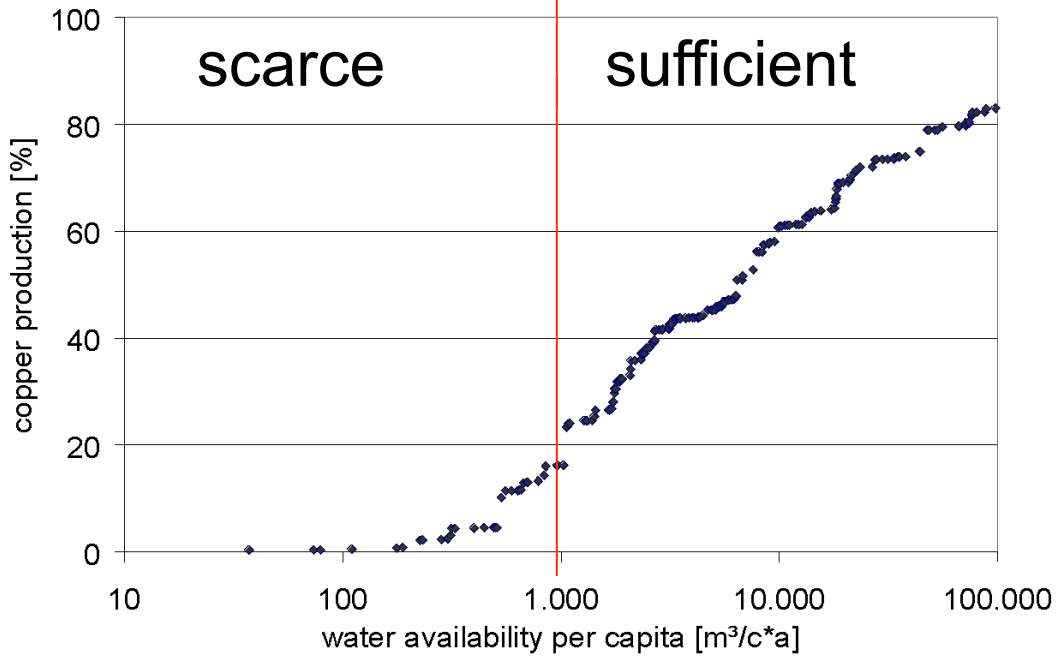
”Water scarcity threshold”: 1000 m3/c*a

global aluminium production



global copper production



Källa: Schetelig et al 2001

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Threshold criteria for the Eco-indicator '95 and the ETlong methods as early attempts (from the mid-1990s) to link LCA impacts to planetary or other related absolute boundaries

Impact Category	Threshold criteria, Eco-indicator '95	Threshold criteria, ETlong
Global warming	0.1 degC per decade, 5% ecosystem impairment	Global max 0.1 degC temerature increase per decade
Ozone depletion	Probability of 1 death per year per million people (due to melanoma)	Cl/Br conncentrations below formation of the polar ozone hole
Acidification	5% system impairment	Ion balance (Ca+Mg+K):Al >1 in soils (Sweden)
Eutrophication	Rivers and lakes, impairment of an unknown of aquatic ecosystems?	Critical loads of nutrients to sea water surrounding Sweden
Photo-oxidants	Winter smog: Occurrence of smog periods health complaints, particularly amog asthma patients and old people Summer smog: as winter smog + occurrence of agricultural damage	5%-il for damages of ozone to crop
Toxic/ecotoxic chemicals	Pesticides: 5% system impairment Heavy maetals in air: Lead levels in childrens' blood, limited life expectancy and learning ability in an unknown number of people Heavy metals in water: Cadmium content in rivers, ultimately also effect on people Carcinogenic substances: Probability of 1 death per year per million people	Critical load of deposition of Mercury

Reppas et al, 2025

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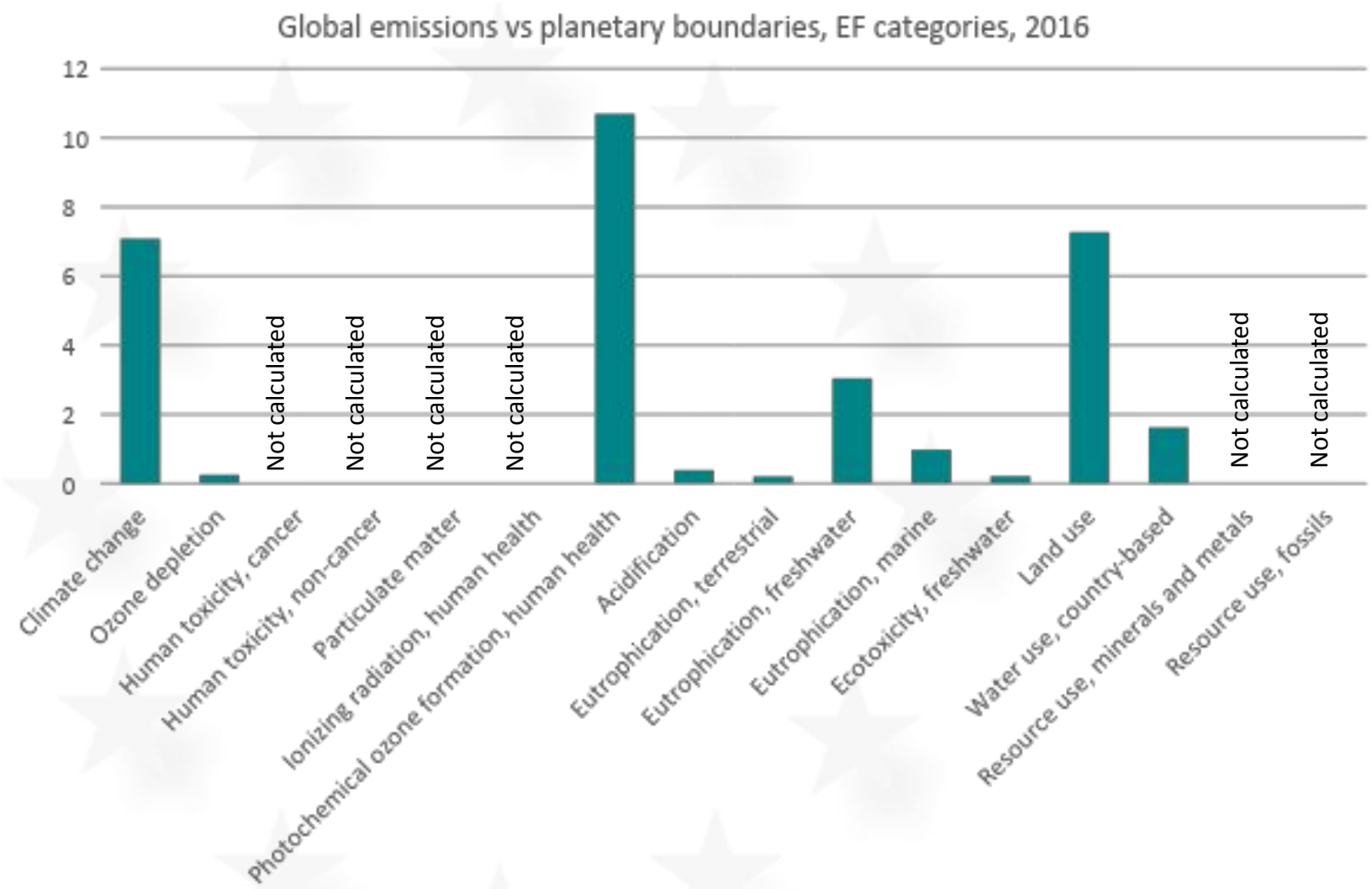

Total global emissions (as NFs) versus estimated planetary boundaries according to JRC calculations

Sala et al, 2016

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How to make use of global reference values, such as PB scores, example

Product Score [category unit] / Normalisation score [category unit] = Normalised score [dimensionless] (10^{-12})

	Cotton	Global score	Cotton
Land use	7.74E+00	-	-
AP	6.12E-02	2.39E+11	2.56E-01
EP	9.23E-02	1.58E+11	5.83E-01
GWP	5.14E+00	4.22E+13	1.22E-01
POCP	1.66E-03	3.68E+10	4.51E-02
Water use	3.85E+03	-	-
EcoTox	1.14E+01	2.94E+14	3.88E-02
HumanTox, cancer	6.55E-10	1.28E+05	5.12E-03
HumanTox, non-cancer	2.39E-08	1.59E+06	1.87E-01

Same characterization models (and version) must be used!

Indicates the importance of one category to another

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From global to product level

- Planetary boundaries say very little about the sustainability of a specific product
- The challenge is to distribute the allowed ”safe operating space” to individual product level
- Attempts so far are based on
  - per capita allowances
    - but doesn’t capture the products *per se*
  - economic value of a product
    - ”the impact of category X can maximum be Y per EURO of product Z”
- Whatever approach – it will have to be based on criteria developed through **agreements among stakeholders!**

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Thank you for listening

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