Comprehensive estimates of the carbon footprint of geoscience laboratories including satellite infrastructures


Credit: ESA - M. Pedoussaut


Credit: ESA - J. Huart,

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Odin MARC, CNRS / GET
Odin.marc@cnrs.fr

Sylvain Biancamaria, Solene Derrien, François Gheusi, Jürgen Knödlseder, Sylvain Kuppel, Marion Maisonobe, Arnaud Mialon, Pierrick Martin, Florian Pantillon, Luigi Tibaldo, and Florence Toublanc

irap astrophysique & planétologie

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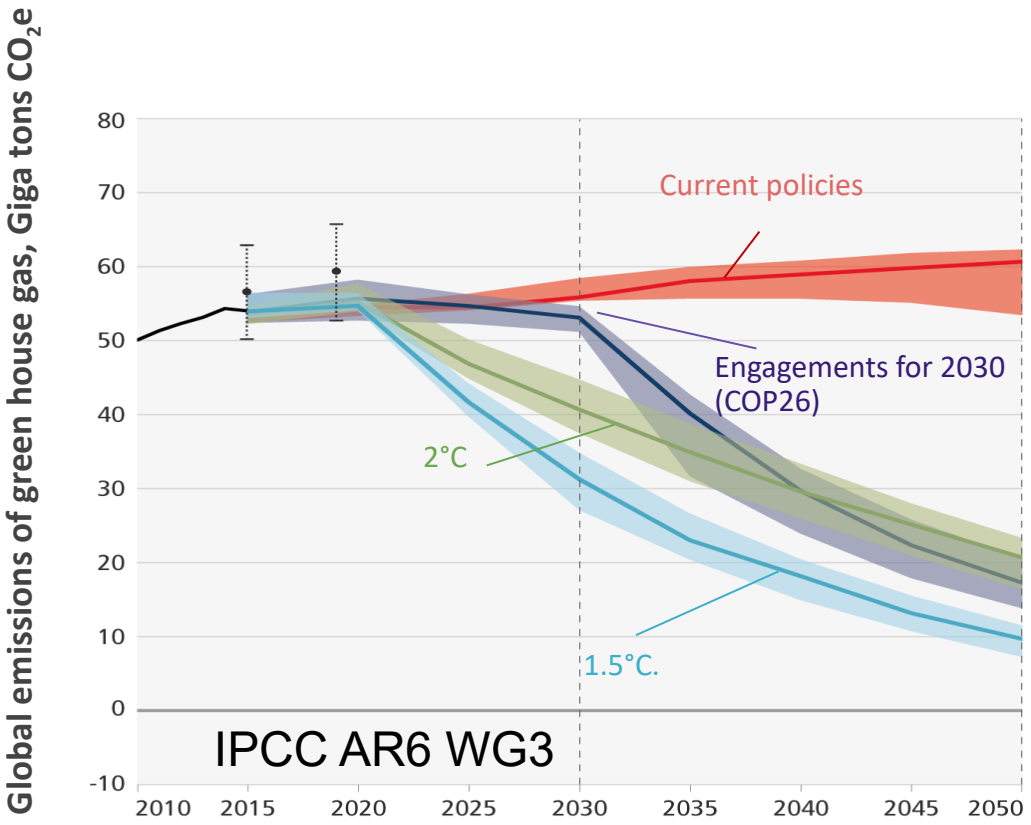
Observatoire Midi-Pyrénées OMP

CESBIO

Laero Laboratoire d'Aérologie

Drastic reduction of GHG emissions are needed



With current policies we are heading towards **+ 3°** in 2100 and **+2° in 2050**

For 1.5°C : ~ 8 %/yr reduction rate

By 2050 all sector of society should have reduced their emissions, including Science.

} World Target : **1-2 tCO2e /p in 2050**

(assuming 10 billion humans)

→ What are the magnitude of the various sources of GHG emissions by scientific activity ?

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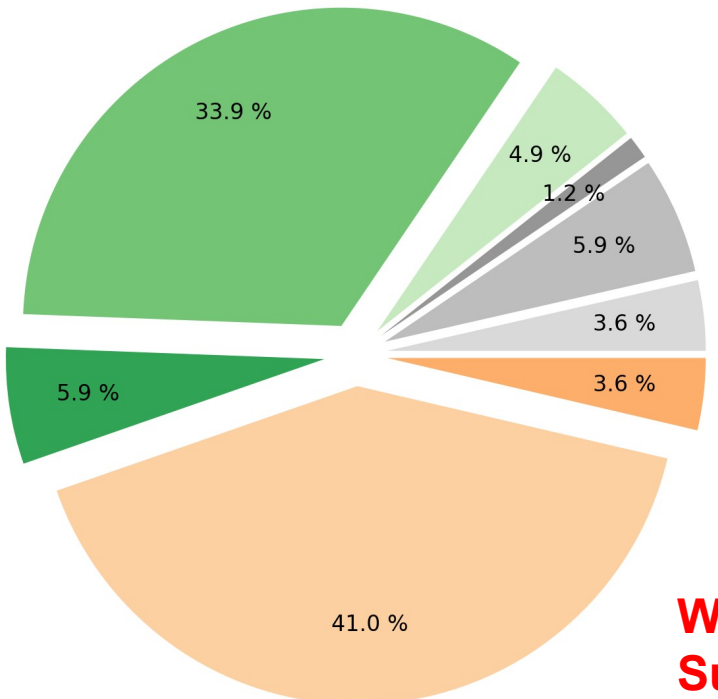
→ How can we reduce them, to achieve **sufficiency** and **exemplarity ?**

In-Situ emissions accounting for purchases

We Follow GES 1.5 for building, travel and purchase emissions (Mariette et al 2022, DePaeppe et al., 2024**)**

GET (242 pers.) - 7.5 tCO2e/p (2019)



Air-travel:
>800 missions, >3.5 10^6 km, >90% CO_{2e} by plane

Expenses:
1.8 M euros (equipment, IT, repairs, services, ...)

What about large outsourced research infrastructures?
Such as Computing or Satellites ?

Method for Astrophysics (Knödlseder et al., 2022)

Proposed Life-Cycle Emission factors for satellite (based on data from 2 ESA missions) :

50 tCO_2e / kg (at launch)

CO_2 mainly due to satellite elements construction, transport and launch

Footprint in CO_2e / yr:

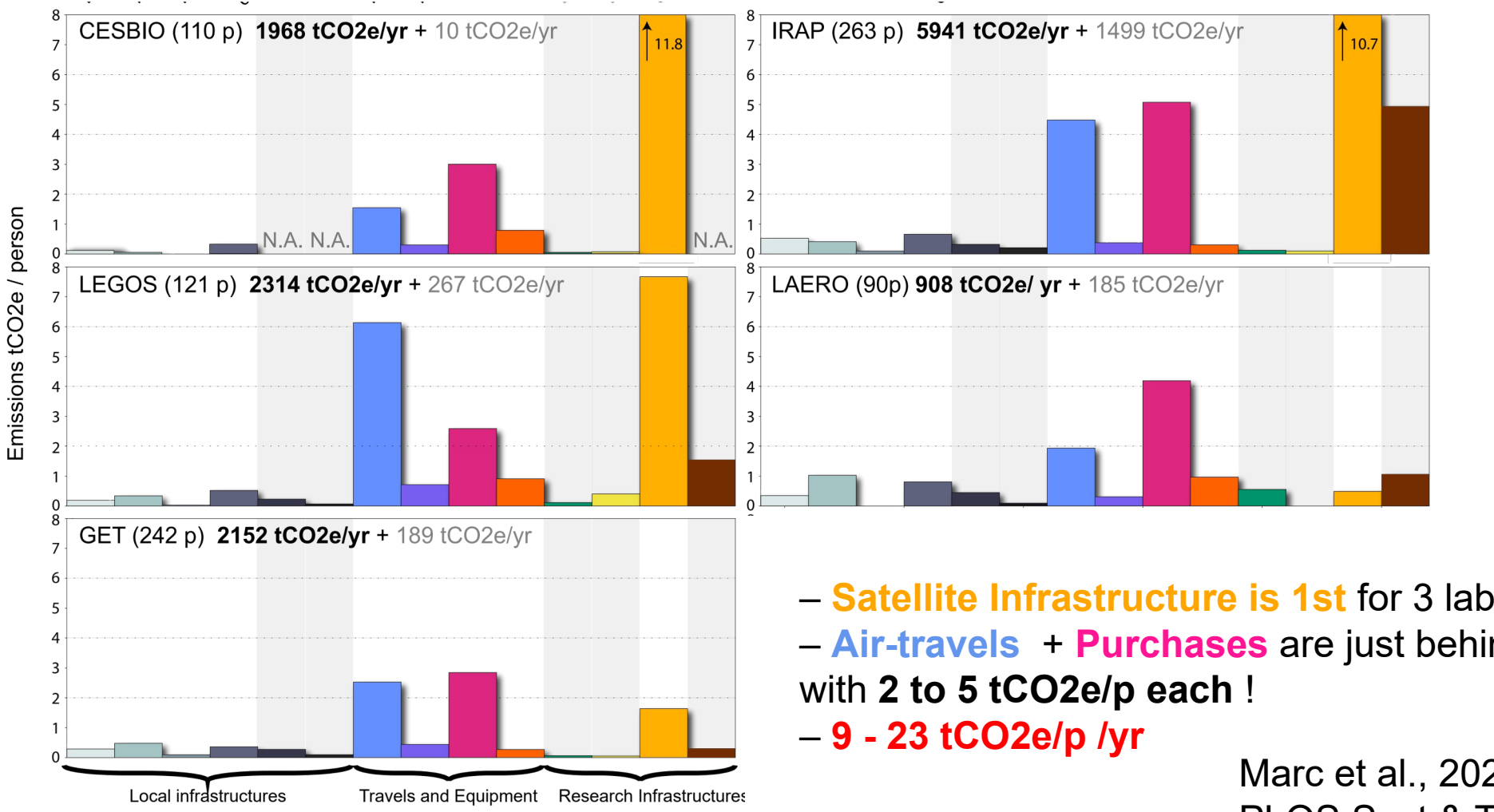
F(i)= Payload (kg) x 50 / (t - t_{launch})

How to assign CO_2 to a lab ?

$$F(i,l,dt) = F(i)\,\frac{Ml(i,l,dt)\,Af(i,l,dt)}{M(i,dt)}\,Ss(i)$$

Manuscript (lab) — *Author fraction* — *Share to Science* — *Manuscript (world)*

Comprehensive budget for various labs



– **Satellite Infrastructure is 1st** for 3 labs !
– **Air-travels** + **Purchases** are just behind with **2 to 5 tCO2e/p each** !
– **9 - 23 tCO2e/p /yr**

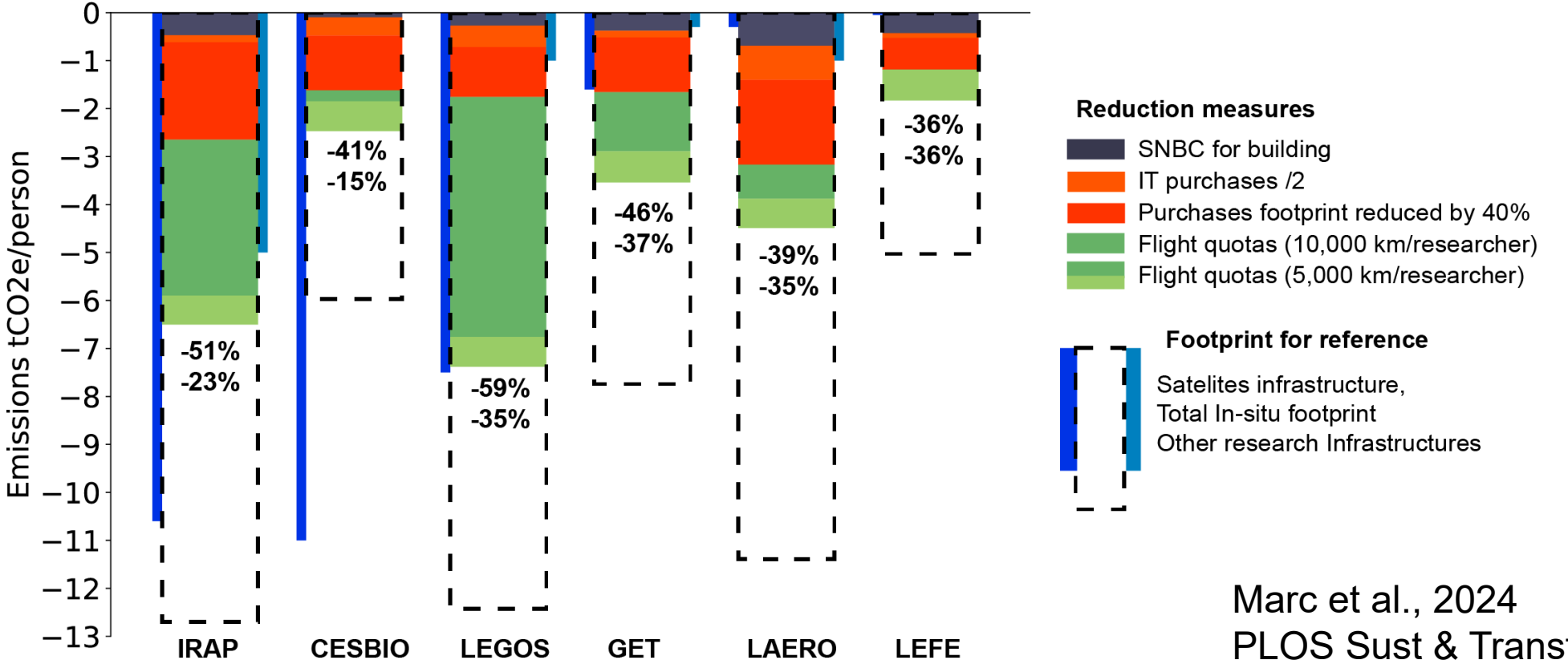
Marc et al., 2024
PLOS Sust & Transform

Substantial reductions require targeting infrastructures

→ Discuss and make community statement

→ Include GHG in infrastructure planning

→ Weight the community service (both scientific and societal) vs impact



Marc et al., 2024
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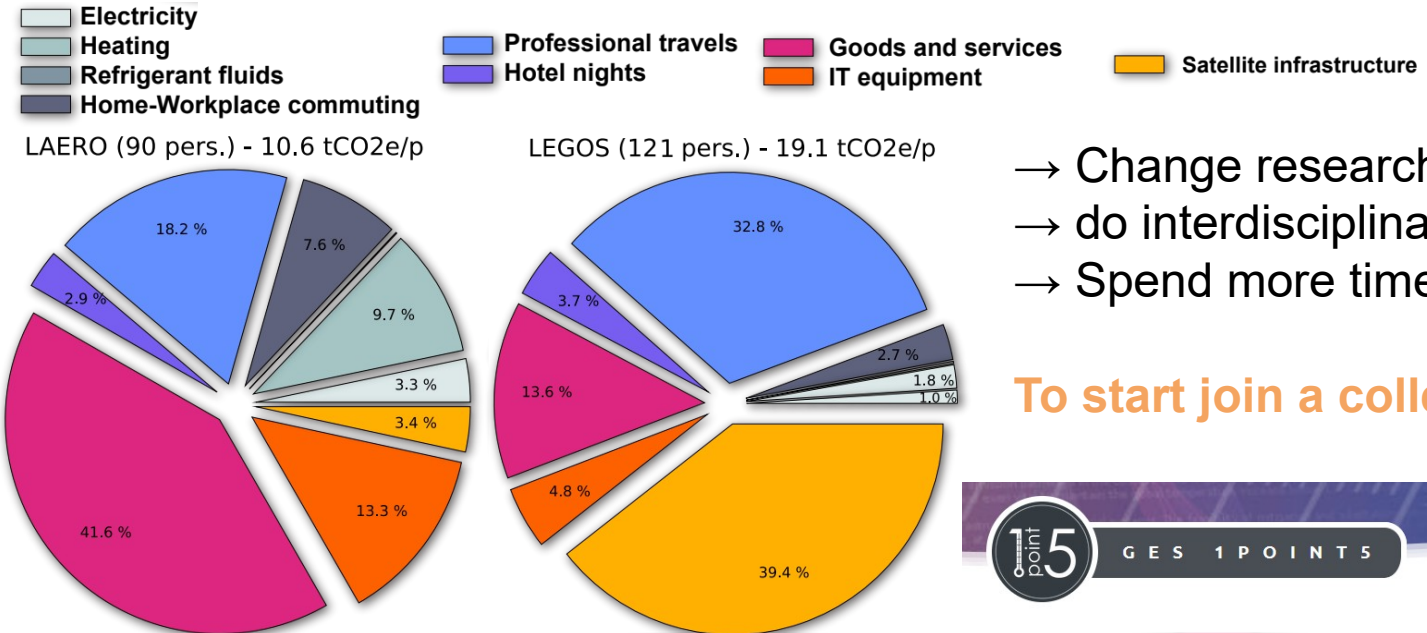
Conclusions

- Professional emissions of 5 Earth and Space Science labs : **9 - 23 tCO2e/p/yr**
- Dominated by **Satellite**, **Purchases** and then **Air-travels**.
- Reduce CO2 from local infrastructures will lead to minor reductions (~5 %).
- More impacting measures require scientists to rethink to some extent their activity :

→ **flight quotas, reduce purchases, limit the size and number of new infrastructures…**
Further, shifting toward « Slow-Science » may allow us to:



→ Change research topics ? Relocate field work ?
→ do interdisciplinary work (with social sciences)
→ Spend more time engaging with society.

To start join a collective !

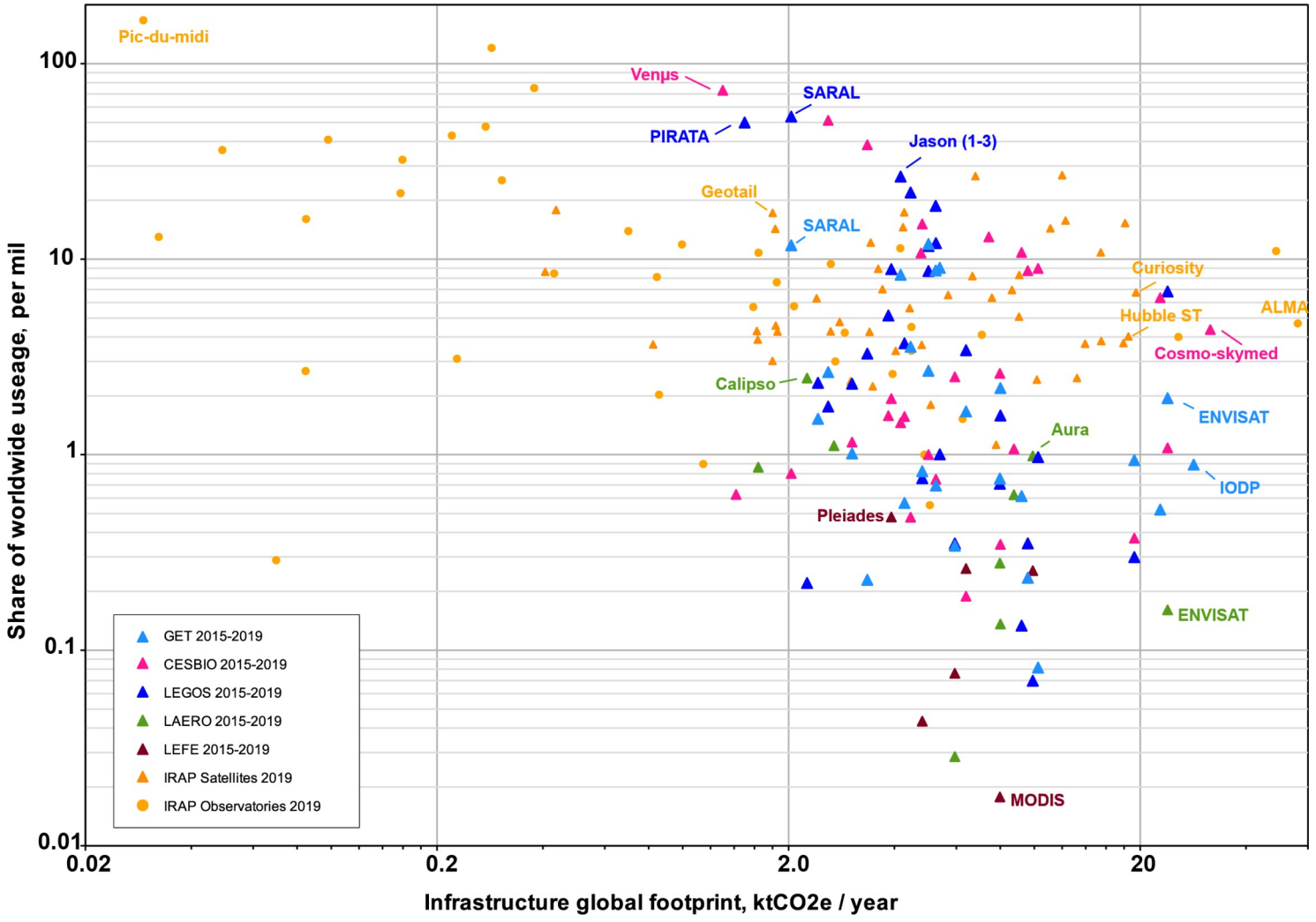
1point5 GES 1POINT5

Atécopol

Scientifiques en rébellion

Extra materials

Footprint vs Attribution for Research infrastructures



Typical Satellite Mission:
1-10 ktCO2e/yr

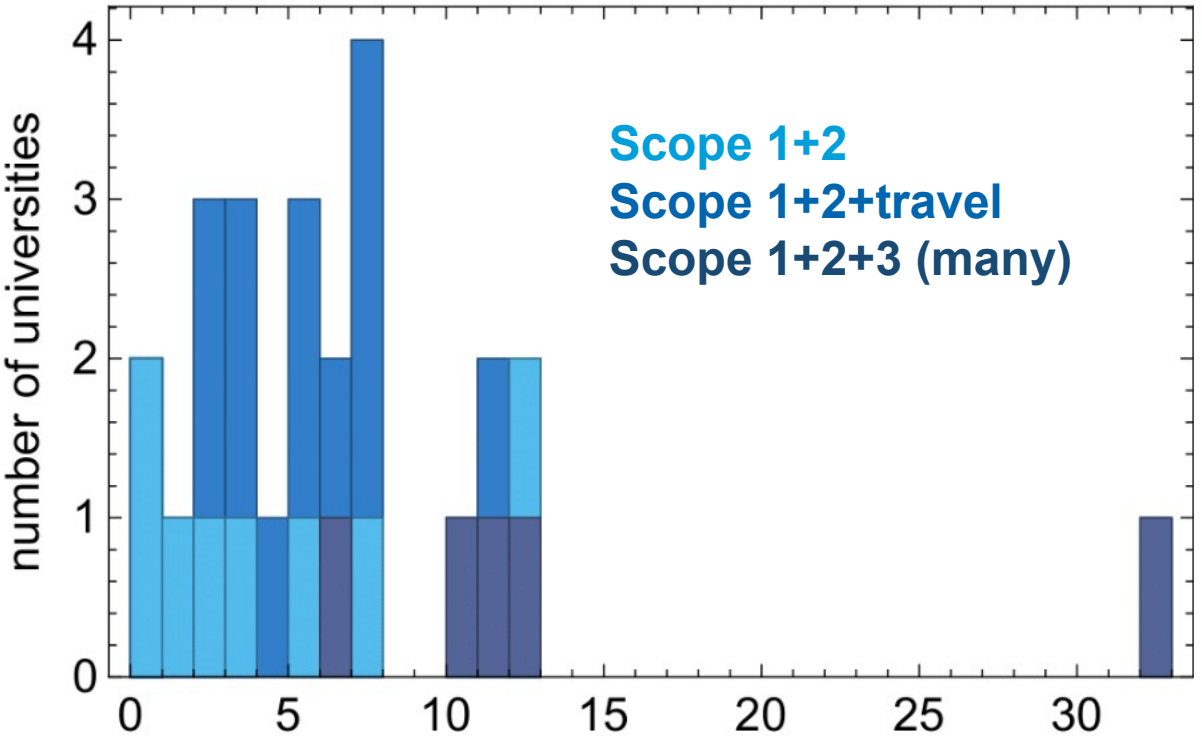
Attribution by Laboratory :
0.1 to 50 per mil

Consistent with the methodology of Knodlseder et al., 2022 for Astrophysics.

Marc et al., 2024
PLOS Sust & Transform

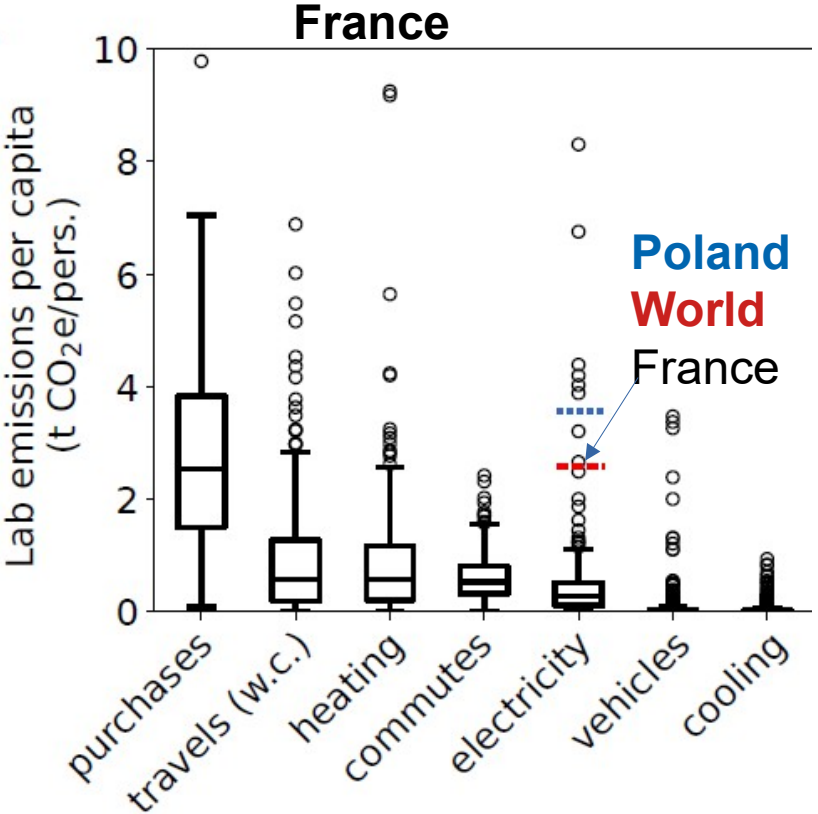
Similar footprint elsewhere

In Europe



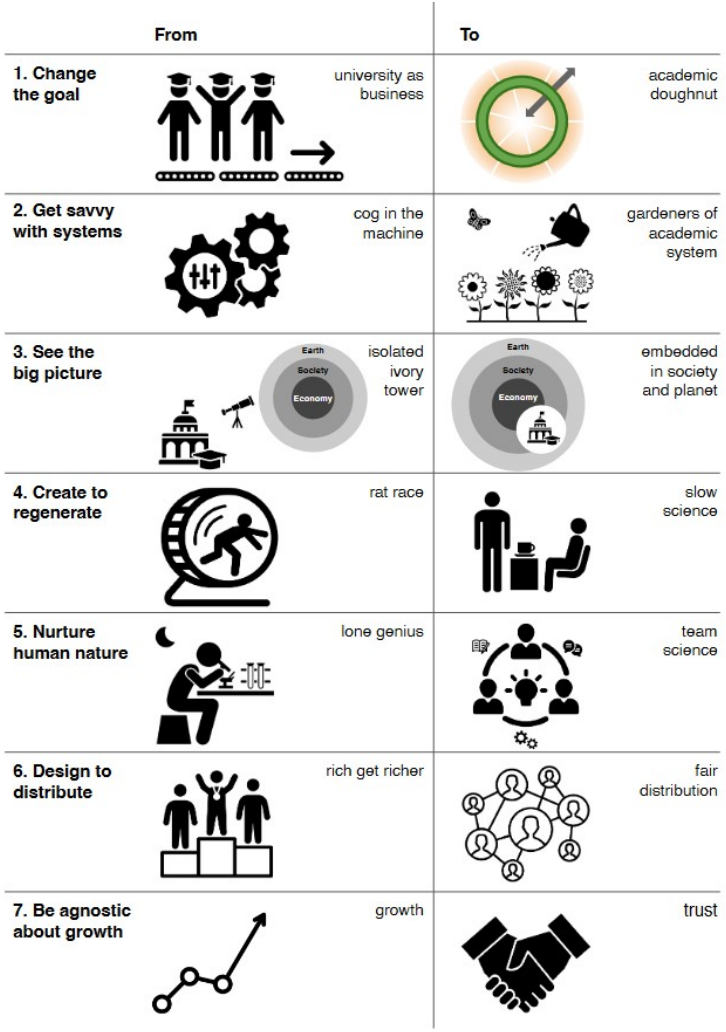
ALLEA report, 2022

In France



De Paeppe et al., 2023

Some avenues for deeper changes



→ Question research **collaboration with industry**

→ Question our **funding** system ? **Our methods and impacts** ?

→**Engage** publicly in the **media**, support some **NGOs** or citizen organization ?
Shift research focus towards **solutions** to the crisis ?

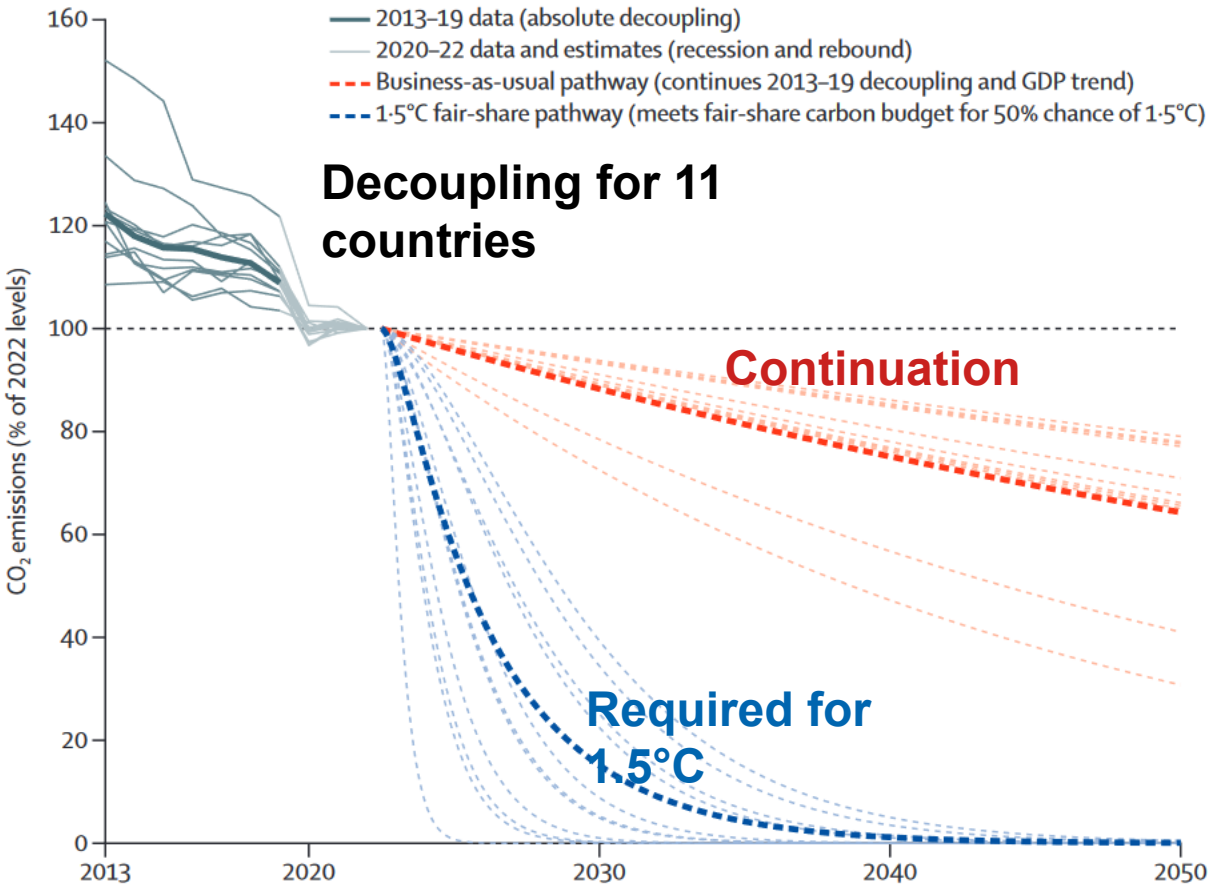
→ **Drop the competition to retrieve time** ?

→ Set up / **Join transdisciplinary projects** with social scientists ? Less machine but more HR on projects ?

→Change our way to research and **collaborate with** scientist from the **Global South** ? **Relocate** your fieldwork ?

Urai and Kelly, 2023

What about green growth ?



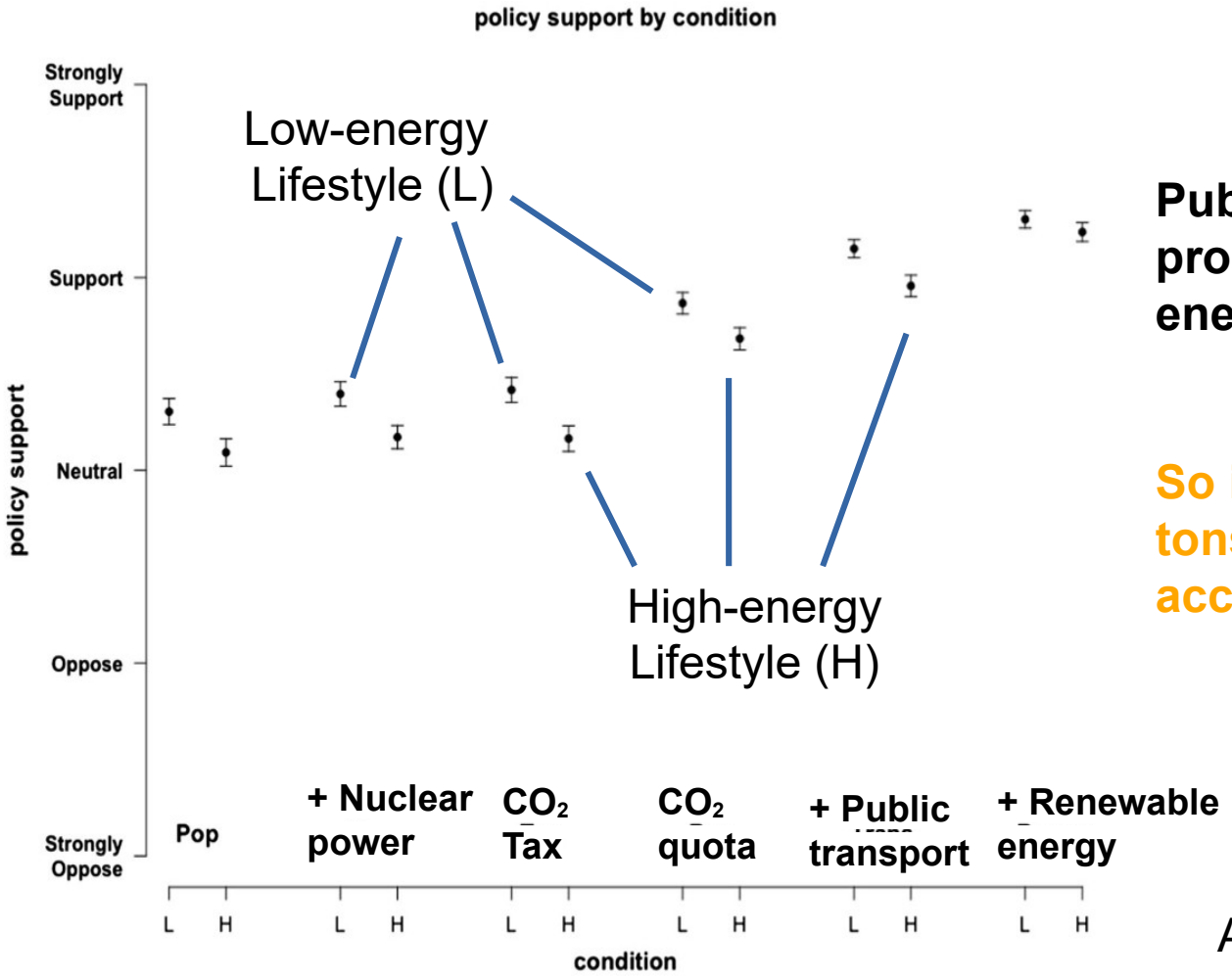
Scrutinizing 36 High Income Countries

11 reported absolute decoupling : Increasing GDP + decreasing CO2

« Green » growth :
-- Only observed in 11 countries
-- Does not decrease emissions fast enough to limit climate change.

Vogel and Hickel, 2023

Exemplarity is key for (Geo-)scientists



Public agree more with policies proposed by scientists with a low energy lifestyle !

So it's not just about saving some tons of CO_2, it's about accelerating society changes.

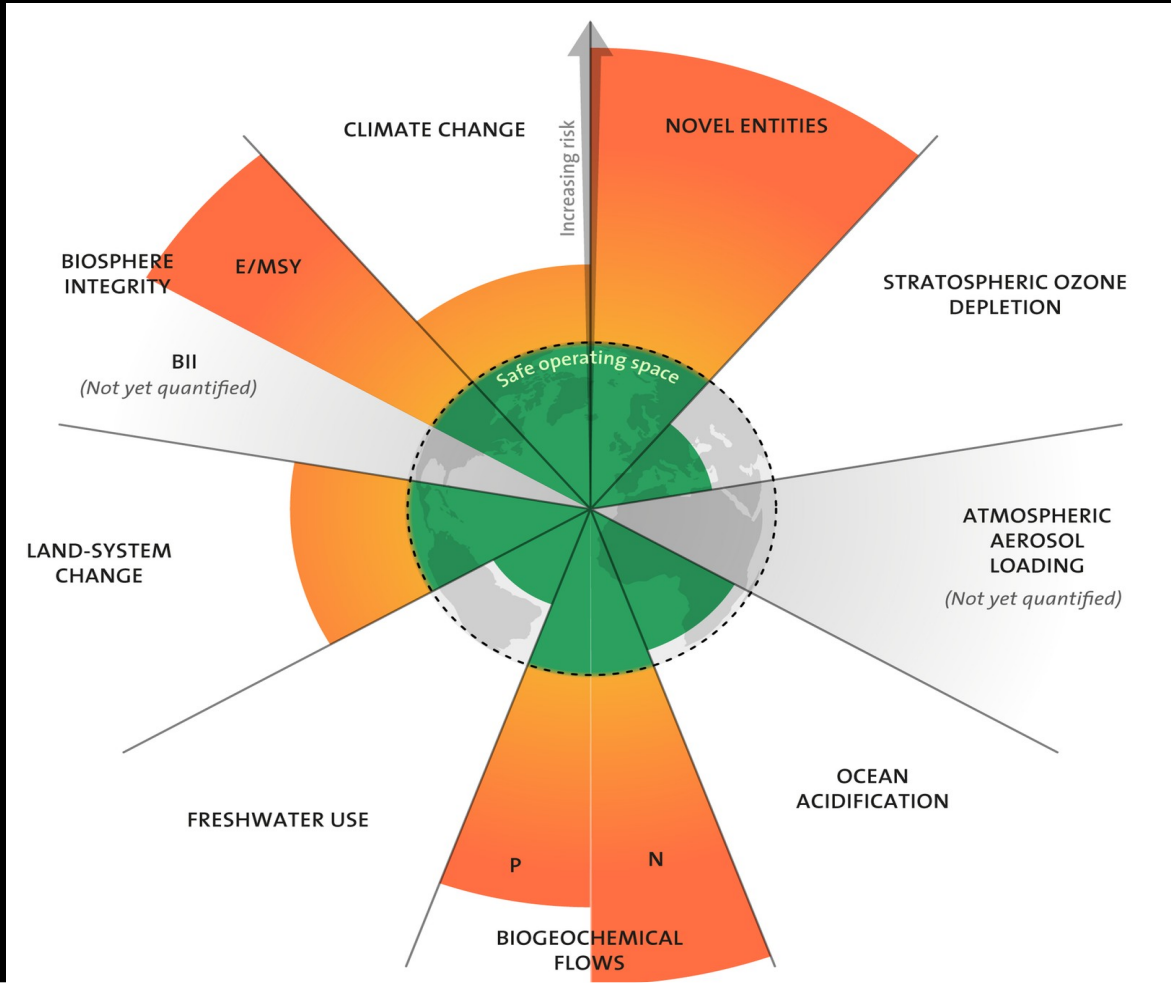
Attari et al., 2016, 2019

A systemic crisis can't be solve only with techno-fixes

"Miracle" solutions?
geo-engineering, carbon capture hydrogen, nuclear power (breeder generator, fusion)

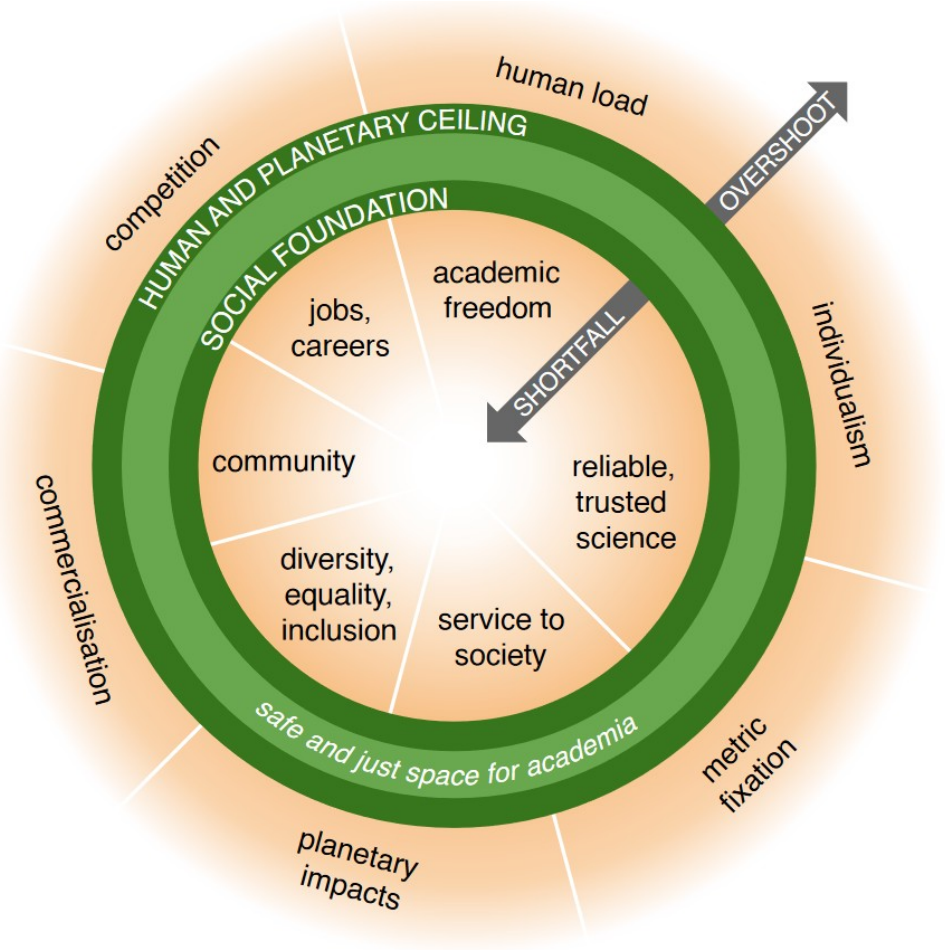
Major problems
- deployment time
- sustainability (limited reserves of uranium, oil or metals)

Sectoral not systemic approach
- increases pressure on other planetary limits...



Sources: Rockström et al. (2009), Hillebrand et al. (2020) d'après Wang-Erlandsson et al. (2022) et https://bonpote.com

Reflecting on the needs and limits to science



Urai and Kelly, 2023

From belief to action: What you can start today !

Reflecting on our academic and professional goal an values, we must carve out time (putting aside some « bullshit work ») to focus on other contributions :

→ Secure **1 hour per week**, and **try to grow** this to what is effective/manageable

→ Set up a **reading group to discuss key papers** on the crisis, its causes and solutions, the role of academics

→ **Add some slides on the climate and biodiversity crisis** in your talks or lectures, to open up new conversations.

→ **Join (set up) a sustainability community at your university / institute**

→ **Join** a local, national or academic **climate action group** (e.g., Scientists4Future, Scientist Rebellion, Faculty for a Future, …)

Urai and Kelly, 2023

Same approach for other infrastructures

IODP (International Ocean Drilling/Discovery Program)

Joides Resolution, 140m long ship.
Performing 85 % of all missions **between 2013 and 2023** :
33 t of fuel/day of **transit (735 days, 21%)**
17 t of fuel/ day of **station (1914 days, 50%)**
7 t fuel/day at **harbour (1007 days, 30%)**

Total fuel : 24 k tCO2e/ yr

+15 % for the Ecord/Chikyu mission (no info)
→ 28.4 ktCO2e/yr
Flights to join the expedition : ~1 ktCO2e / yr extra.

Bibliographic search for GET :
0.085 % Global share = 25 tCO2/yr

Marc et al.,
PLOS Str, in revision