Changing the world of research based on solid measurements

Labos 1point5: Reducing the environmental footprint of our research activities

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ICHEP 2024 — Prague
19 July 2024

cnrs NUCLÉAIRE & PARTICULES

Labos 1point5

amU Aix Marseille Université

EN 2023, LE CPPM CÉLÈBRE SES 40 ANS
40
CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE
CPPM
AU CŒUR DE LA MATIÈRE ET DE L'UNIVERS

What is Labos 1point5?

1) A grassroot collective action « to understand and reduce the environmental footprint of research » :

- Created in March 2019
  - (op-ed in French leading newspaper *Le Monde* & website with call for participation)
- Network of people, labs and initiatives
- ~4000 following our work


«Face à l'urgence climatique, les scientifiques doivent réduire leur impact sur l'environnement»

Un collectif de chercheurs de diverses disciplines, Labos 1point5, s'est créé pour promouvoir des pratiques de recherche plus sobres et construire une autre éthique de la recherche.

Publié le 19 mars 2019 à 06h00, mis à jour le 19 mars 2019 à 10h33 | Lecture 4 min.

2) A research project called GdR (Groupement de Recherche)

- Created in November 2021
- ~250 participating in research activities (all genders, disciplines, ages)
- Develop tools to help labs to change their practices
- Scientific publications on the evaluation and analysis of research carbon footprint

https://labos1point5.org/

The « principles » of Labos 1point5

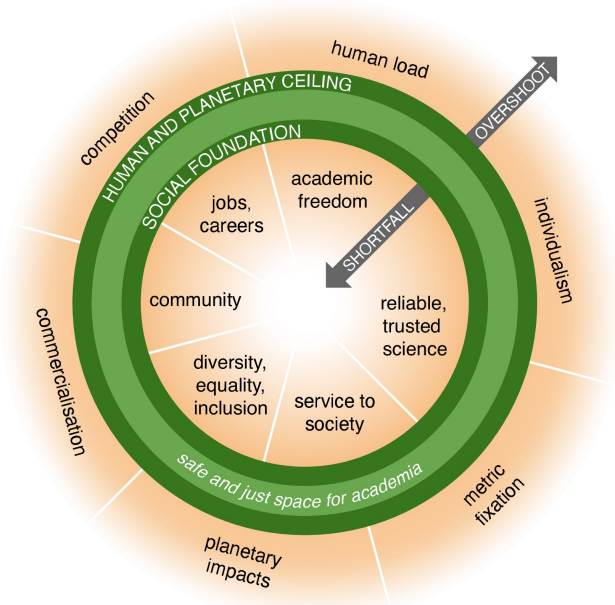
- Essential to quantify and understand the carbon footprint of research, its determinants, uncertainties and heterogeneity
- Implementing locally designed and deliberated solutions in research laboratories, to re-appropriate our labs as decision-making places

GdR

- Organize reflexive work on the coherence, responsibility and ethics of research in relation to the low-carbon transformation of our societies (carbon emissions main but not only focus)

→ **Reinventing a way of doing research compatible with planetary boundaries**

(keeping in mind that fundamental/physics research may not be considered essential to a society in crisis...)

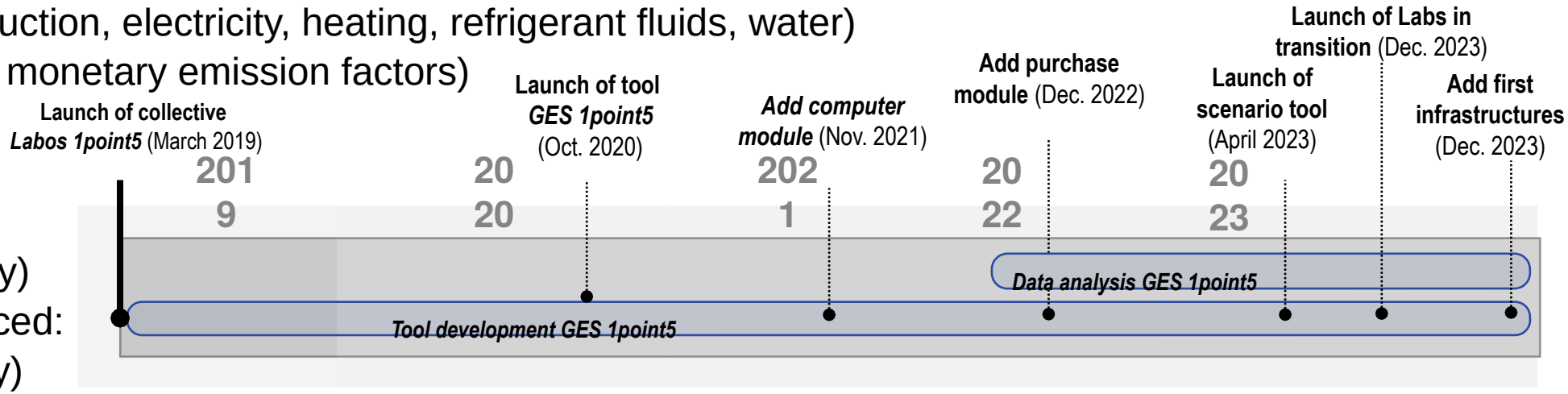


Urai&Kelly (2023)

GES 1point5: a tool to measure the carbon footprint of laboratories

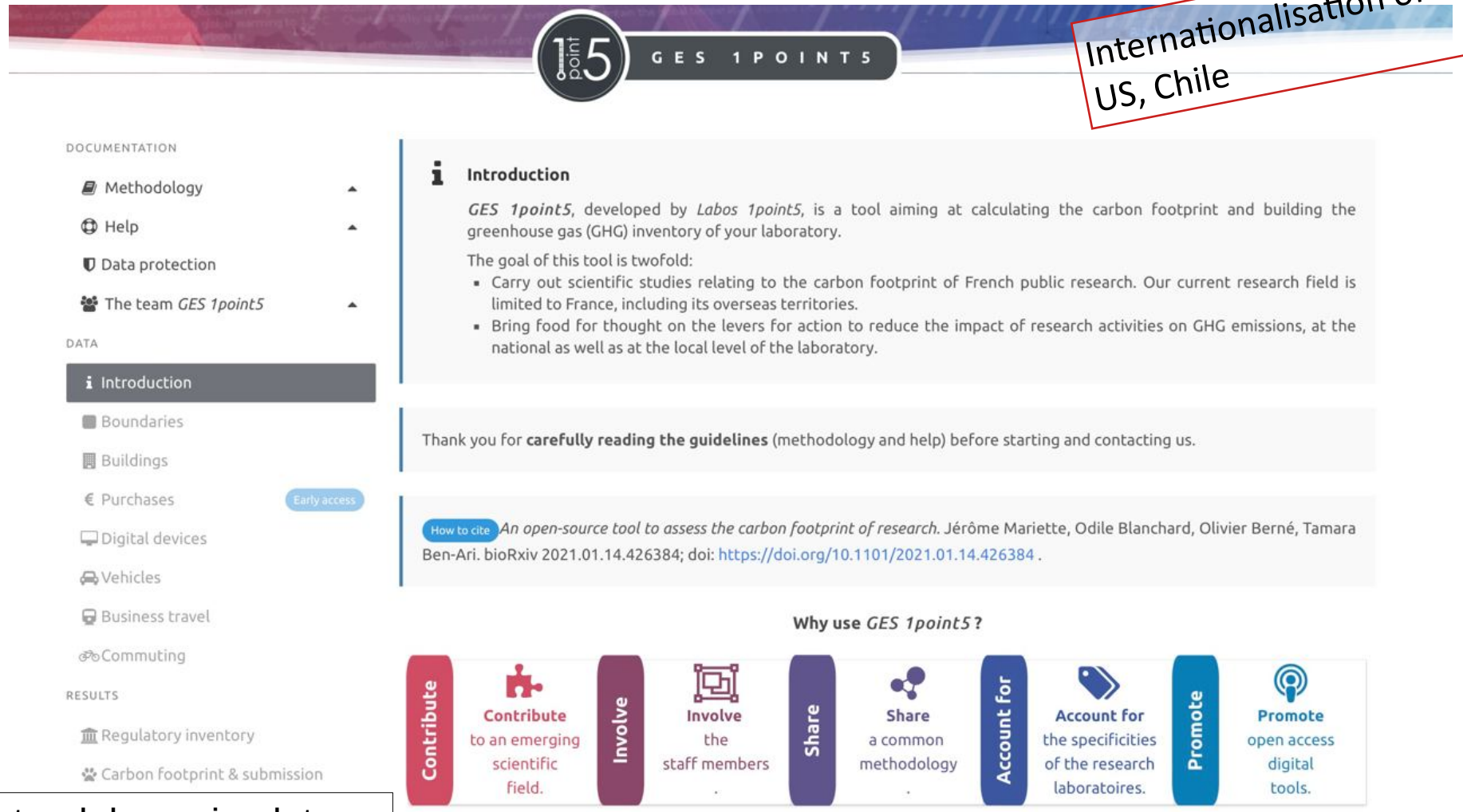
- GES 1point5:
  - 1 free, open source & online tool to carry out GHG inventory of laboratories
  - 1 methodology
  - 1 GHG inventory = 1 year & 1 laboratory
  - Recommended by

- Emissions categories:
  - Buildings (construction, electricity, heating, refrigerant fluids, water)
  - Purchases (from monetary emission factors)
  - Digital devices
  - Lab vehicles
  - Business travels
  - Commute (survey)
  - Recently introduced:
    - Food (survey)
    - **Research infrastructures** (CERN, GENCI [HPC], astronomical observatories)
    - Research farming activities (fertilisers, livestock)
    - More to come soon (WLCG?)



Huge diversity, tricky metric choice

GES 1point5: a free and online tool



Internationalisation of tools:
US, Chile

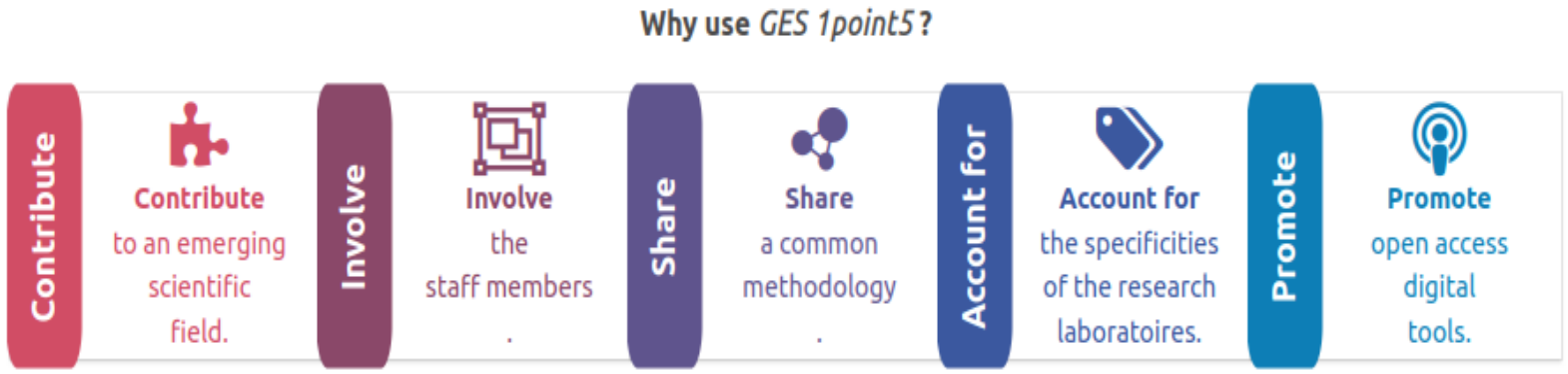
J. Mariette et al 2022
An open-source tool to assess the carbon footprint of research
Environ. Res.: Infrastruct. Sustain. 2 035008

GitLab source code:
https://framagit.org/labos1point5/l1p5-vuejs

Available standalone simulators:
- commute
- travels
- food

Anonymous usage possible, English available, give it a try:
https://apps.labos1point5.org/ges-1point5

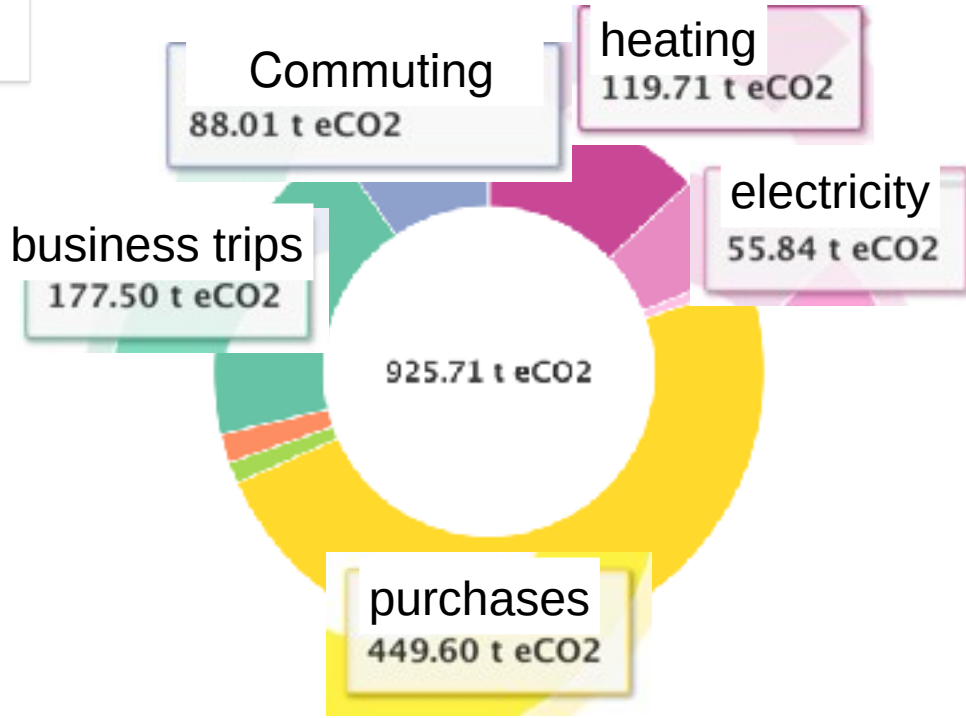
GES 1point5, a tool for GHG assessment and analysis



- High adoption rate and increasing
- Already ~1300 labs (out of ~ 2000 labs/UMR) and >2600 GHG inventories

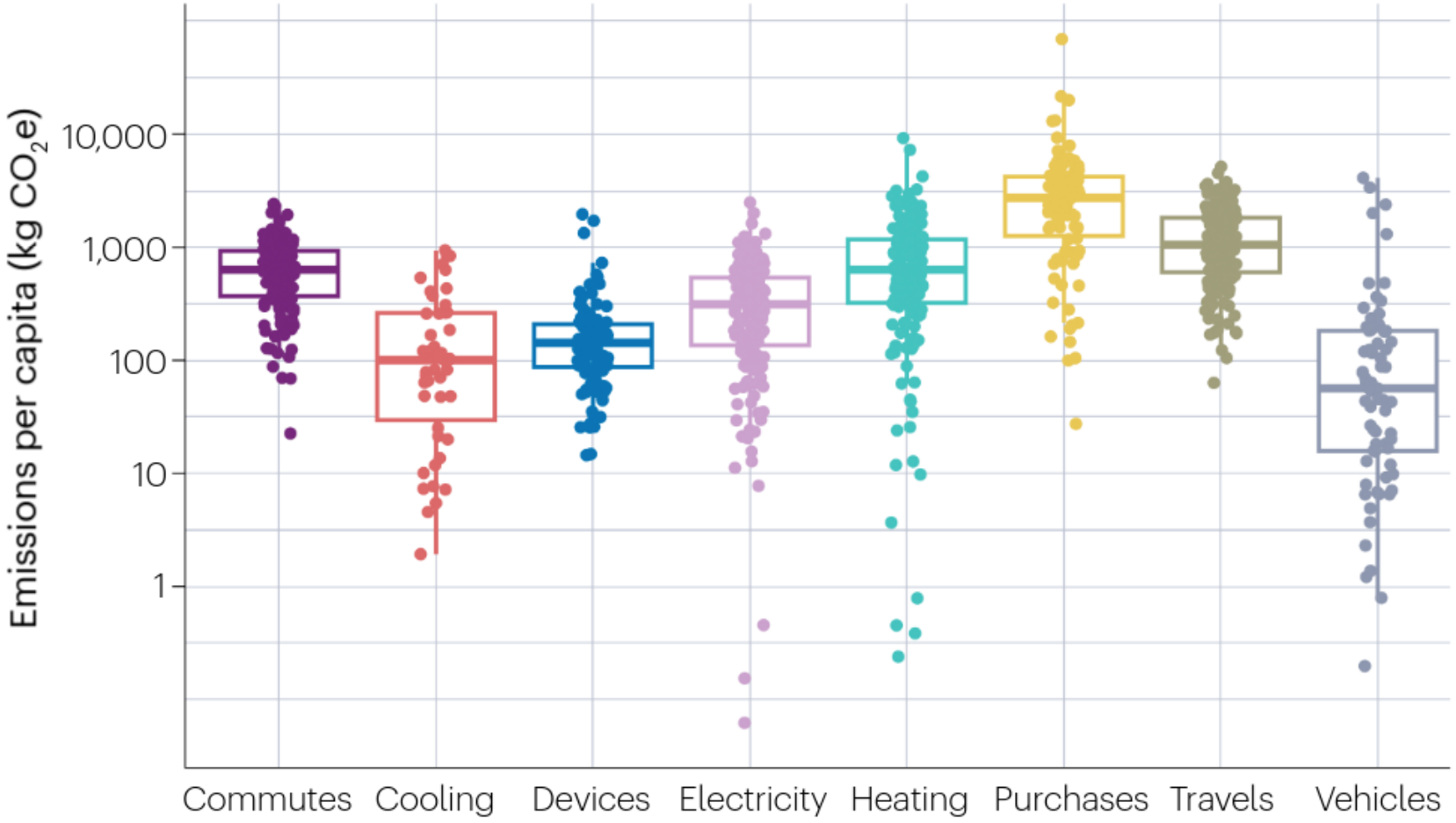
- Several papers out already [list], e.g. (see backup):
  - Travels: *Flight quotas outperform focused mitigation strategies in reducing the carbon footprint of academic travel*
    [Tamara Ben-Ari et al 2024 Environ. Res. Lett. 19 054008]
    [EarthArXiv]
  - Procurement: *Purchases dominate the carbon footprint of research laboratories* [bioArXiv]

Estimation of the annual carbon footprint of a fictive laboratory



https://apps.labos1point5.org/ges-1point5

Distribution of the carbon footprint of laboratories



- Year 2019 (~150 labs)
- Validated reports
- Heterogeneity between laboratories
  - But French HEP labs (IN2P3) rather homogeneous
- Purchases (40%) and travels (25%) dominate lab footprint
- Research infrastructures not included

~1000 t CO2e / year per lab
~7,3 t CO2e/year per capita
~1 250 000 t for the whole sector

[T. Ben-Ari, *How research can steer academia towards a low-carbon future,* Nat Rev Phys 5, 551–552 (2023)]

CERN: Splitting the impact among users

- Non trivial given the available inputs (CERN's environment reports, reporting evolving with time)
  - Share of accelerators?
  - Fair share of LHC emissions between experiments and users?
  - How to split Scope 3?
- Account for LHC construction and tunnel?
  - Choice to ignore them (details in backup)
    - Philosophically not crazy: what matters today is new emissions
    - But important to ***keep it in mind for future infrastructures***
- Count only physicists, or also technicians, engineers, etc?
  - Share it among the physicists using CERN (CERN's goal is to provide them with data)
  - Well known numbers, by CERN and labs → PhD student, post-doc, staff on 31st Dec (details in backup)
    - Taken from CERN Annual Personnel Statistics in CDS
- **In the end, keep it simple for GES 1point5 users**

CERN emissions (from environmental reports)

https://hse.cern/environment-report-2021-2022/emissions

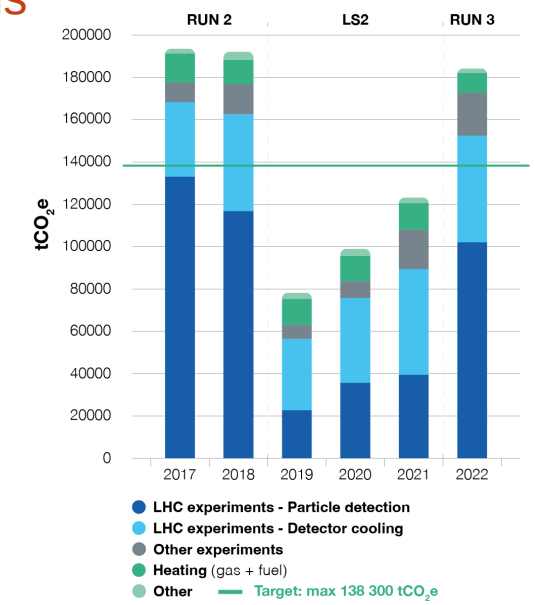
- **Scope 1**
  - LHC: Particle detection, detector cooling
  - Non-LHC: other experiments
  - All users: heating, “others”

1		2017	2018	2019	2020	2021	2022
2	**Runs**	Run 2	Run 2	LS2	LS2	LS2	Run 3
38	scope 1 LHC/user	18.35	17.51	6.04	8.80	10.74	17.53
39	scope 1 nonLHC/user	2.98	4.30	2.22	2.83	6.45	6.44
40	scope 1 any	1.29	1.21	1.21	1.34	1.37	0.96

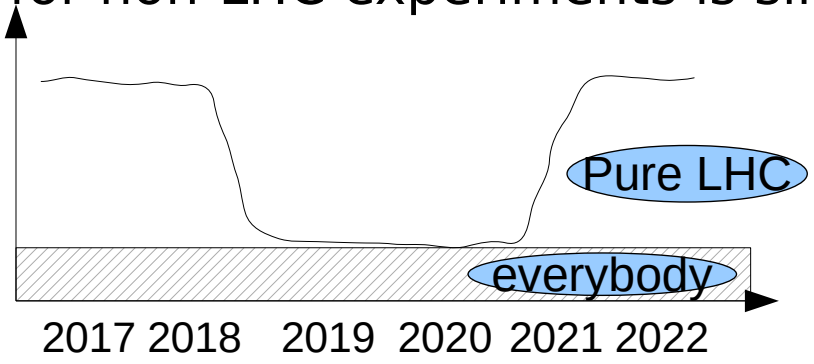
18.35t/phys (for LHC experiment users)

2.98t/phys (for non-LHC experiment users)

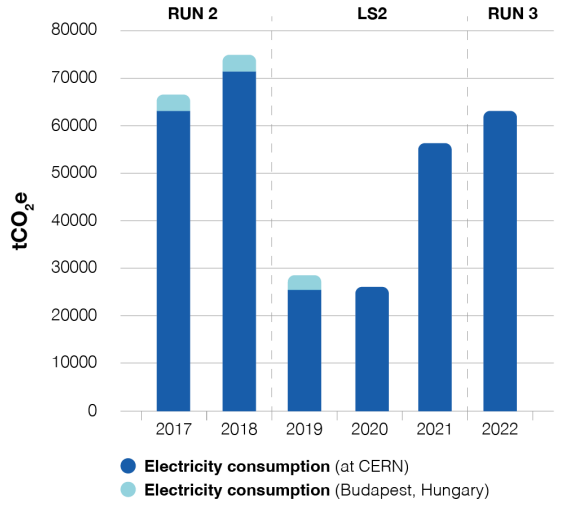
+ 1.29t/phys (LHC or non-LHC)



- **Scope 2 (mostly electricity)**
  - Hypothesis: during shutdown electric consumption per physicist for non-LHC experiments is similar to LHC physicist consumption

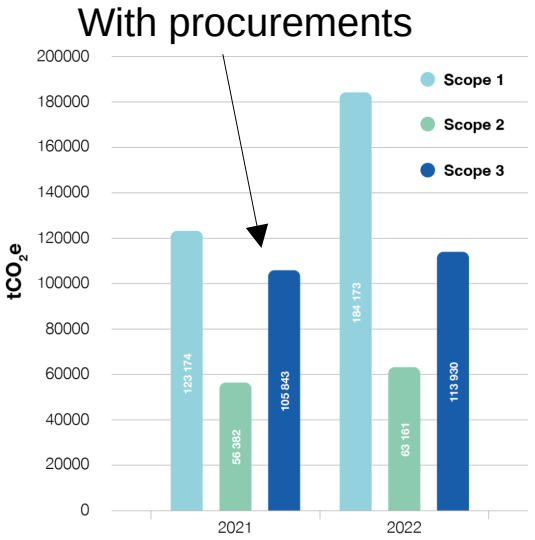


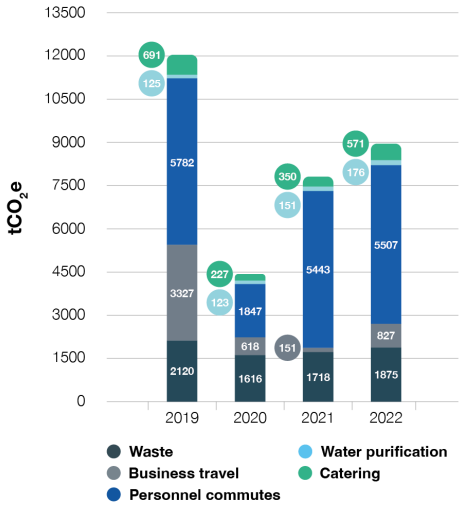
Numbers retroactively increased (2017-2020) in latest report 2021-2022



CERN emissions

- **Scope 3**
  - Fully available (incl. procurement) for 2021-2022
    → assumptions for previous years
    - 2017-2018: 2022 running conditions for waste and water, pre-covid conditions (2019) for travel, commute and catering
    - 2017-2020: adding 2021-2022 average of procurement





- **Uncertainties**
  - Methodology: comparaison between two methods (affecting everything to LHC users or not):
    - LHC: [15, 27%] → 30%
    - Non-LHC : [10,16%] → 20%
  - Emission factors: (from GES 1point5)
    - Gases : 30%
    - Electricity (FR): 10%

CERN emissions

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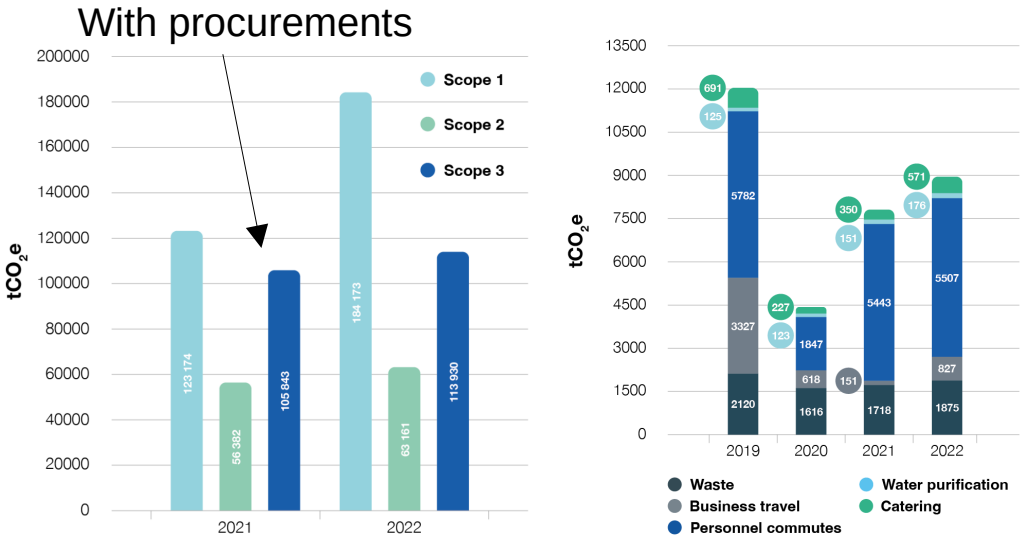

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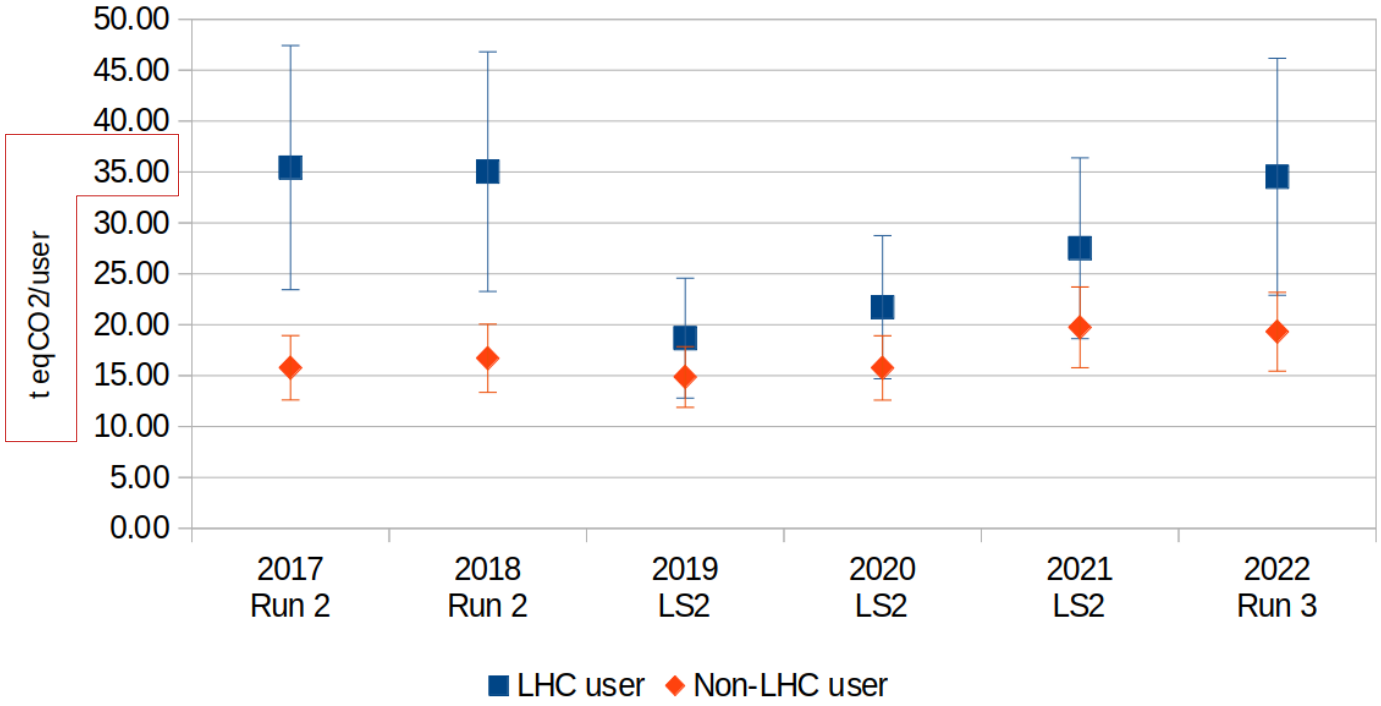
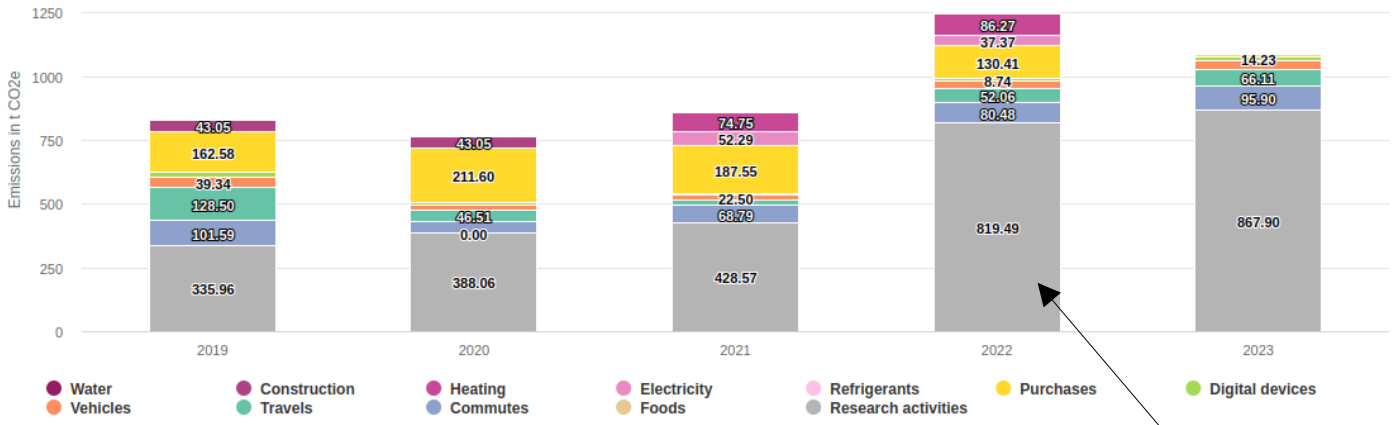


Single lab example: LPCA

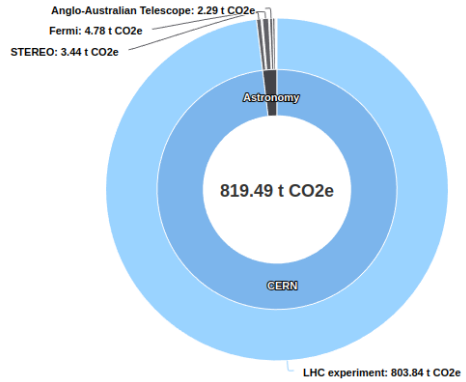


Just a single number to be provided:

- Number of LHC users that year

	Category	Type	Sub-type	Amount	Unit
	Research facilities	CERN	LHC experiment	32	User(s)
	Research facilities	Astronomy	STEREO, TESS, GAIA, GALEX, WISE...		Utilisation
	Research facilities	Astronomy	STEREO	0.1	% facility usage
	Research facilities	Astronomy	TESS	0.01	% facility usage
	Research facilities	Astronomy	GAIA	0.01	% facility usage
	Research facilities	Astronomy	GALEX	0.02	% facility usage
	Research facilities	Astronomy	WISE	0.01	% facility usage
	Research facilities	Astronomy	HST	0.01	% facility usage
	Research facilities	Astronomy	SWIFT	0.01	% facility usage
	Research facilities	Astronomy	Fermi	0.04	% facility usage
	Research facilities	Astronomy	Pic-du-Midi Observatory	2.74	% facility usage
	Research facilities	Astronomy	Anglo-Australian Telescope	0.06	% facility usage
	Research facilities	Astronomy	VLT (Paranal)	0.01	% facility usage
	Research facilities	Astronomy	GTC	0.09	% facility usage
	Research facilities	Astronomy	TAROT	2	% facility usage
	Research facilities	Astronomy	VLA	0.01	% facility usage

10 persons



CERN

Figure : *Carbon footprint of laboratory research activities separated by their types.*

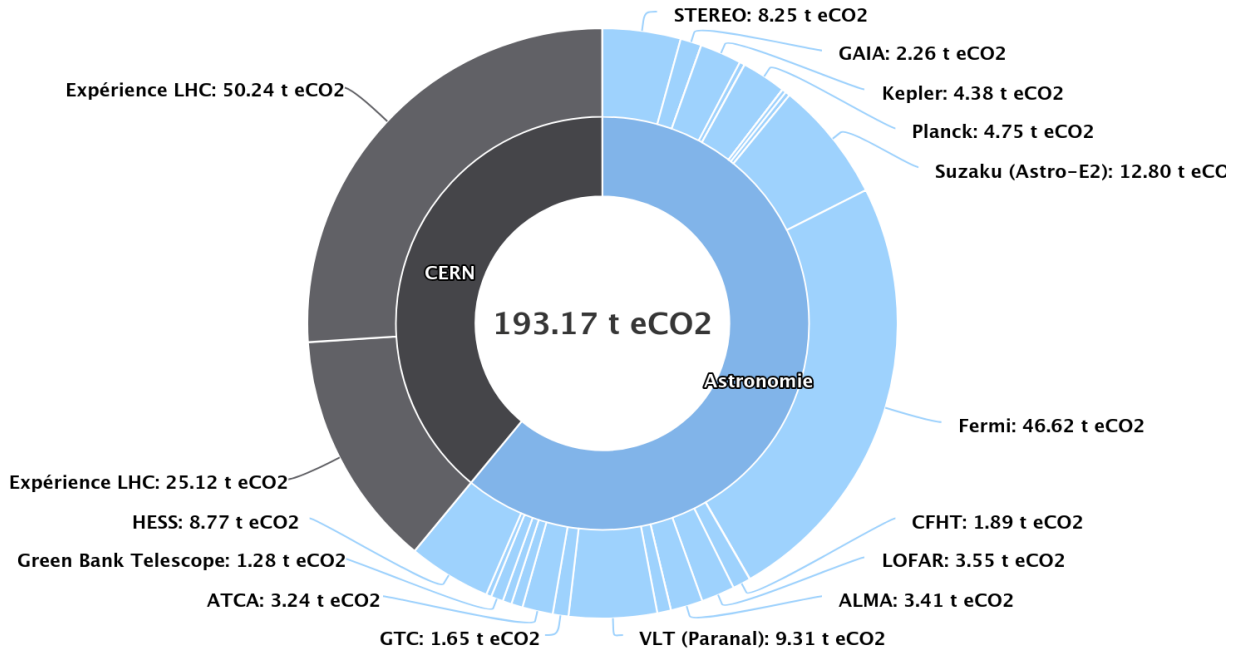
Type of research activity	Emissions (t CO2e)	Share of the research activity footprint
CERN	803.84 ± 297.42	98 %
Astronomy	15.64 ± 12.52	2 %

Astronomy

- Takes into account telescopes (in space and on Earth) used in laboratory's publications
- Easy to use: just provide lab's name
- Emissions attributed with ratio of *lab authors who published articles citing infrastructure* and *all authors in the world who published articles citing the same infrastructure*
- Amortisation: 38 years for telescopes and 18 years for satellites
- Bibliometric data extracted from ADS
- Does not include yet recent infrastructures like Euclid, CTA, LSST, etc.
- Ref : arXiv: 2201.08748 [astro-ph.IM]

$$EC_{\text{infra}} = \frac{GES_{\text{construction}}}{\text{amortissement}} + GES_{\text{opérations}}$$

$$EC_{\text{labo}} = \sum_i \left(EC_{\text{infra}_i} \times \%\text{utilisation}^{\text{labo}}_{\text{infra}_i} \right)$$

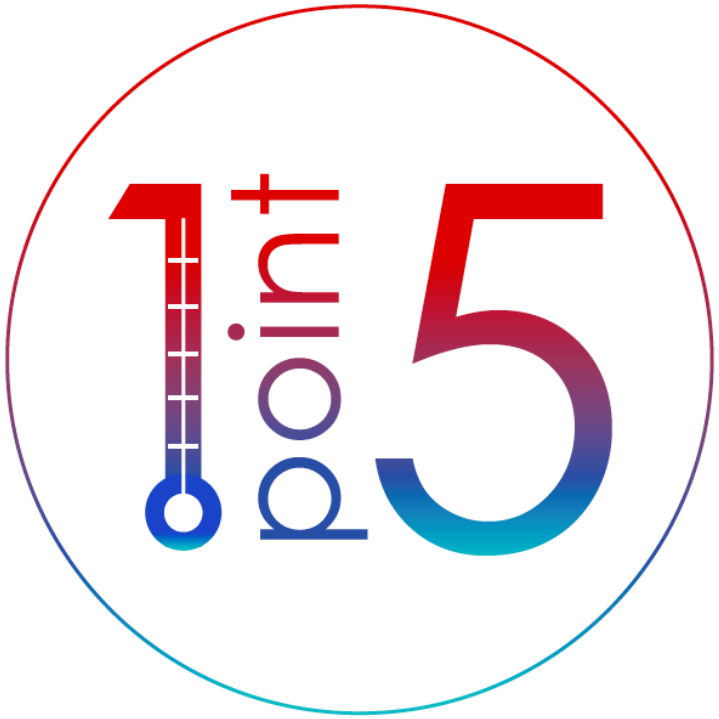


CPPM (fake LHC to see astro)

Conclusion

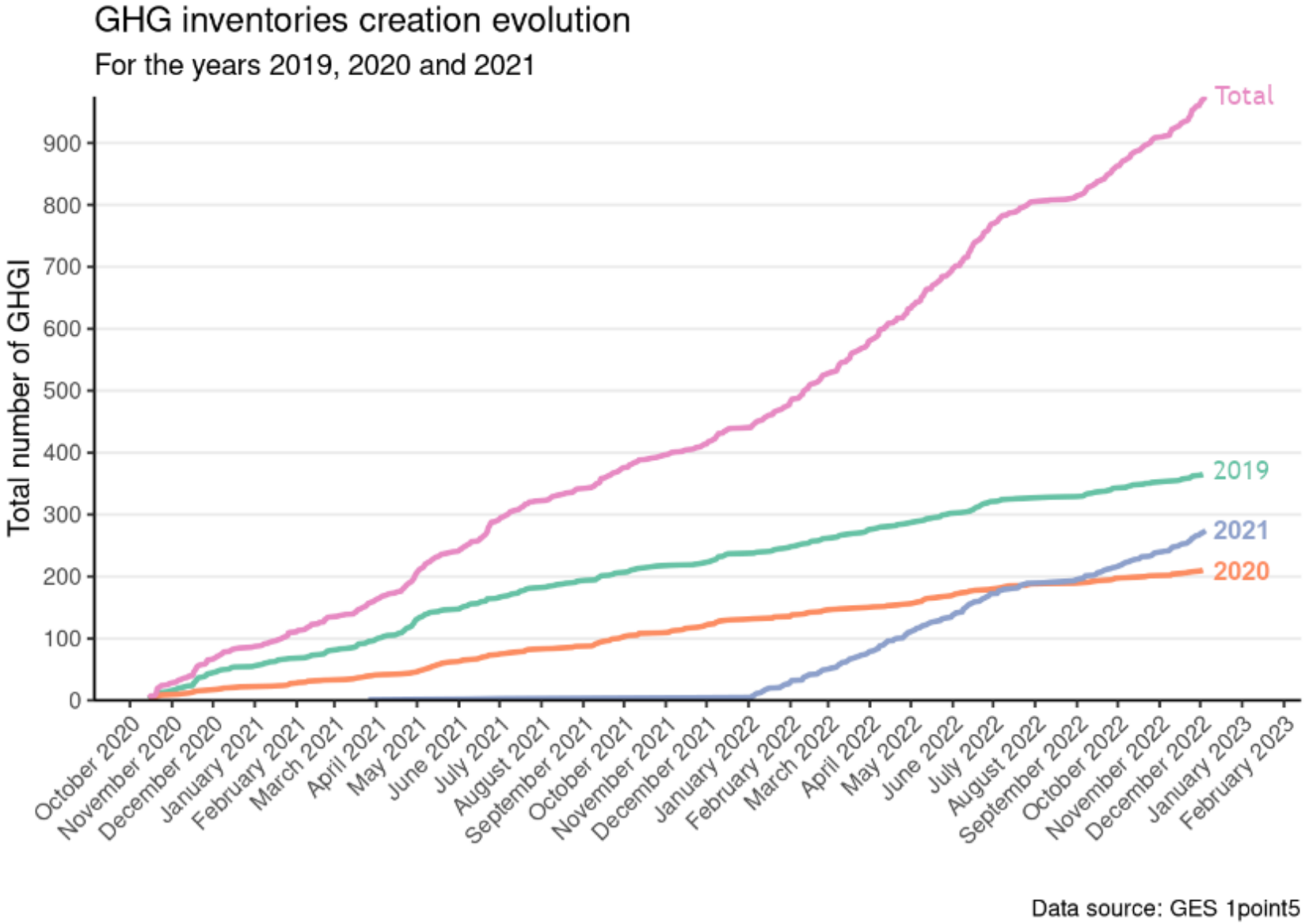
- French research community got together in Labos 1point5 to tackle climate change:
  - All research areas involved
  - Started as grassroot initiative, now supported officially and encouraged by hierachy and funding agencies
  - Provides tools, methods, webinars, scientific papers, etc
- First step: standardised GHG emissions for all labs with single tool: GES 1point5
- Large database to analyse structure of research emissions:
  - Importance of purchases
  - Impact of various scenarios on travel emissions
  - Sizeable impact of big research infrastructures
    - Includes already astronomy, CERN, national computing center

- From this knowledge, **call for action**
  - Labs designing GHG emission reduction plans (goal: -50% by 2030), simulating impact with Scenario 1point5
  - Sharing experience with Transition 1point5



https://labos1point5.org/

Footprint: GES 1point5 as a GHG common base



- High adoption rate and increasing
- Already >1200 labs

(out of ~ 2000 labs/UMR) and >2500 GHG inventories

[J. Mariette et al (2022)]

CERN: Splitting the impact among users

- Non trivial given the available inputs (CERN's environment reports, reporting evolving with time)
  - Share of accelerators?
    - No accelerator = no physics in detectors
  - Fair share of LHC emissions:
    - ¼ per experiment? By number of physicists? By integrated luminosity? By construction cost?
  - Scope 3 not available with experiment split → how to share?
- Account for LHC construction?
  - Estimated as much smaller than yearly usage → choice to ignore it (details in backup)
    - Philosophically not crazy: what matters today is new emissions
    - But important to keep it in mind for future infrastructures
- Account for tunnel construction? → choice to ignore it (already there from LEP)
- Average over data-taking and Long Shutdown years or accept yearly variations?
- Count only physicists, or also technicians, engineers, etc?
  - Share it among the physicists using CERN (CERN's goal is to provide them data)
  - Well known numbers, by CERN and labs → PhD student, post-doc, staff on 31st Dec (details in backup)
    - Taken from CERN Annual Personnel Statistics in CDS
- **In the end, keep it simple for GES 1point5 users**

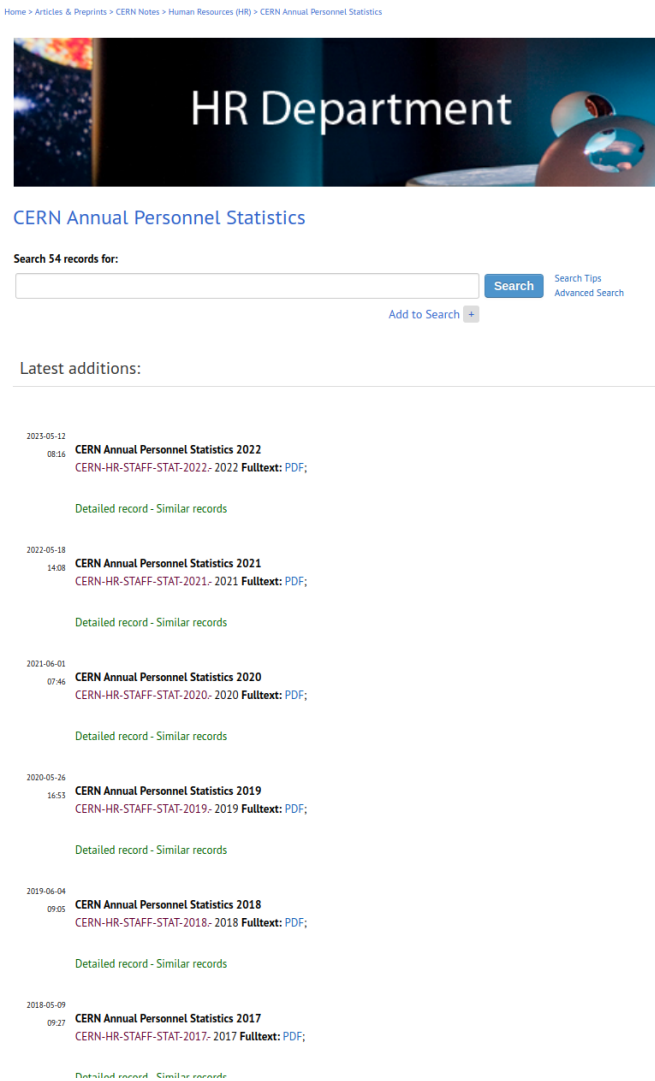
Backup

- Numbers from graph on slide 11

			2017	2018	2019	2020	2021	2022		
55										
56			Run 2	Run 2	LS2	LS2	LS2	Run 3		
57	**FE t/user (LHC)**		**35.43**	**35.04**	**18.68**	**21.72**	**27.51**	**34.53**	divide all 3 scopes	
58		30%	10.63	10.51	5.60	6.52	8.25	10.36	methodology	
59		30%	5.51	5.25	1.81	2.64	3.22	5.26	gases	
60		10%	0.65	0.73	0.23	0.23	0.59	0.64	electricity	
61	**total uncertainty**		**11.99**	**11.77**	**5.89**	**7.03**	**8.88**	**11.64**		
62										
63	**FE t/user (exp non-LHC)**		**15.77**	**16.70**	**14.86**	**15.75**	**19.74**	**19.31**		
64		20%	3.15	3.34	2.97	3.15	3.95	3.86	methodology	
65		10%	0.22	0.22	0.23	0.23	0.24	0.23	electricity	
66	**total uncertainty**		**3.16**	**3.35**	**2.98**	**3.16**	**3.96**	**3.87**		

CERN personnel statistics

- How to distribute the footprint?
  - Share it among the physicists using CERN
    - CERN's goal is to provide them data
    - Well known numbers, by CERN and labs
    - PhD student, post-doc, staff on 31st Dec
  - CERN Annual Personnel Statistics in CDS



		2017	2018	2019	2020	2021	2022
2	**Runs**	Run 2	Run 2	LS2	LS2	LS2	Run 3
3	**Users CERN (31-déc.)**	**12236**	**12569**	**12428**	**11399**	**11175**	**11860**
4	Atlas	3912	3971	3983	3699	3517	3580
5	CMS	3076	3092	3055	2862	2749	2940
6	Alice	1314	1320	1329	1180	1159	1208
7	LHCb	870	913	946	887	910	959
8	**->Exp LHC**	**9172**	**9296**	**9313**	**8628**	**8335**	**8687**
9		74,96%	73,96%	74,94%	75,69%	74,59%	73,25%
10	LHC	78					
11	SPS	733	745	718	676	695	711
12	PS	219	229	204	179	177	221
13	**-> Acc**	1030	974	922	855	872	932
14		8,42%	7,75%	7,42%	7,50%	7,80%	7,86%
15	**--> Autres Expe**	**2034**	**2299**	**2193**	**1916**	**1968**	**2241**

LHC experiment users

Accelerator sector
→ added to "other experiments"

Other-experiment users

Construction of LHC

- Not clear how to handle it
  - Tunnel already existing (LEP)
  - Amortisation period (how long?) or single shot at construction time?
  - How to take into account the upgrades ?

- Order of magnitude

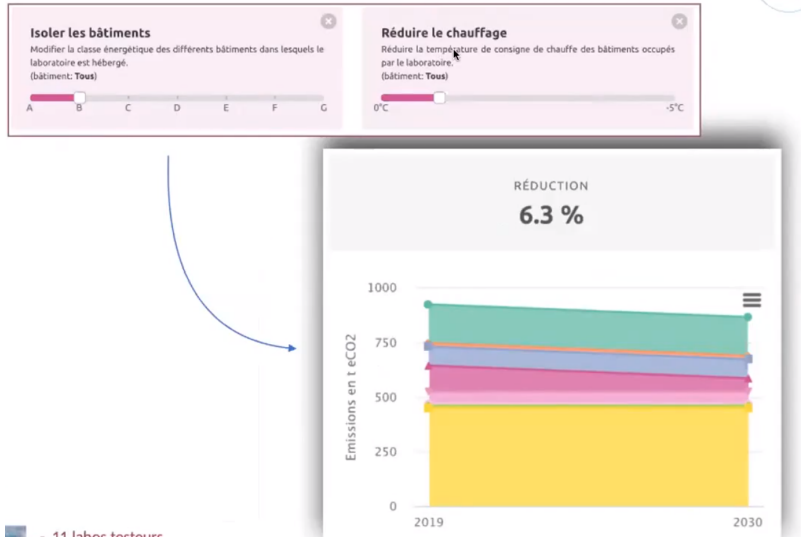
12	cost:	4.50E+09	euros	LHC+4 experiments (CHF=euros)	
13	years:	2008	2040	32	years
14				1.41E+08	euros/year
15	EF:	0.3	kg/euros		
16	Co2eq:	4.22E+04	tonnes		
17	physicists:	8600			
18		4.91	t/phys		

→ Much smaller than yearly usage → choice to **ignore** it

- Philosophically not crazy: what matters today is new emissions
- But important to keep it in mind for future infrastructures

Implementing CERN reduction in Scenario 1point5

- Scenario 1point5: tool to evaluate impact of measure on GHG emissions by 2030 (goal: reduce by 50%)



- Goals to include CERN emissions:
  - do not count on CERN improvements to decrease own lab emissions (e.g. "*our biggest GHG emission source is CERN, and they're going to cut back on gas, so we don't have much left to do for our 50% reduction*")
  - Raise awareness of the long-term consequences of our technological choices
  - Especially relevant with upcoming FCC discussions

- So … What will the CERN footprint be in 2030?
  - CERN plans to reduce Scope 1 by 28% (wrt/ 2018) by 2025
    → Scope 1(2018) *28% / nb of phys = -5.8t
- To be applied only if the reference year is not a Long Shutdown

Travels

Flight quotas outperform focused mitigation strategies in reducing the carbon footprint of academic travel
[T. Ben-Ari et al 2024 Environ. Res. Lett. 19 054008]

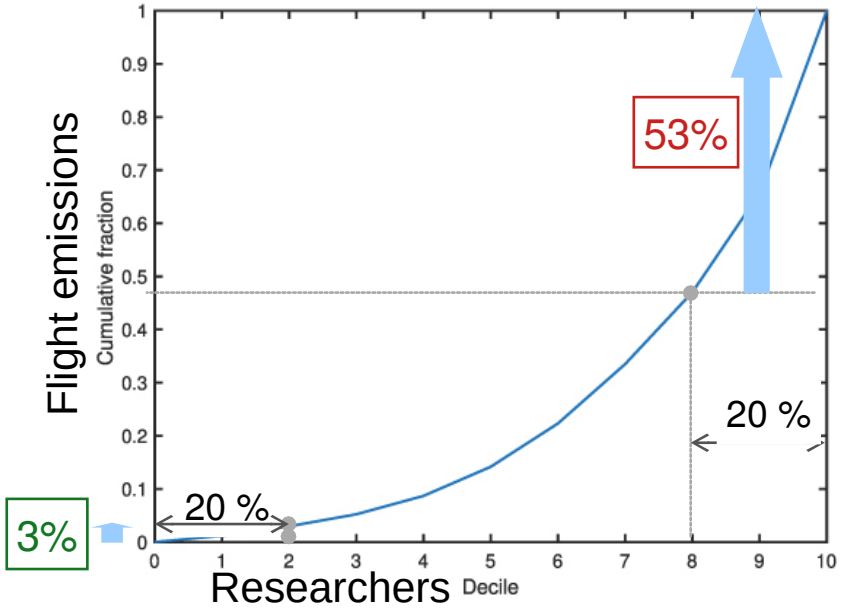
- 137k travels
- Planes ~95% of emissions
- Evaluate replacement of air travel by train
- -50% by 2030

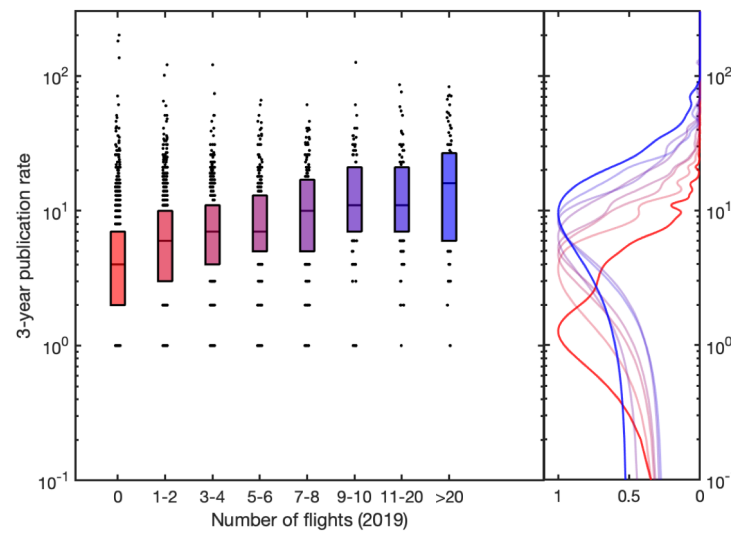
Current ministerial guideline

Minimum Allowable Distance (in distance or approximate duration) for Air Travel Clearance

Air Mileage Moderation in Quantity or Distance		No modal shift policy	375km (~2h30)	600km (~4h)	In mainland France	900km (~6h)	1000km (~6h40)	1200km (~8h)	1500km (~10h)
No moderation policy		0	0.3	3	8	12	15	18	21
Reduce air travel number for conferences	20% fewer trips	8	8	10	13	17	20	23*	26*
	50% fewer trips	19	19	21	24	27	30	32	34
	1 r. trip/3 years	14	13	14	17	18*	19*	21**	22**
	1 r. trip/4 years	18	18	19	22	22	23*	24*	23**
Reduce long–haul air travel number	20% fewer trips	13**	14**	16**	21**	26**	28**	32**	35**
	50% fewer trips	32**	33**	35**	40**	44**	47**	51**	53**
	1 r. trip/4 years	28**	28**	31**	35**	40**	43**	46**	49**
	1 r. trip/6 years	37**	38**	40**	45**	50**	52**	56**	59**
Reduce air travel mileage	20% decrease	20***	20***	22***	26***	30***	32***	34***	37***
	50% decrease	48***	49***	50***	52***	54***	56***	57***	59***
	5800km/year	38***	38***	39***	41***	42***	44***	45***	46***
	4500km/year	47***	47***	48***	50***	51***	52***	52***	53***
Reduce air travel number	20% fewer trips	19	20*	22*	25*	29*	31*	34*	36**
	50% fewer trips	48	48	49	52	54	55	57*	58*
	1 r. trip/year	36*	36*	33	32*	29*	28**	27**	27***
	1 r. trip/2 years	61	61	58	57	51*	50*	46*	44**

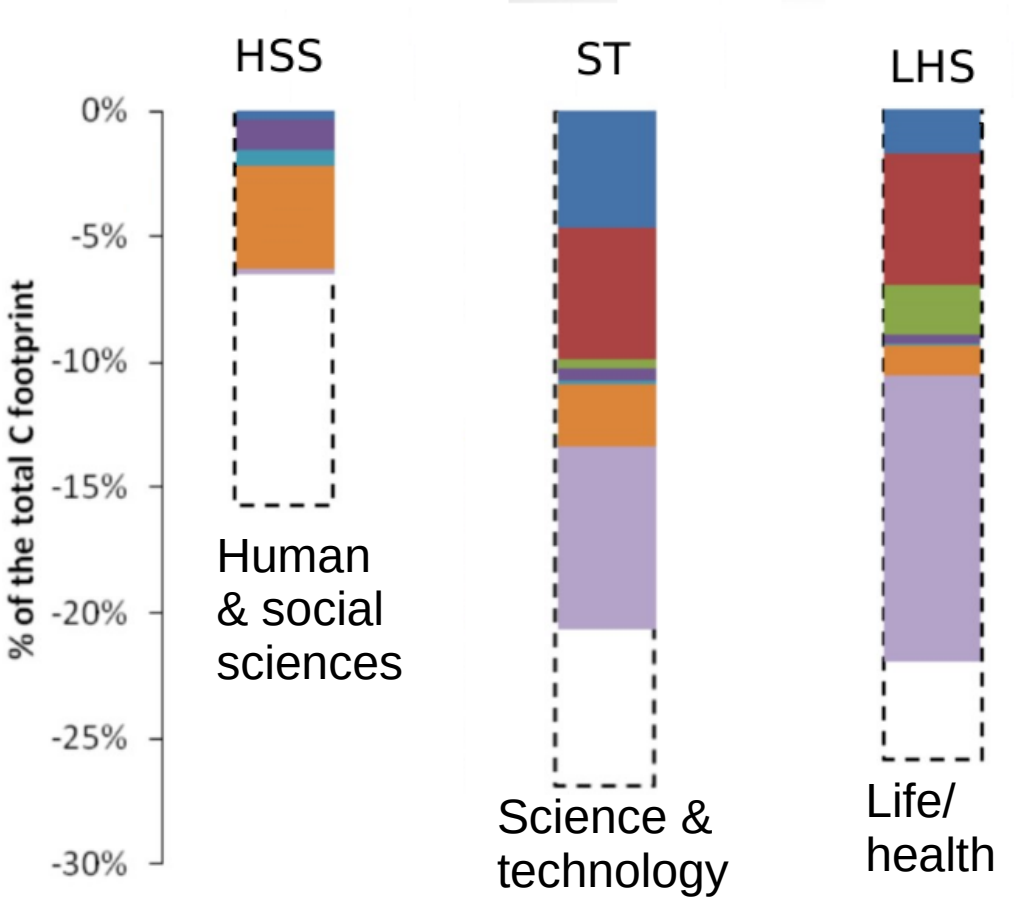
The carbon footprint of scientific visibility
[O. Berné et al 2022 Environ. Res. Lett. 17 124008]





Procurement

- Difficult to quantify properly
- Using monetary emission factors:
  - Good for large-scale orders of magnitude
  - Tricky at smaller scales
  - Large uncertainties



- Relies on French procurement system with ~250 categories (Nacres)
  - Single EF per category
- Serious limitation
  - "good" practice costs more → "more" emissions

MS1	+ 50% of equipment time
MS2	50% pooling equipment
MS3	Replace 80% of plastic by glass
MS4	75% vegetarian catering
MS5	- 50% in furniture
MS6	- 50% in computing purchases
MS7	- 50% in consumable purchases

Purchases dominate the carbon footprint of research laboratories [bioArXiv]

Demand-based strategies can achieve a 20% reduction in the total footprint (-40% in the purchasing footprint).