# A sustainable future in High-Energy physics

What do (or should) HEP, Astro and Nuclear organisations do to minimise their footprint?

- **A tour of the report** [HECAP+, to appear in JINST, arXiv:2306.02837]
- **Including some recommendations, from the report**
- **And some statements for discussion, which are mine**

On behalf of the Sustainable HECAP+ initiative

[muted]

–Patrick Koppenburg
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Nikhef

# I declare my interests


Sustainable HECAP+ Initiative

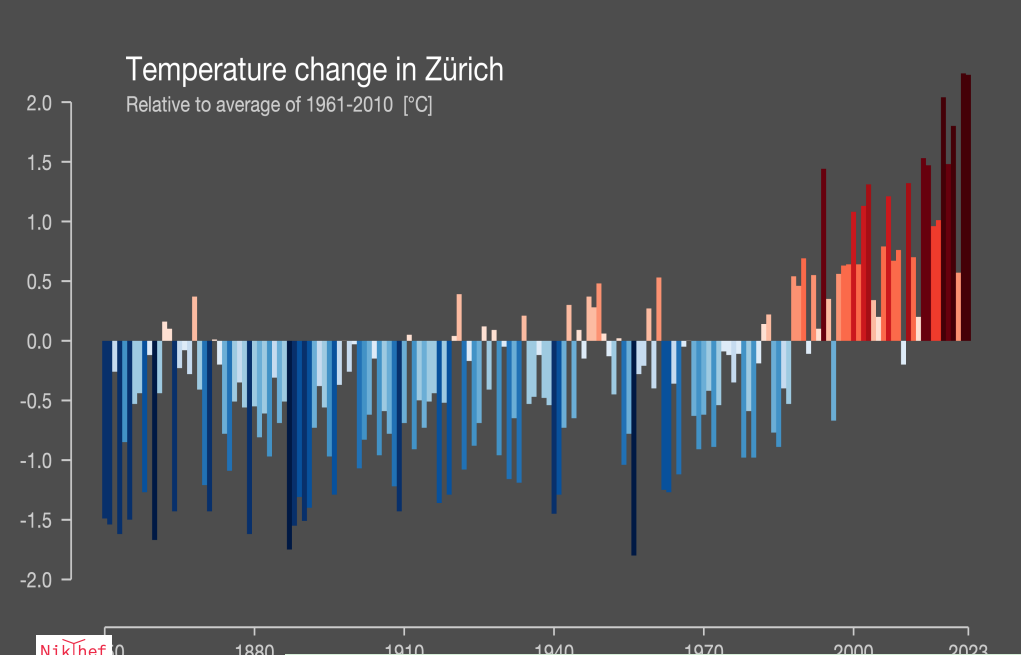

Nikhef sustainability ambassador


LHCb


$e^+e^-$ Higgs/EW factory convener


Laboratory Directors Group WG on sustainability assessment of future accelerators

Swiss politics

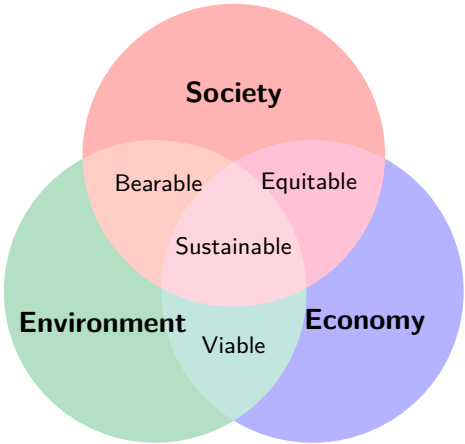

Temperature change in Zürich
Relative to average of 1961-2010 [°C]
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
1880
1910
1940
1970
2000
2023

# Sustainability

Sustainability is the ability to maintain an activity at a certain rate or level. It integrates three stakes: Society, Economy and Environment.

A science programme is sustainable if

1. has obtained a "social license" to operate,
2. avoids the depletion of natural resource
3. long-term affordable with well-understood and managed risks.



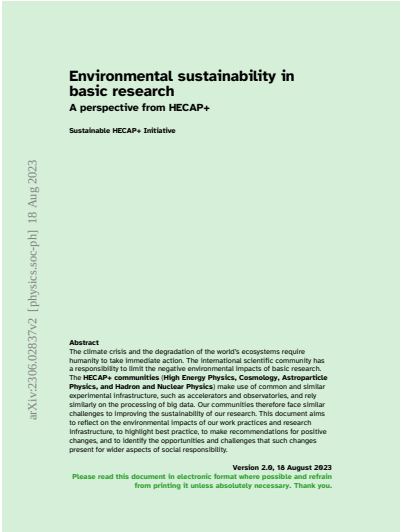
# HECAP+ SUSTAINABLE SCIENCE REPORT

Reflection document following Sustainable HEP workshops [indico] and [indico]

Gives an overview over current status of sustainability in HECAP+

➜ High Energy Physics, Cosmology and Astroparticle Physics + Hadron and Nuclear Physics

Sustainable HECAP+ Initiative, "Environmental sustainability in basic research: A perspective from HECAP+", 2023, available at: [https://sustainable-hecap-plus.github.io/]. [HECAP+, to appear in JINST, arXiv:2306.02837]. Accepted by JINST.



**Environmental sustainability in basic research**

**A perspective from HECAP+**

**Sustainable HECAP+ Initiative**



**Abstract**

The climate crisis and the degradation of the world's ecosystems require humanity to take immediate action. The international scientific community has a responsibility to limit the negative environmental impacts of basic research. The **HECAP+ communities** (**High Energy Physics, Cosmology, Astroparticle Physics, and Hadron and Nuclear Physics**) make use of common and similar experimental infrastructure, such as accelerators and observatories, and rely similarly on the processing of big data. Our communities therefore face similar challenges to improving the sustainability of our research. This document aims to reflect on the environmental impacts of our work practices and research infrastructure, to highlight best practice, to make recommendations for positive changes, and to identify the opportunities and challenges that such changes present for wider aspects of social responsibility.

**Version 2.0, 18 August 2023**

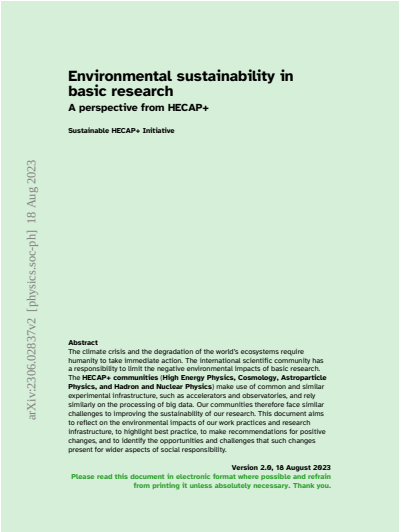
**Please read this document in electronic format where possible and refrain from printing it unless absolutely necessary. Thank you.**

# HECAP+ SUSTAINABLE SCIENCE REPORT

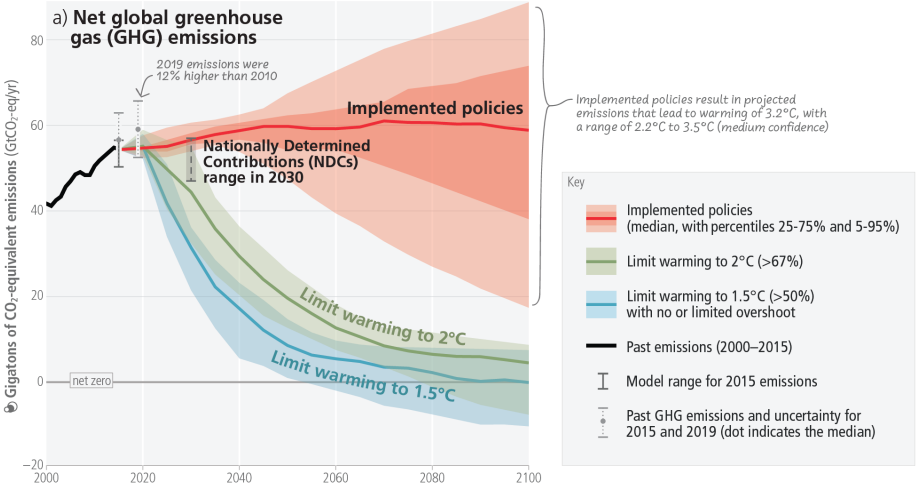
Chapters in alphabetical order on

1. Computing
2. Energy
3. Food
4. Mobility
5. Research Infrastructure and Technology
6. Resources and Waste

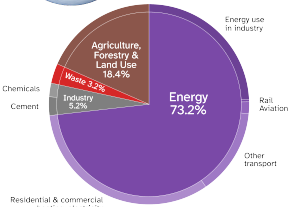
Including best practices, recommendations and case studies.



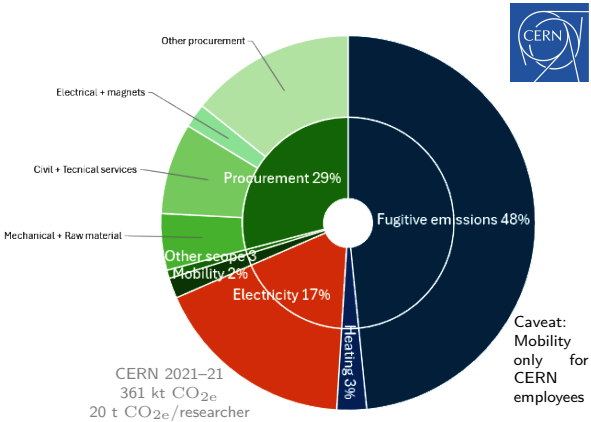
# Introduction



# Introduction




Global, 2016
49.4 $GtCO_2e$
6.3 $tCO_2e$/capita



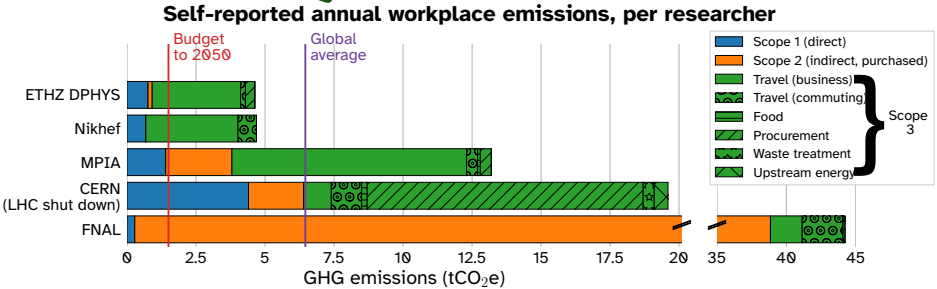

CERN 2021–21
361 kt $CO_{2e}$
20 t $CO_{2e}$/researcher

Caveat: Mobility only for CERN employees

The dominant GHG sources depend on location and activity.
For CERN 50% are gas emissions (2021–22).

# Introduction

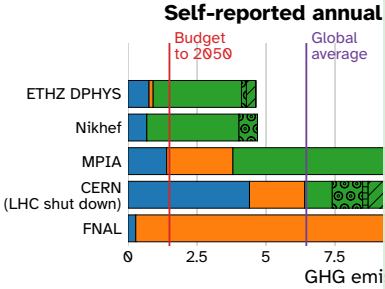
Note!

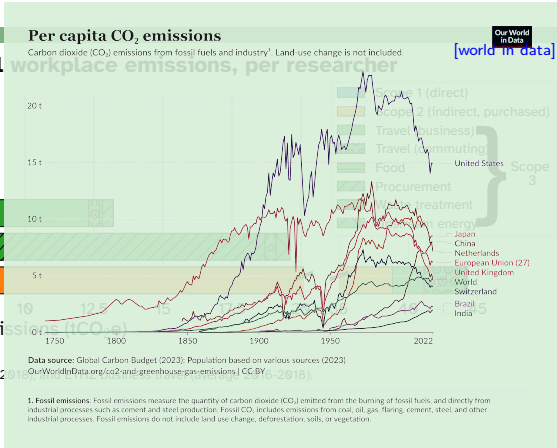



2019 data, save MPIA (2018), and ETHZ business travel (average 2016-2018).

- ✔ ETH and Nikhef are top
  - ✗ But away from 2050 target
- ✗ Labs like MPIA (Heidelberg), CERN or FNAL (Fermilab) are well above the world average
  - ➜ Science causes GHG

# Introduction




- ✔ ETH and Nikhef are top
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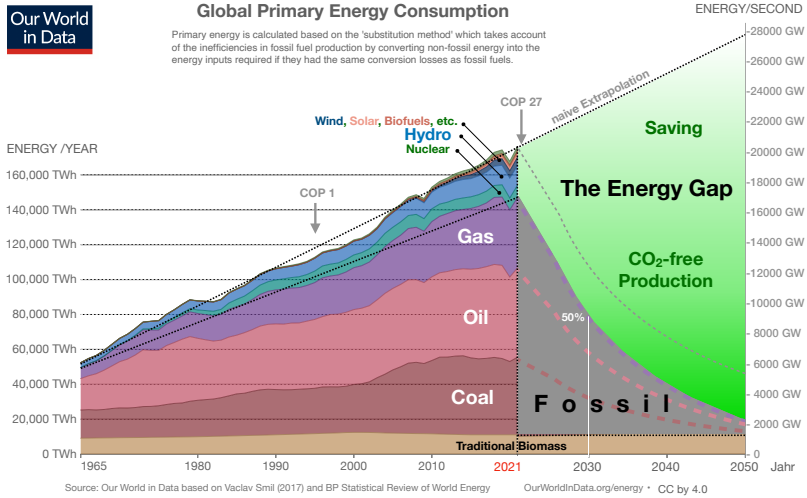
# Do as we say not as we do


# How do we improve?

Symbol: sustainable way of getting up the hill

# Energy

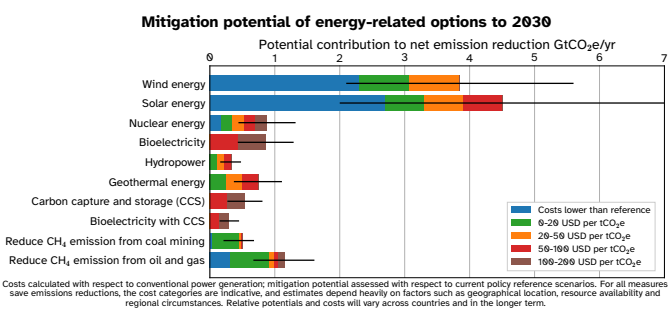

Our World in Data
Global Primary Energy Consumption
Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.
ENERGY /YEAR
ENERGY/SECOND
160,000 TWh
140,000 TWh
120,000 TWh
100,000 TWh
80,000 TWh
60,000 TWh
40,000 TWh
20,000 TWh
0 TWh
28000 GW
26000 GW
24000 GW
22000 GW
20000 GW
18000 GW
16000 GW
14000 GW
12000 GW
10000 GW
8000 GW
6000 GW
4000 GW
2000 GW
0
COP 1
COP 27
naive Extrapolation
Wind, Solar, Biofuels, etc.
Hydro
Nuclear
Gas
Oil
Coal
Traditional Biomass
Saving
The Energy Gap
CO2-free Production
50%
Fossil
1965
1980
1990
2000
2010
2021
2030
2040
2050
Jahr
Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy
OurWorldInData.org/energy • CC by 4.0

[sesame.org.jo] [CDS]

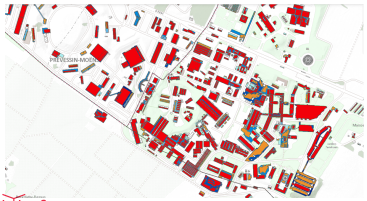
# SESAME

**The first accelerator powered by renewable energy!**

# Energy: Electricity

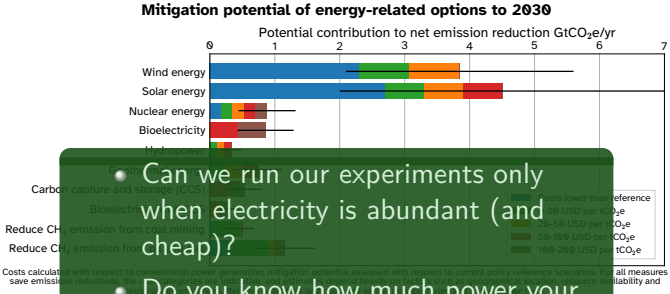



[IPCC, 2022]



1. Use low-carbon sources
2. Produce in house? Works for SESAME. Far off for CERN.
3. Production (*i.e.* low costs) may be intermittent

# Energy: Electricity




[IPCC, 2022]

- Can we run our experiments only when electricity is abundant (and cheap)?
- Do you know how much power your group uses?

1. Use low-carbon sources
2. Produce in house? Works for SESAME. Far off for CERN.
3. Production (*i.e.* low costs) may be intermittent

# Nikhef renovation

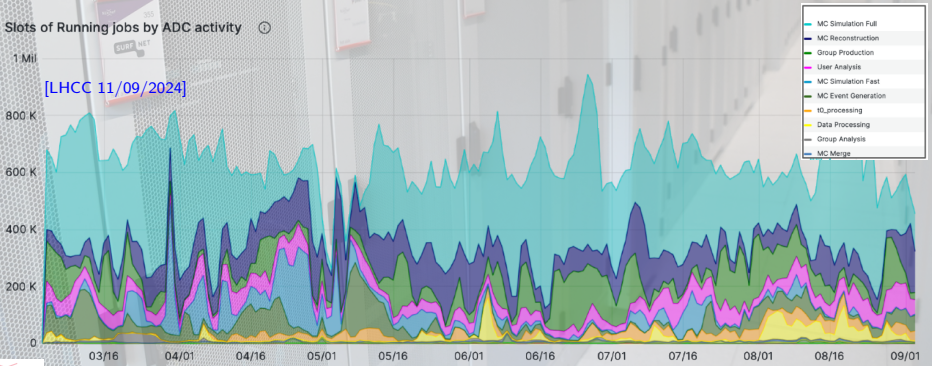

Nikhef's footprint is improving as we now heat the building from the computing centre

# ATLAS CPU usage (2024)

700k jobs running on average

➜ 6 MW [CERN] ➜ 50 GWh/year ➜ 10 kt $CO_2$ for 3000 authors

➜ More than 3 t $CO_2$ per author



# ATLAS CPU usage (2024)

700k jobs running on average

➜ 6 MW [CERN] ➜ 50 GWh/year ➜ 10 kt $CO_2$ for 3000 [illegible]ors

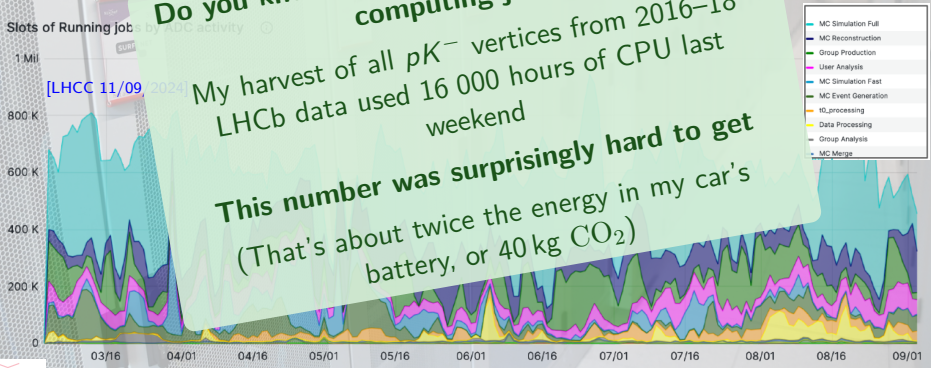
➜ More than 3 t $CO_2$ per author

**Do you know the GHG emissions of your last computing job?**

My harvest of all $pK^-$ vertices from 2016–18 LHCb data used 16 000 hours of CPU last weekend

**This number was surprisingly hard to get**

(That's about twice the energy in my car's battery, or 40 kg $CO_2$)




[LHCC 11/09/2024]

# Computing

[SURF site in the Nikhef building]

**Infrastructure** Mostly cooling (but don't forget construction)

- ✔ Sustainable cooling [CSCS]
- Heat-reuse [LHCb]
- Optimisation of frequency [Szczepanek et al., arXiv:2408.12445]
- ✔ Smart queuing systems

➜ Power usage effectiveness ➜ $\sim 1.$ (world average 1.55)

**Hardware** Manufacturing is 80% of personal equipment.

- Keep as long as possible. Upgrade and repair.

**Software** Dedicated measures can have a huge immediate impact.

➜ Needs effort from everyone involved

# Mobility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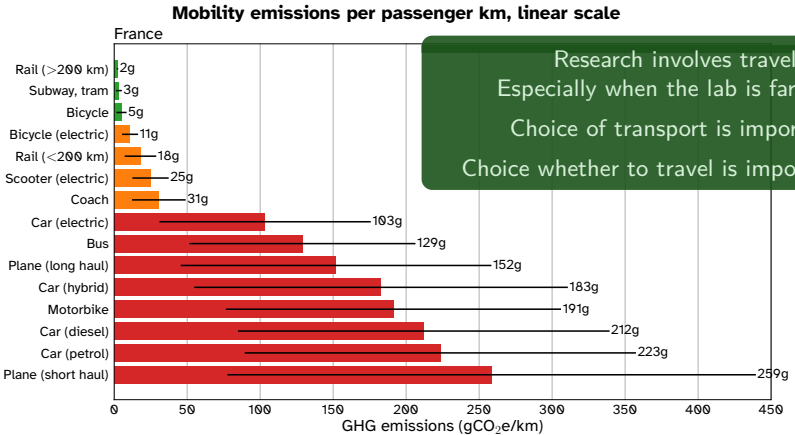
On behalf of the Sustainable HECAP initiative
Patrick Koppenburg

# Mobility

## Travel = Commute + Fieldwork + Conferences




Research involves travel

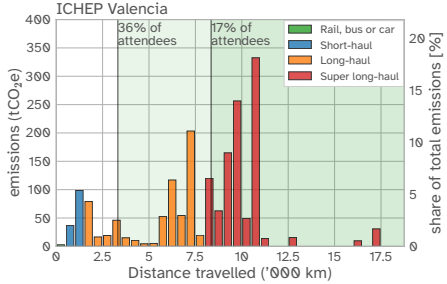
Especially when the lab is far away

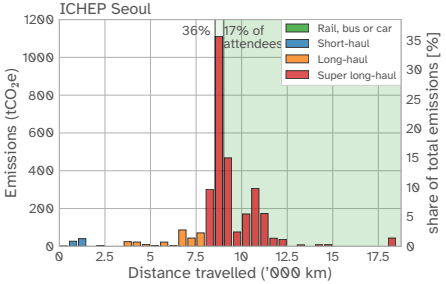
Choice of transport is important

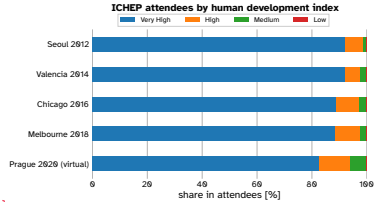
Choice whether to travel is important too

Source: Labos1.5 database. Estimates include production emissions, and may vary slightly based on occupancy of public transport, and between countries.

# Mobility : Conferences

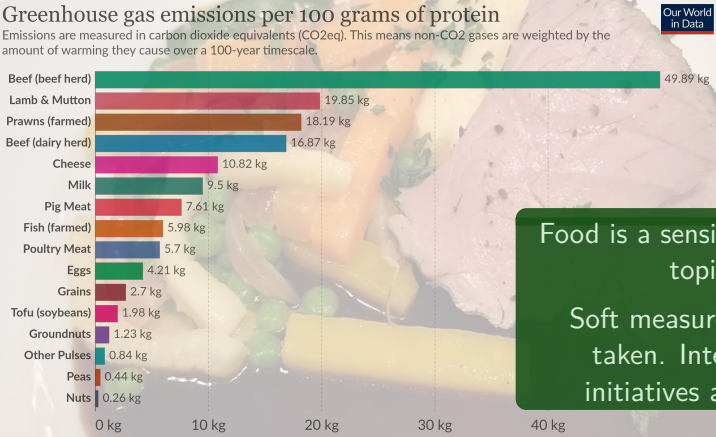



- Conference location has large impact
- But optimising forces people from remote areas to travel more
- Virtual conferences slightly improve accessibility

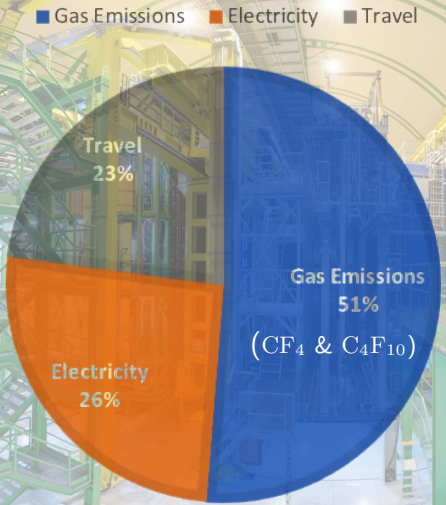
# Food




Food is a sensitive cultural topic

Soft measures can be taken. Interesting initiatives at EPFL.

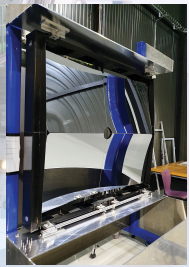
# Technology




Half of LHCb's GHG emissions are hydrofluorocarbon gases [LHCb-TDR-023].

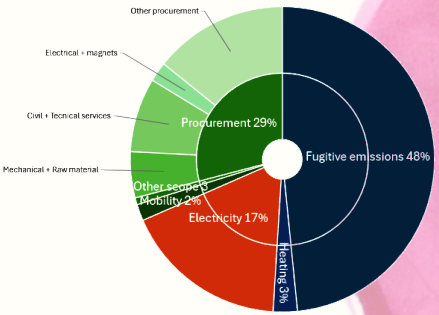
➜ Minimise leaks and use different gas mixtures.

- These measures are best taken when designing experiments.



[HECAP+, to appear in JINST, arXiv:2306.02837]

# Resources




The elephant in the room is procurement

It's hard to quantify. It's hard to address. But it's a big contributor to GHG emissions.

[HECAP+, to appear in JINST, arXiv:2306.02837]

# Recommendations

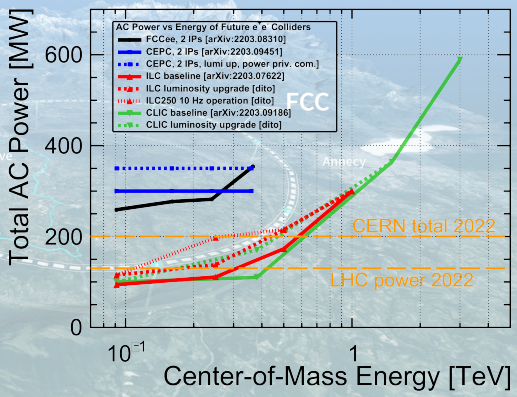
- Make and **model positive change** in research activities
- **Save energy**
- Make sustainable personal **computing** choices
  - Schedule **queuing** systems with environmental sustainability in mind
- Reduce consumption of **animal products**, especially ruminants
- Assess need and mode of **business travel**
  - Re-assess needs for in-person **meetings**
- Share, repair, reuse and refurbish to **minimise waste**

# Recommendations

- Monitor, assess, report on and **set targets** in relation to the environmental impacts of research activities
  - Ensure that environmental sustainability is an essential consideration at all stages of **projects**
  - Critically assess the environmental impact of **materials**
  - Prioritise **suppliers** instituting sustainable sourcing
  - Make environmental sustainability is a core consideration when **designing and choosing sites**
- Allow flexibility in policies and procedures e.g., **budget** allocation, that enable environmentally sustainable choices to be made
  - Support sustainable **commuting and travel**
- Monitor and report **energy usage**. Prioritise renewable energy.
- Incentivise consumption of plant-based **food**

# Standardisation

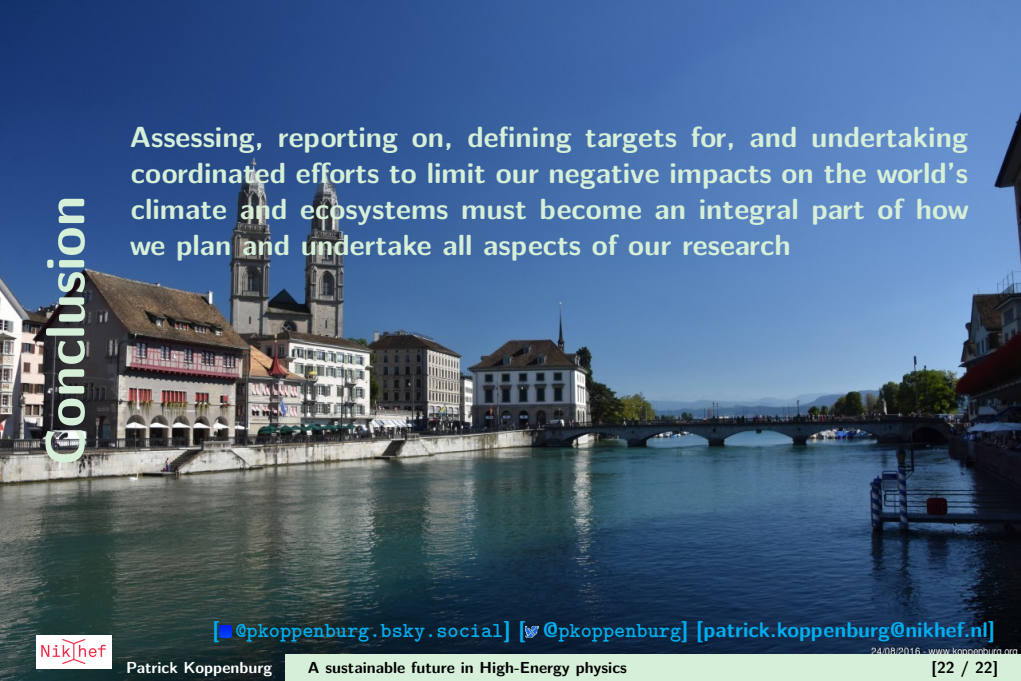
- ✗ Limited availability of data on emissions and resources consumption for basic research infrastructure,
- ✗ Data not standardised
  - ➜ Comparisons are difficult
- ✔ Good examples: ESO, GRAND, RUEDI, CLIC. . . , [Labos 1.5]




Need a fair comparison of projects with standard life-cycle and cost-benefit analyses

# Conclusion

Assessing, reporting on, defining targets for, and undertaking coordinated efforts to limit our negative impacts on the world's climate and ecosystems must become an integral part of how we plan and undertake all aspects of our research



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