Environmental sustainability in basic research: a perspective from HECAP+

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Einstein Telescope Sustainability workshop, IJCLab, Orsay

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In this talk

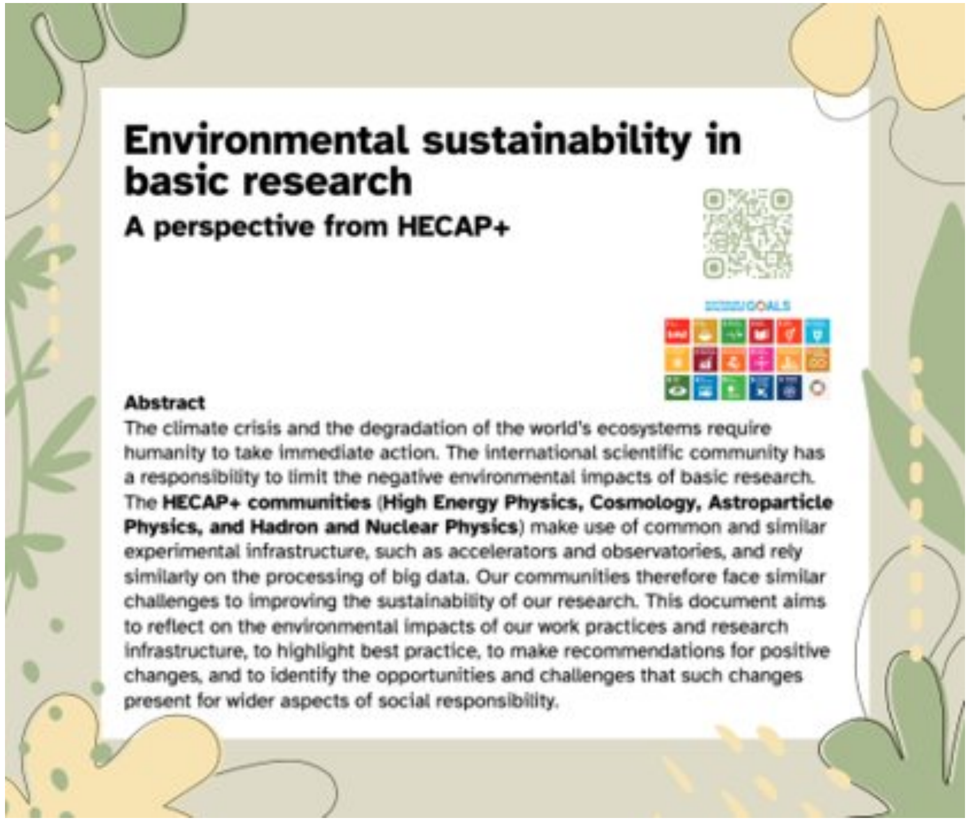
- What is the Sustainable HECAP+ initiative?
- Our motivation
- Our reflection document and its recommendations

I am hugely indebted to Peter Millington (Manchester U.) for letting me adapt his slides

Document: arXiv:2306.02837, released on UN World Environment Day, 5 June 2023, revised version released, 18 August 2023

- grassroots initiative of a small (~20-30) group of concerned people from across High Energy Physics, Cosmology, Astroparticle Physics, and Hadron and Nuclear Physics (HECAP+)

- conceived at the (online) workshop “Sustainable HEP”, 28 – 30 June 2021, hosted by CERN



Environmental sustainability in basic research

A perspective from HECAP+

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.

https://sustainable-hecap-plus.github.io

Other similar documents:

ALLEA (European federation of academies of science and the humanities), “Towards climate sustainability of the academic system in Europe and beyond,” https://doi.org/10.26356/climate-sust-acad, 2022.

K. Bloom et al., “Climate impacts of particle physics,” in 2022 Snowmass Summer Study, 3, https://doi.org/10.48550/arXiv.2203.12389, 2022.

Young High Energy Physicists association, “yHEP recommendations on improvement of environmental sustainability in science,” https://yhep.desy.de/sites/sites_custom/site_yhep-association/content/e61887/e122133/yHEPStatementonenvironmentalsustainabilityinScience_final.pdf, 2020.

LHCb …

“In a world with increasing demand on limited resources and undergoing climate change, as a collaboration we feel a responsibility to consider energy consumption, sustainability and efficiency when discussing our scientific proposal.”

Chapter 8, Environmental protection and safety, LHCb Technical Design Report 23, 2022

Reasons to act:

We have a responsibility to limit our negative impacts on the climate and ecosystems.

As scientifically literate citizens, we should lead the way and reduce the gap between our awareness of climate change and our actions

Our research activities and our “social licence to operate” will be under increasing scrutiny.

Motivation and introduction to the reflection document

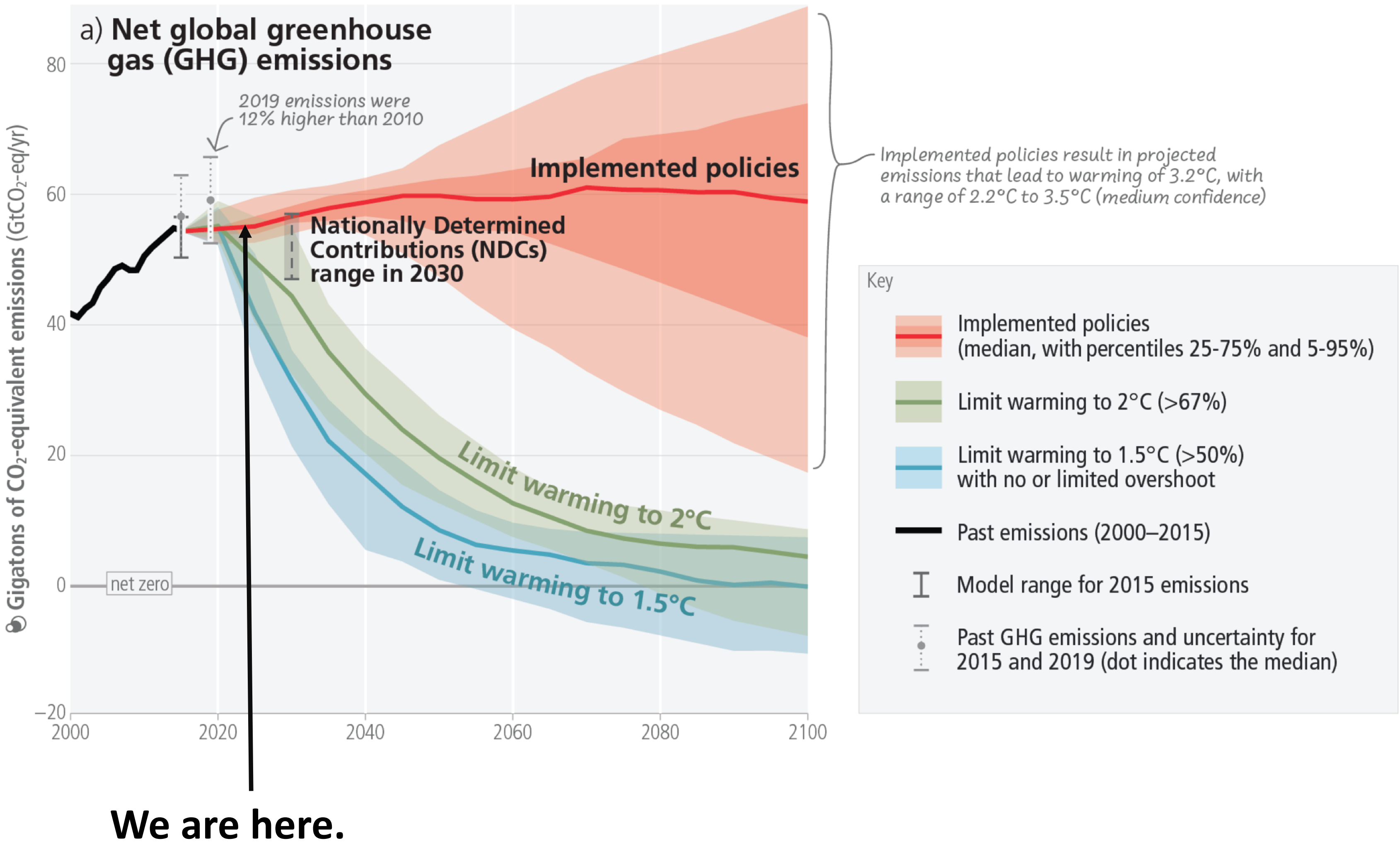
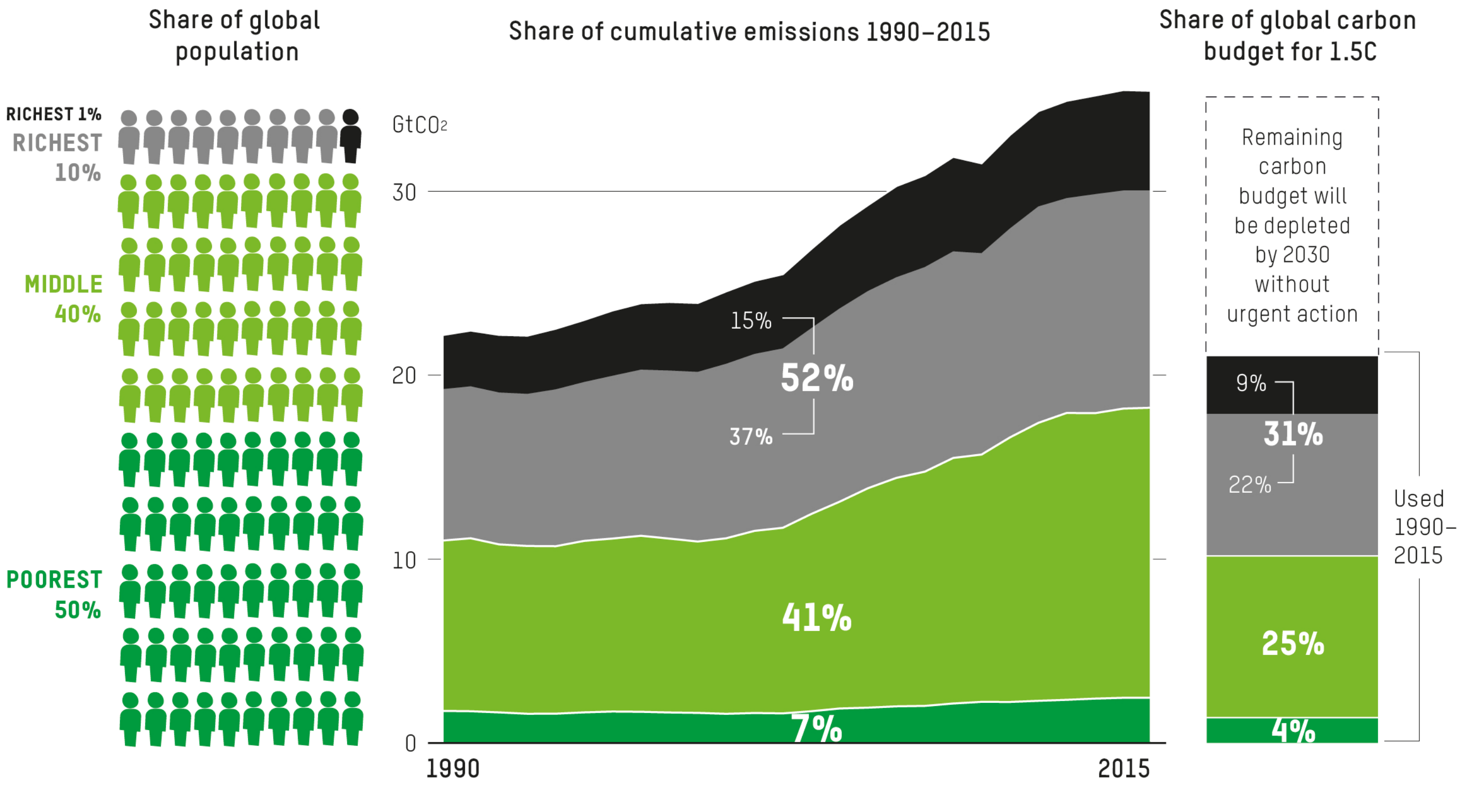


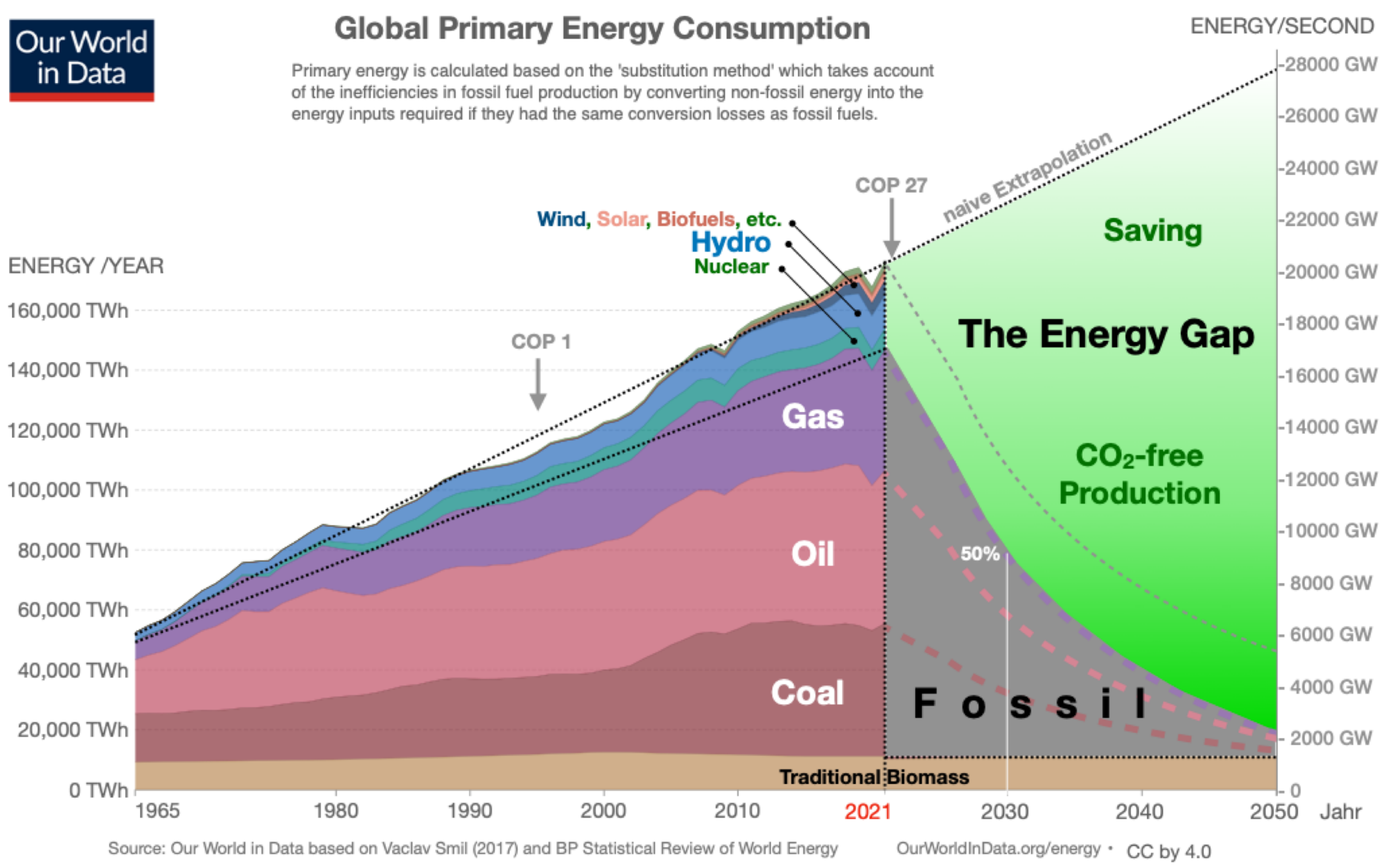
Figure excerpted from [IPCC 2023 Synthesis Report, Summary for Policymakers].



Per capita income threshold ($PPP2011) of richest 1%: $109k; richest 10%: $38k; middle 40%: $6k; and bottom 50%: less than $6k.
Global carbon budget from 1990 for 33% risk of exceeding 1.5C: 1,205Gt.

Richest 10% of the world's population means **annual income > €34,000.**

Notes: This figure, appearing in the document, is reproduced from [Gore 2020] with the permission of Oxfam, Oxfam House, John Smith Drive, Cowley, Oxford OX4 2JY, UK, https://www.oxfam.org.uk/. Oxfam does not necessarily endorse any text or activities that accompany the materials.



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/SECOND
ENERGY /YEAR
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
Saving
The Energy Gap
Gas
Oil
Coal
CO_2-free Production
50%
F o s s i l
Traditional Biomass
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

The document (arXiv:2306.02837) …

A broad-scope reflection on the environmental impacts of our research activities, across six axes:

- Hardware
- Software
- Data Centres

- Sources
- Saving
- Recuperation

- Conferences
- Canteens

- Commuting
- Conferences
- Collaboration

- Life-Cycle
- F-Gases

- Consumables
- E-Waste

Summary discussions, best practices, case studies, and recommendations for

Individuals

Groups

Institutions

Computing

Computing is a significant part of our research infrastructure, and contributes to resource use, e-waste and energy consumption.

Opportunities:

- right-sizing hardware needs
- reassessing hardware life cycles
- improving data-processing efficiency
- green scheduling
- heat recovery

Recommendations — Computing

Individual actions:

- Make sustainable personal computing choices by considering the necessity of hardware upgrades, the repurposing of hardware, and the environmental credentials of suppliers and their products.
- Assess and improve the efficiency and portability of codes by considering, e.g., the required resolutions and accuracy.
- Assess and optimise data transmission and storage needs.
- Follow best practice in open-access data publishing, prioritising reproducibility and limiting repeat processing.
- Read the section on E-waste (Section 7).

Further group actions:

- Right-size IT requirements and optimise hardware lifecycles.
- Schedule queueing systems with environmental sustainability in mind, so as to maximise the use of renewables, accounting for the geographical location of servers/data centres.

Further institutional actions:

- Ensure that environmental sustainability is a core consideration when designing and choosing sites for large computing infrastructure, such as data centres, including, e.g., the availability of renewables, the efficiency of cooling systems and the reuse of waste heat.
- Proceduralise the repair, upgrade and repurposing of existing computing, the de-inventorising of personal equipment for leaving personnel or for donation, and the responsible recycling of retired hardware.
- Select cloud computing services for their carbon emission mitigation policies.

Some of the above recommendations are based on those made by Jan Rybizki [34].

Energy

Energy use cuts across all our research activities.

Opportunities:

- monitoring, reporting and assessing, e.g., labos1point5
- prioritising energy efficiency and recovery, included in comprehensive Life Cycle Assessment

Recommendations — Energy

Individual actions:

- Save energy in all ways practicable, e.g., by avoiding unnecessary heating or cooling of workspace, and by turning off electrical items when not in use.
- Read the sections about computing (Section 2) and mobility (Section 5).

Further group actions:

- Ensure that energy efficiency is a major focus in experimental design, and prioritise technologies that minimise consumption and maximise energy recovery.
- Monitor, report, and assess energy usage with the aim of reducing consumption and resulting emissions.
- Read the section on research infrastructure and technology (Section 6).

Further institutional actions:

- Ensure that energy efficiency is a major factor in the renovation of existing estates and the design and construction of new infrastructure.
- Prioritise moving to sustainable and renewable energy sources via both local generation, and energy import and export.
- Collate and publish energy usage and emissions statistics, stratifying by source, e.g., heating, experimental infrastructure, computing, transportation, and procurement.
- Lobby for environmentally sustainable energy policy.

Food

A **sensitive topic**, but, e.g., “substituting all beef meals at R1 [CERN] with farmed fish or chicken would result in reduction of its annual carbon footprint by 528 tCO_2e … approximately 260 return flights from London to New York.” (case study 4.1)

Opportunities:

- considering the environmental impact of food choices when deciding on conference and cafeteria catering
- minimising food waste

Recommendations — Food

Individual actions:

- Reduce consumption of animal products, especially those that result in the highest emissions, e.g., ruminant meat, and dairy.
- Minimise food waste.

Further group actions:

- Prioritise plant-based options in conference catering, and optimise service method to reduce food waste.

Further institutional actions:

- Incentivise the consumption of plant-based products at on-site restaurants by increasing their variety and quality, and subsidising their cost.
- Highlight the environmental impact of food choices through service layout and labelling.
- Minimise food waste by providing multiple portion sizes and donating unused food.
- Read section on waste (Section 7) and limit food-service waste e.g., through industrial composting of biodegradable food containers.

Mobility

Another **sensitive topic** and a key example of tensions that can arise in environmental sustainability, in particular with productivity and equity, diversity, inclusion and access (EDIA).

Opportunities:

- reprioritising business travel
- using remote technologies
- prioritising low-carbon travel (for unavoidable travel)
- overhauling (career) requirements for hypermobility
- incentivising sustainable commuting

Recommendations — Mobility

Individual actions:

- Re-assess business travel needs, using remote technologies wherever practicable.
- Choose environmentally sustainable means of transport for daily commutes as well as unavoidable business travel, amalgamating long-distance trips where possible.

Further group actions:

- Define mobility requirements and travel policies that minimise emissions, while accounting for the differing needs of particular groups, such as early-career researchers or those who are geographically isolated.
- Re-assess needs for in-person meetings, and prioritise formats that minimise travel emissions and diversify participation by making use of hybrid, virtual or local hub participation, and optimising the meeting location(s).

Further institutional actions:

- Support environmentally sustainable commuting by improving on-site bicycle infrastructure, subsidising public transport and providing shuttle services.
- Disincentivise car travel where viable alternatives exist, facilitate car pooling, and provide on-site charging stations.
- Incentivise the reduction of business travel, e.g., by implementing carbon budgets with appropriate concessions.
- Ensure unavoidable travel is made via environmentally sustainable means through flexible travel policies and budgets, and the use of travel agents that offer multi-modal itineraries. Employ carbon offsetting only as a last resort.
- Remove any requirement on past mobility as an indication of quality in hiring decisions.
- Lobby for improved and environmentally sustainable local and regional transport infrastructure.

Research Infrastructure & Technology

Bottom line: Comprehensive **Life Cycle Assessment** should be integral to all projects.

Opportunities:

- seeking out best practices and innovation
- working with industry partners
- accreditation and tools, e.g., LEAF and labos1point5

Recommendations — Research Infrastructure and Technology

Individual actions:

- Seek out new innovations and best practice.
- Rethink how the impact of frequently-used equipment can be reduced, and reduce "over-design" by reassessing safety factors and other margins to reduce resource consumption.
- Read section on resources and waste (Section 7).

Further group actions:

- Ensure that environmental sustainability is an essential consideration at all stages of projects, from initial proposal, design, review and approval, to assembly, commissioning, operation, maintenance, decommissioning and removal, using life cycle assessment and related tools.
- Engage with industrial partners who exemplify best practice and sustainable approaches.
- Appoint a dedicated sustainability officer to oversee project development, and institute regular meetings with a focus on environmental sustainability.

Further institutional actions:

- Critically assess the environmental impact of materials, construction and the operational life cycle as an integral part of the design phase for all new infrastructure.
- Provide training opportunities, required tools and technical support to assess and improve the environmental sustainability of project life cycles.
- Recognise and reward innovations that minimise negative environmental impacts, regardless of revenue.
- Promote knowledge exchange on sustainability initiatives between groups and institutions, including decision-makers, designers and operators of projects, setups and infrastructure.

For example …

ARUP

Life Cycle Assessment

Comparative environmental footprint for future linear colliders CLIC and ILC

Final Report

July 2023

https://edms.cern.ch/ui/file/2917948/1/Life_Cycle_Assessment_for_CLIC_and_ILC_Final_Report_July_2023.pdf

CERN

KEK-JAPAN

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Resources & Waste

Scope-3 emissions are some of the largest and most challenging to address, since they rely on the supply chain (both up- and down-stream).

Opportunities:

- demand-side reduction
- sharing, repairing, reusing and refurbishing
- prioritising suppliers with sustainable sourcing and operating policies

Recommendations — Resources and Waste

Individual actions:

- Limit purchases and consider environmental credentials such as repairability and recyclability of products in purchasing decisions.
- Service appliances regularly; share, repair, reuse and refurbish to minimise waste; sort and recycle.
- Read the sections on computing (Section 2), energy (Section 3), food (Section 4), and research infrastructure and technology (Section 6).

Further group actions:

- Adopt life cycle assessments and associated tools to assess environmental impact of all activities.
- Institute sustainable purchasing, usage and end-of-life policies in the management of group consumables, office supplies and single-use plastics e.g., in conference events (see also Section 7.2.3 and Best Practice 7.4).

Further institutional actions:

- Prioritise suppliers instituting sustainable sourcing and operating policies, with a particular focus on the raw materials processing stage (see Best Practice 7.1) and with the aim of creating demand for recycled (secondary) raw materials.
- Provide an institutional pool of infrequently-used equipment to avoid redundancy in purchasing.
- Proceduralise and prioritise repair of equipment, and enable through provision of tools and know-how.
- Assess waste generation and management for the design, operation and decommissioning of IT and infrastructure projects by right-sizing needs, establishing specific treatment channels for all waste categories, and setting recycling targets that include the recycling of all construction waste, see, e.g., Best Practice 7.3.

Overall message:

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.

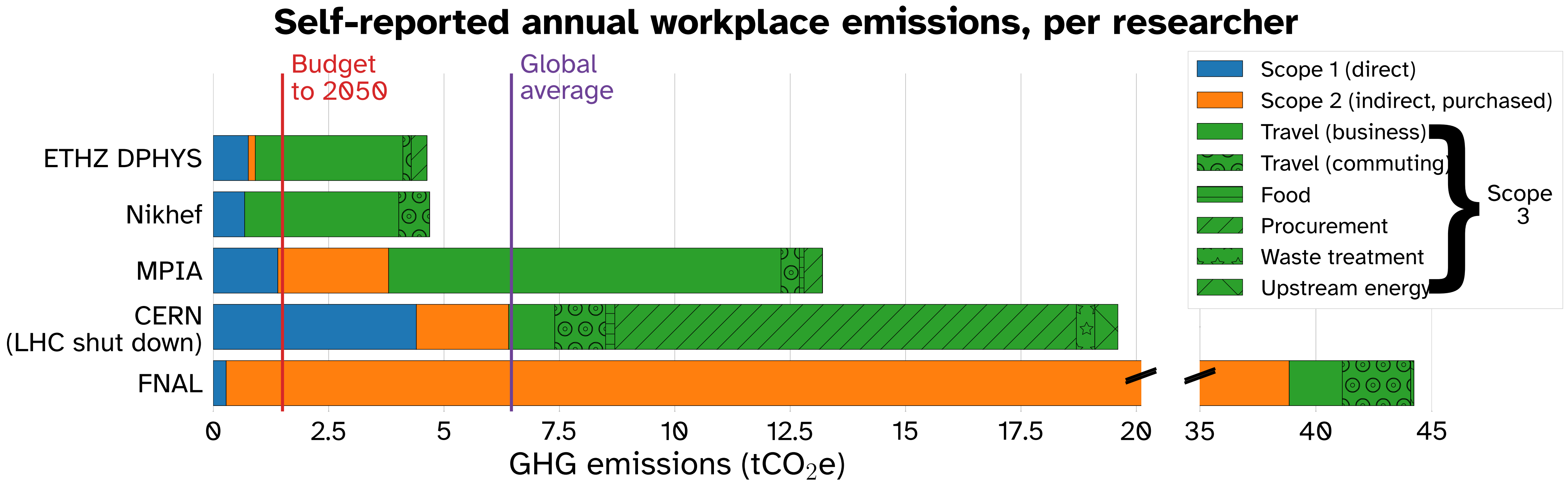
Your collaboration is in a very good place to incorporate these criteria in its design phase

Please read the document: https://sustainable-hecap-plus.github.io.

Please support it publicly via the links in the document and consider endorsing it

Thank you.

Backup Slides and References



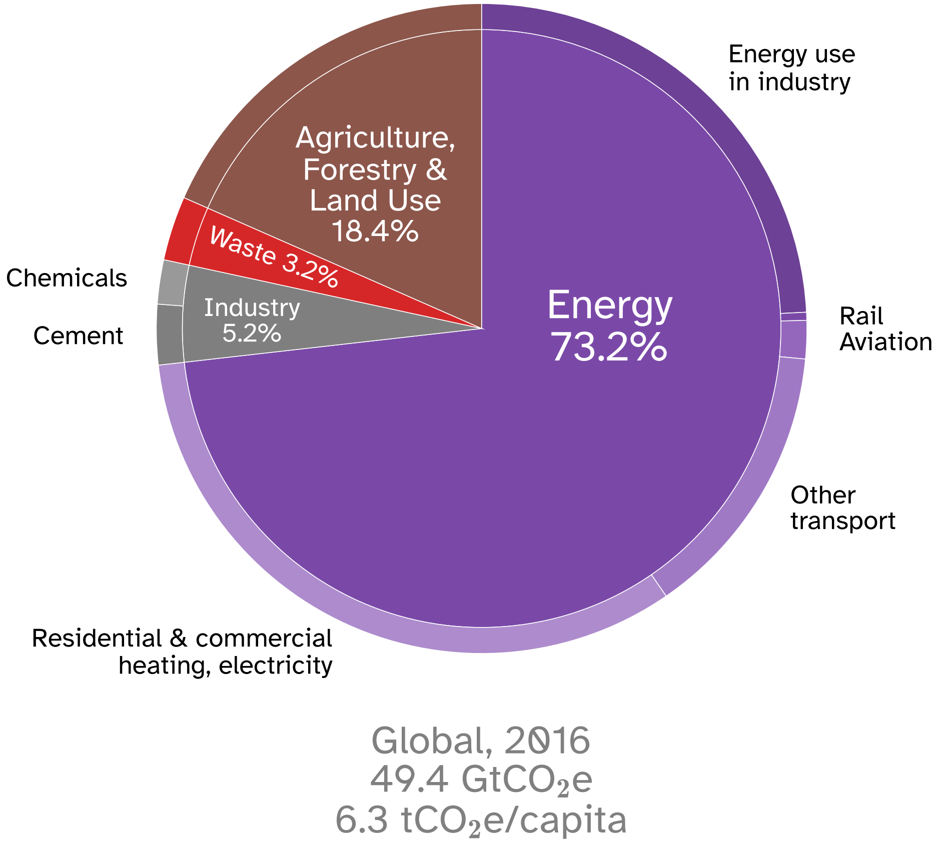
2019 data, save MPIA (2018), and ETHZ business travel (average 2016-2018).

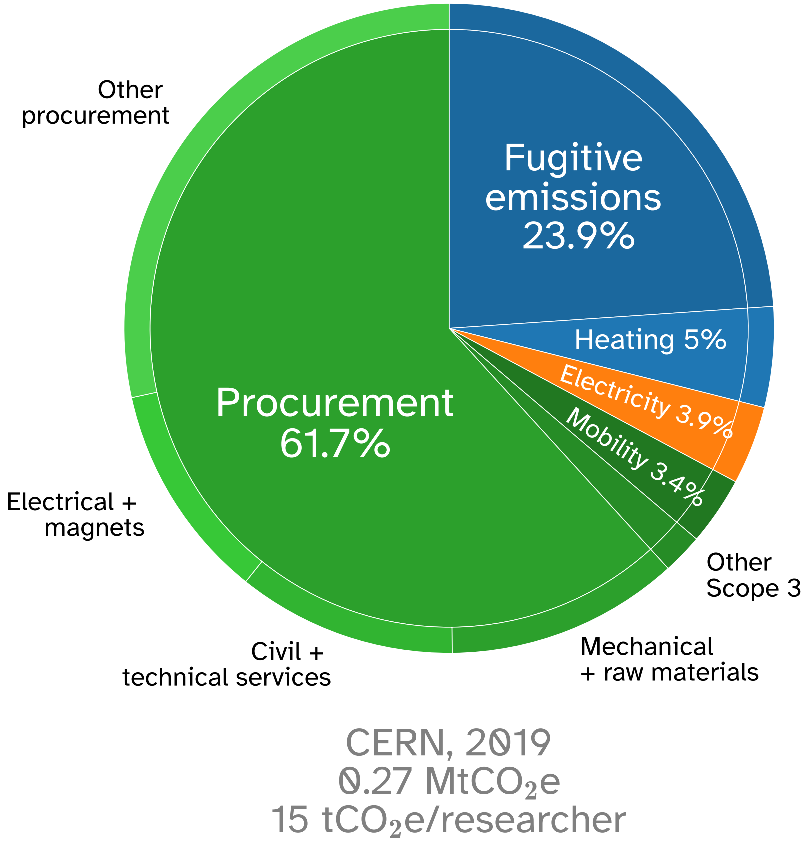
"Budget to 2050" is the carbon "budget" to stay within the **Paris Climate Accord** limit of **1.5° of warming**.

Direct and **indirect emissions** more than **double** when the **LHC is running** [CERN Environment Report 2021].

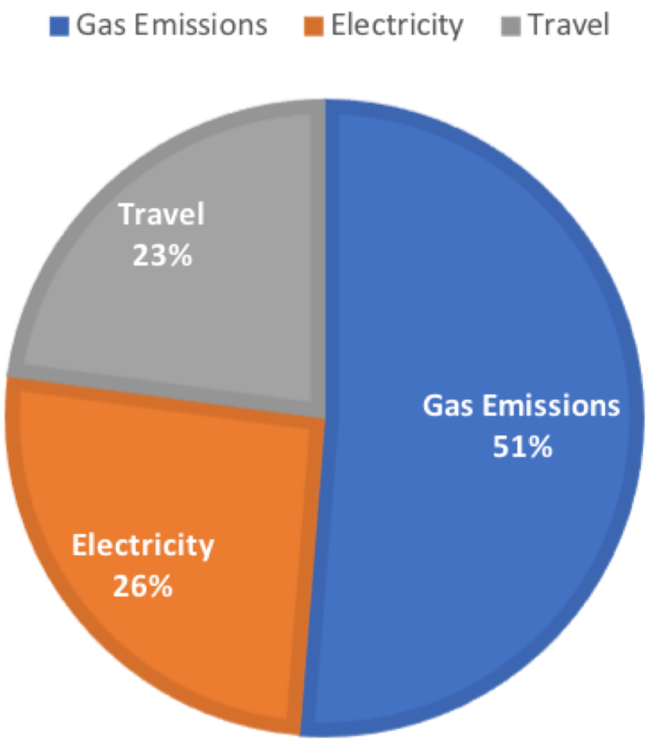
Notes: Scope 3 emissions are incomplete for all but CERN. Total emissions for each category were divided by the nominal number of users for that resource. Sources: for full refs. to institutional reports, see p. 24 of the document.

Total GHG emissions



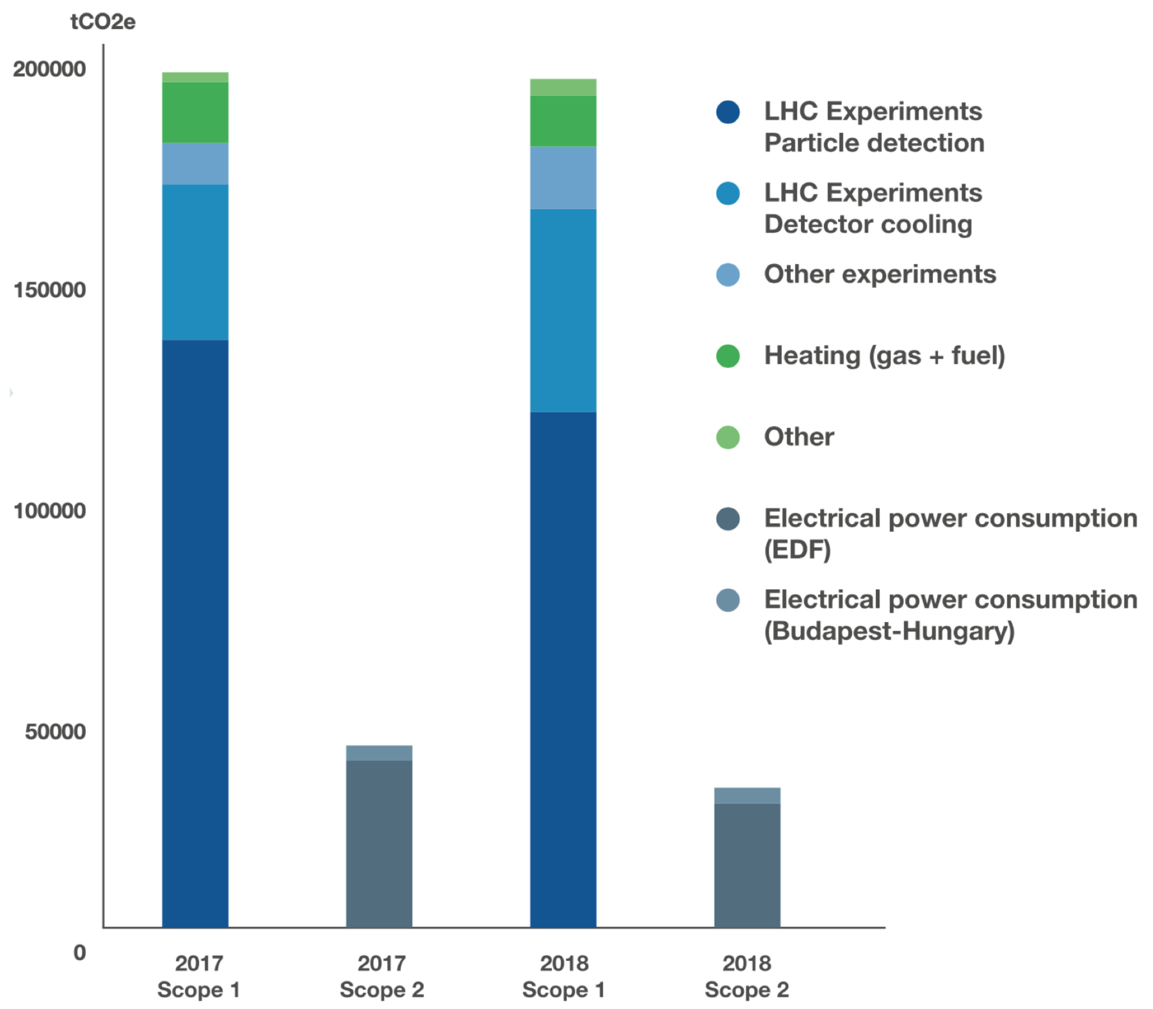


Notes: CERN 2019 emissions were divided equally amongst its 17,000 users to obtain a "per capita". Sources: [H. Ritchie et al., "CO_2 and Greenhouse Gas Emissions", Our World in Data, 2020] (left) and CERN Environmental Reports (right). For full refs., see p. 23 of the document.



Estimated **4,400 tonnes C02 equivalent** emissions for **LHCb** in **Run 3** [LHCb TDR 23].

Notes: Figure 8.2 from LHCb TDR 23, 2022. “Expected relative contribution to CO2 equivalent emissions from LHCb operations in Run 3.”



CERN Scope 1 (direct) and Scope 2 (indirect, i.e., electricity consumption) for 2017 and 2018.

Reproduced from [CERN Environment Report 2020].

References:

For complete references to the various institutional environment reports used, please see the document arXiv:2306.02837.

IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001.

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CERN, "Vol. 2 (2021): CERN Environment Report—Rapport sur l'environnement 2019–2020," https://doi.org/10.25325/CERN-Environment-2021-002, CERN, Geneva, Tech. Rep., 2021.

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