Sustainability recommendations from the European Strategy: a historical (and personal) perspective

Véronique Boisvert (b. 329.7 CO_2 ppm)

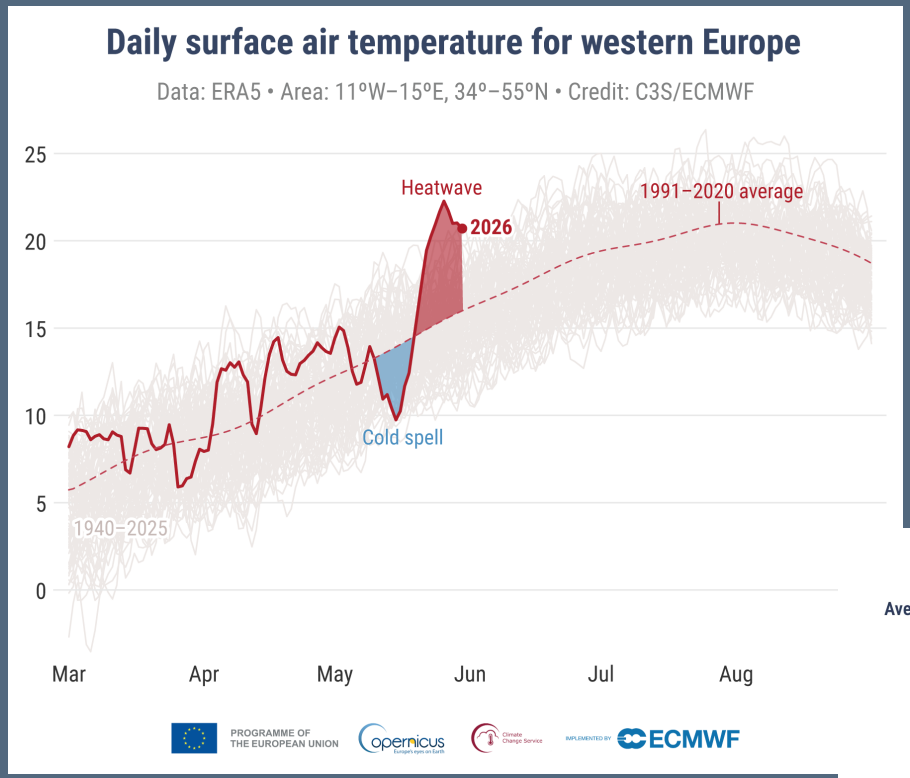
ROYAL HOLLOWAY UNIVERSITY OF LONDON

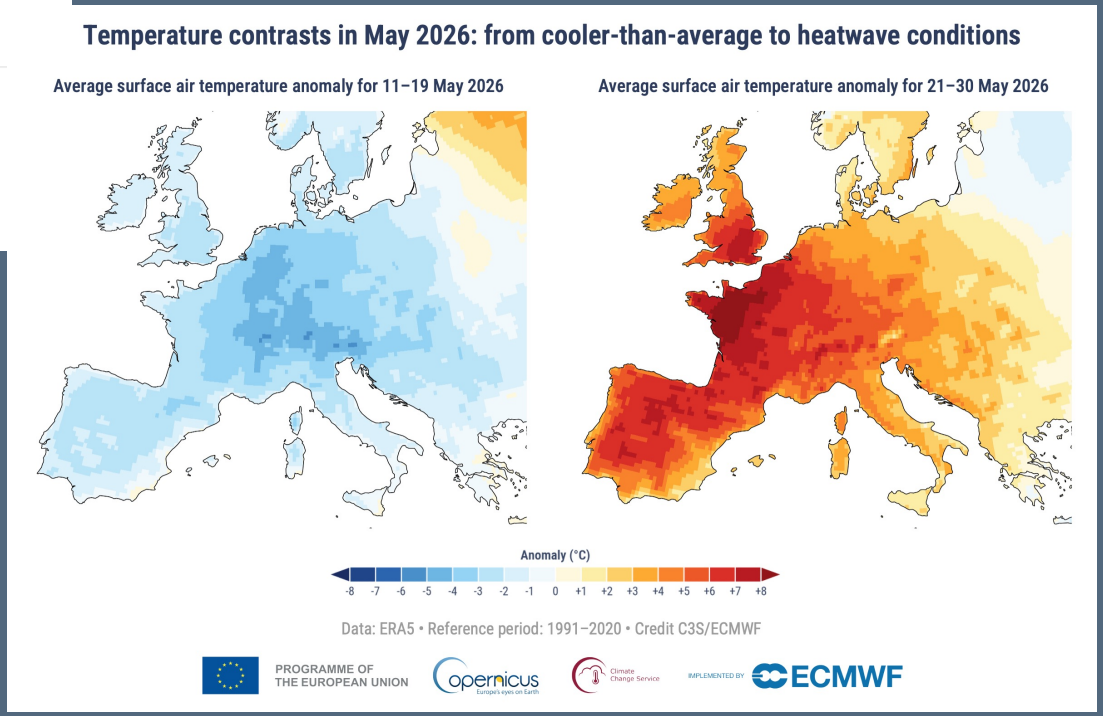
8th July 2026 (430.0 CO_2 ppm)

Sustainable HEP 2026

Disclaimer: this is not an exhaustive list of activities in this area!

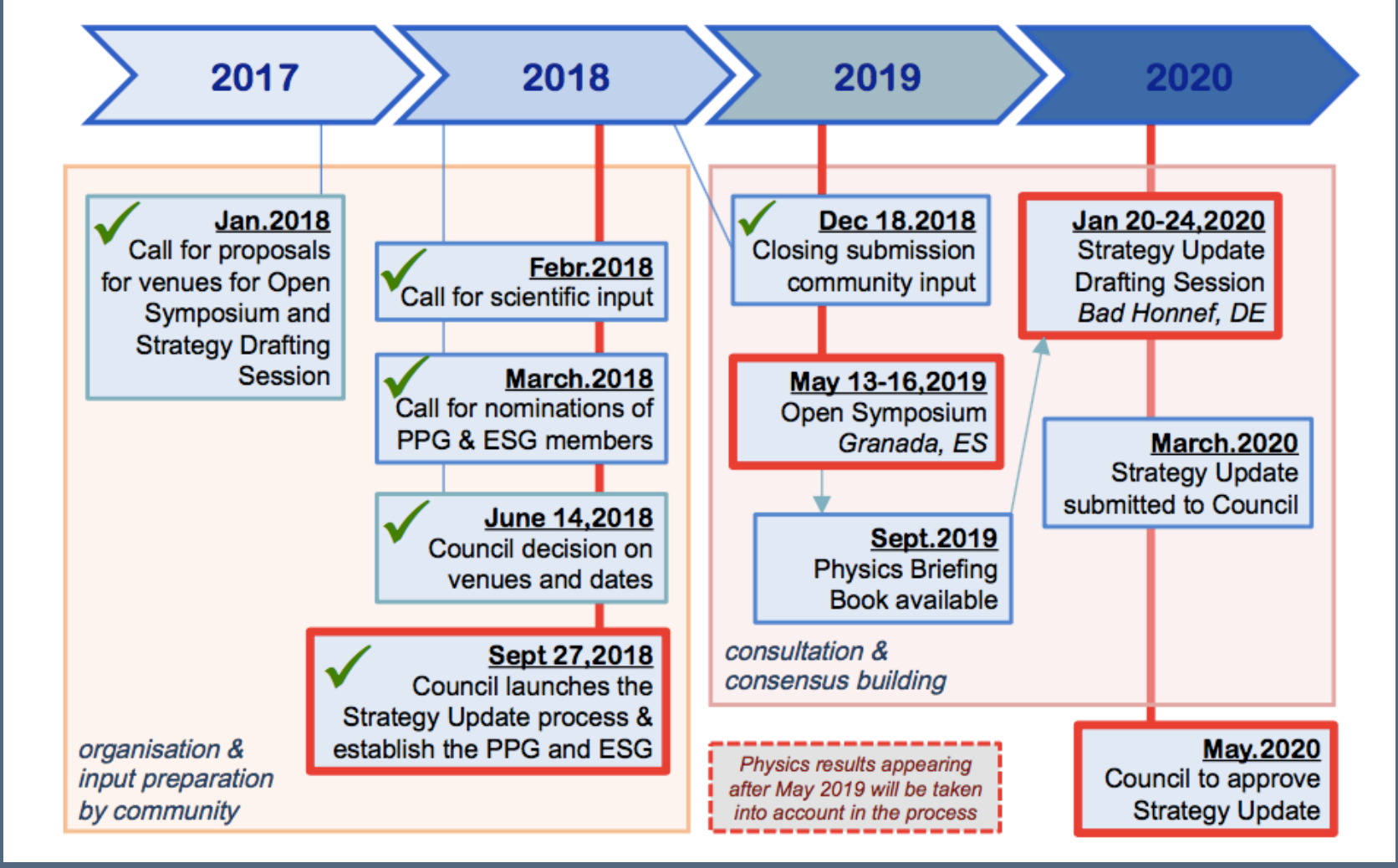
A reminder of why…





European Strategy Update

- "The Strategy is due to be updated by May 2020 to guide the direction of the field to the mid-2020s and beyond."



Input to the ESU

VB (RHUL)
Cham Ghag (UCL)
Francesco Spano (RHUL)
David Waters (UCL)

CERN Courier article

ECFA group of early career researchers asked to give input to European Strategy, document released which includes statements supporting the environmental sustainability of the field

Input to the ESU: recommendations

- Recommendation 1:
  - As part of their grant-giving process, European laboratories and funding agencies should include criteria evaluating the energy efficiency and carbon footprint of particle physics proposals, and should expect to see evidence that energy consumption has been properly estimated and minimised.
- Recommendation 2:
  - Any design of a major particle physics experiment should consider plans for reduction of energy consumption, increased energy efficiency, energy recovery and carbon offset mechanisms. Similarly, any design for new buildings associated with particle physics research should consider the highest building and energy efficiency standards.
- Recommendation 3:
  - European laboratories should invest in the development and affordable deployment of next-generation digital meeting spaces including virtual reality (VR) tools in order to minimize the need for frequent travelling to the laboratory, thereby minimizing the travel carbon and energy footprint of their users.

ATLAS Sustainability Forum

- Presentation in CB matters of February 2020 ATLAS Collaboration week
  - Group discussion later that day
- Creation of mailing list (currently 52 members), monthly meetings, organizers: Kristin Lohwasser, Daniel Britzger, VB
- Then got busy with latest ESPPU ☺

European Strategy Update 2020

7

Environmental and societal impact

A. The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. ***The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.***

B. Particle physics, with its fundamental questions and technological innovations, attracts bright young minds. Their education and training are crucial for the needs of the field and of society at large. ***For early-career researchers to thrive, the particle physics community should place strong emphasis on their supervision and training. Additional measures should be taken in large collaborations to increase the recognition of individuals developing and maintaining experiments, computing and software. The particle physics community commits to placing the principles of equality, diversity and inclusion at the heart of all its activities.***

C. Particle physics has contributed to advances in many fields that have brought great benefits to society. Awareness of knowledge and technology transfer and the associated societal impact is important at all phases of particle physics projects. ***Particle physics research centres should promote knowledge and technology transfer and support their researchers in enabling it. The particle physics community should engage with industry to facilitate knowledge transfer and technological development.***

D. Exploring the fundamental properties of nature inspires and excites. It is part of the duty of researchers to share the excitement of scientific achievements with all stakeholders and the public. The concepts of the Standard Model, a well-established theory for elementary particles, are an integral part of culture. ***Public engagement, education and communication in particle physics should continue to be recognised as important components of the scientific activity and receive adequate support. Particle physicists should work with the broad community of scientists to intensify engagement between scientific disciplines. The particle physics community should work with educators and relevant authorities to explore the adoption of basic knowledge of elementary particles and their interactions in the regular school curriculum.***

A) The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. *The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.*

Start of Sustainable HEP!

Sustainable HEP

28–30 Jun 2021
Zoom
Europe/Zurich timezone

Enter your search term

- Overview
- Timetable
- Contribution List
- Speaker List
- Book of Abstracts
- Participant List
- Talk Recordings
- Closing Statement

Workshop "Sustainable HEP"

This virtual Zoom workshop aims at discussing the transition to a sustainable future in the field of high-energy physics (HEP), in particular, changes in our travel culture, based on some of the crucial lessons we learned during 2020: Online formats can be a viable alternative to traditional in-person meetings and enable broader participation and inclusion of previously underrepresented groups of researchers. At the same time, efficient communication and networking can be challenging in online formats. The workshop will therefore bring together various perspectives to develop a balanced and deliberate approach to our post-pandemic travel culture and its connection to the questions of climate action, sustainability, and social justice. The workshop will take place from 3 to 7 pm CEST on Monday through Wednesday. The program will consist of impulse talks, panel discussions, input and discussion sessions, and asynchronous flash talks accompanied by a discussion forum on Mattermost: mattermost.web.cern.ch/sustainable-hep. All talks will be recorded and made available to the participants for the duration of the workshop, so as to allow for participation from all time zones.

Niklas Beisert
Valerie Domcke
Astrid Eichhorn
Kai Schmitz

SnowMass2021

- Community Engagement Frontier: TG07
  Environmental & Societal Impacts
- Coordinators: VB, Ken Bloom (U of Nebraska), Mike Headley (SDSTA-SURF)
- White papers released 15th March 2022, Community meeting in Seattle in July

Climate impacts of particle physics

Kenneth Bloom[1,*], Veronique Boisvert[2,**], Daniel Britzger[3], Micah Buuck[4], Astrid Eichhorn[5], Michael Headley[6], Kristin Lohwasser[7], and Petra Merkel[8]

[1]University of Nebraska-Lincoln, Lincoln, NE, USA
[2]Royal Holloway University London, United Kingdom
[3]Max-Planck-Institute for Physics, Munich, Germany
[4]SLAC National Accelerator Laboratory, Menlo Park, CA, USA
[5]CP3-Origins, University of Southern Denmark, Denmark
[6]Sanford Underground Research Facility (SURF), Lead, SD, USA
[7]University of Sheffield, United Kingdom
[8]Fermi National Accelerator Laboratory (Fermilab), Batavia, IL, USA

Abstract. The pursuit of particle physics requires a stable and prosperous society. Today, our society is increasingly threatened by global climate change. Human-influenced climate change has already impacted weather patterns, and global warming will only increase unless deep reductions in emissions of CO_2 and other greenhouse gases are achieved. Current and future activities in particle physics need to be considered in this context, either on the moral ground that we have a responsibility to leave a habitable planet to future generations, or on the more practical ground that, because of their scale, particle physics projects and activities will be under scrutiny for their impact on the climate. In this white paper for the U.S. Particle Physics Community Planning Exercise ("Snowmass"), we examine several contexts in which the practice of particle physics has impacts on the climate. These include the construction of facilities, the design and operation of particle detectors, the use of large-scale computing, and the research activities of scientists. We offer recommendations on establishing climate-aware practices in particle physics, with the goal of reducing our impact on the climate. We invite members of the community to show their support for a sustainable particle physics field [1].

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

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**Contact author, e-mail: Veronique.Boisvert@rhul.ac.uk

SnowMass2021

- Summary report:

> Finally, **HEP must take greater responsibility for its impacts on climate change** by addressing and mitigating these impacts through DOE project policies and individual community member actions.

- P5 Town meetings:
  - SLAC on 3-4th May: talk from Ken Bloom
- P5 presented their report on 7th December 2023…

P5 presentation/report

Exploring the Quantum Universe

Area Recommendations

Software, Computing, and Cyberinfrastructure

16. Resources for national initiatives in **AI/ML, quantum, computing, and microprocessors** should be leveraged and incorporated into research and R&D efforts to maximize the physics reach of the program.

17. Add support for a sustained R&D effort at the level of **$9M per year in 2023 dollars to adapt software and computing systems to emerging hardware,** incorporate other advances in computing technologies, and fund directed efforts to transition those developments into systems used for operations of experiments and facilities.

18. Through targeted investments at the level of **$8M per year in 2023 dollars**, ensure sustained support for key **cyberinfrastructure** components. This includes widely-used software packages, simulation tools, information resources such as the Particle Data Group and INSPIRE, as well as the shared infrastructure for preservation, dissemination, and analysis of the unique data collected by various experiments and surveys in order to realize their full scientific impact.

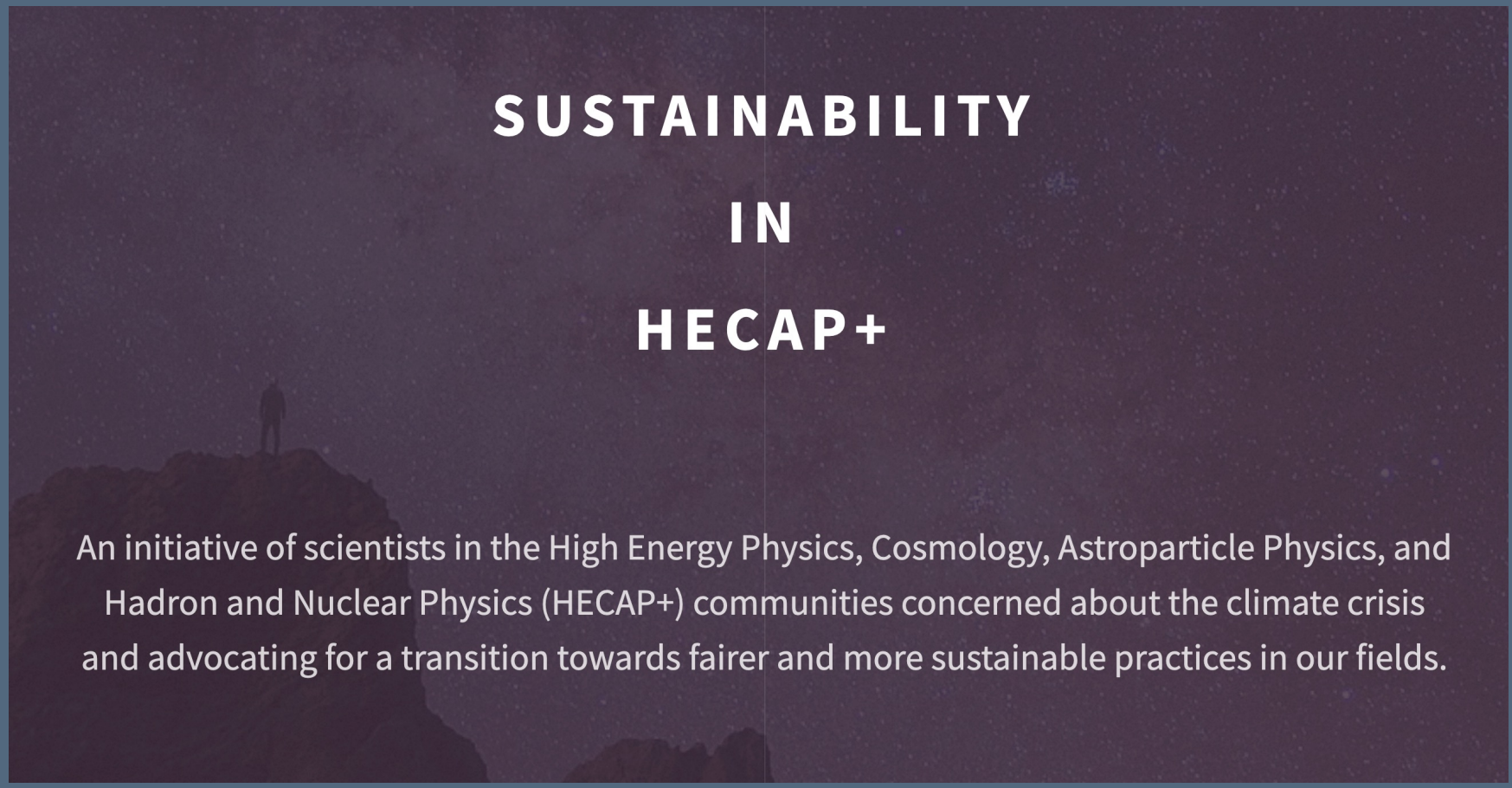
19. **Research software engineers and other professionals at universities and labs** are key to realizing the vision of the field and are critical for maintaining a technologically advanced workforce. We recommend that the funding agencies embrace these roles as a critical component of the workforce when investing in software, computing, and cyberinfrastructure.

Sustainability

20. HEPAP, potentially in collaboration with international partners, should conduct a dedicated study aiming at **developing a sustainability strategy for particle physics.**

And then…. nothing

Now: “The High Energy Physics Advisory Panel (HEPAP) was terminated effective August 8, 2025. Current charges will be transferred to the new Office of Science Advisory Committee (SCAC).”



Released on 5th June 2023: Full report available

Additional recommendations

- PP researchers need to be informed about the climate emergency
- Accounting of CO_2e emissions in particle physics should follow some common standards and get reported clearly to stakeholders
- Particular attention to gas detectors
- Costing of future experiments need to take into account of the climate policy context:
  - Net zero commitments
  - Demand on electricity grids
  - Possible carbon taxes, etc.
- Monitor emissions from universities/labs, travel, catering
- Be visible to our colleagues and society about our actions in that area
- Directly contribute to the energy/climate field

Recommendations

- New experiments and facility construction projects should report on their planned emissions and energy usage as part of their environmental assessment
  - Eg LHCb TDR for Phase II, CLIC LCA, ISIS-II LCA (H. Wakeling)
- Review across all international laboratories to ascertain whether emissions are reported clearly and in a standardized way
  - know your footprint!, France Labos 1.5
- Take steps to mitigate impact on climate change by setting concrete reduction goals and defining pathways to reaching them
  - spend a portion of research time on directly tackling challenges related to climate change

Sustainable Concrete Construction

CIPEA
CERN Innovation Programme on Environmental Applications

CERN for Climate Action Day

CIPEA 2025 Event

October 28 @CERN

https://indico.cern.ch/e/CIPEA-2025

- **Learn** about the CERN Innovation Programme on Environmental Applications (CIPEA)
- **Meet** CERN experts working on projects for the environment
- **Discover** how you can get involved

*CIPEA embraces **over 25** projects in the areas of:*

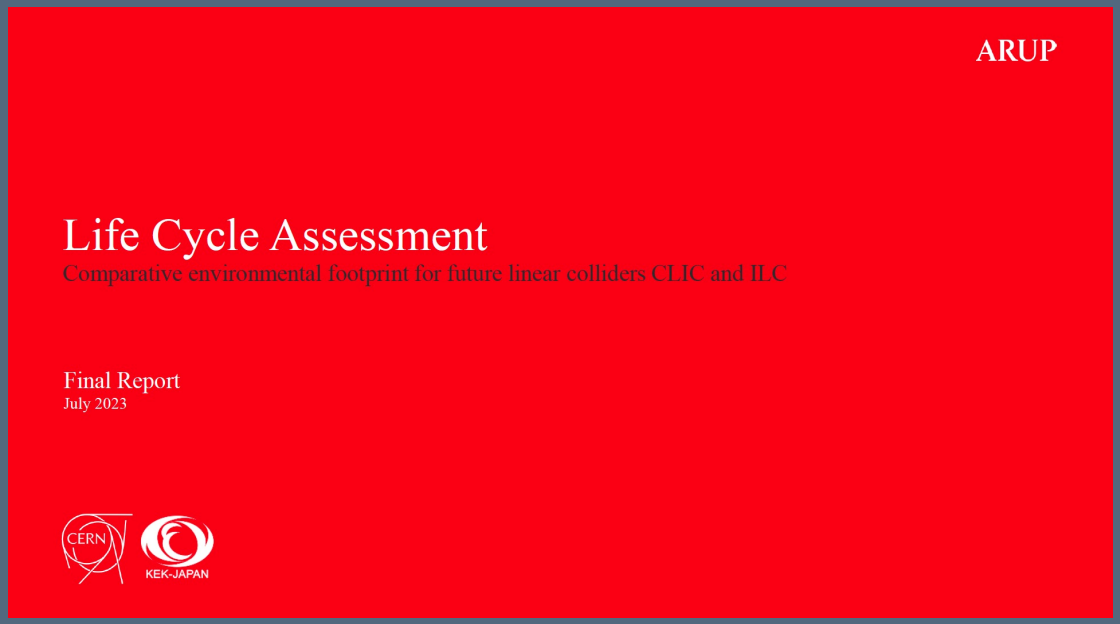
- RENEWABLE AND LOW-CARBON ENERGY
- CLEAN TRANSPORTATION AND FUTURE MOBILITY
- SUSTAINABILITY AND GREEN SCIENCE
- CLIMATE CHANGE AND POLLUTION CONTROL

Knowledge Transfer
Accelerating Innovation

CERN Innovation Programme on Environmental Applications

The rise of LCAs!

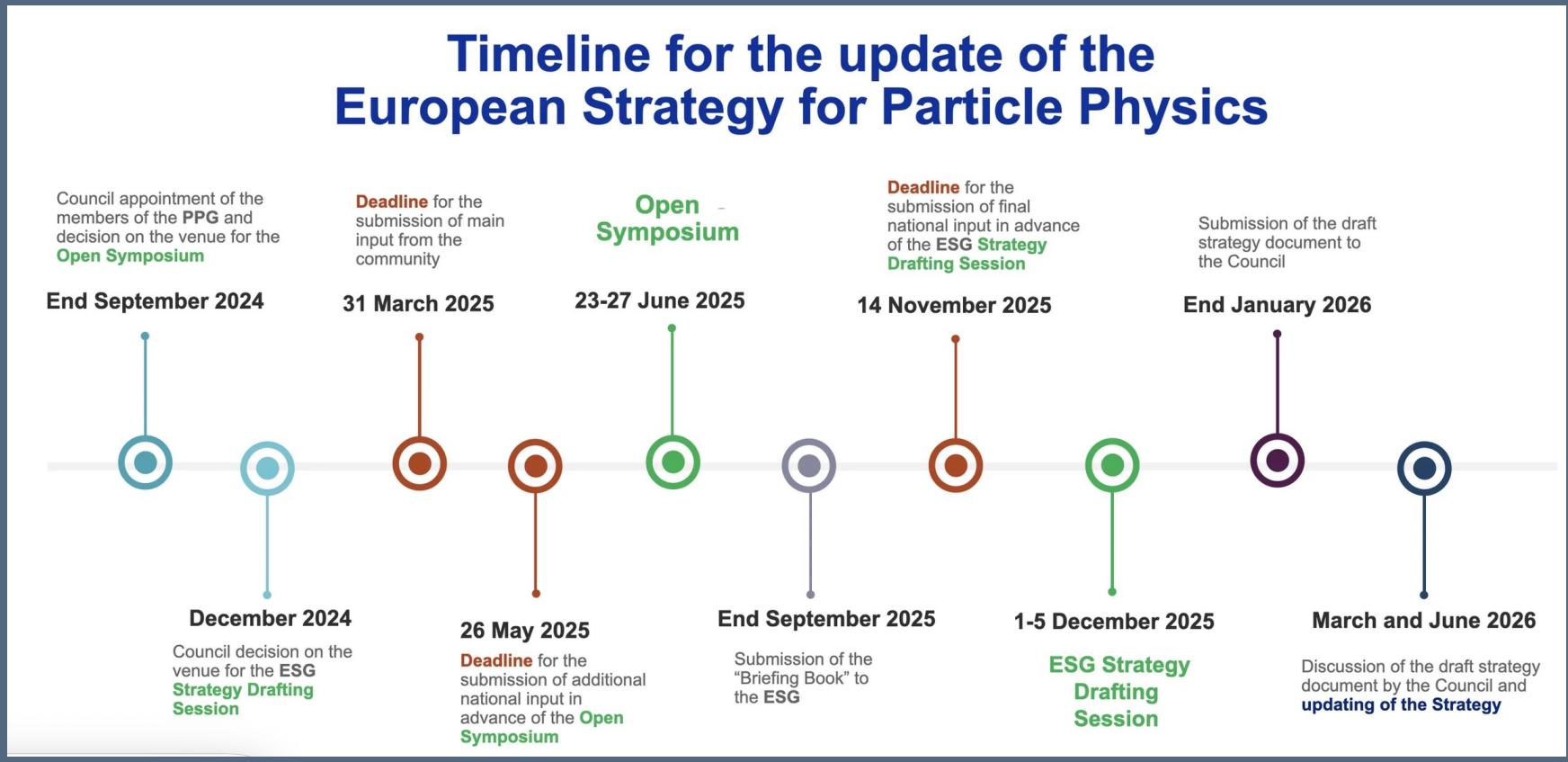
ARUP report



ISIS-II LCA by Hannah Wakeling

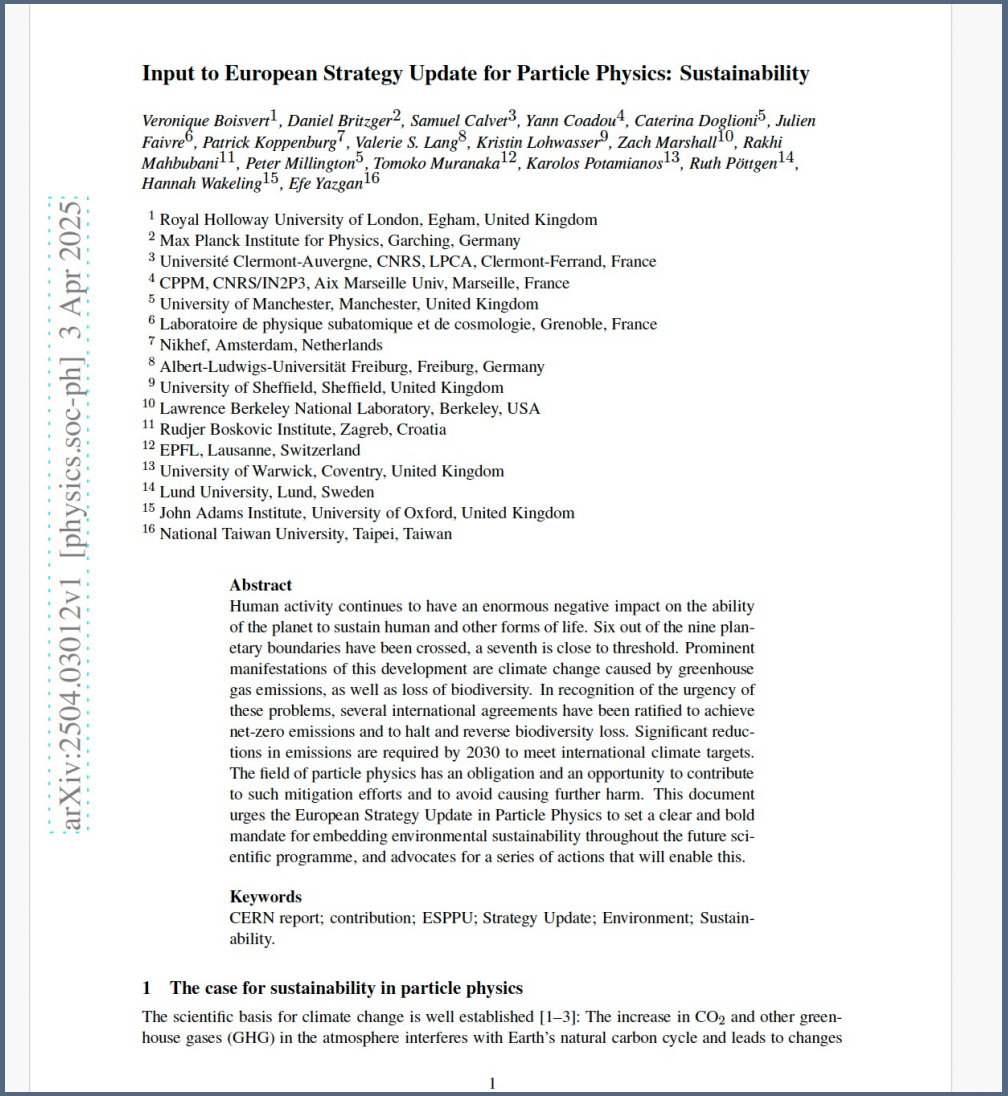
The Large Particle Physics Laboratory Directors Group (LDG) established the Working Group (WG) on the Sustainability Assessment of Future Accelerators in 2024, current comprehensive guide:
Sustainability Assessment of Future Accelerators

European Strategy PP Update



Input on Sustainability

- September 2024: Kick off
- Then series of meetings and discussions
- Preparation and submission of document (31st March 2025):
  - https://arxiv.org/abs/2504.03012
- Several more inputs! ☺



Input to European Strategy Update for Particle Physics: Sustainability

Veronique Boisvert[1], *Daniel Britzger*[2], *Samuel Calvet*[3], *Yann Coadou*[4], *Caterina Doglioni*[5], *Julien Faivre*[6], *Patrick Koppenburg*[7], *Valerie S. Lang*[8], *Kristin Lohwasser*[9], *Zach Marshall*[10], *Rakhi Mahbubani*[11], *Peter Millington*[5], *Tomoko Muranaka*[12], *Karolos Potamianos*[13], *Ruth Pöttgen*[14], *Hannah Wakeling*[15], *Efe Yazgan*[16]

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[7] Nikhef, Amsterdam, Netherlands
[8] Albert-Ludwigs-Universität Freiburg, Freiburg, Germany
[9] University of Sheffield, Sheffield, United Kingdom
[10] Lawrence Berkeley National Laboratory, Berkeley, USA
[11] Rudjer Boskovic Institute, Zagreb, Croatia
[12] EPFL, Lausanne, Switzerland
[13] University of Warwick, Coventry, United Kingdom
[14] Lund University, Lund, Sweden
[15] John Adams Institute, University of Oxford, United Kingdom
[16] National Taiwan University, Taipei, Taiwan

Abstract

Human activity continues to have an enormous negative impact on the ability of the planet to sustain human and other forms of life. Six out of the nine planetary boundaries have been crossed, a seventh is close to threshold. Prominent manifestations of this development are climate change caused by greenhouse gas emissions, as well as loss of biodiversity. In recognition of the urgency of these problems, several international agreements have been ratified to achieve net-zero emissions and to halt and reverse biodiversity loss. Significant reductions in emissions are required by 2030 to meet international climate targets. The field of particle physics has an obligation and an opportunity to contribute to such mitigation efforts and to avoid causing further harm. This document urges the European Strategy Update in Particle Physics to set a clear and bold mandate for embedding environmental sustainability throughout the future scientific programme, and advocates for a series of actions that will enable this.

Keywords

CERN report; contribution; ESPPU; Strategy Update; Environment; Sustainability.

1 The case for sustainability in particle physics

The scientific basis for climate change is well established [1–3]: The increase in CO_2 and other greenhouse gases (GHG) in the atmosphere interferes with Earth's natural carbon cycle and leads to changes

Input Recommendations

- Future particle physics projects, including next energy-frontier machines, be evaluated on adherence to principles of environmental sustainability from design to disposal, based on comprehensive Life Cycle Assessments (LCAs).

- All institutions involved in particle physics, including laboratories and universities, publish environmental reports at least every two years and use these to define ambitious emissions targets that they hold themselves accountable to.

- CERN, with its leading role in particle physics, hold itself to emissions reduction beyond its current targets, demonstrating the field's commitment to realizing net zero on a timescale compatible with the goals of the Paris Agreement, and setting the standard for basic scientific research worldwide.

- Laboratories that host particle physics experiments hold themselves accountable to and go beyond the environmental pledges of their hosting countries, including those from which they may be exempt, e.g., the upcoming ban on the emission of fluorinated gases (F-gases).

- CERN, national laboratories, funding agencies, and institutions encourage, reward, and provide opportunities for their scientists and engineers to contribute to addressing and communicating the environmental crisis.

- Negative environmental impacts of particle physics computing be quantified and reduced by integrating sustainability into hardware and software practices.

Input Recommendations

- CERN, national laboratories, funding agencies, and institutions develop flexible policies to enable and encourage environmentally friendly business travel, commuting, and methods of collaboration.

- CERN, national laboratories, funding agencies, and institutions enable and encourage practices that minimize food-related GHG emissions and other associated negative environmental impacts.

- Existing research sites be managed and future sites designed to enhance habitat diversity, halt local biodiversity loss, minimize water use, and encourage natural water cycles.

Review article: April 2025

Link

ANNUAL REVIEWS

Annual Review of Nuclear and Particle Science

Sustainability and Carbon Emissions of Future Accelerators

Kenneth Bloom[1] and Véronique Boisvert[2]

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Annu. Rev. Nucl. Part. Sci. 2025. 75:35–55

The *Annual Review of Nuclear and Particle Science* is online at nucl.annualreviews.org

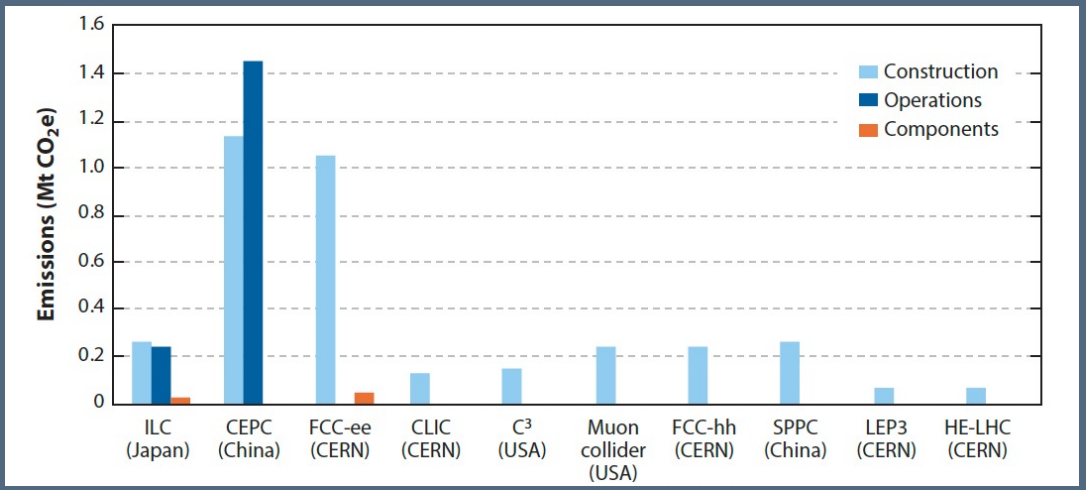
https://doi.org/10.1146/annurev-nucl-121423-100906

Keywords

accelerators, climate change, carbon emissions

Abstract

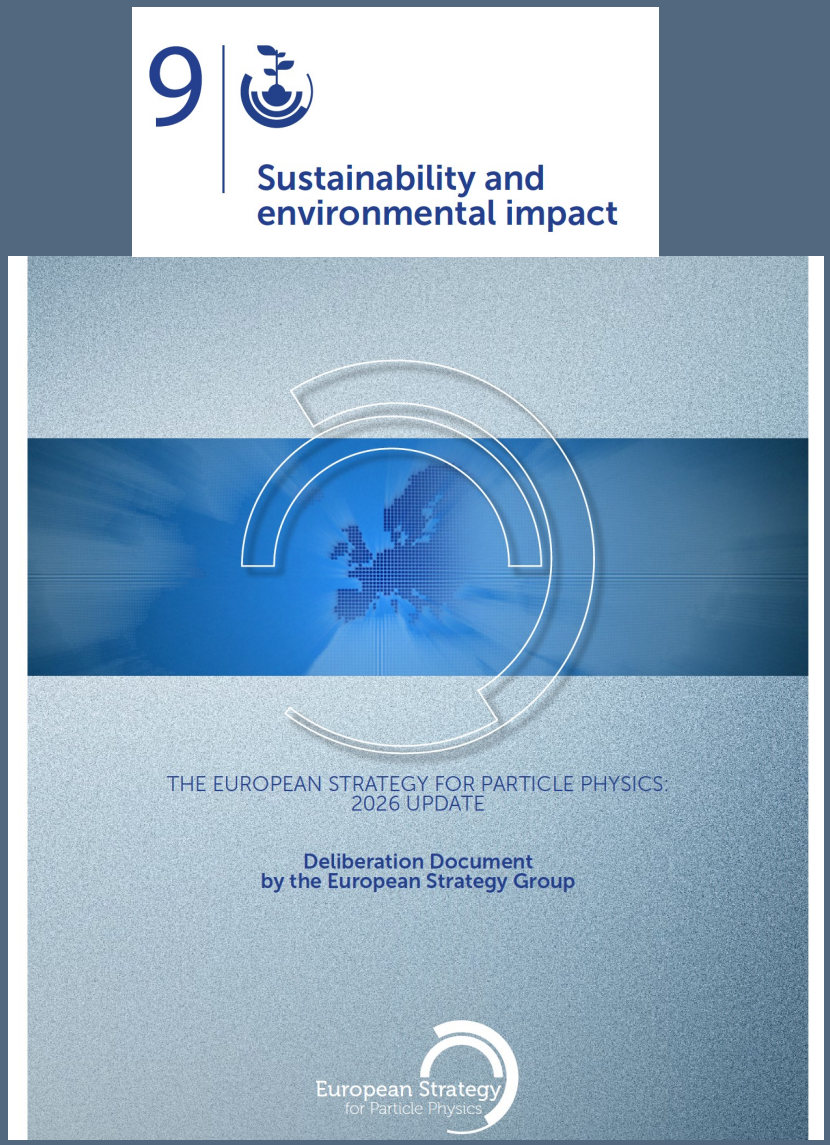
Future accelerators and experiments for energy-frontier particle physics will be built and operated during a period in which society must also address the climate change emergency by significantly reducing emissions of carbon dioxide. The carbon intensity of many particle physics activities is potentially significant, such that as a community particle physicists could create substantially more emissions compared to the amount created by average citizens, which is itself currently more than budgeted to limit the increase in average global temperatures. We estimate the carbon impacts of potential future accelerators, detectors, computing, and travel, and find that while emissions from civil construction dominate by far, some other activities make noticeable contributions. We discuss potential mitigation strategies as well as research and development activities that can be pursued to make particle physics more sustainable.



Also discussion of negative emissions options, including DAC

ESG reports

Brochure



WG 5

CERN-ESU-2026-009
15 February 2026

Report by ESG Working Group 5: Sustainability and Environmental Impact

Tommaso Boccali[1], Jim Clarke[2], Jens Jørgen Gaardhøje[3], Tadeusz Lesiak*[4], Panos Razis[5], Heidi Sandaker[6] and Dezső Varga[7]

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[5]University of Cyprus
[6]University of Oslo
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Abstract
This report summarises the outcome of the discussions of WG5 of the European Strategy Group (ESG).

1 Executive summary

Sustainability can be defined as the ability to maintain an activity over time without compromising the opportunities available to future generations [1]. Securing sustainable development implies a continuous shared responsibility at many levels. The high-energy physics (HEP) community is already carrying out many activities revolving around improving sustainability and minimising environmental impact and all such actions are appreciated by society. In this report we provide recommendations for the continuation and consolidation of these efforts in our community. The recommendations are structured into two sets: the generic recommendations listed below and guidelines specific to individual sustainability issues like those associated with accelerators, instrumentation, computing, etc., which are presented at the end of each individual section of this report.

Our overall observations/recommendations are as follows:

- The high-energy physics (HEP) community, being aware of its impact on the environment, climate change, energy efficiency and sustainability, acknowledges its responsibility to mitigate such effects at several levels, including the institutional, the project and the individual levels.
- The field should make every effort to actively mitigate the consequences of its large-scale research activities by minimising energy consumption, greenhouse gas (GHG) emissions, etc., in planning, realising and operating HEP facilities and projects. Developing new energy-saving technologies and the replacement of traditional materials, in particular gases, by environmentally friendly substances, should be pursued wherever possible. These solutions and knowledge should then be transferred to society.
- The environmental and energy efficiency aspects of new and existing HEP projects should be carefully assessed and the necessity of projects should be documented. The proponents of new projects are encouraged to include proposals for mitigation of the above-mentioned challenges and accompanying cost assessments in their project proposals, allowing governing authorities to consider and hopefully fund sustainability-friendly solutions. They are strongly encouraged to perform detailed lifecycle assessments (LCAs) at all stages of the project, including initial R&D and eventual decommissioning.

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ESG reports

Civil engineering work contributes in a substantial way to the environmental impact of major accelerator projects. It is typically the largest single contributor to emissions during construction and is driven mainly by the very large amount of concrete employed. Mitigation measures are being developed globally to reduce the environmental impact of major civil engineering work. Particle physics infrastructures should aim to benefit from such measures, even if this means incurring additional costs. Full sustainability considerations are also required at the earliest stages of projects for the materials extracted during the excavation of underground structures.

A. For new proposed projects, a detailed life cycle assessment should be carried out at each stage, from concept to design and implementation, in order to quantify and minimise environmental impact.

Laboratories are encouraged to formulate strategies for the environment and sustainability together with periodic reports about their implementation. It is desirable that these strategies should be as coherent as possible among HEP research infrastructures. Also, stringent

A robust educational framework to equip future generations of particle physics researchers with the necessary knowledge and skills for sustainable practices should be developed. Research oriented in these directions should be recognised and promoted.

Communication and collaboration are at the core of the scientific life and productivity of the particle physics community, but must be balanced against the environmental consequences.

ESG reports

B. The particle physics community should continue and intensify its efforts to develop and adopt sustainable solutions.

Among the best-practice approaches to optimising air travel are: shifting to environmentally-friendly land-based travel for short distances, taking the CO_2eq travel emissions into account in the choice of venues for conferences, workshops and meetings. Moreover, environmentally-friendly, sustainable means of transport for daily commutes should also be supported.

C. An effective balance between in-person and online meetings should be considered in order to mitigate the environmental impact of carbon-intensive travel.

PERSONAL THOUGHTS…

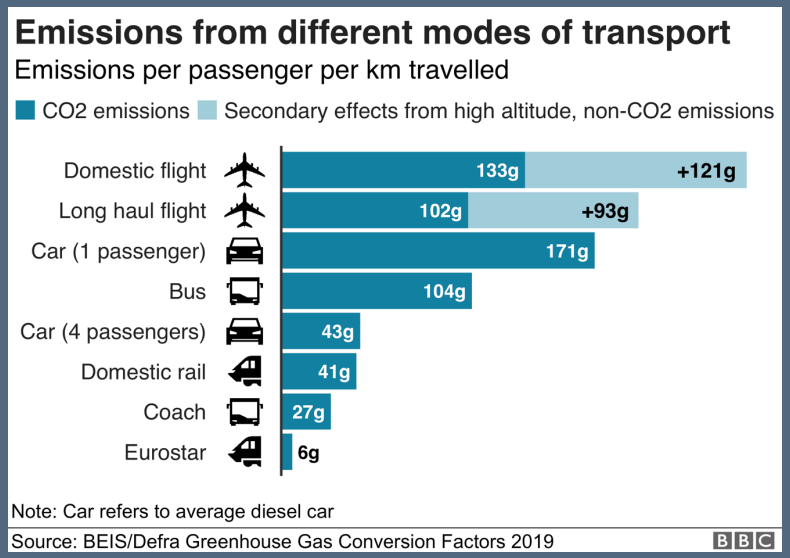
- Recommendations don't go as far and wide as our submitted inputs…
- But they go further than previously!
- Now the question is whether they will be implemented
  - Not just by CERN
  - But also by all European Labs and universities
  - It is up to us to hold institutions to account!
  - And to individually do our parts
- Will it be enough?

DISCUSSION/QUESTIONS

BACK UP

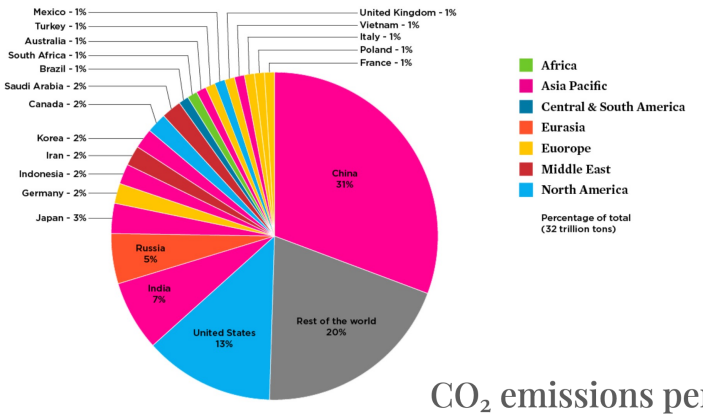
Carbon footprint of PP researchers

- Flying!
  - 15% of E consumption for an average UK citizen
  - Particle Physicists fly a lot (esp. seniors)! Let's say, per year:
    - 8 European trips (eg use from London to Zurich): 8 x 148 Kg CO_2: 1184 Kg CO_2
    - 1 overseas trip (eg use from London to NYC): 986 Kg CO_2
    - Total: 2170 Kg CO_2: ~87 countries where the average citizen emits less CO_2 in a year (incl. India, Morocco, Peru, Colombia)!
    - Using: Guardian calculator
  - A nearly carbon-neutral conference model
  - Best calculator: https://www.atmosfair.de/en/offset/fix/



Top Annual CO_2 Emitting countries, 2020

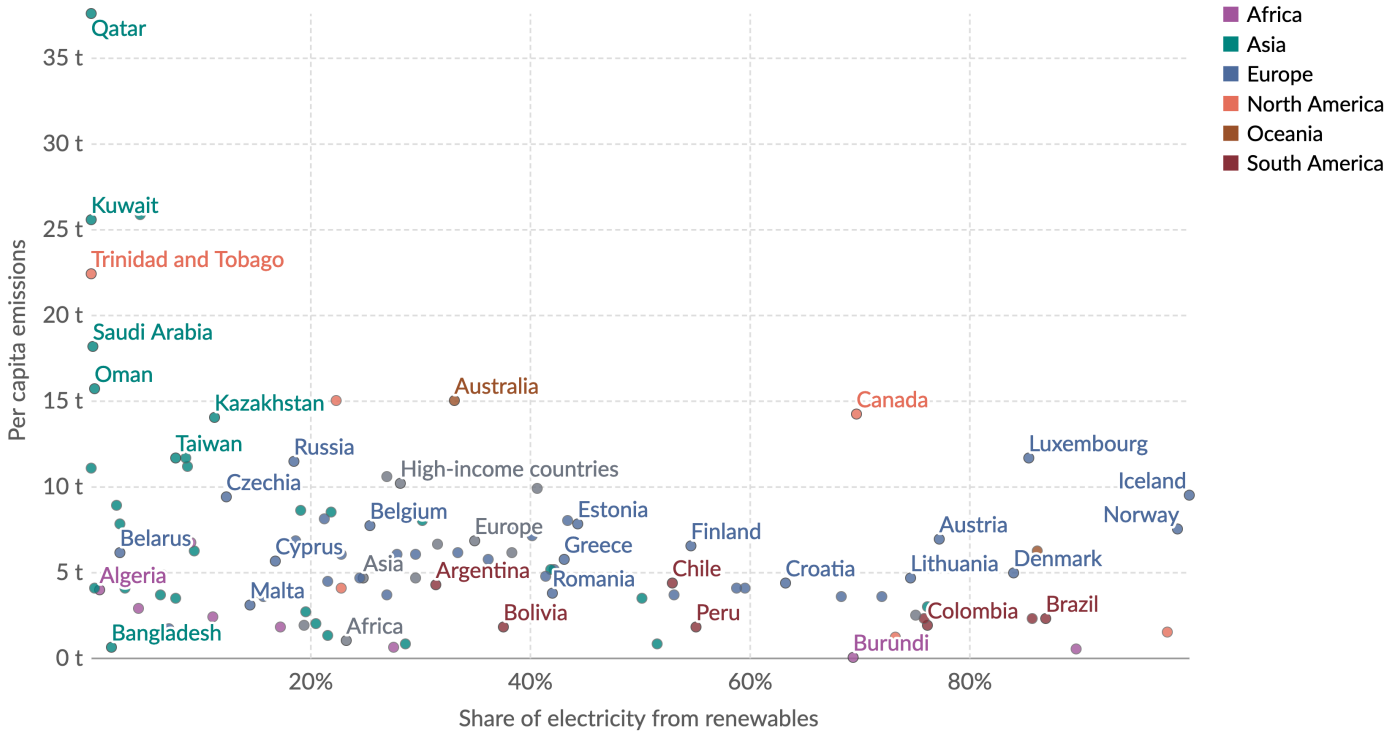
(from fossil fuels)



CO_2 emissions per capita vs. share of electricity generation from renewables, 2022

Our World in Data

Carbon dioxide (CO_2) emissions are measured in tonnes per person.



Data source: Global Carbon Budget (2023) and other sources

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY