Sustainable HEP 2024

Highlights of the 3rd edition of the Sustainable High Energy Physics Workshop 2024

Indico

Dr. Shreya Saha
University of Adelaide

ICHEP 2024

Organizing Committee: Shreyasi Acharya (INFN), Juliette Alimena (DESY), Daniel Britzger (MPP), Brendon Bullard (SLAC), Shreya Saha (Adelaide), Hannah Wakeling (Oxford)

Motivation

V. Boisvert

Human activities throughout the years have caused global warming

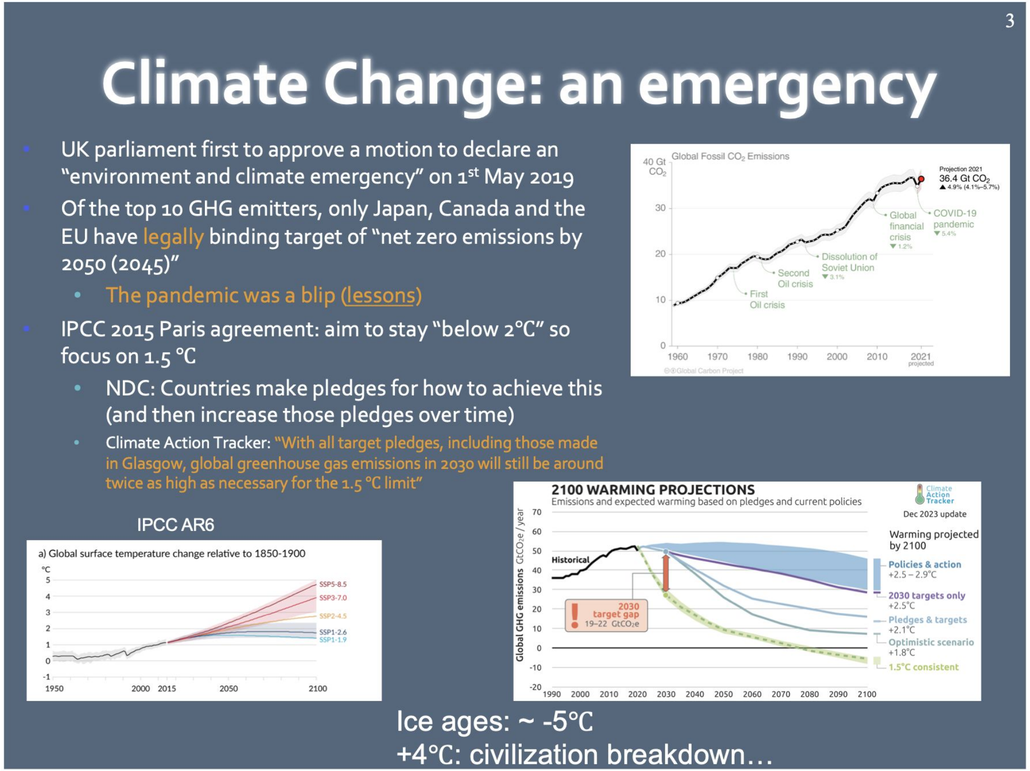
→ Temperatures increasing by **1.5℃ or higher** in the next decades.

→ **Greenhouse gas emissions** across various sectors.

→ Countries contributing least to the climate change are most **vulnerable** to its impact.

→ **Climate-resilient** development strategies.

→ Raising **awareness, international cooperation** in reducing inequality.



Overview

- Workshop held from **10 - 12 June** - [Indico]
- 233 registrants from 31 countries with 87 peak online presence
- 30 presentations with 8 plenary talks and 22 contributed talks on current and future developments in HEP
- Workshop was recorded for assisting people to participate across time zones

2021, 2022

ORGANIZING COMMITTEE

SHREYASI ACHARYA (INFN BARI)
JULIETTE ALIMENA (DESY)
DANIEL BRITZGER (MPP)
BRENDON BULLARD (SLAC)
SHREYA SAHA (ADELAIDE)
HANNAH WAKELING (OXFORD)

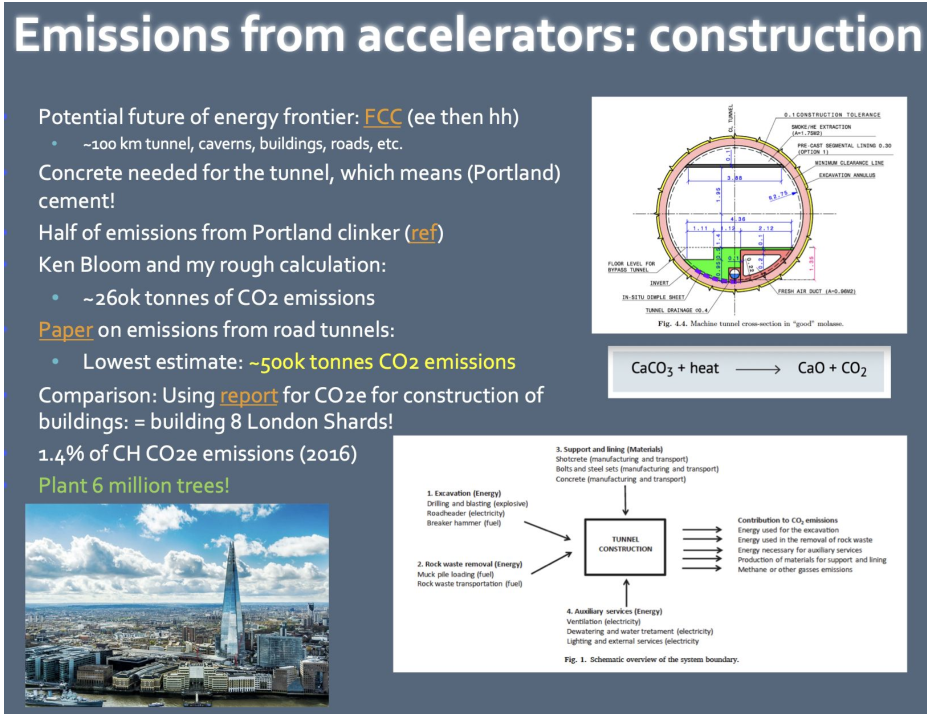
ADVISORY COMMITTEE

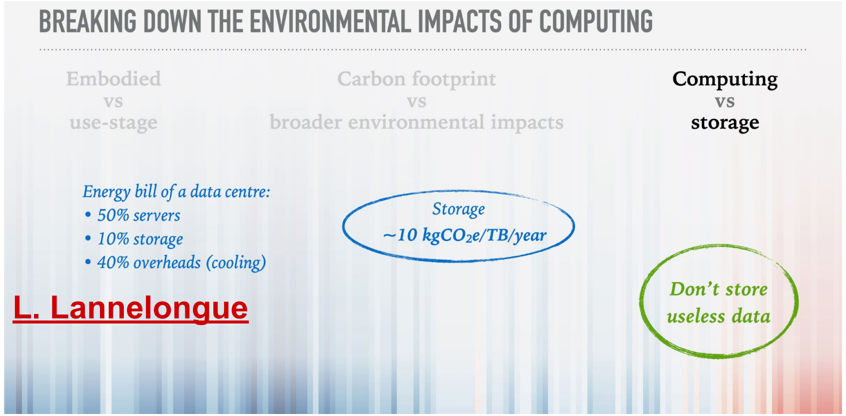
SHANKHA BANERJEE (IMSC CHENNAI)
NIKLAS BEISERT (ETHZ)
VALERIE DOMCKE (CERN)
VALERIE LANG (FREIBURG)
PETER MILLINGTON (MANCHESTER)
AYAN PAUL (NORTHEASTERN)

Major Contributors in HEP

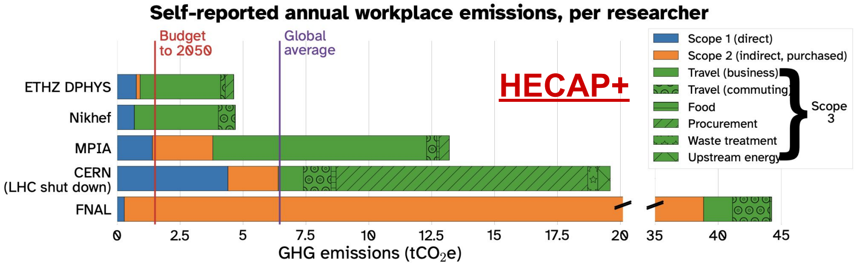
Greenhouse gases are primarily emitted from accelerator and detector construction and operations, computing, travel and food choices.

V. Boisvert





L. Lannelongue



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

Workshop Format

- Three plenary sessions with **invited talks**, two **non HEP talks** and **one industry talk**
- **Contributed talks** on diverse topics
- **Know Your Footprint workshop**

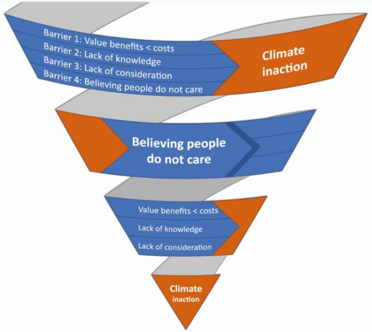
Day 1	**Day 2**	**Day 3**
Keynote Speech on Climate Change ***Prof. Jyoti K Parikh***	Overview on Sustainable Accelerators ***Prof. Masakazu Yoshioka***	Industrial scale involvement on sustainability development (ARUP) *Suzanne Evans*
Intersection of HEP and the Climate ***Prof. Veronique Boisvert***	Contribution from the IOP PABG - Sustainable Accelerator R&D in the UK ***Dr. Ben Shepherd***	Best Practices in HECAP+ (High-energy, Cosmology, Astro (Particle) Physics) ***Dr. Ayan Paul***
Computational Science and Sustainability ***Dr. Loïc Lannelongue***	Psychology of Climate Change ***Dr. Thijs Bouman***	**Workshop**
Session A : Computation Detectors in HEP experiments	**Session A** : Accelerators	
Session B: Climate Crisis Mitigation efforts in non-HEP fields	**Session B**: Large Scale facilities in HEP	

Sociological aspects

- Psychology is one of the driving factors for taking steps to support sustainability.
- **Acknowledging** the reality of the climate crisis.
- **Involve** in **design, development** and **implementation** for sustainable research goals.

Why "so little" action?

- Are we lying?
- Lack of knowledge
- Lack of capabilities
- Value conflicts
- Value instantiations
- Misperceiving others



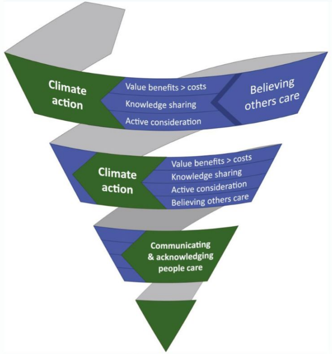
21

ENVIRONMENTAL PSYCHOLOGY GRONINGEN

References: Bouman, Steg & Perlaviciute, 2021; Bouman, Van der Werff, Perlaviciute & Steg, 2021;

How to increase action

T. Bouman



- Address the relevant motivations
- Reduce big costs
- Enable & increase opportunity
- Increase knowledge & assist
- Increase Awareness

26

ENVIRONMENTAL PSYCHOLOGY GRONINGEN

References: Bouman, Steg & Perlaviciute, 2021; Bouman, Van der Werff, Perlaviciute & Steg, 2021;

See also **T. Kuhr** (Belle II), **Y. Coadou** (Labos 1Point5, **Talk**), **S. Renner** (Scientists as Climate Activists), **D. Horan** (Future of Particle Astrophysics meetings), **S. Wagner** (A4E)

Sustainable Accelerators - Life Cycle Assessment

Life Cycle Assessment for large scale accelerator facilities -

- Crucial in **analysing** and **reducing** carbon footprint at every stage of the project.
- Techniques to **recover** and **reuse** thermal energy, disposed materials and focus on technology transfer.
- Collaborate with **local communities**.

(1) **LCA:** Future accelerators must be assessed for sustainability during their **life cycle**, including construction, operation, and decommissioning, to meet the global goal of carbon neutrality by 2050.

From construction to operational phase

- Stopping global warming is an urgent task for the entire human.
- To achieve this goal, we should aim to reduce greenhouse gas emissions to practically zero by 2050.
- Currently, the concept of **Life Cycle Assessment** is based on **all industries,** such as (for example) automobiles, metal production, cement production, civil engineering and construction, agriculture, forestry, and fisheries, etc.
- **Accelerators are no exception**, and their CO2 emissions should be assessed on a life cycle basis.

M. Yoshioka

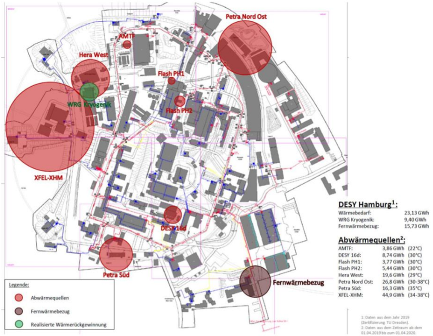
Waste Heat Usage

Potential at DESY Campus in Hamburg

A. Klumpp

SUSTAINABLE DESY.

- Project with University of applied science in Hamburg (HAW) to identify potential
- Result: 129 GWh/y of waste heat available at a temperature level of 30°C - 40°C
- Possible CO_2 savings at DESY campus of about 4.000 tons/y
- Surplus can be used in neighborhood; if we get the 129GWh in use saving will be up to 40.000 tons CO_2/y



HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Andrea Klumpp | Sustainable HEP 2024 - 3rd edition | 11.06.2024

See also N. Bunijevac (Cooling Infrastructure, CERN)

Designing eco-friendly accelerators

- Novel accelerator technologies to **improve performance** and **reduce energy consumption**
  - Thin films RF, efficient permanent magnets, cool copper colliders
- Innovate for Sustainable Accelerating Systems (iSAS) focusing on Superconducting RF cryomodule (Talk)

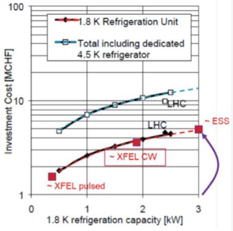
Thin Films: impact on cost and energy usage

B. Shepherd

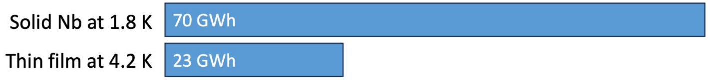
- Capital costs:
  - Cooling to 1.8 K represents **35-40%** of the total →
- Operating costs:
  - Combination of Carnot efficiency (thermodynamic limit) and refrigerator efficiency (technological limit)

$$\eta_C = \frac{T_{cold}}{T_{hot} - T_{cold}}$$

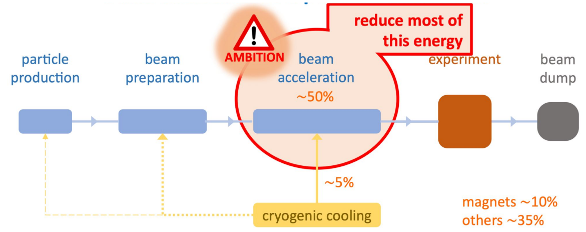
	1.8 K	4.2 K
η_C	0.6%	1.4%
η_{th}	15-20%	25-30%



- **3x lower cooling power at 4.2 K**
- Approx annual figures for an 8 GeV SC linac

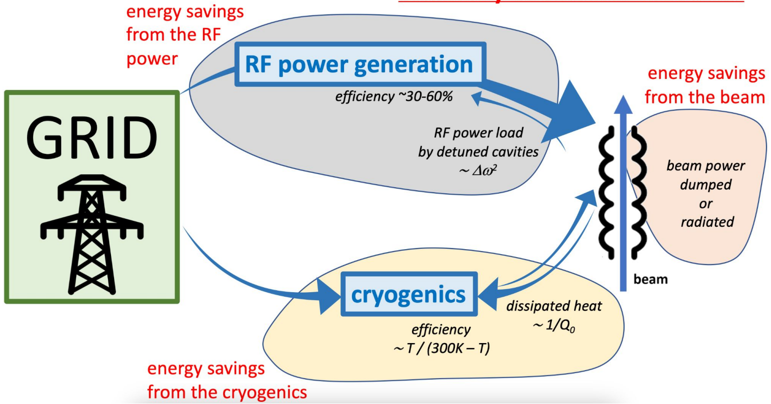


Ben Shepherd • Sustainable Accelerators • SusHEP × IOP PAB, June 2024 10



J. D'Hondt

Three key innovation directions



See also **D. Ntounis** (Cool Copper colliders, Talk), **G. Burt** (RF), **T. Roser** (ICFA Strategy), **G. Hallewell** (Green Cherenkov detectors, Talk)

Future Colliders

Colliders such as ILC, CLIC, CEPC, ISIS-II are actively incorporating sustainability goals

- Life Cycle Assessment, new technologies to increase efficiency and reduce carbon footprint

S. Evans

ARUP

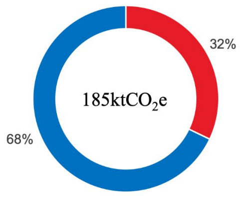
Construction and operation carbon

CLIC Drive Beam

Operational estimates provided by CERN. Based on a projected electricity mix in 2050 (50% nuclear, 50% renewables).

380GeV

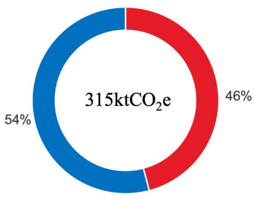
Construction GWP is equivalent to 1.7 decades of running accelerator



■ A1-A5 Construction (tunnel: 11.47km)
■ Operation over 8 years

1.5TeV

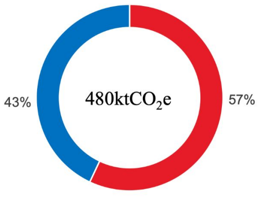
Construction GWP is equivalent to 0.8 decades of running accelerator



■ A1-A5 Construction (tunnel: 17.56km)
■ Operation over 7 years

3TeV

Construction GWP is equivalent to 0.6 decades of running accelerator

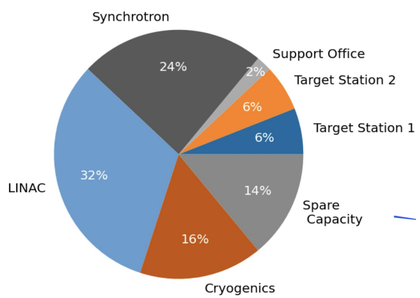


■ A1-A5 Construction (tunnel: 21.08km)
■ Operation over 8 years

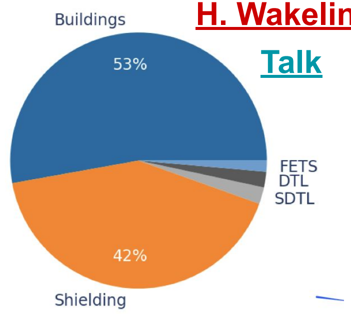
29

See also **R. Ge** (Energy recovery and reuse for Accelerators)

H. Wakeling Talk



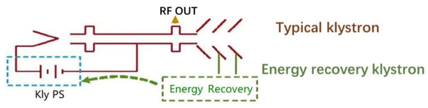
Estimated ISIS-II electricity requirements Big Science Scheme



Estimated CO_2e impacts of various ISIS-II LINAC components for construction.

Energy recovery by decelerating the used beams

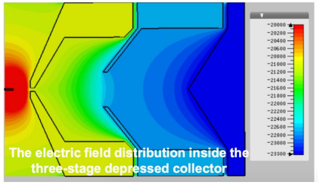
- CPI (USA) has developed multiple models of multi-stages decelerating collector klystrons
- Many research institutes in Japan, UK and so on has conducted similar efforts.

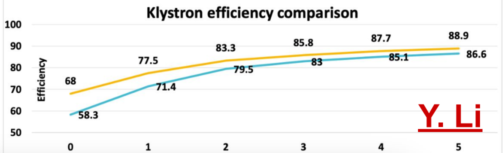


- CEPC will carry out the researches as well
  - Theoretical studies of efficiency v.s. collection stages for normal and high-efficient klystrons

CEPC high efficiency klystron prototype H.V. 113kV Cur. 9.5A		
Coll. Qty	Coll. Eff.	Kly. Eff.
0	0.0%	68.0%
1	29.8%	77.5%
2	47.7%	83.3%
3	55.6%	85.8%
4	61.4%	87.7%
5	65.2%	88.9%

CEPC first prototype H.V. 81.5kV Cur. 15.3A		
Coll. Qty	Coll. Eff.	Kly. Eff.
0	0.00%	58.3%
1	31.4%	71.4%
2	50.9%	79.5%
3	59.2%	83.0%
4	64.3%	85.1%
5	67.9%	86.6%





Y. Li

GHG Emissions from Detectors

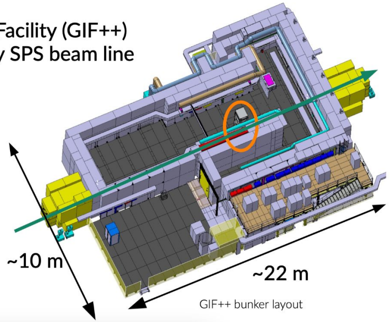
Gases used for particle detection, especially in the muon spectrometer systems (78% are **fluorinated gases**) → Released in the atmosphere, **costly to recycle**.

Eco-friendly gas mixtures → Ongoing efforts for ANUBIS, ATLAS RPC system

L. Quaglia

The RPC ECOGas@GIF++ collaboration

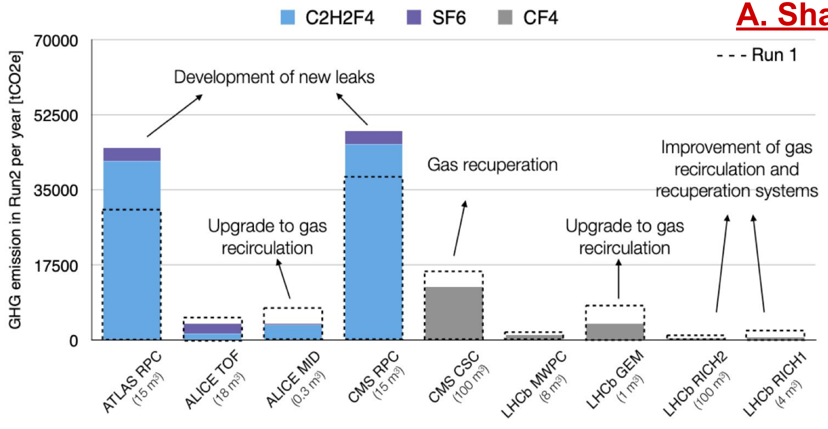
- Cross-experiment collaboration to join forces and perform aging/beam test studies with eco-friendly gas mixtures for RPCs
  → Includes CMS, ALICE, ATLAS, SHiP/LHCb and the detector technology group of CERN
- Studies carried out at the CERN Gamma Irradiation Facility (GIF++)
  → Experimental facility located on the H4 secondary SPS beam line
- 12.5 TBq ^{137}Cs source, high activity allows one to simulate long operating periods in much shorter time spans (**aging studies**) – irradiation can be modulated by means of attenuation filters (absorption factors)
- High energy (~150 GeV/c) muon beam in dedicated **beam time periods**



GIF++ bunker layout

See also O. Brandt (Muon Scattering Tomography with RPCs)

A. Shah



Short term

Gas Recirculation

- Optimization of current technologies
- Particular attention to operation
- Improve control and monitoring

Gas Recuperation

- Pressure Swing
- Membrane separation
- Cryogenic/Cold separation

Long term

Alternative Gases

- $C_2H_2F_4$
- SF_6
- CF_4
- … etc.

Greener Computing

- Computing in HEP comes at a cost, data centers emit ~126 Mt of carbon dioxide per year.
- Processing data smartly, using efficient software.

Use your hardware as long as possible! B. Brüers

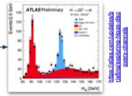
- **Also production matters for CO2e!**
  - 75% for a PC
  - 50% for a server
- **Use hardware as long as possible!**
  - Replace/fix failing parts
- But: new hardware may be more efficient! → Trade-off
- Construct "old hardware" computing centers running only on green energy?

13-inch MacBook Pro life cycle carbon emissions

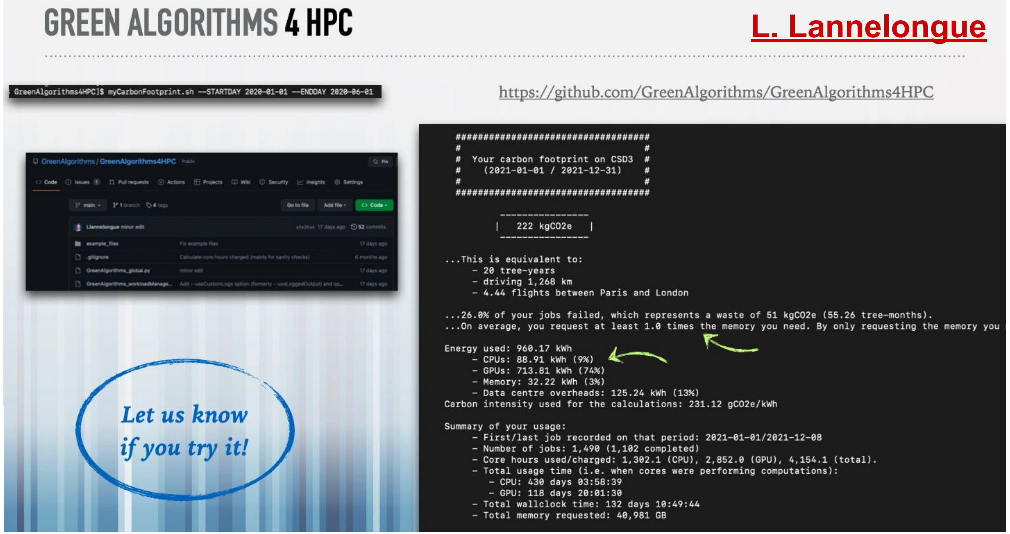
73%	Production
7%	Transport
19%	Use
<1%	End-of-life processing

- **Trade off between transforming / storage → "smart" transformations**

Particle detector → Raw data 010001101 → (Convert / Calibrate) → Processed data: x, y, z, t, p_x, p_y, p_z, E → (Reduce) → Reduce data: x, t, p_x, E →



- Reusing existing data is efficient → has led to several surprises in the past
- **Smart transformations for easy, long-term access of data → FAIR principles**



L. Lannelongue

See also A. Oyanguren (Real time data analysis, LHCb)

Green Algorithms4HPC
Green Algorithms

Know Your Footprint Workshop

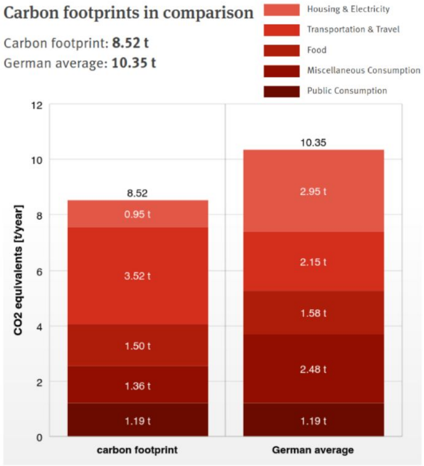
Interactive session and discussion about **personal** and **professional** carbon footprint, insights about work-related travel, computing, carbon emissions dependent on experiments.

Know Your Footprint Calculator

universität freiburg yHEP

- Know your footprint (Kyf) calculator → tool to estimate carbon emissions for researchers
  - Private emissions in Germany: Carbon Calculator by German Federal Environment Ministry (UBA)*
  - Professional emissions in HEP and related fields → split into 4 categories:
    - ⇒ Experiment
    - ⇒ Institute
    - ⇒ Computing
    - ⇒ Travel

> - Each category configurable for an individual, i.e. for your individual research situation
> - Investigate the impact of each category



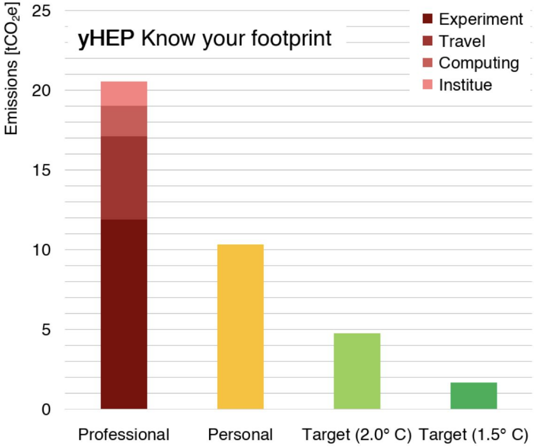
- Know your footprint calculator now live: Kyf calculator
- Paper discussing the basis of Kyf calculator available online on arXiv: arXiv:2403.03308

*Permission duly granted by UBA

Naman Kumar Bhalla | Know Your Footprint! | 12 June 2024 | 7 / 13

N. Bhalla

Doctoral student (benchmark)



Know your footprint

arXiv, Talk

Looking Ahead

Energy transition is possible, adhering to the goals of **IPCC**, but is **time sensitive** → highlighted by our keynote speaker, Prof. Jyoti Parikh.

Recommendations for **reducing emissions** classified into **individual**, **groups** and **institutions** actions (**HECAP+**)

See also **K. Shaw** (SDGs and Science), **A. Bender** (Renewable Energy at the South Pole)

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.

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.

Energy Transition

J. Parikh

- Due to uncertain availabilities, renewable energy transition requires a diversified mix of renewable sources and robust energy storage solutions to address intermittency.
- Significant investment is essential, and low or zero interest loan assistance can accelerate the transition in developing countries.
- Research and development of next-generation materials for batteries and storage technologies are required.
- Global cooperation is essential to achieve a unified and sustainable energy transition for all.

Energy Transition can be done

But would we do it in time?

A. Paul

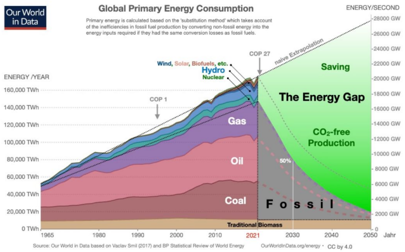


Figure 3.1: Global primary energy consumption is dominated by fossil fuels, the use of which has been increasing steadily despite repeated warnings from the climate change conferences of the United Nations (COP) dating as far back as 1995. Decreasing emissions by 50%, as recommended by the IPCC to avoid irreversible tipping points [64] (see blue line in Figure 1.1) creates a large energy gap that must be filled by additional climate-neutral power generation, or by energy savings and recuperation. Consumption was extrapolated linearly from 1965–2021 to account for additional demand from emerging countries. Left part of figure taken from Ref. [65], based on data from Refs. [60, 66], reused and adapted under the terms of the Creative Commons Attribution 4.0 International (CC BY 4.0) license.

consumption

CERN uses 1300 GWh of electricity annually,

This is the equivalent of what is used in a city of > 100,000 people in the USA

This is the equivalent of what is used in a city of > 600,000 people in Brazil

This is the equivalent of what is used in a city of > 2,00,000 people in India

[60] British Petroleum, "bp Statistical Review of World Energy," https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf, BP, Tech. Rep., 2022.

[64] OECD, *Climate Tipping Points: Insights for Effective Policy Action.* OECD Publishing, Paris, 2022. https://doi.org/10.1787/abc5a69e-en

[65] H. Ritchie *et al.*, "Energy," *Our World in Data*, 2020. https://ourworldindata.org/energy

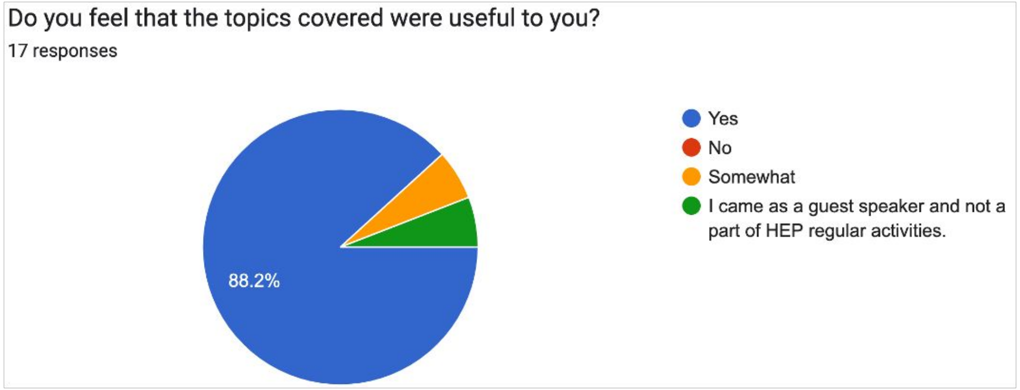
[66] V. Smil, *Energy Transitions: Global and National Perspectives.* Praeger, 2016.

Feedback

Overall positive reception by participants.
All talks by invited and contributed speakers were extremely well-received.

Future workshop suggestions -

- Extend the timetable to a **full day conference**
- **More time** and discussion allotted for talks
- Request for **no parallel sessions**
- **Panel Session** request - Efforts were made for this workshop, but unsuccessful considering the availability of panelists



Conclusion

- The workshop (Indico) was a great success and led to several **interesting discussions** and is currently ongoing in the Mattermost channel.
- Strive for increased **awareness** and **tangible outcomes** in the HEP community and highlight ongoing efforts related to **future developments** in the field.
- Work with **funding agencies** and **local communities** to make sustainability **accessible for everyone**.
- Work on an **individual level** in day-to-day life for the sake of our future generations.

We are looking for the next organizing committee for the 4th Sustainable HEP workshop!

Ideas are welcome!

Please contact **hannah.wakeling@physics.ox.ac.uk** if you are interested!

Social media

HECAP+

SCIENTISTS FOR EXTINCTION REBELLION

scientistsforxr.earth

scientist rebellion_

scientistrebellion.org

ASTRONOMERS FOR PLANET EARTH

astronomersforplanet.earth

Organizers

Juliette Alimena (DESY)

Brendon Bullard (SLAC)

Daniel Britzger (MPP)

Hannah Wakeling (Oxford)

Shreya Saha (Adelaide)

Shreyasi Acharya (INFN Bari)

Acknowledgements

International Advisory Committee :

Shankha Banerjee - Institute of Mathematical Sciences (IMSC), India

Niklas Beisert - Eidgenössische Technische Hochschule (ETH) Zürich, Switzerland

Valerie Domcke - European Organization for Nuclear Research (CERN), Switzerland

Valerie Lang - University of Freiburg, Germany

Peter Millington - University of Manchester, UK

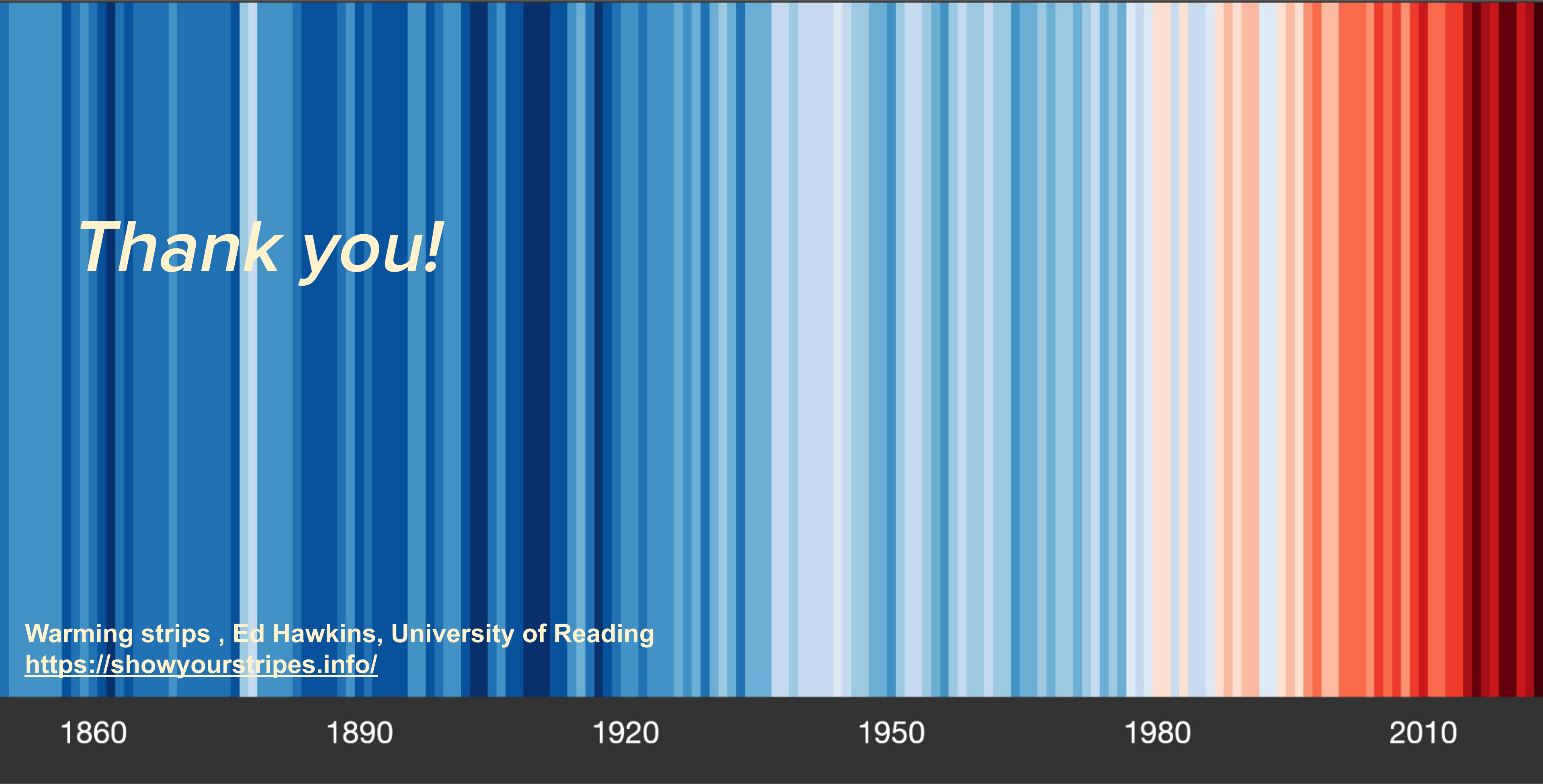
Ayan Paul - Northeastern University, USA

UK IoP Particle Accelerators and Beams Group (PABG) - Joint Conference on 11th June

Website Host: The John Adams Institute for Accelerator Science, Particle Physics Department of the University of Oxford.

Zoom Host: CERN (User License)

Thank you!



Warming strips , Ed Hawkins, University of Reading
https://showyourstripes.info/

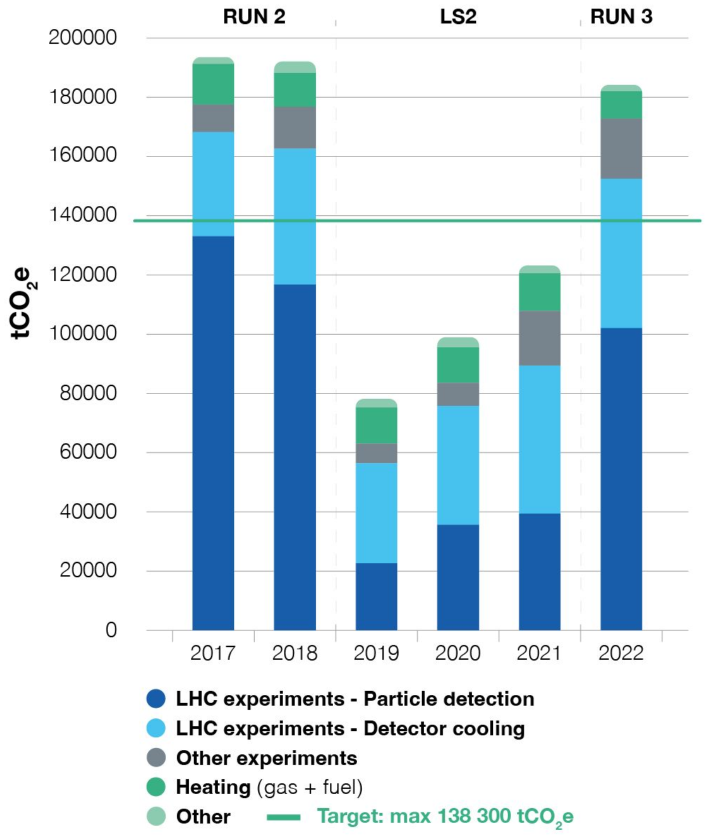
Backup

SDGs

UN 2030 Agenda

CERN Case Study

GROUP	GASES	tCO_2e 2021	tCO_2e 2022
Perfluorocarbons (PFCs)	CF_4, C_2F_6, C_3F_8, C_4F_{10}, C_6F_{14}	55 921	68 989
Hydrochlorofluorocarbons (HFCs)	HFC-23 (CHF_3) HFC-32 (CH_2F_2) HFC-134a ($C_2H_2F_4$) HFC-404a HFC-407c HFC-410a HFC-507	36 557	86 211
Other F-gases	SF_6, NF_3	16 838	18 355
Hydrofluoroolefins (HFO)/HFCs	R-449 R1234ze NOVEC 649	86	199
	CO_2	13 771	10 419
Total Scope 1		123 174	184 173



CERN HSE