

ENVIRONMENTAL SUSTAINABILITY AT FUTURE COLLIDERS

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Science and
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INTRODUCTION

- Collider facilities are:
 - resource consumptive
 - grow in size and/or power, therefore consumption
- We as a community need to contribute to meeting sustainability goals
- The UK must reach **net-zero by 2050**
- Sustainability is not **just** carbon emissions!
- Environmental sustainability as a whole is often attempted retroactively, low priority, dropped out of consideration, not considered at all, etc.
- However, the focus on sustainability within particle physics is growing
- In the next steps of future colliders, sustainability needs to be included earlier in the planning stages

SUSTAINABILITY AT FUTURE COLLIDERS?

Consider
object, material, waste, transport, packaging, energy etc.

REFUSE

- e.g., the most environmentally impactful options.

REDUCE

- e.g., waste before its created.

REUSE

- e.g., shielding.

RECYCLE

- rather than waste (energy consumptive!).

ROT

- e.g., make waste safer for disposal.

STRATEGY

European Strategy for Particle Physics

- Use energy efficient technologies
 - Low loss superconducting resonators
 - Efficient radio frequency sources
 - Permanent magnets
 - Highly efficient cryogenic systems
 - Superconducting electrical links
 - Use of heat pumps
- Use of energy efficient accelerator concepts
 - Energy recovery linacs
 - Intensity frontier machines
 - Muon colliders
 - Energy management
 - Accelerator driven systems
- General sustainability
 - Carbon footprint analyses in design phases: i.e., Life Cycle Assessments
 - Consumption analyses e.g., water, helium
 - Optimize cooling.
 - More environmentally friendly materials and better sourcing/procurement.

T. Roser and M. Seidel,
Sustainability considerations, in:
European Strategy for Particle Physics - Accelerator R&D Roadmap,
Ed. N. Mounet, p. 247.

PROGRESS

- Many efforts ongoing around the world:
 - Carbon emissions reports
 - Carbon impact studies such as construction/tunnelling
 - R&D for increased efficiency of machines (klystrons, cryo., etc.)
 - Reduction in resource consumption (water, helium, etc.)
 - Air-travel reduction
 - Sustainability guidelines
 - And more...

More information in backup

THANK YOU

BACKUP

Additional information on sustainability at future colliders that is, by all means, a non-exhaustive list.

Please contact me at
hannah dot wakeling at physics dot ox dot ac dot uk
to suggest additional material.

GENERAL PUBLICATIONS

- Environmental sustainability in basic research: a perspective from HECAP+

[arXiv:2306.02837](https://arxiv.org/abs/2306.02837), released on UN World Environment Day, 5 June 2023.

A grassroots initiative of researchers from across High Energy Physics, Cosmology, Astroparticle Physics, and Hadron and Nuclear Physics (HECAP+)

Endorse-able: <https://indico.cern.ch/event/1293733/>

- SNOWMASS (<https://arxiv.org/abs/2209.07684>)
- CERN Environment Report (<https://hse.cern/environment-report>)
- Light Sources (<https://www.ipac23.org/preproc/pdf/THODB3.pdf>)
- SLAC (<https://www.slac.stanford.edu/pubs/slacreports/reports21/slac-r-1144.pdf>)
- + many more

EVENTS

- Sustainable HEP
(2nd: <https://indico.cern.ch/event/1160140/>)
- Sustainable Accelerators Workshop
(<https://indico.stfc.ac.uk/event/646/>)
- Energy for Sustainable Science at Research Infrastructures
(6th: <https://indico.esrf.fr/event/2/>)
- Proton Driver Efficiency Workshop
(<https://indico.psi.ch/event/3848/> with report
https://indico.psi.ch/event/3848/attachments/6982/8957/pdriver-efficiency-summary_compilation_V6.pdf)

Increasing plenaries, parallel sessions and presentations at conferences, including most recently:

- [FCC Week 2023](#)
- [LCWS 2023](#)
- [IPAC 2023](#)

ORGANIZATIONS/PROJECTS

- I.FAST - Innovation Fostering in Accelerator Science and Technology
(<https://cordis.europa.eu/project/id/101004730>)
- I2SL - Internation Institute for Sustainable Laboratories
(<https://www.i2sl.org/>)
- LEAF - Laboratory Efficiency Assessment Framework
(<https://www.ucl.ac.uk/sustainable/leaf-laboratory-efficiency-assessment-framework>)
- HEIKA – High Efficiency Klystron International Activity
(<https://ieeexplore.ieee.org/document/8673883>)
- EAJADE – Europe-America-Japan Accelerator Development Exchange Programme
(<https://www.eajade.eu/>)

R&D

Examples include:

- Increased efficiency of klystrons:
 - Efficiency frontiers of the high power klystrons (https://indico.cern.ch/event/952778/contributions/4013794/attachments/2112765/3553942/CLWeek_2020_Septemper.pdf)
- CO₂ impact studies such as construction/tunnelling:
 - Linear Collider Carbon Assessments: A Life Cycle Assessment of the CLIC and ILC Linear Collider Feasibility Studies (<https://indico.slac.stanford.edu/event/7467/contributions/5902/>)
- Permanent magnets (replacing electromagnets):
 - The ZEPTO Dipole: Zero Power Tuneable Optics for CLIC (<https://accelconf.web.cern.ch/ipac2017/papers/thpik105.pdf>)
- Comparison of superconducting linacs and warm linacs:
 - Pulsed proton drivers by Sang-Ho Kim (<https://indico.psi.ch/event/3848>)

SUSTAINABILITY AS A WHOLE

Sustainability is not **just** environmental sustainability.

Sociological and economical sustainability must also be considered.

- Human impact of extraction is large.
- Physics creates jobs and economic benefits.
- SNOWMASS Report of the Topical Group on Environmental and Societal Impacts of Particle Physics for Snowmass 2021 (<https://arxiv.org/abs/2209.07684>)