Environmental considerations in High Energy Physics / CERN

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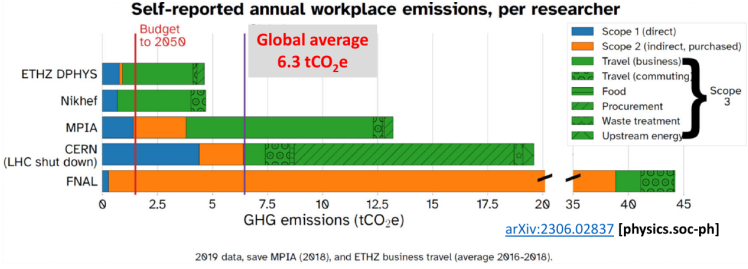
Context

- Growing awareness of sustainability issues in HEP
  - Large facilities → large impacts from construction, accelerator and detector operation and cooling, electricity
  - Also computing, travel, procurements, etc.
- Topics for today
  - CERN's environmental report
  - Future Circual Collider (FCC) and other future projects
  - Update of the European Strategy for Particle Physics (ESPPU)

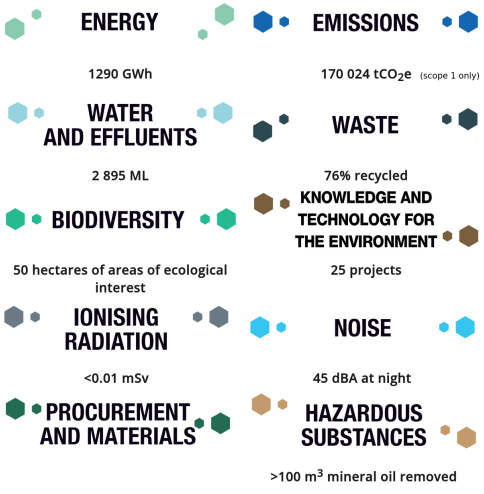


1. CERN's environmental report

CERN's environmental report

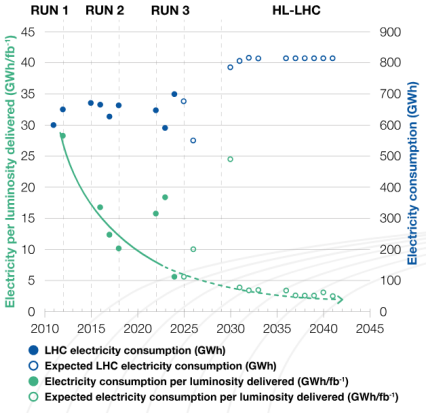
https://environmentreports.web.cern.ch/environment-report-2023-2024/

- Every two years
- Fourth one (for 2023–2024) out in November 2025
- Covers GHG emissions but also energy, water, waste, biodiversity, ...
- Reduction plans and goals for the future (2030)



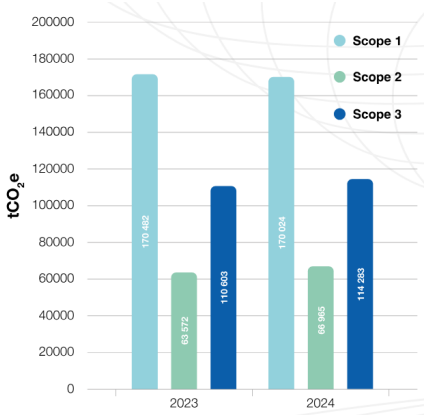
Electricity

- Peak consumption $\approx$ 200 MW
- Increased efficiency for LHC operation
- Heat recovery
  - New computing centre (PUE $\approx$ 1.1) will provide heating to CERN buildings (2027)
  - Heat from cooling towers: Ferney-Voltaire (since 2024, $\approx$ 20 GWh/y), Meyrin (2027)



Greenhouse gas emissions

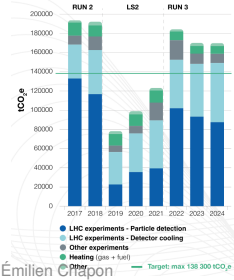
- Scope 1: dominated by contribution from detector operation and cooling (mostly F-gases from ATLAS and CMS)
- Scope 2: electricity (mainly of nuclear origin → relatively low)
- Scope 3: procurement, waste, travel, personnel commute...



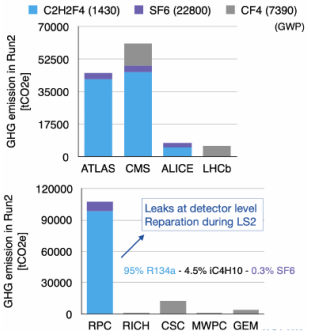
CERN'S TOTAL SCOPE 1, 2 AND 3 EMISSIONS 2023–2024

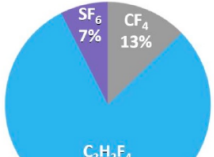
Detector operation and cooling

- Main sources:
  - Gaseous detectors (mostly Resistive Plate Chambers for muon detection): R134A ($C_2H_4F_4$ – GWP 1430), SF_6 (GWP 22800)
  - Detector cooling: C_3H_8 (GWP 8830), C_6F_{14} (GWP 9300)
- Mitigation: fix leaks, gas recovery, replacement with other gases (CO_2 where possible)



GROUP	GASES	tCO_2e 2023	tCO_2e 2024
Perfluorocarbons (PFCs)	CF_4, C_2F_6, C_3F_8, C_4F_{10}, C_6F_{14}	65 223	75 177
Hydrofluorocarbons (HFCs)	HFC-23 (CHF_3), HFC-32 (CH_2F_2), HFC-134a ($C_2H_2F_4$), HFC-404a, HFC-407c, HFC-410a, HFC-507, HFC	80 988	64 092
Other F-gases	SF_6, NF_3	14 906	21 567
Hydrofluoroolefins (HFOs)	R-449, R-1234ze, NOVEC 649, R-1233ef	145	1
	CO_2	9 220	9 187
Total Scope 1		170 482	170 024





Computing: example of ATLAS

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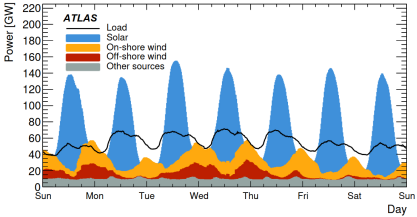
- User responsibility: CO_{2eq} as part of the job report
  - **Independent of the site** to avoid stressing “greener” computing sites
- Discussion of many more aspects within the experiment
  - Site construction and operation (e.g. adjustment to the availability of renewable energy)
  - Choice between CPU technologies, accelerators (GPU, FPGA)
  - Impact of unused data, data replication

Estimated Carbon Footprint for the Task

Category	gCO2
Succeeded	0.06 gCO2
Failed	0 gCO2
Cancelled	0 gCO2
Total	**0.06 gCO2**

More details on estimation: https://panda-wms.readthedocs.io/en/latest/advanced/carbon_footprint.html

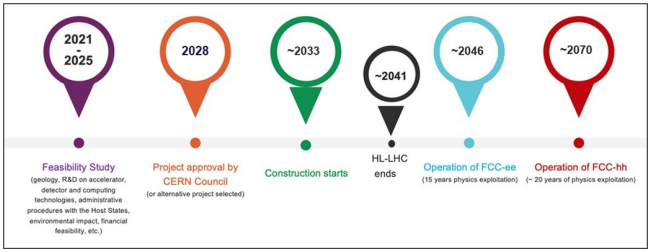


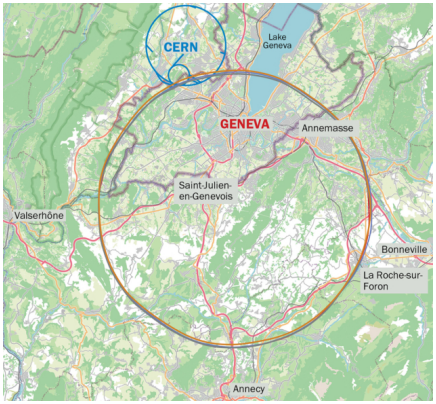
2. Future projects

FCC

FCC Faisability Study (report)

- One of the projects beyond LHC
- 91 km tunnel
- FCC-ee first (electron-positron), then FCC-hh (proton-proton)

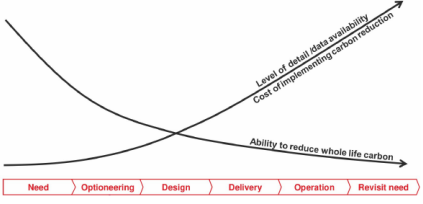




Life-cycle assessment

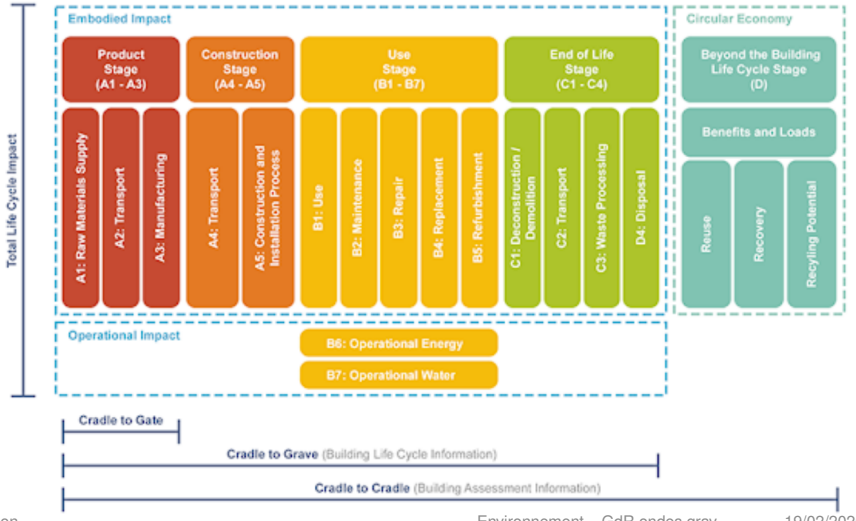
Sustainability assessment of future accelerators

- Pour minimiser l'impact des infrastructures, il faut **inclure les contraintes environnementales le plus tôt possible** dans le processus
- **Anticiper les leviers de mitigation et de compensation:**
  - Optimisation du génie civil et des matériaux
  - Approvisionnement responsable
  - Optimisation des fournisseurs d'énergie, récupération de chaleur
  - Investissements dans des R&D pour des technologies + vertueuses
  - ...



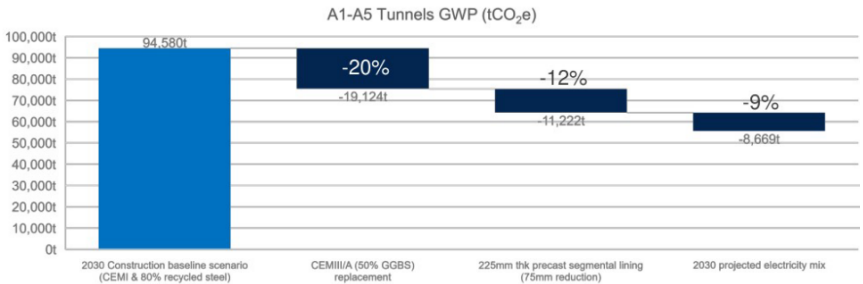
Life-cycle assessment

Source



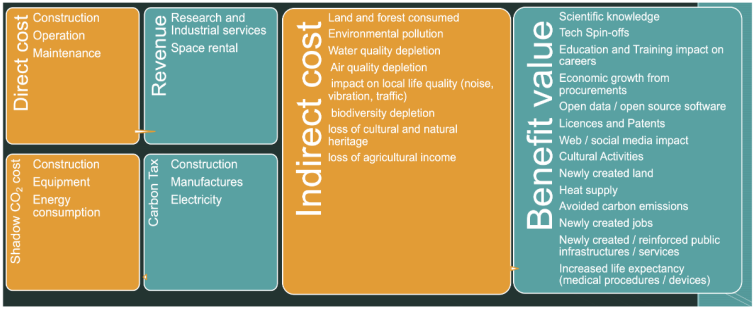
Sustainability for FCC

- Land use minimised (down to around 40 ha for 8 surface sites)
- Civil engineering and concrete
- Power and efficiency (e.g. RF klystron technology)



Comparing different projects

- Need to agree on common methodology and indicators to compare different projects
  - LCA, GHG emissions, mitigation and compensation measures...
- Sustainability WGs from ECFA (European Committee for Future Accelerators), LDG (Laboratory Directors Group)
- Report available
- See also the accelerator R&D roadmap



3. ESPPU

Context

- Ongoing process: update of the European Strategy for Particle Physics
- Major deliverable: preferred option for the next collider at CERN
- Discussions at all levels (labs, countries)
  - e.g. French symposium in January 2025, including sustainable development contribution

Discussions

- Environmental considerations are put forward in general
  - Physics reach is the key objective, but the environmental (and financial) costs are substantial
- Discussions at the French symposium
  - Optimise science vs CHF/EUR vs CO_2
  - Strategy for going beyond words: invest in detector R&D, importance of efficiency in computing, accelerator technology.
  - “Science first” vs “environmental budget first” in the context of social acceptability

Recommendations

- FCC-ee is the preferred option for the next CERN flagship collider project (a descoped FCC-ee is the preferred alternative)
- Sustainability
  - For every new proposed project, a detailed Life Cycle Assessment should be carried out at each stage from concept, design and implementation to quantify and minimise environmental impact.
  - The particle physics community should continue and intensify its efforts to develop and adopt sustainable solutions.
  - An effective balance between in-person and online meetings should be considered, in order to mitigate the environmental impact of travel.