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CERN ACCELERATES SUSTAINABILITY

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Abstract

CERN is pursuing several initiatives to reduce its impact on the environment through an integrated approach to address the objectives set by the relevant United Nations (UN) Sustainable Development Goals (SDG). In particular CERN is committed to explore all possible avenues to respect the net-zero paradigm for future machines and has established a Sustainable Accelerators Panel to harmonize the approach to sustainability of the various studies for future accelerators. In this paper we will describe the efforts taken in the responsible management of our technical installations and the process we are setting up to perform the lifecycle assessment of the different future projects to better understand the main drivers of CO_2 emissions in order to minimize them by design.

CERN AND THE ENVIRONMENT

CERN sits in a gorgeous valley between the French Alps and the Jura Mountain. Close to the Léman Lake, straddling the border between France and Switzerland, CERN is involved in tripartite discussions with its host States, France and Switzerland, about the scientific development of the region and the preservation of its exceptional surroundings. Internally, for about ten years, environmental objectives are set and monitored through the CERN Environmental Protection Steering board (CEPS) that has the mandate to identify the priorities for investments in environmental projects. Several projects have been or are being realised since, including the replacement of oil-based electrical transformers with dry type transformers, the excavation of new storm water management retention basins, the replacement of Green-House Gases (GHG) in Heating, Ventilation and Air Conditioning (HVAC) and Cryogenic (Cryo) installations with environmentally friendly alternatives, the recovery of waste heat from the cooling towers to heat neighbouring towns and infrastructures within the CERN campus itself.

CERN has published bi-ennial Environmental reports [1], since 2020 following the template of the Global Reporting Initiative (GRI) [2], the most diffused independent sustainability report standard for Businesses, Governments and Organisations. These reports describe CERN's efforts to minimise its impact on the environment, focussing on the main areas of impact of its activities, including CO2 emissions, energy and water consumption, ionising radiation, and noise and waste management. Moreover, CERN monitors the biodiversity over the about 600 hectares of lands allocated to its activities by the host countries (France and Switzerland), out of which some 200 are exploited for the campus and the research facilities, the rest being devoted to forests, meadows, and agriculture. Concerning emissions, direct (Scope 1), and indirect Scope 2 (from Energy sources) and 3 (from the value chain) emissions are reported, with the addition, in the last report which spans 2021 and 2022, of a first estimate of Scope 3 emissions related to procurement (see Fig. 1).

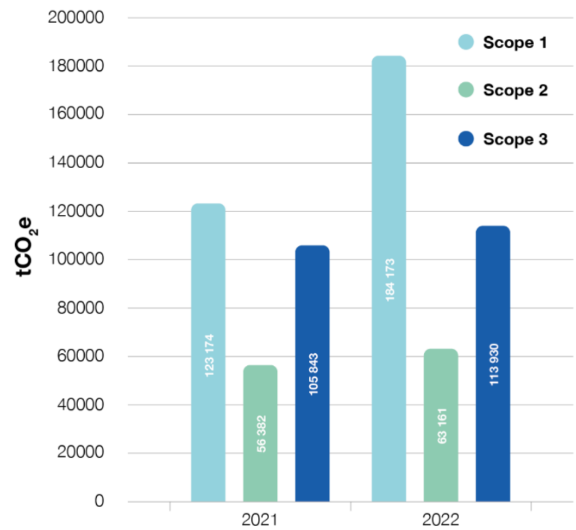

Figure 1: CERN's total emissions in tons equivalent of CO_2 in 2021 and 2022.

The main contribution to direct emissions come from the use of Green House Gases in the LHC experiments. CEPS fixed the objective to reduce such emissions by 28% by the end of 2025, through an emissions reduction strategy centred on gas recirculation, gas recovery and the adoption of natural refrigerants as alternatives to the synthetic ones currently used. A project of note is under way to replace the gases, mainly perfluorocarbons, used for cooling the experiments to about -50˚C, with CO2 [3]. Many difficulties have to be overcome to make this possible, including the little space available underground, that requires installation of the plants on the surface, and the very specific temperature to be reached at the level of the experiments, that is very close to that of the triple point of CO2, leaving very little margin for heat losses and much below the temperatures normally used in industrial CO2 cooling plants. To this end, CERN performed a thorough and successful R&D programme in collaboration with the NTNU University in Norway, demonstrating the feasibility of the approach, and is now procuring the plants to be installed during the Long Shutdown 3, due to start in 2026. Among the R&D topics, there was the design of specific transfer lines and distribution boxes, and the characterisation, industrialisation and test of dedicated operation and temperature control procedures to ensure the transport from the surface to underground (100-m elevation difference) and from the secondary units to the detectors. Once the CO2 cooling plants will be operational, about 40 000 tCO2e will be saved for every year of operation. In addition, an R&D programme to replace GHG used for particle detection is ongoing, with the

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goal to identify alternative fluids with low Global Warming Potential (GWP) that could potentially be used.

THE ENERGY MANAGEMENT PANEL AND THE ISO 50001 CERTIFICATION

CERN exploits a complex with more than 50 km of accelerators and transfer lines, serving a large variety of users, from high energy physics to nuclear physics and many others. CERN's energy consumption is therefore not negligible: during the periods of operation, known as "runs", CERN consumes about 1.3 TWh of electrical energy, mostly derived from the French grid, where the energy mix is almost entirely (~90%) derived from low-carbon sources. France in fact emits on average at most 55 gCO_2/kWh, while most countries in Europe sit at 200 gCO_2/kWh or above [4]. While the Scope 2 emissions due to energy consumption are therefore very limited, the absolute amount of energy consumed is such that every effort must be made to reduce it.

Table 1: CERN Energy Use Improvement Plan

Project	Savings
HVAC Consolidation	6 GWh/year
Buildings consolidation	10 GWh/year
New PV installation	200 MWh/year
Optimised Cryo Oper.	25 GWh/year
Waste Heat Recovery	50 GWh/year

CERN receives energy directly from the French 400 kV grid, with a possible back-up from Switzerland in case of major blackout of the French grid and distributes it on the different experimental sites with either 66 kV or 18 kV dedicated grids. The last decade saw a strong effort made to improve the granularity of the measurement of the energy used by the different users of electricity, allowing a better understanding of the possible margins for improvement. Today we therefore have a very clear real-time image of how energy is used and have built tools to make precise forecasts of the amount of energy that will be drawn from the grid during a given year, starting from the official schedules approved by the CERN Research Board every year. This process is managed through a panel (the Energy Management Panel, EMP) including the CERN grid managers (EN-EL group), the accelerator Operations group and the main groups of users (Radiofrequency, Cryogenics, HVAC, large Experiments, Magnets and power converters, etc...). In 2022 CERN decided to apply for ISO 50001 certification, the standard for the management of energy in an organisation. The objectives of the certification foresee:

- The development of a policy to improve energy efficiency
- Fixing targets and objectives to meet the policy
- Developing monitoring tools to better understand, measure the results and review how well the policy works
- A continuous improvement process, with concomitant modifications of the policy or the tools to improve energy management

CERN uses 95% of its energy for the exploitation of the accelerators. The CERN improvement plan has been developed according to the three pillars "Less, Better, Recover". Under this umbrella several specific actions have been initiated with some remarkable results.

Less

Several electromechanical systems in the CERN accelerators have been designed in periods from '60s of last century until the beginning of LHC operation in the early 2000. The main requirement at the time was to maximise the performance with respect to the physics needs rather than making a balance between physics and energy performance. Today, we have several actions in place to ensure that projects address sustainability from the design phase, especially when it comes to consolidating old facilities. For instance:

- Equipment is no longer procured on the lowest bidder on Capital Expenditure (CAPEX), but on CAPEX + 10 years Operational Expenditure (OPEX). This ensures that the overall efficiency is optimised.
- When refurbishing the East experimental hall during the Long Shutdown 2 in 2020-2022, additional funds were allocated to replace all the old magnets with new laminated ones. The measured yearly reduction attained more than 10 GWh.

Better

The improvement of our use of energy starts from the detailed monitoring of the use of electricity. Every group responsible for equipment in the accelerator complex is informed of the electricity used by the systems under their responsibility through a webtool and with "virtual" invoices, stimulating the motivation to propose, follow up and measure improvements.

Different accelerator operational scenarios can be tested and the effect on energy consumption measured in near real time. Economical modes have thus been identified for the CERN SPS extraction towards the North experimental hall, as well as for the LHC cryogenics. In some technical buildings the regulation of temperature now has a higher temperature target, meaning a different trade-off between the need to save energy and the risk of failure in electronic equipment. Several efforts are also undertaken to improve the regulation of HVAC installations.

Recover

CERN has made a complete study of the possibility to recover the waste heat from the cooling towers and identified the most attractive opportunities to recover such heat. The first project has been realised in Point 8 of the LHC where about 20 GWh/year will be transferred to the local

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town of Ferney-Voltaire. Two other projects have been started, one on the site of Meyrin, to recover the waste heat from the newly built cooling towers of the HL-LHC project, and the other connected to the new Data Center built on the site of Prévessin. Both will be used by the CERN heating plants to save more than 30 GWh/year currently obtained by burning natural gas.

THE SUSTAINABLE ACCELERATORS PANEL

In 2023 a new panel called the CERN Sustainable Accelerators Panel (SAP) was created with the aim of harmonising the approach to sustainability across CERN, in particular with regards to future projects, and to share information inside and outside CERN. The panel focuses in particular on the impact of new projects and on the development of methodologies and technologies to reduce them. Within this framework, topics such as lifecycle assessment, efficient technologies such as high temperature superconductors, or high efficiency klystrons are addressed.

The SAP serves as a forum for exchange of information not only among CERN people, but also with other laboratories and institutions such as STFC, DESY, INFN, KIT and others.

Recover

Concerning lifecycle assessment, two different approaches are being pursued for the studies of large future colliders such as FCC, CLIC and the Muon Collider, and the activities of design of components.

For future colliders the need to produce data before the next European Strategy for Particle Physics Update (ESPPU) calls for support from external consultants. CLIC has already performed an initial evaluation of the equivalent Carbon footprint due to the construction of the civil engineering infrastructures, while FCC is in the process of developing such an analysis. The assessment has been performed following international standards such as the methodologies established by ISO 14040/44, and more particularly EN 17472:2022, targeting specifically the sustainability assessment of civil engineering works. The assessments are limited to the construction phases (A1-A5 in EN 17472:2022) and, for CLIC, resulting in values of the order of ~8000 tCO_2e/km for tunnels of 5.5 m diameter in the region of Geneva. Ideas for optimization and reduction of such footprints have been identified and future studies, if requested, might allow to reduce such values in line with the guideline of the UN roadmap 2030 (about 40%).

For what concerns the present activities and the long-term future, CERN intends to train its engineers to embed sustainability from the start when designing new facilities or components. To this end, a series of training courses is being organized in two steps. Firstly, an online course will be made available to raise awareness on what a Life Cycle Assessment (LCA) is, why it is important to do it, and what techniques can be used to perform it. In a second step, designers will also be required to follow a class training to perform LCA exercises with one of the tools available on the market (for instance openLCA [5], SimaPro [6], or LCA for Experts (GaBi) [7]). The objective will be to enable designers to perform at least simple LCAs autonomously during the design process in order to perform optimizations from the start. Strategic decisions have to be taken on the common methodology, the software tool and the databases to be used. These choices will be made mainly with the goal of optimizing the design. Different choices might apply with respect to different goals, such as addressing a specific legislation or making a comparison of different projects in different regions of the world. Discussions are also ongoing with other institutions to try and agree on a common approach in the field of Particle Accelerators. One hypothesis is to develop a specific database for all typical materials that are used in particle accelerators.

Finally, the SAP is active in following the different technology R&D that may lead to more efficient operation, among them High Temperature Superconductors, metamaterials, high efficiency klystrons, etc. These technologies are not presented here for the sake of brevity, and they are also presented individually in other papers.

CONCLUSIONS

CERN is committed to enhance the sustainability of its accelerators and has made outstanding progress in the last 15 years, for instance saving several GWh a year through consolidation of facilities, optimization of operational processes and recovering waste heat. Future projects will therefore build on a solid know-how and will constantly improve tools and methodologies.

ACKNOWLEDGEMENT

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REFERENCES

[1] CERN Environment Reports, https://hse.cern/environment-report.

[2] Global Reporting Initiative, https://www.globalreporting.org/

[3] P. Barroca, *et al.*, "An ultra-low temperature transcritical R744 refrigeration system for future detectors at CERN LHC", *Appl. Sci.,* vol 11, p 7399, 2021. doi:10.3390/app11167399

[4] https://app.electricitymaps.com/

[5] https://www.openlca.org/

[6] https://simapro.com/

[7] https://sphera.com/life-cycle-assessment-lca-software/