CERN-ESU-011
12 February 2020

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE

CERN **EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH**

DOCUMENT FOR THE 2020 UPDATE OF THE EUROPEAN STRATEGY FOR PARTICLE PHYSICS

Report by Working Group 6 on

Sustainability and Environmental impact

Report by Working Group 6 on
Sustainability and Environmental impact

Members of WG6: *D. Ryckbosch, J.J. Gaardhøje, C. Biscari*

In a world with increasing demand on limited resources and with climate change a reality, it is crucial to bear energy consumption, sustainability and efficiency in mind when discussing the future of high-energy physics (HEP). A lot of attention has already been given to these subjects and much work is being done at existing facilities and laboratories in the design of new experiments or accelerators. It is essential that the HEP community is seen to be contributing to reducing or offsetting our environmental impact, both to demonstrate our responsible role in society and to maintain our attractiveness for young researchers. Topics of particular importance are as follows.

1. Carbon footprint of future accelerators

1.a Energy efficiency

The next generation of high-energy particle colliders will aim at unprecedented high collision energies and luminosities, for electrons on positrons and/or for hadrons on hadrons. In both cases, the present designs foresee power consumptions in the hundreds of MW of grid power[1] as compared to about 100 MW for the HL-LHC. This can become problematic, both in terms of cost and, depending on the source of the electricity, because of the large associated carbon footprint. Europe's accelerator laboratories, in particular CERN, ESRF and ESS, are actively discussing strategies to design new infrastructures that are reliable, affordable and climate-friendly. These discussions take place at the biennial workshops on "Energy for Sustainable Science at Research Infrastructures", of which the most recent one was held at PSI in November 2019 [1]. Such efforts need to be further supported, and the results of the studies integrated into the design of upgrades of existing and new facilities. Comparing the energy efficiency of different designs or facilities is not a trivial exercise. For similar facilities (e.g. lepton colliders with similar centre-of-mass energies) parameters such as integrated luminosity per unit of primary energy could be used. For facilities with differing beams, other ways need to be found to normalise the physics potential versus the energy consumed.

Many ways of improving the energy efficiency of HEP accelerator complexes exist, including waste heat recovery, optimisation of cryo-cooling plants, beam energy recovery. It is important to underline that investments in dedicated R&D for energy efficiency techniques will already pay off in the medium term, with significant impacts on the operating costs of the accelerators.

In discussions about the optimal choice of a new facility, the energy efficiency of the accelerator should be part of the decision matrix, alongside factors such as cost, timescale and physics reach. R&D in energy efficiency should be supported as an essential part of accelerator research.

[1] Present estimates are about 350 MW for FCC-ee and 180 MW for CLIC @380 GeV, going up to 600 MW for CLIC @ 3 TeV. Estimates for FCC-hh are about 580 MW.

1b. Civil engineering

In most large infrastructure projects it is estimated that the relatively short period of construction is responsible for about 15-20% of the total lifetime carbon footprint [2]. The materials mostly associated with this carbon footprint are steel and, in particular, concrete. It is estimated that the cement industry, which produces the key ingredient of concrete, contributes about 8% to the world's CO_2 emissions[3]. Steel and concrete are obviously also strongly present in the construction of large collider facilities and this would certainly be an issue in the construction of a 100-km tunnel for a future circular collider.

The carbon footprint of the civil engineering components of future collider projects, as well as other environmental impacts, should be taken into account in the development and implementation of these projects and should be minimised.

2. Carbon footprint of experiments

2.a Detector technology

The power consumption and civil engineering (except for experimental halls) for experiments is not of the same magnitude as for accelerators. However, the technologies required for detectors are a potential source of greenhouse emissions. The most obvious example is that of the special gases needed to operate certain types of detectors, like Resistive Plate Chambers. These gases, which include freons and hydrofluocarbons, have GWP (greenhouse warming potential) values in the thousands, as compared to the base value of 1 for CO_2. Significant research efforts are already being dedicated to finding alternatives for these gases [4]. This kind of work also gets attention outside the HEP community (see [5]) and helps to demonstrate the responsible behaviour of HEP laboratories. It is also clear that including a very stringent recirculation requirement for any such gas, already in the early phases of the design of experiments, is much easier than trying to implement it during or even after installation.

Research into eco-friendly alternatives to materials with high GWP for use in HEP detectors should be stimulated and supported. The extensive use of recirculation systems needs to be included from the start of the design.

2.b HEP Computing needs

The greater the luminosity, the greater the data volumes and computing needs. The energy efficiency of computer centres has improved markedly in recent years, an area in which large HEP computing centres should continue to take the lead. Good examples are GSI’s Green Cube and CERN’s planned new computing centre. In addition, dedicated efforts in software development can also have a significant impact on resources requirements. The HEP community is already working on these, for instance in the HEP Software Foundation (HSF). Professional software engineering might be helpful in this respect.

The HEP community should invest in both hardware and software efforts to improve the energy efficiency of their computing infrastructures.

3. Carbon footprint of travel

The international nature of the HEP community and the concentration of experiments at a few large facilities call for a high level of coordination and inevitably result in people needing to travel to meetings. The emission of greenhouse gases linked to air transport, in particular, accounts for a sizeable fraction of the world's carbon footprint. The HEP community once revolutionised the way information is shared and accessed by inventing the Worldwide Web.

The community might therefore be expected to be in the vanguard of alternatives to physical travel, such as virtual meeting rooms.

A significant fraction of travel is associated with (international) conferences and workshops. Attending (and being invited to) these is particularly important for younger physicists aspiring to permanent positions. The community must bear this in mind. Several schemes have been proposed to reduce the need for travel, such as the clustering of conferences in geographical and temporal terms. This is an area where the HEP community as a whole must take responsibility and weigh up the need for a conference (local visibility, topical workshop etc.) against the environmental impact of the associated travel.

The HEP community should be aware of the environmental impact of extensive (air) travel. Ways to reduce the need for such travel should be explored and implemented.

Conclusions and recommendations

There are already many initiatives and efforts to study and limit the environmental impact of HEP experimental activities, in particular with respect to the emission of greenhouse and other gases. **These efforts should be supported and expanded. All new projects should present an environmental impact assessment and a plan to minimise such impact as part of the project approval process.**

The energy efficiency of present and future accelerators, and of computing facilities, should remain an area requiring constant attention. A detailed plan for energy saving and the minimisation of energy consumption should be an integral part of the proposal for any future accelerator project.

CERN and HEP must play a role in developing new technologies that can positively affect (reduce) energy consumption, e.g. in the areas of HTSC or energy recovery. Such efforts should be strengthened.

The HEP community travels a lot. Efforts should be made to reduce this. **R&D into alternatives such as virtual or better video meetings should be stimulated.** Alternatives to travel should be explored and encouraged.

References

[1] https://indico.psi.ch/event/6754/

[2] United Nations Environment Programme, 2007, Buildings and Climate Change: Status, Challenges and Opportunities, UNEP 2007, ISBN: 978-92-807-2795-1 http://www.unep.fr/pc/sbc/documents/Buildings_and_climate_change.pdf

[3] https://reader.chathamhouse.org/making-concrete-change-innovation-low-carbon-cement-and-concrete

[4] Guida, R & Mandelli, B & Rigoletti, G. (2019). Performance studies of RPC detectors with new environmentally friendly gas mixtures in presence of LHC-like radiation background. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 10.1016/j.nima.2019.04.027.

[5] https://cen.acs.org/environment/greenhouse-gases/Scientists-CERN-hunt-greener-gases/97/i17