

Climate impacts of particle physics: a Snowmass white paper

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On behalf of [arXiv:2203.12389](https://arxiv.org/abs/2203.12389) co-authors: V. Boisvert, D. Britzger,
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Snowmass in the US

- The “Snowmass” community study is part of the development of the next long-range plan for particle physics in the US.
 - History of Snowmass meetings going back to 1980s.
 - Organized by American Physical Society Division of Particles and Fields.
- “identify the most important questions for the field and promising opportunities to address them” — no prioritization of projects/experiments at this stage.
- Meetings/discussions/white papers over the course of \pm 2 years, culminating in 10-day workshop this past July.
- This iteration of Snowmass included an area on “community engagement” as part of the study.

Community engagement, societal impacts

Dear Mike, Ken, and Veronique,

1 March 2021

We are inviting you to serve as co-conveners of the newly-established Topical Group **Societal Impacts**, within the **Snowmass 2021 Community Engagement Frontier (CEF)**. CEF consists of several Topical Groups, namely:

1. Applications and Industry
2. Career Pipeline and Development
3. Diversity and Inclusion
4. Physics Education
5. Public Education and Outreach
6. Public Policy and Government Engagement
7. Societal Impacts

The objective of CEF is to improve and sustain strategic engagements within our field and among our communities in order to strengthen and draw support for the field of particle physics. These engagements require well-coordinated efforts in many areas where the communities of experts and non-experts can gauge and appreciate the impacts of our field and its importance in the global socioeconomic development. The

CEF07: Societal Impacts Topical Group will expand CEF's scope to examine the ways in which the US HEP program affects the environment and communities in which we do our work, and develop recommendations to improve our relationships in those areas. Examples of topics to be addressed include developing sustainable practices to minimize detrimental impacts on the environment, building mutually beneficial partnerships with communities affected by our projects, and grappling with issues related to computational ethics. For some of CEF07's work, we hope to draw on the experience of our European colleagues documented in ["Input to the European Strategy Update: Ensuring the Future of Particle Physics in a More Sustainable World"](#). CEF07: Societal Impacts will have three co-conveners (2 US-based, and one international), with CEF conveners serving in an ex-officio capacity.

Climate impacts white paper

Climate impacts of particle physics

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Abstract. The pursuit of particle physics requires a stable and prosperous society. Today, our society is increasingly threatened by global climate change. Human-influenced climate change has already impacted weather patterns, and global warming will only increase unless deep reductions in emissions of CO₂ and other greenhouse gases are achieved. Current and future activities in particle physics need to be considered in this context, either on the moral ground that we have a responsibility to leave a habitable planet to future generations, or on the more practical ground that, because of their scale, particle physics projects and activities will be under scrutiny for their impact on the climate. In this white paper for the U.S. Particle Physics Community Planning Exercise (“Snowmass”), we examine several contexts in which the practice of particle physics has impacts on the climate. These include the construction of facilities, the design and operation of particle detectors, the use of large-scale computing, and the research activities of scientists. We offer recommendations on establishing climate-aware practices in particle physics, with the goal of reducing our impact on the climate. We invite members of the community to show their support for a sustainable particle physics field [1].

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

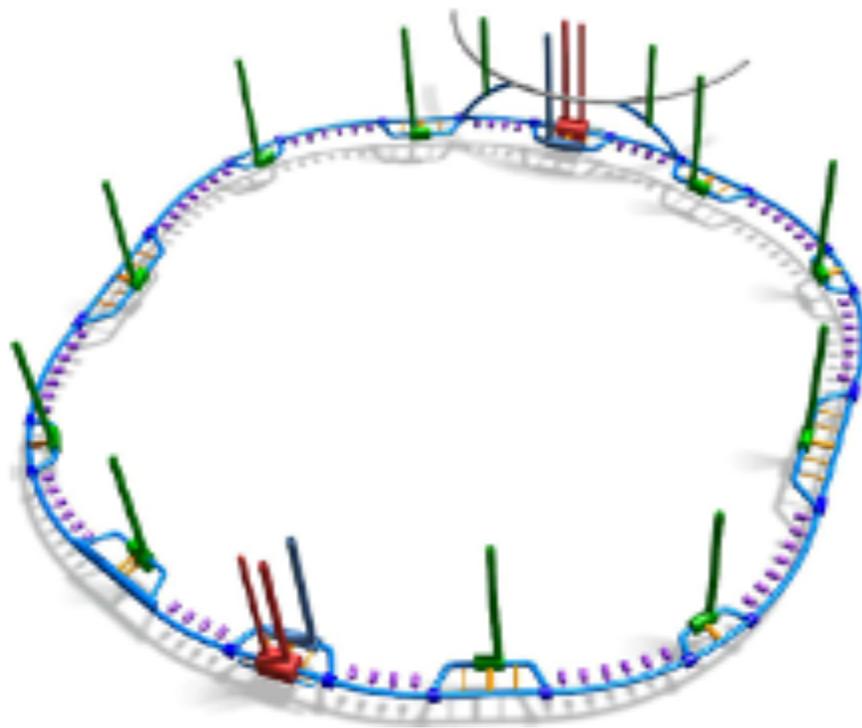
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**Contact author, e-mail: Veronique.Boisvert@rhul.ac.uk

- Self-organized, relatively late in the Snowmass game.
- Organized a half-day workshop on the topic in November 2021, recruited speakers, found co-authors willing to do some work.
 - Perspectives turned out to be energy frontier, European dominated.
- Hardly comprehensive, chose a few topics to look at:
 - Facility construction, detector gases, computing, research activities.
- Want to at least stimulate some discussion.

Facility construction

- Building construction industry contributes 10% of world's total carbon emissions.
 - Cement made via $\text{CaCO}_3 + \text{heat} \rightarrow \text{CaO} + \text{CO}_2$, 1 ton CO_2 per 1 ton cement, hard to decarbonize.
- Our field is considering major construction projects for future facilities.
 - If electric grid is decarbonized by ~2040, facility construction rather than operation could dominate carbon impacts!
- Example: FCC(-ee,-hh), 97.75 km tunnel would be one of the world's largest, plus many bypass tunnels, access shafts, experimental caverns, surface facilities....
 - Excavation of 7M m³ of spoil



Facility construction

- Carbon impact of main tunnel?
- Bottom up: calculate volume of tunnel walls, concrete is 15% cement → ~240 kt CO₂.
- Top down: studies of road tunnel construction give rule of thumb of 5,000-10,000 kg CO₂/km of tunnel → > ~500 kt CO₂.
- 6 million trees required for carbon offset!

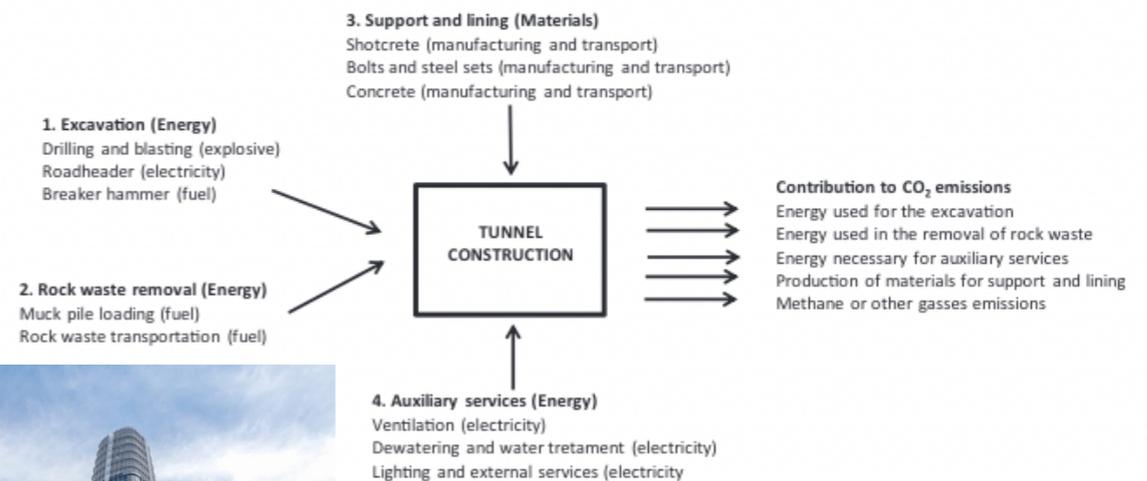
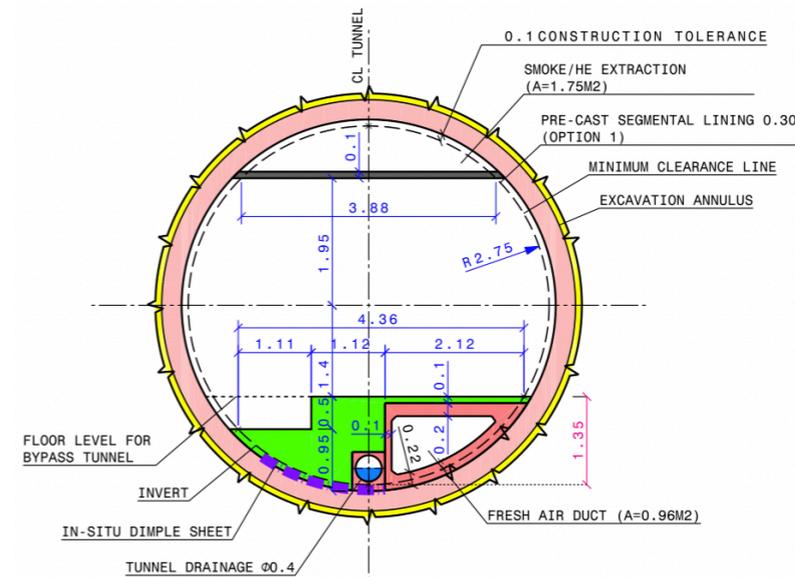


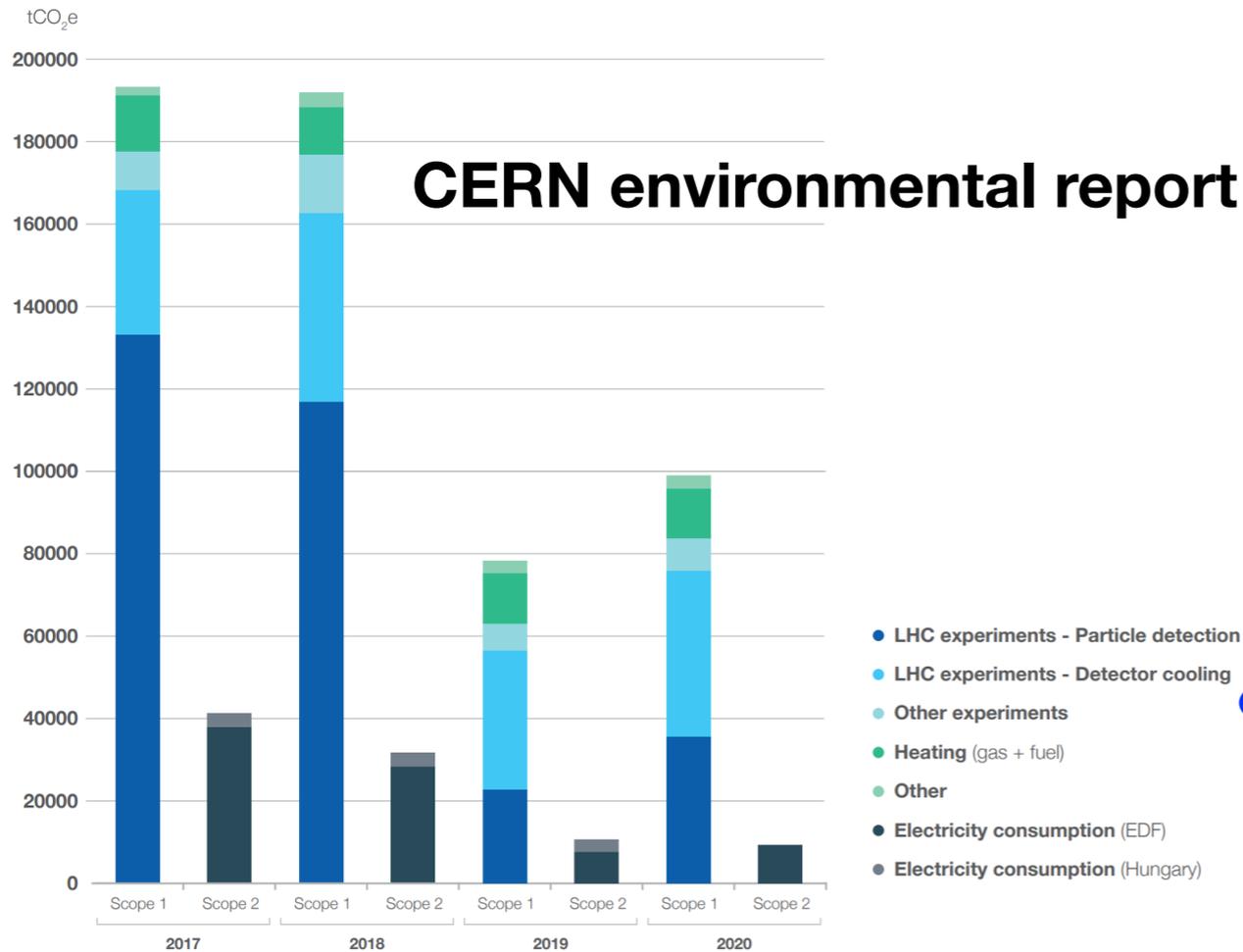
Fig. 1. Schematic overview of the system boundary.



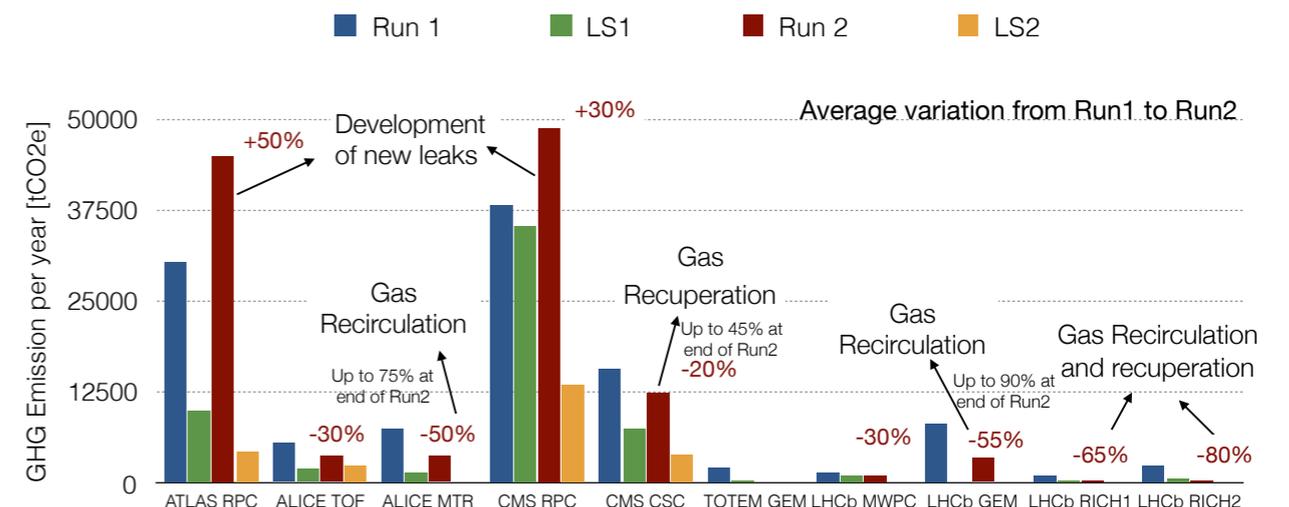
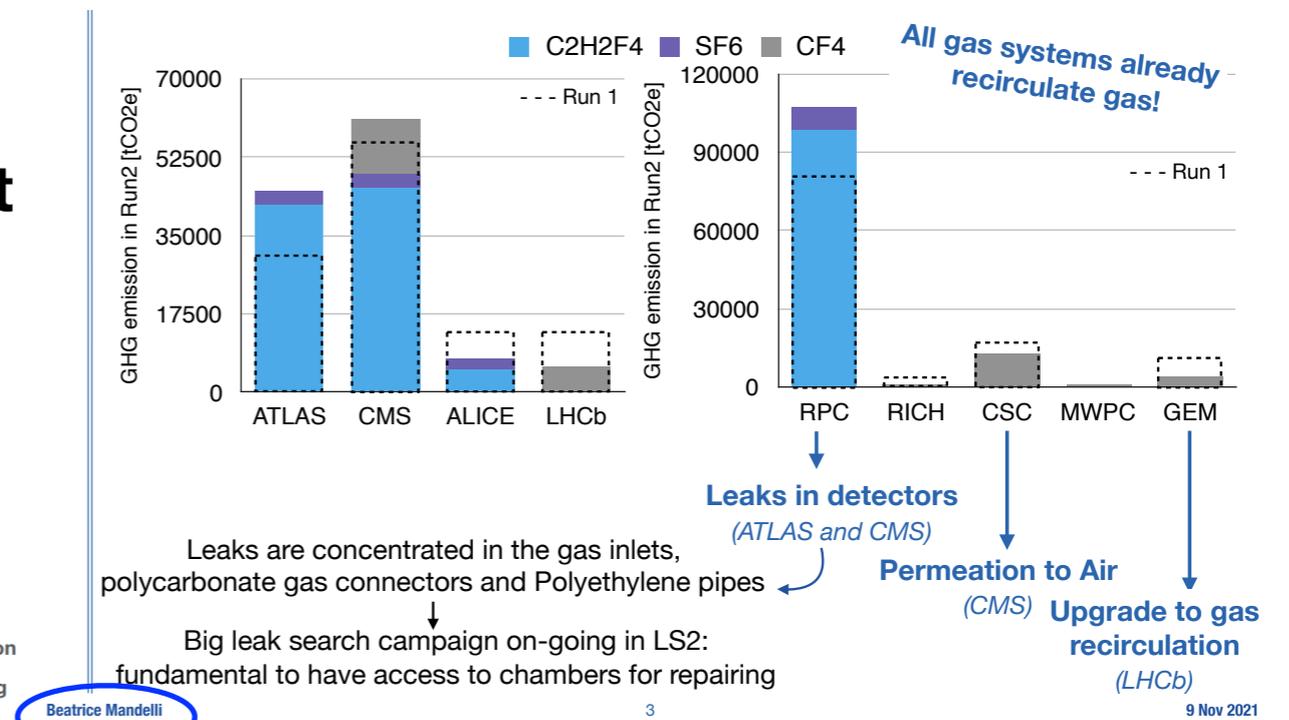
- Salesforce Tower: 1.4M ft², ~550 kg embodied carbon/m² → ~79 kt CO₂e.

Experiment gases

- CERN emissions are dominated by experiment gases!



- Scope 1: direct emissions from organization
- Scope 2: indirect emissions from electricity, heating, etc.
- Scope 3: all other emissions upstream and downstream (business travel, commuting, catering etc.); harder to quantify



Why was Snowmass here?



Personal observations

- <https://arxiv.org/abs/2208.10466> is interesting but ignores the issues of construction and detector operations.
- When I was asked to co-lead the Societal Impacts topical group, I was pretty new to this topic, and I learned a lot from working on the white paper.
- Colleagues are interested in this area and want to learn more.
 - White paper authors have been getting seminar invitations and audiences are engaged.
- However, like perhaps everything else about addressing climate change, US appears to be behind compared to Europe in this area.
 - Climate-change issues are noted, but they are not driving decision-making.
 - No organized community on this issue in the US.
 - We set up a supporters page, but got more signatories from Europe than from the US!
- How can we turn interest into action?
 - Next question in the US: how will sustainability issues be reflected in the Snowmass summary, and then in the report of the Particle Physics Project Prioritization Panel (P5), which will be actionable for the funding agencies?

Our recommendations

- New experiments and facility construction projects should **report on their planned emissions and energy usage as part of their environmental assessment**, which will be part of their evaluation criteria. These reports should be inclusive of all aspects of activities, including construction, detector operations, computing, and researcher activities.
- U.S. laboratories should be involved in a **review across all international laboratories to ascertain whether emissions are reported clearly and in a standardized way**. This will also allow other U.S. particle physics research centers (including universities) to use those standards for calculating their emissions across all scopes.
- Using the reported information as a guide, all participants in particle physics – laboratories, experiments, universities, and individual researchers – should **take steps to mitigate their impact on climate change by setting concrete reduction goals and defining pathways to reaching them** by means of an open and transparent process involving all relevant members of the community. This may include **spending a portion of research time on directly tackling challenges related to climate change in the context of particle physics**.

Our recommendations

- U.S. laboratories should invest in the development and affordable deployment of **next-generation digital meeting spaces in order to minimize the travel emissions of their users**. Moreover the particle physics community should actively promote hybrid or virtual research meetings and travel should be more fairly distributed between junior and senior members of the community. For in-person meetings, the meeting location should be chosen carefully such as to minimize the number of long-distance flights and avoid layovers.
- Long-term projects should **consider the evolving social and economic context**, such as the expectation of de-carbonized electricity production by 2040, and the possibility of carbon pricing that will have an impact on total project costs.
- All U.S. particle physics researchers should **actively engage in learning about the climate emergency and about the climate impact of particle-physics research**.
- The U.S. particle physics community should **promote and publicize their actions surrounding the climate emergency to the general public and other scientific communities**.
- The U.S. particle physics community and funding agencies should **engage with the broader international community to collectively reduce emissions**.