# How to do particle physics in a climate emergency?

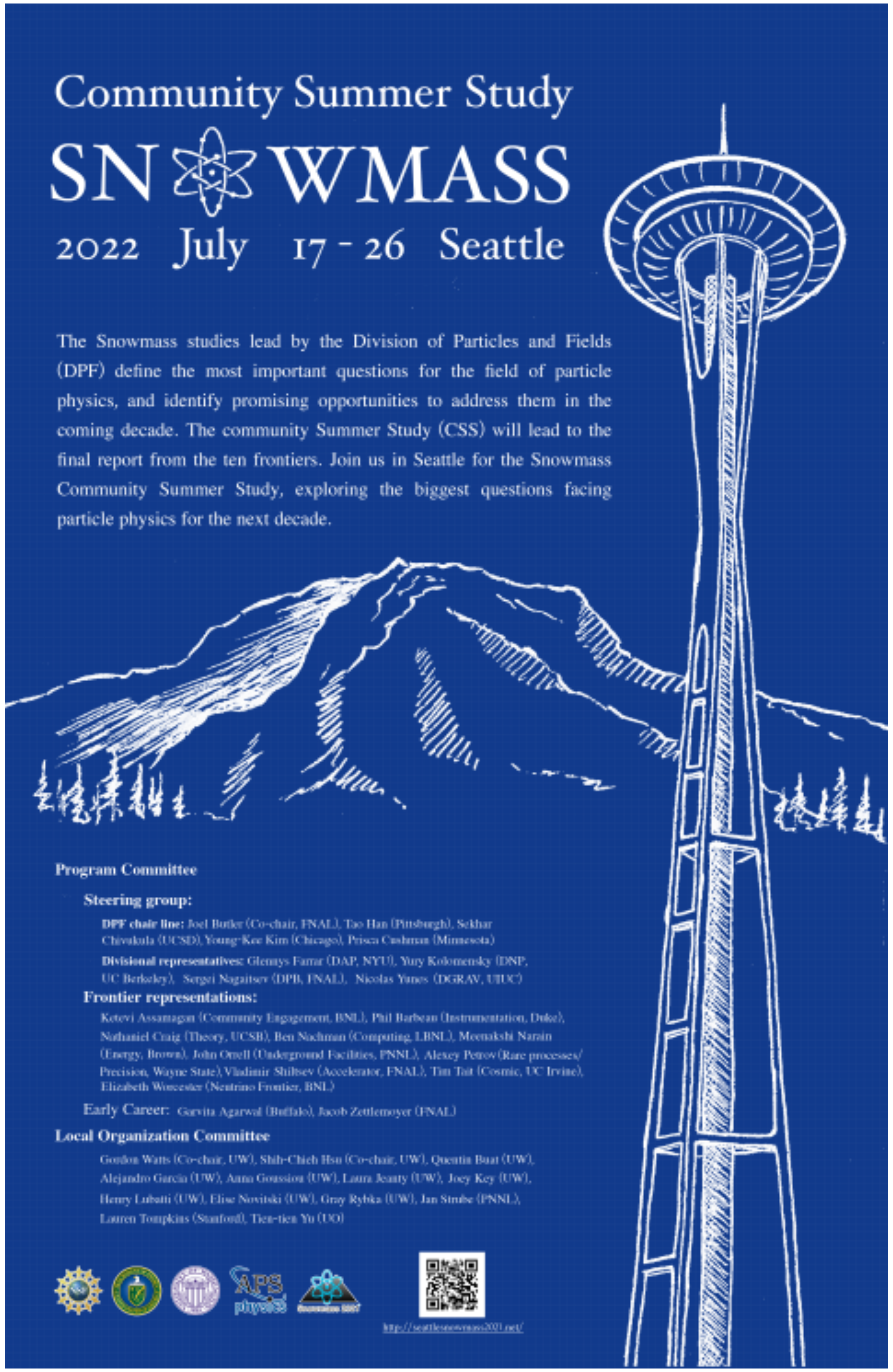
Ken Bloom
University of Nebraska-Lincoln
PURSUE — 3 June 2024
With thanks to Véronique Boisvert and co-authors of arXiv:2203.12389

# European Strategy Update


- Highlighted in CERN Courier article.

# Snowmass "2021"

- Periodically, APS Division of Particles and Fields organizes a community-wide study to identify the most important questions for the field and promising opportunities to address them.
- Used to be three weeks at Snowmass, near Aspen → optics problems.
- This time, ~~1~~ 2 years of discussions/meetings/white papers culminating in 10-day meeting at U. Washington.
- "Community engagement" issues were explicitly part of the study.



# Snowmass "2021"

**1 March 2021**

Dear Mike, Ken, and Veronique,

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.

# CEF07 outputs



## Climate impacts of particle physics

Kenneth Bloom[1,*], Veronique Boisvert[2,**], Daniel Britzger[3], Micah Buuck[4], Astrid Eichhorn[5], Michael Headley[6], Kristin Lohwasser[7], and Petra Merkel[8]

[1]University of Nebraska-Lincoln, Lincoln, NE, USA
[2]Royal Holloway University London, United Kingdom
[3]Max-Planck-Institute for Physics, Munich, Germany
[4]SLAC National Accelerator Laboratory, Menlo Park, CA, USA
[5]CP3-Origins, University of Southern Denmark, Denmark
[6]Sanford Underground Research Facility (SURF), Lead, SD, USA
[7]University of Sheffield, United Kingdom
[8]Fermi National Accelerator Laboratory (Fermilab), Batavia, IL, USA

**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 $CO_2$ 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)

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

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



## Societal impacts of particle physics projects

Rochelle Zens[1], Michael Headley[1], Debra Wolf[1], Alison Markovitz[2], Faith Dukes[3], Jennifer Tang[3], Kenneth Bloom[4], and Veronique Boisvert[5]

[1]Sanford Underground Research Facility (SURF)
[2]Fermi National Accelerator Laboratory (Fermilab)
[3]Lawrence Berkeley National Laboratory (LBNL)
[4]University of Nebraska-Lincoln, Lincoln, NE 68588
[5]Royal Holloway University London

**Abstract.** Large particle physics projects funded by the U.S. Government require an evaluation and mitigation of each project's potential impacts on the local communities. However, beyond meeting governmental requirements, particle physics projects stand to play an essential role in local decision-making, building relationships, and framing discussions about key projects by becoming meaningfully engaged in their local communities. In this white paper for the U.S. Particle Physics Community Planning Exercise ("Snowmass"), we examine several local community engagement efforts made by three facilities: Lawrence Berkeley National Laboratory (Berkeley Lab), Fermi National Accelerator Laboratory (Fermilab), and the Sanford Underground Research Facility (SURF). Although each facility focuses on a different endeavor in varying types of communities, each study highlights the importance and benefits of employing consistent outreach techniques, promoting diversity, establishing lasting relationships, and creating environments for open and honest communication.

### 1 Executive Summary

As large employers and leading entities within their communities, particle physics laboratories can benefit from community engagement focused on local impacts. Community engagement plays an essential role in local decision-making, building relationships, and important discussions about the implementation of key projects. Large particle physics projects funded by the U.S. Government require an evaluation and mitigation of each project's potential impacts on the local communities. Beyond satisfying governmental requirements, lasting and positive change can result when laboratories work alongside their respective communities in a meaningful way, which broadens the positive societal impacts of particle physics research.

# Caveats

- I’m not a climate scientist!
- The Snowmass paper is hardly exhaustive (and not the only work on this topic).
- Energy Frontier/European slant, driven by the authors.

- I hope that this presentation gets you thinking more about the impacts we all have on climate change, and what we (as individuals and as a society) can do about it.

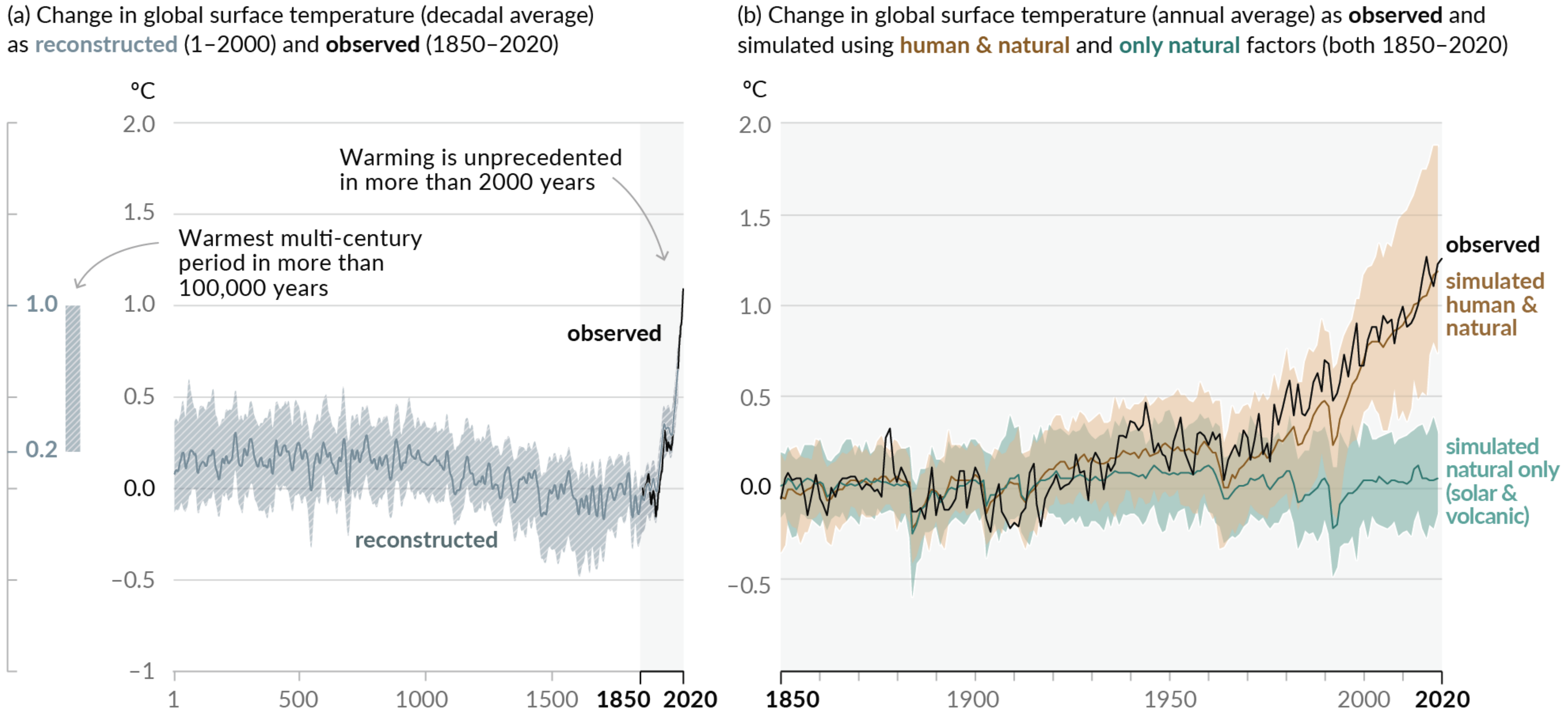
# Climate change is real

- International Panel on Climate Change:
  - "It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred."
  - "Global warming of 1.5C and 2C will be exceeded during the 21st century unless deep reductions in $CO_2$ and other greenhouse gas emissions occur in the coming decades."

# Climate change is real

## Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

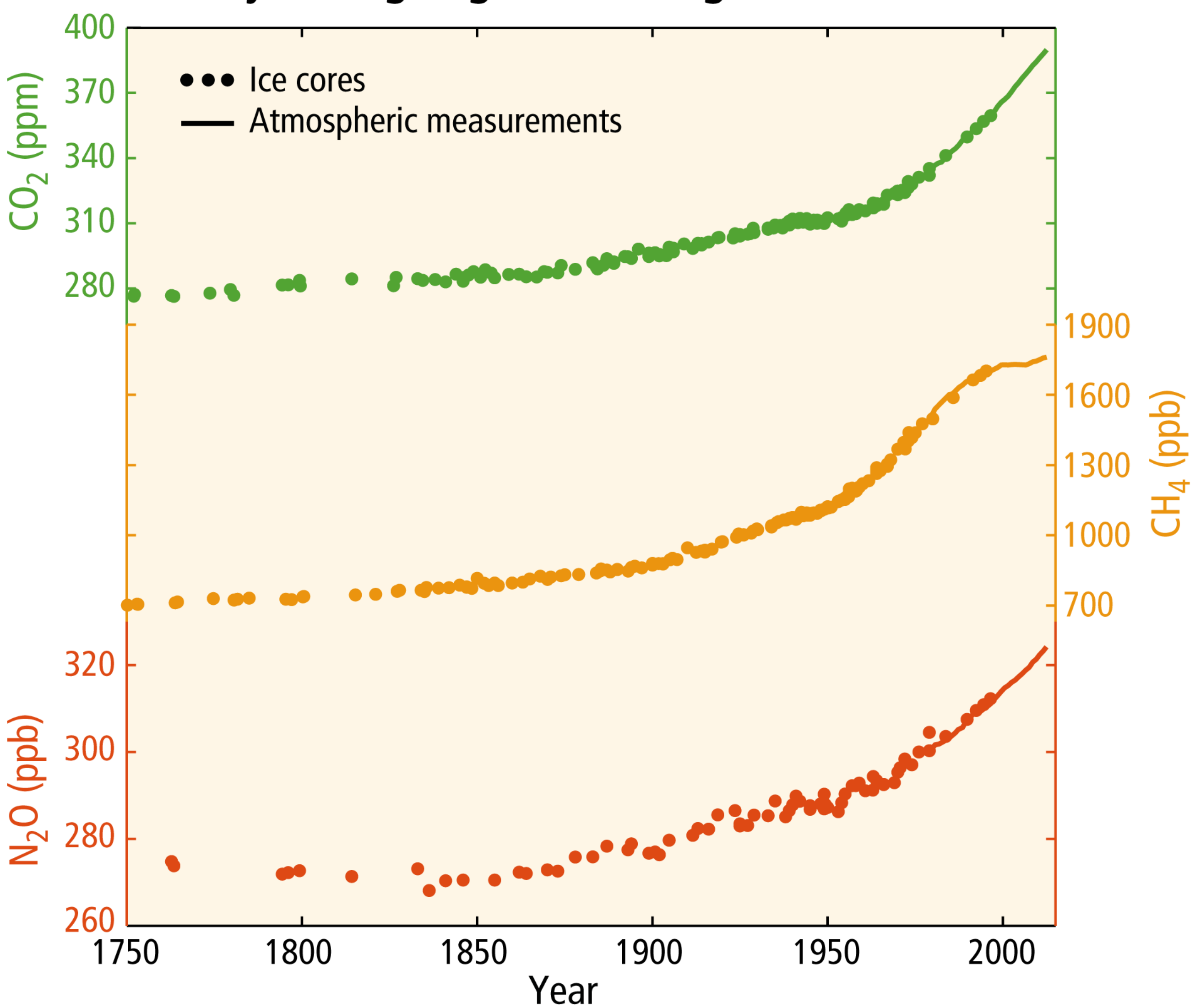
**Changes in global surface temperature relative to 1850–1900**




**(IPCC AR6)**

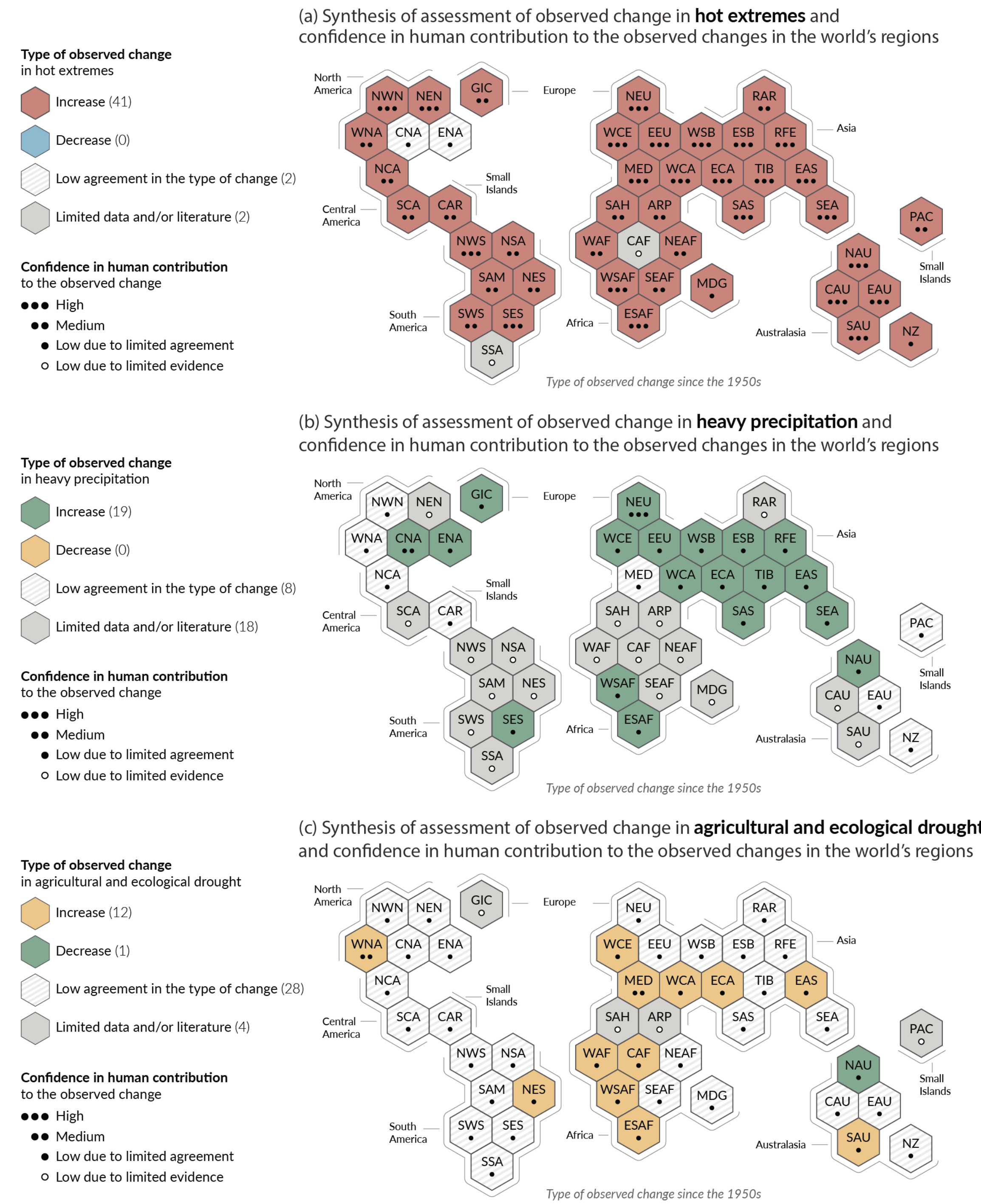
# Climate change is real

Globally averaged greenhouse gas concentrations




**(IPCC AR5)**

**Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes**




**(IPCC AR6)**

# Carbon budgets

- Limiting warming requires significant reductions in $CO_2$ and other greenhouse gas emissions, in line with Paris Agreement.
  - Every 1000 gigaton of cumulative $CO_2$ emissions leads to 0.27-0.63 C increase in warming → must adhere to a carbon budget.
  - IPCC: Total budget of 300 gigaton CO2e ($CO_2$ equivalent) emissions for 83% chance to limit warming to < 1.5 C → 1.1 tCO2e per capita per year until 2050.
- U.S. has a significant role to play in this:
  - Current per capita per year rate: ~14 tCO2e, ~3x global average.
  - Top producer/consumer of oil and natural gas, 2nd largest # of coal-fired power plants, but largest nuclear capacity, 2nd largest renewable capacity.
  - Current administration pledged to reduce GHG emissions 50-52% below 2005 levels by 2030, net-zero no later than 2050.
    - 2005 levels ≃ 20 tCO2e per capita.

# Particle physics in this context

- Activities associated with particle physics have the potential for scientists to have a carbon impact well above that of average citizens, so we must pay attention.
- Moral reason: We are responsible for leaving behind a habitable planet.
- Practical reason: Future major projects will have significant carbon impact and will be scrutinized for it.
    - More intense project review?  Paying for a price on carbon?
- Particle physics is a world leader in international cooperation for common goals — can we do the same here?
- How can we pursue the science we love sustainably?

# Astronomy impacts

nature astronomy

ARTICLES

https://doi.org/10.1038/s41550-022-01612-3

Check for updates

## Estimate of the carbon footprint of astronomical research infrastructures

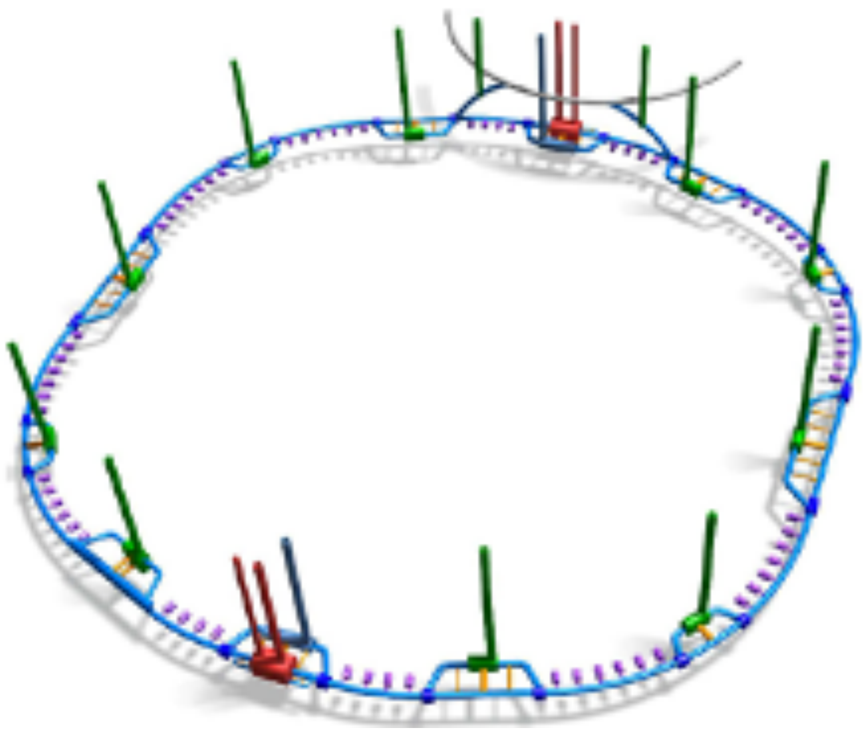
Jürgen Knödlseder ✉, Sylvie Brau-Nogué, Mickael Coriat, Philippe Garnier, Annie Hughes, Pierrick Martin and Luigi Tibaldo

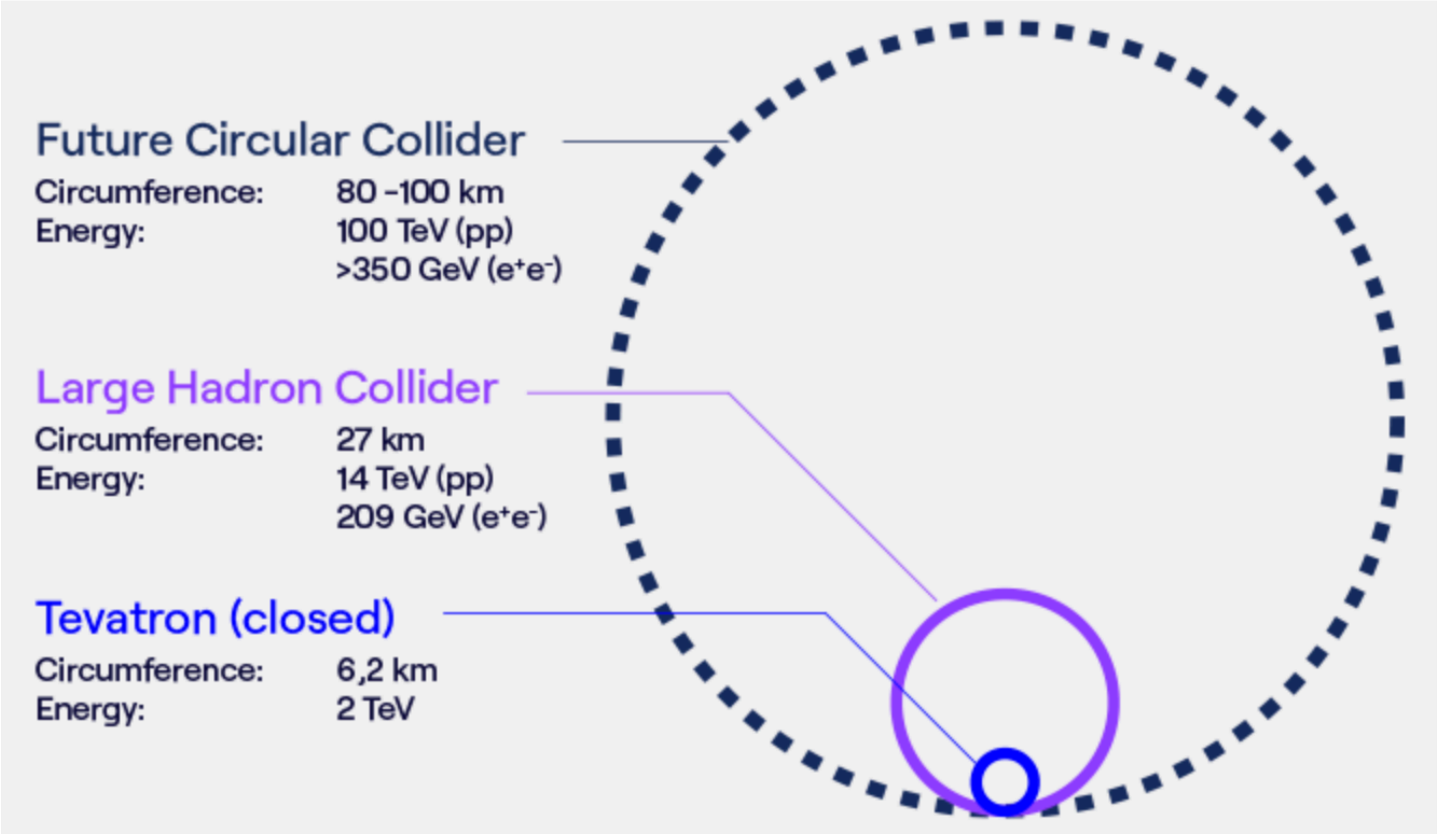
**The carbon footprint of astronomical research is an increasingly topical issue with first estimates of research institute and national community footprints having recently been published. As these assessments have typically excluded the contribution of astronomical research infrastructures, we complement these studies by providing an estimate of the contribution of astronomical space missions and ground-based observatories using greenhouse gas emission factors that relates cost and payload mass to carbon footprint. We find that worldwide active astronomical research infrastructures currently have a carbon footprint of 20.3 ± 3.3 $MtCO_2$ equivalent ($CO_2e$) and an annual emission of 1,169 ± 249 $ktCO_2e\,yr^{-1}$ corresponding to a footprint of 36.6 ± 14.0 $tCO_2e$ per year per astronomer. Compared with contributions from other aspects of astronomy research activity, our results suggest that research infrastructures make the single largest contribution to the carbon footprint of an astronomer. We discuss the limitations and uncertainties of our method and explore measures that can bring greenhouse gas emissions from astronomical research infrastructures towards a sustainable level.**

"Just to give you some perspective — 20 million tonnes of CO2 — this is the annual carbon footprint of countries like Estonia, Croatia, or Bulgaria," says Jürgen Knödlseder, an astronomer at IRAP, an astrophysics laboratory in France.

# Emissions from construction

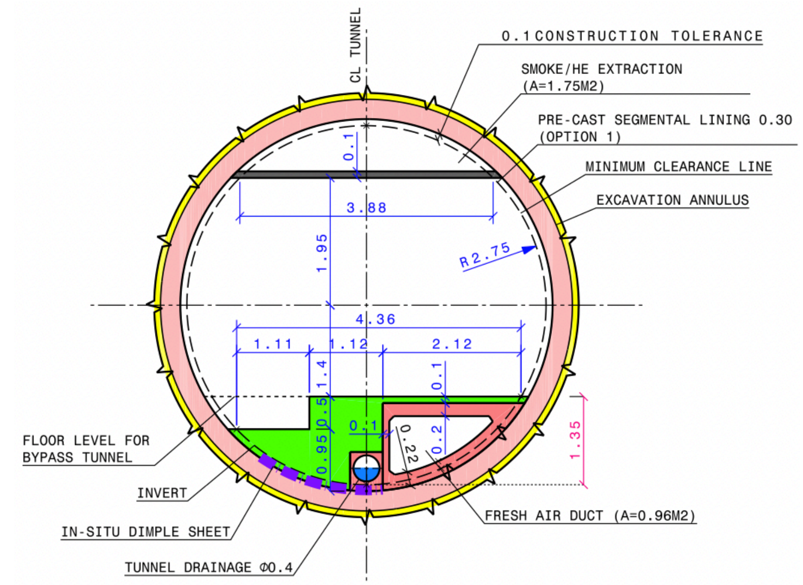
- Building construction industry contributes 10% of world's total carbon emissions.
  - Cement made via $CaCO_3$ + heat → $CaO + CO_2$, 1 ton $CO_2$ per 1 ton cement, hard to decarbonize.
- Our field is considering major construction projects for future facilities.
  - If electric grid is decarbonized by ~2040, facility construction rather than operation could dominate carbon impacts!
- Example: FCC(-ee,-hh), ~90 km tunnel would be one of the world's largest, plus many bypass tunnels, access shafts, experimental caverns, surface facilities….
  - Excavation of 7M $m^3$ of spoil





# Emissions from construction

- Carbon impact of main tunnel?
- Bottom up: calculate volume of tunnel walls, concrete is 15% cement → ~240 kt $CO_2$.
- Top down: studies of road tunnel construction give rule of thumb of 5,000-10,000 kg $CO_2$/km of tunnel → > ~500 kt $CO_2$.
- 6 million trees required for carbon offset!



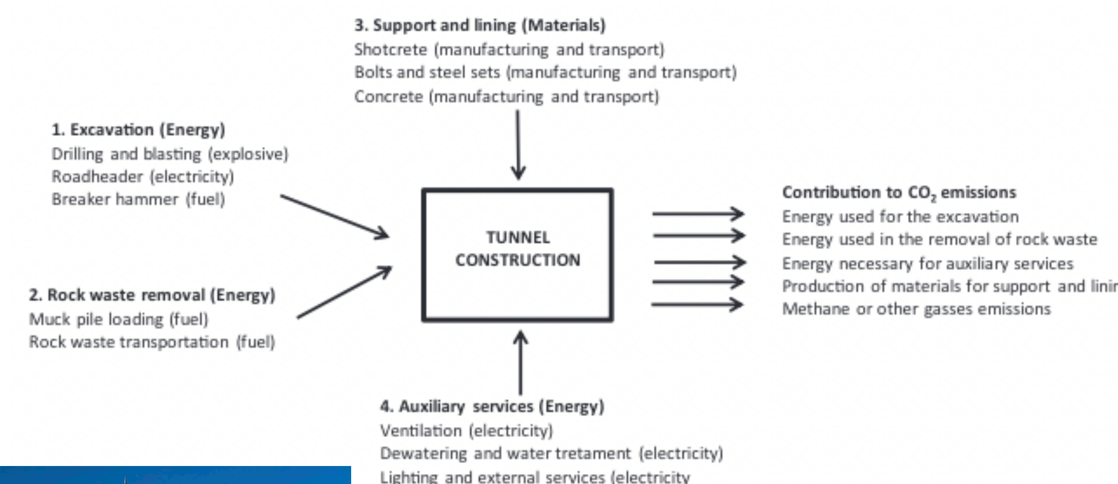




Fig. 1. Schematic overview of the system boundary.

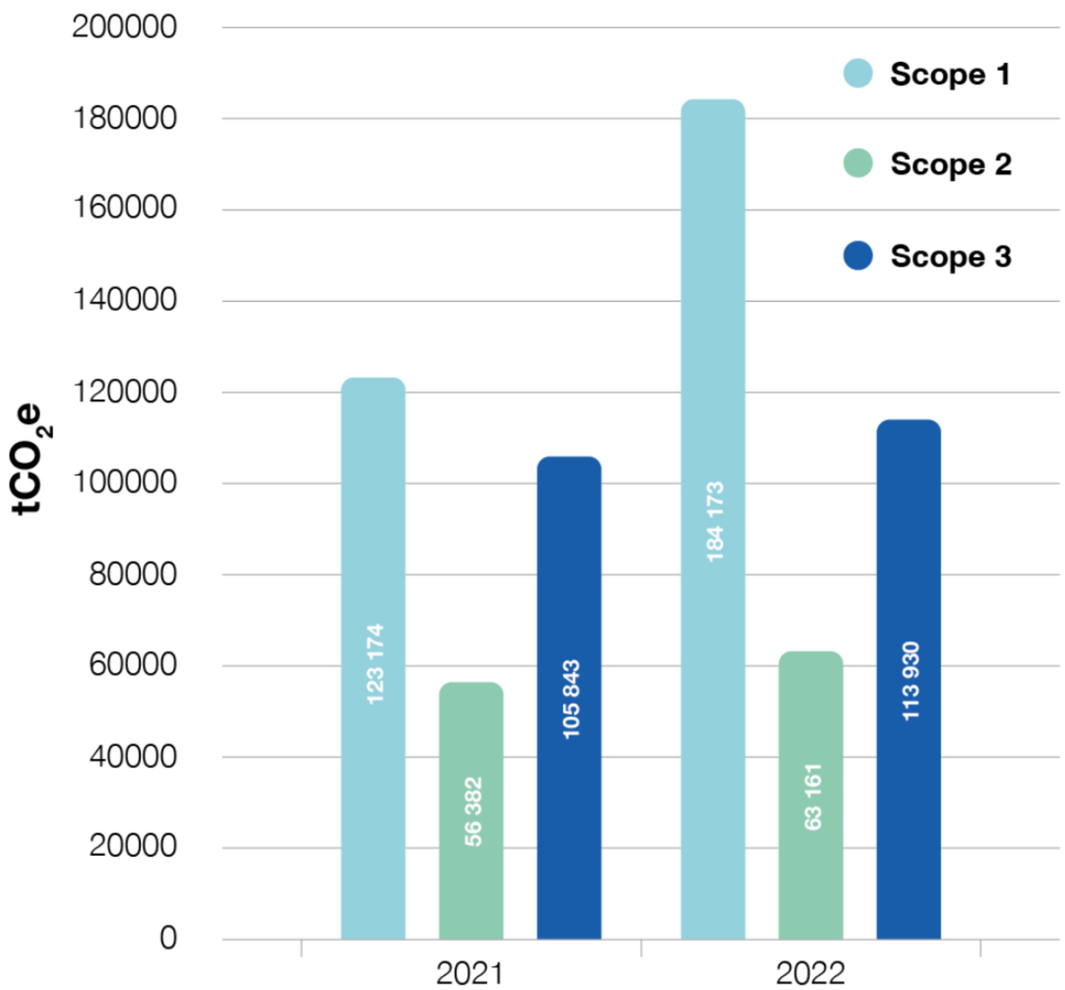
- 1 World Trade Center: 3.5M ft², ~550 kg embodied carbon/m² → ~197 kt CO2e.

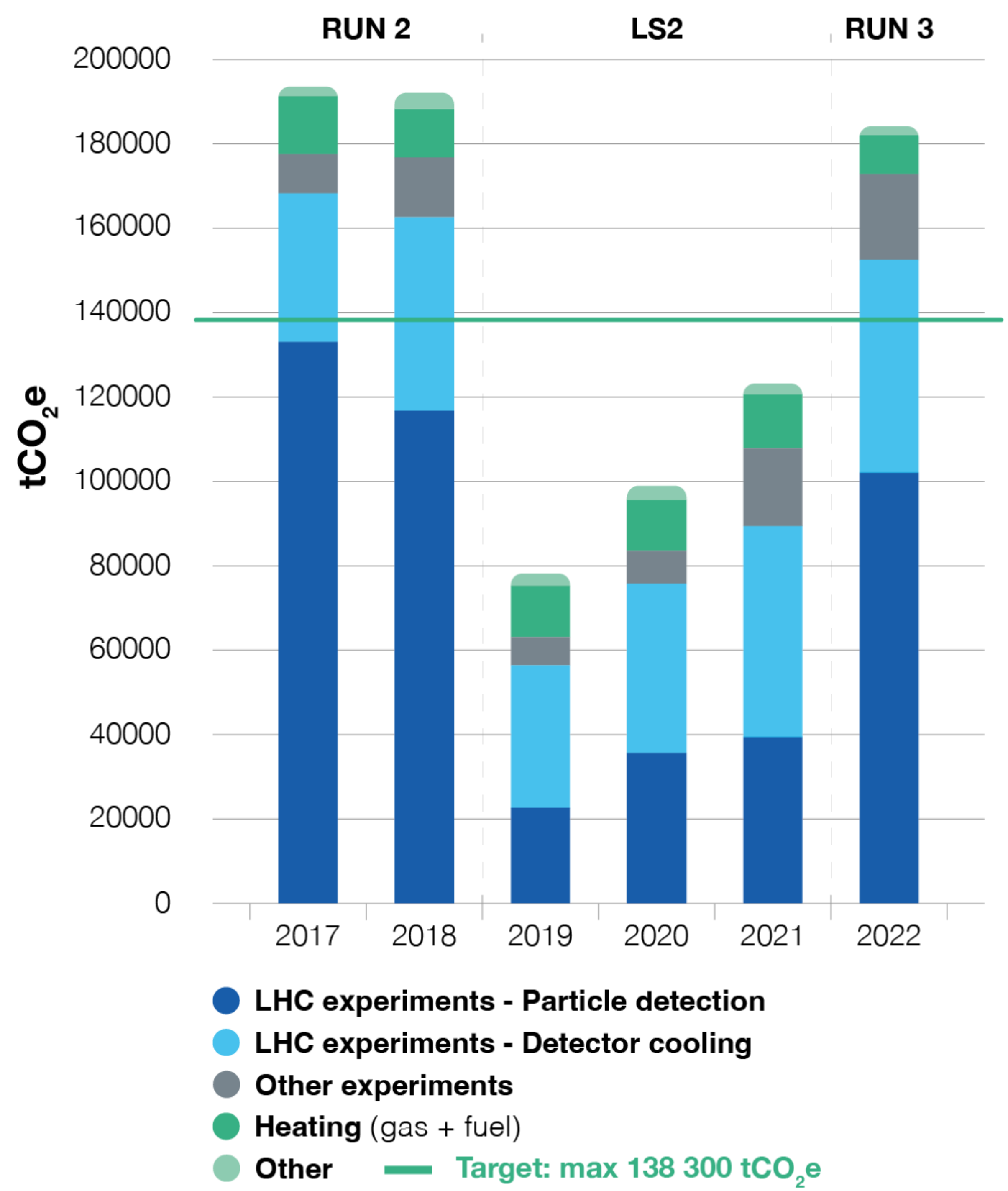
# Facility construction considerations

- Constructing a major future facility will have similar carbon impact to the development of an urban neighborhood — and could receive similar scrutiny.
- Be prepared:
  - Collect and analyze data on carbon impacts of construction for future environmental reviews.
  - Develop and use low-carbon materials (and reuse/recycle).
- Beyond construction, invest in accelerator R&D on energy efficiency and power reduction:
  - See Snowmass paper https://arxiv.org/abs/2203.07423.
  - Energy efficient technologies (e.g. permanent magnets, low loss superconducting resonators) and energy efficient accelerator concepts (e.g. ERL).

# Emissions from detectors

**CERN environment report (2021-22)**




- 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, procurement etc.); harder to quantify

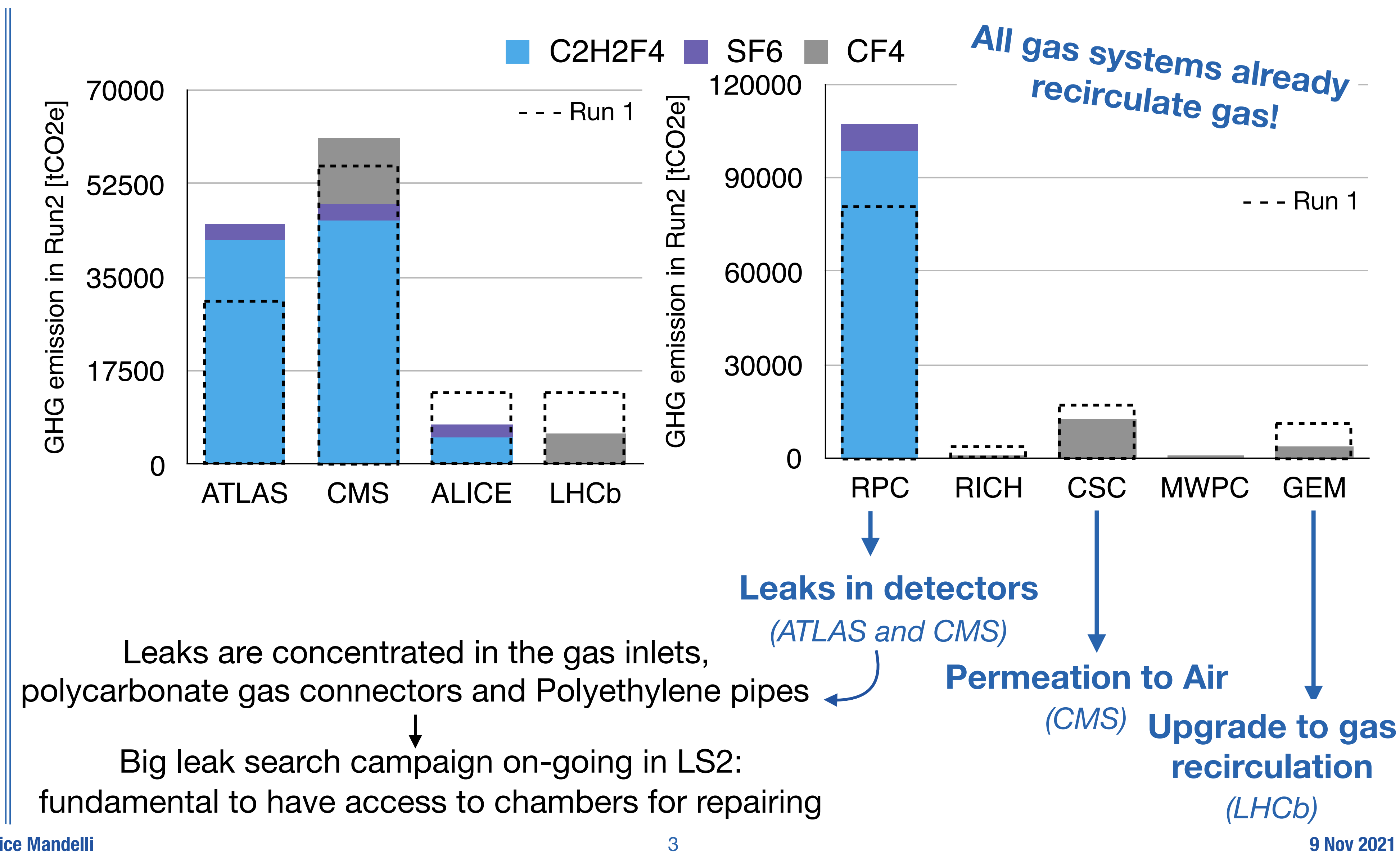
# Emissions from detectors

| GROUP | GASES | $tCO_2e$ 2021 | $tCO_2e$ 2022 |
|---|---|---|---|
| Perfluorocarbons (PFCs) | $CF_4$, $C_2F_6$, $C_3F_8$, $C_4F_{10}$, $C_6F_{14}$ | 55 921 | 68 989 |
| Hydrochlorofluorocarbons (HFCs) | HFC-23 ($CHF_3$)<br>HFC-32 ($CH_2F_2$)<br>HFC-134a ($C_2H_2F_4$)<br>HFC-404a<br>HFC-407c<br>HFC-410a<br>HFC-507 | 36 557 | 86 211 |
| Other F-gases | $SF_6$, $NF_3$ | 16 838 | 18 355 |
| Hydrofluoroolefins (HFO)/HFCs | R-449<br>R1234ze<br>NOVEC 649 | 86 | 199 |
| | $CO_2$ | 13 771 | 10 419 |
| **Total Scope 1** | | 123 174 | 184 173 |

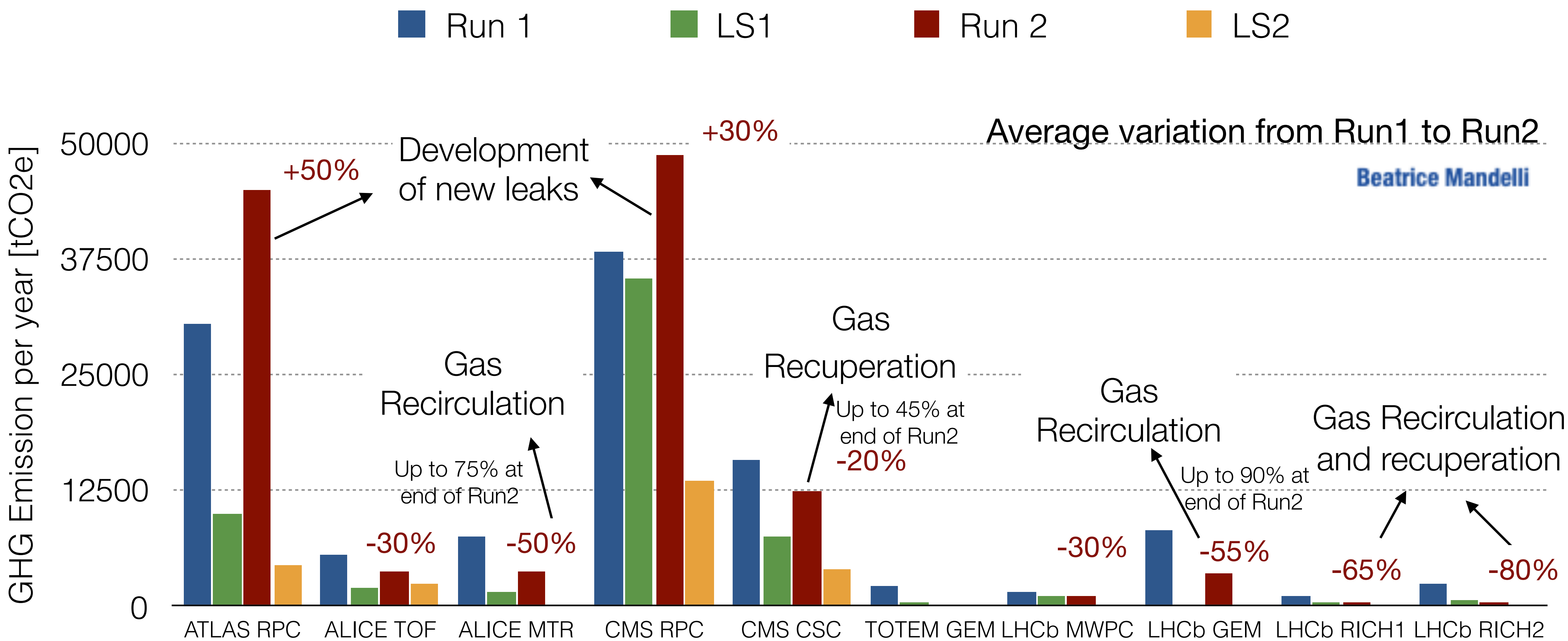
- Gases used for particle detection, detector cooling, A/C, electrical insulation
- $C_2H_2F_4$ has 1300x global warming potential (GWP) of $CO_2$.
- $CF_4$ has 6630x GWP, $SF_6$ has 23500x GWP!

# Emissions from detectors

- Complicated infrastructure: LHC experiments have ~90 km of gas pipes over 30 systems!
- Basic challenge: the detectors are leaky.



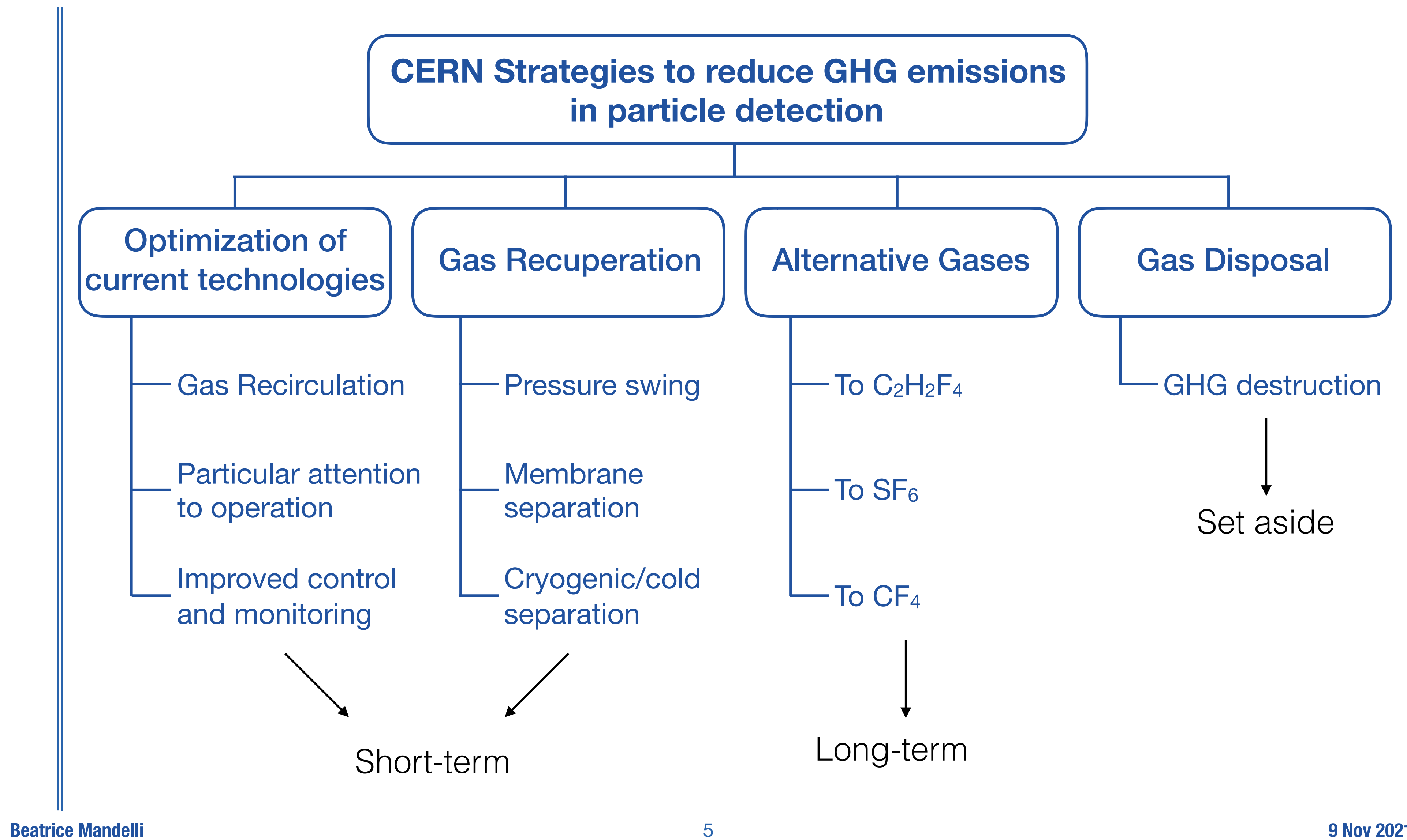
# Emissions from detectors




- F-gases are good for detector operations, but highly regulated in the EU (phased-down sales → more expensive), mandatory reporting in the US.
- Procurement subject to availability and price increases → potential threat to long-term LHC program.

# Emissions from detectors

- CERN ran a working group in 2020-21 to address F-gas issues: centralized procurement, leak detection, replacement alternatives, training, traceability, reporting.
- New eco-friendly gases/liquids good for refrigerants, not as much for particle detection in existing systems.



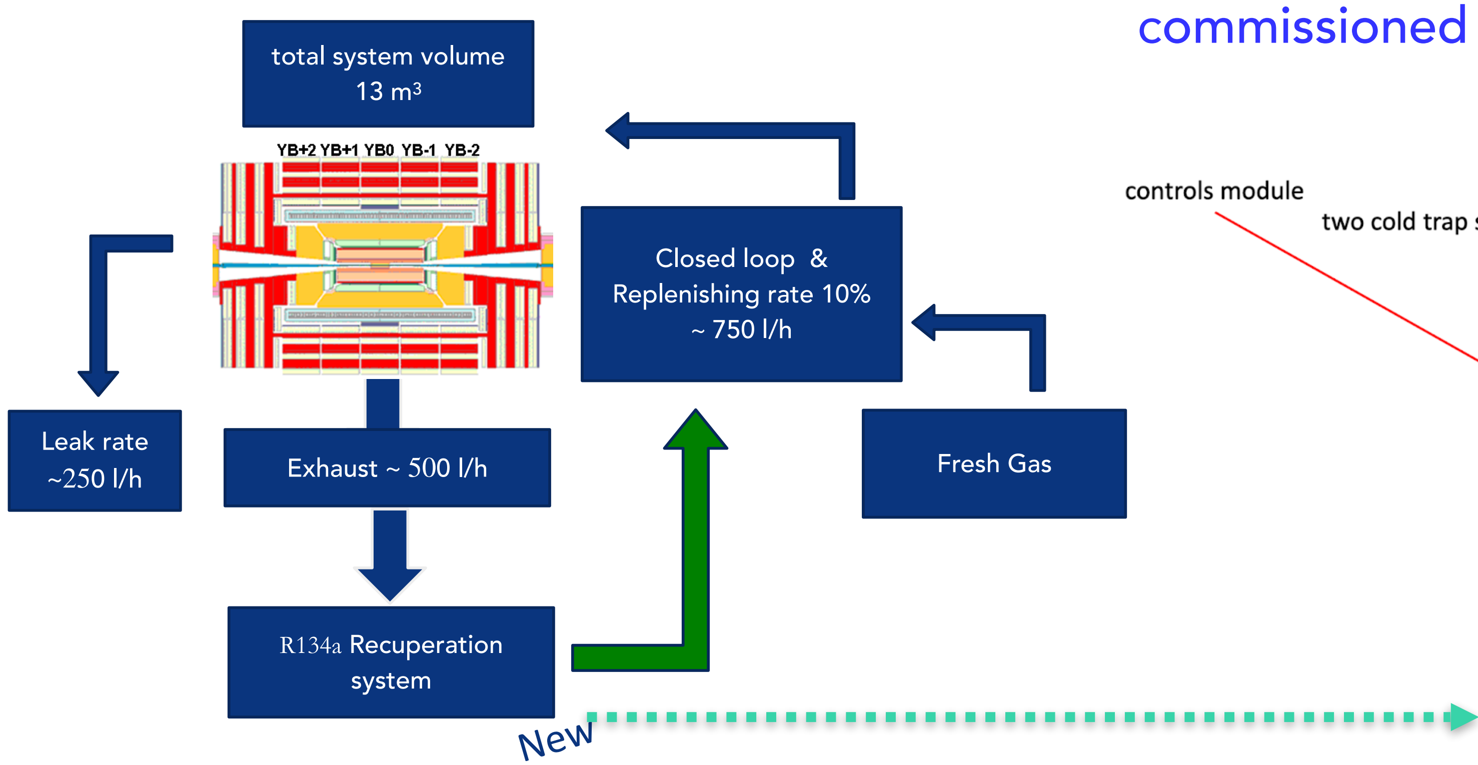
# Improvements at CMS

**P. McBride, October 2023 JOG**

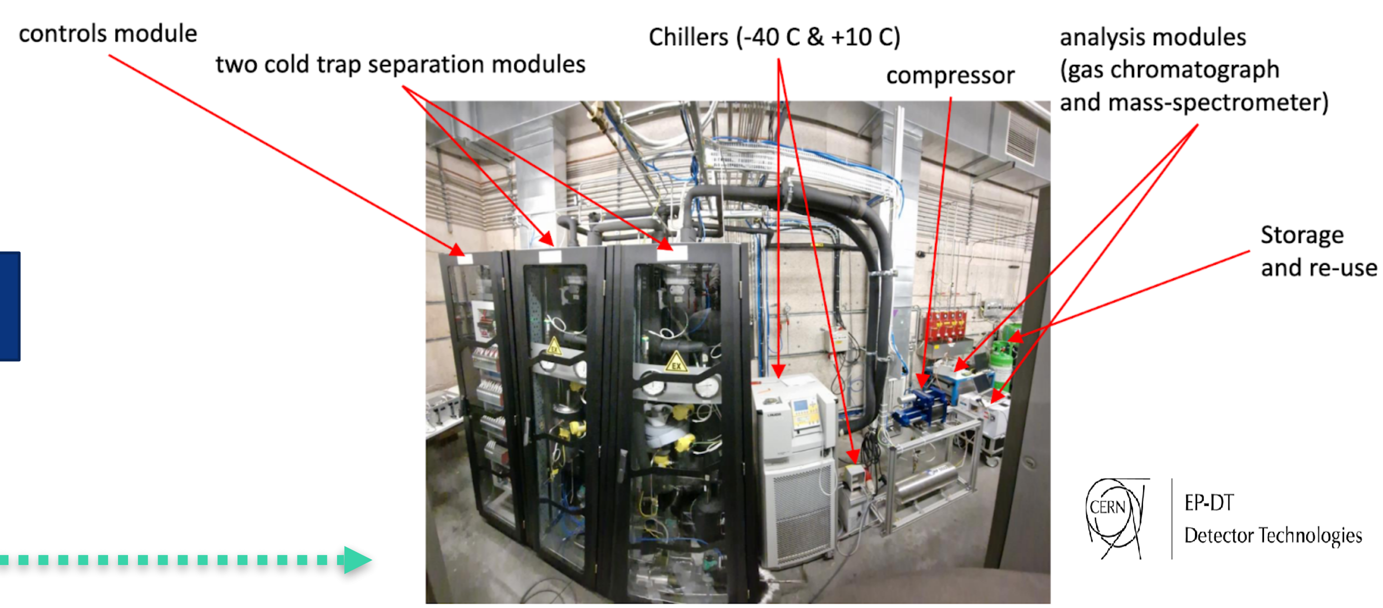
## Emissions reductions

- CMS is working to reduce Green House Gases (GHG) emissions where possible.
- For example, Muon CSCs will run with 5% of $CF_4$ (2.5% fresh and 2.5% recuperated gas) during the Heavy Ion run

**RPC gas mixture: R134a + $iC_4H_{10}$ + $SF_6$**
**95.2% + 4.5% + 0.3%**




- The first Freon (R134a) recuperation system was built and installed in CMS at the **RPC exhaust**. The system was commissioned in June 2023 and is in operation at P5.



# Emissions from detectors

## Why it is so difficult to find good GHG alternatives

*When looking for alternatives eco-friendly gases, several factors have to be taken into account*

**Safety**

Safety first for detector operations
- Gas mixture not flammable
- Gas components cannot have high toxicity levels

Tradeoff between flammability and GWP
- Replacing F with Cl or H: it shortens atmospheric lifetime BUT increase flammability limit
- Adding C=C bound: it increases reaction with $O_2$


**Performance**

GWP is related to IR absorption over time. Low GWP gases have short atmospheric lifetimes
- Water solubility —> rain out
- OH reactivity —> oxidation
- UV absorbance —> photolysis

RPC short and long term performance are affected
- Good quenching gases required
- Radiation-hard gas required
- Gases cannot heavily react with $H_2O$ or UV radiation

**Environment**

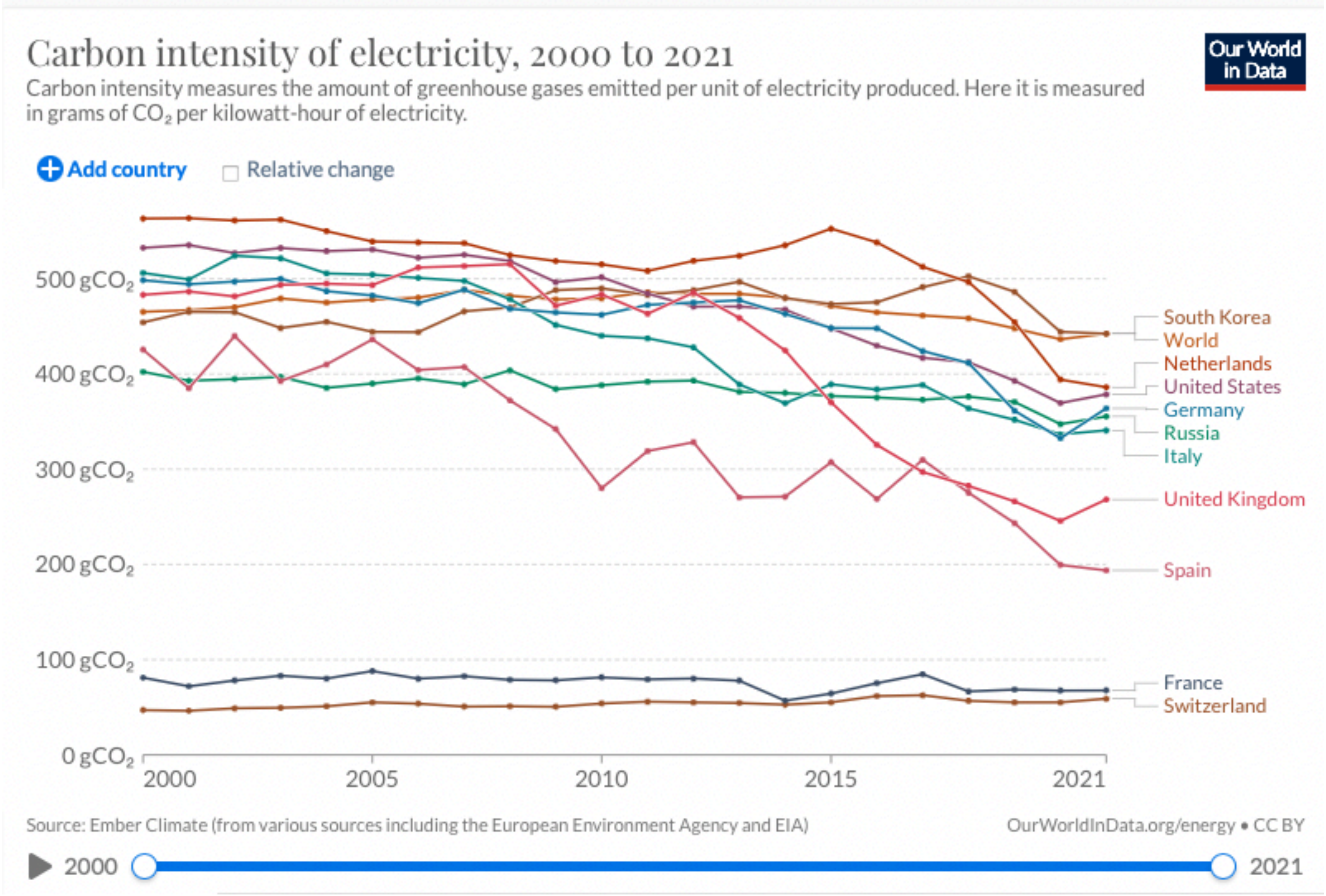
GWP represents the main environment concern

Beatrice Mandelli 19 9 Nov 2021

- Now is the time for R&D on replacement gases, leak-free detectors, recirculation systems for future detectors!

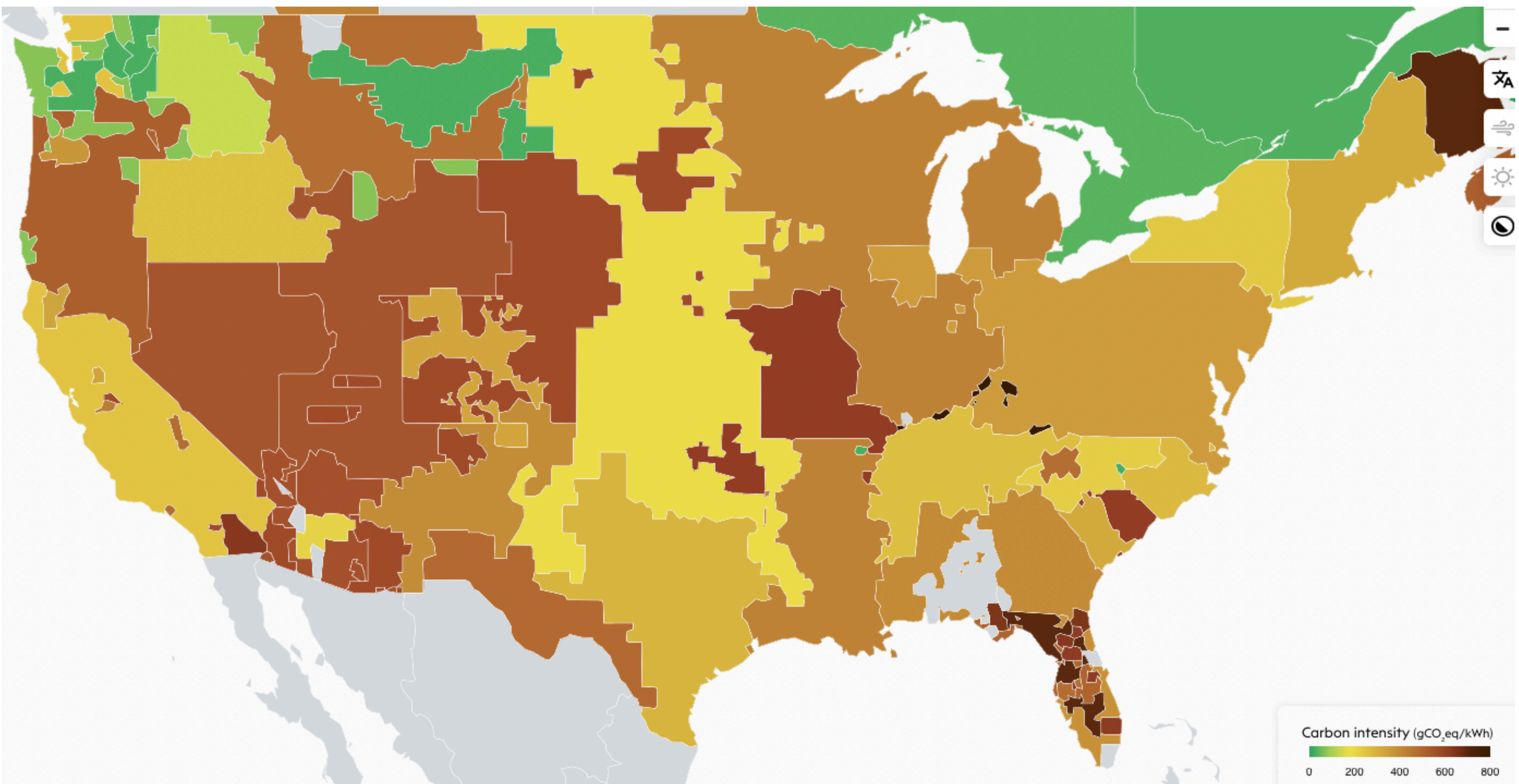
# Emissions from computing

- Data centers and computing contribute 2-4% of global GHG emissions, only expected to grow.
- Up-front considerations: where do we place computing facilities and how are they powered?
  - Great variation of electricity emissions across countries and even regions.



# Emissions from computing

- Data centers and computing contribute 2-4% of global GHG emissions, only expected to grow.
- Up-front considerations: where do we place computing facilities and how are they powered?
  - Great variation of electricity emissions across countries and even regions.






**electricitymap.org**

# Emissions from computing

- Can we be smarter about how we use existing facilities?
  - Can compute centers expose information on their specific carbon impact, so that experiments can use it in scheduling?
  - Can we schedule jobs to run at times when electricity supplies tend to be cheaper/cleaner (midday/nighttime)?
  - Can we consider carbon impact as an element of computing “performance” in benchmarking?
  - Can we invest in optimization of power consumption for products/libraries in widespread use in the field?
    - (Or at least track progress over release history?)
- Looking ahead: electricity must be de-carbonized, but:
  - Expect higher demand for electricity overall.
  - Concerns about “embodied carbon” in computing facilities.

# Emissions from laboratories

- DOE requires yearly reports on environmental impacts.
- Fermilab 2022 sustainability report:

### Scope 1 & 2 Greenhouse Gas Emissions

Goal: Reduce direct GHG emissions by 50 percent by FY 2025 relative to FY 2008 baseline
Interim Target (FY 2022): -40.0%

**Current Performance: -71.3%**

| | FY 2008 | FY 2021 (PY) | FY 2022 | % Change from Baseline | % Change from Last Year |
|---|---|---|---|---|---|
| Facility Energy | 343,366.8 | 131,612.5 | 125,536.5 | -63.4% | -4.6% |
| Non-Fleet V&E Fuel | 142.6 | 116.0 | 113.7 | -20.3% | -2.0% |
| Fleet Fuel | 691.6 | 273.2 | 308.6 | -55.4% | 13.0% |
| Fugitive Emissions | 40,165.1 | 441.4 | 308.9 | -99.2% | -30.0% |
| On-Site Landfills | 0.0 | 0.0 | 0.0 | N/A% | N/A% |
| On-Site WWT | 0.0 | 0.0 | 0.0 | N/A% | N/A% |
| Renewables | 0.0 | 0.0 | 0.0 | N/A% | N/A% |
| RECs | 0.0 | -14,569.4 | -15,865.8 | N/A | 8.9% |
| **Total (MtCO2e)** | **384,366.1** | **117,873.7** | **110,401.9** | **-71.3%** | **-6.3%** |

renewable energy certificates

### Scope 3 Greenhouse Gas Emissions

Goal: Reduce indirect GHG emissions by 25 percent by FY 2025 relative to FY 2008 baseline
Interim Target (FY 2022): -19.0%

**Current Performance: -64.2%**

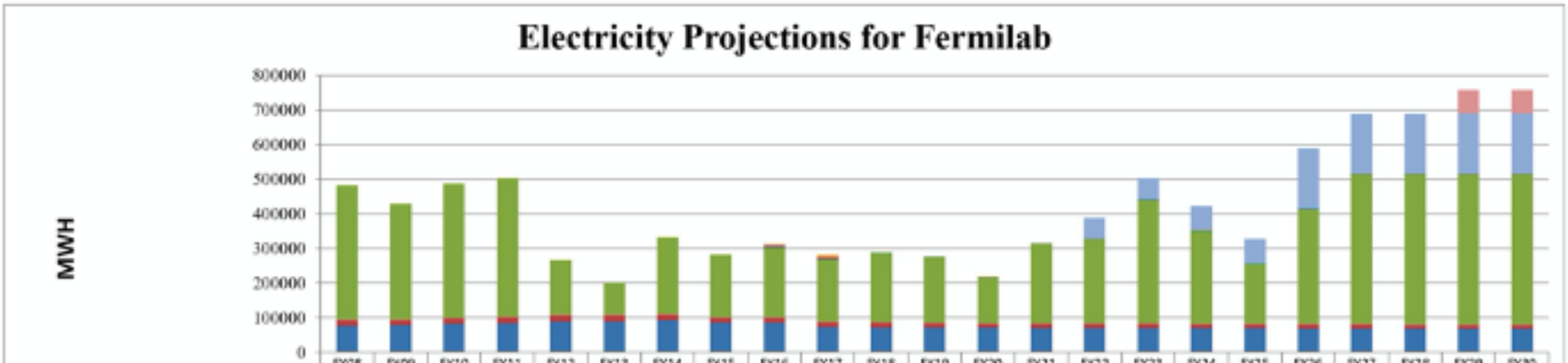
| | FY 2008 | FY 2021 (PY) | FY 2022 | % Change from Baseline | % Change from Last Year |
|---|---|---|---|---|---|
| T&D Losses* | 22,287.8 | 6,828.2 | 6,758.5 | -69.7% | -1.0% |
| T&D RECs Credit | 0.0 | -959.7 | -1,045.1 | N/A | 8.9% |
| Air Travel | 2,215.8 | 144.2 | 1,236.0 | -44.2% | 757.1% |
| Ground Travel | 168.9 | 111.2 | 77.6 | -54.1% | -30.2% |
| Commute | 4,633.3 | 2,634.2 | 3,372.4 | -27.2% | 28.0% |
| Off-Site MSW | 191.8 | 157.2 | 150.8 | -21.4% | -4.1% |
| Off-Site WWT | 4.8 | 10.9 | 10.9 | 127.1% | 0.0% |
| **Total (MtCO2e)** | **29,502.4** | **8,926.2** | **10,561.1** | **-64.2%** | **18.3%** |

# Emissions from laboratories

- More on Fermilab: electricity usage is expected to increase by 30% over historic peak levels due to PIP-II, LBNF operations.

| | 2008 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| Scope 1+2 | 384,666 | 128,304 | 144,013 | 106,961 | 163,818 |
| Scope 3 | 29,503 | 16,495 | 14,468 | 6,516 | 17,456 |

**Table 1.** Summary of Fermilab GHG emission data from 2008 (reference year) and 2018 - 2021. Emissions are divided into the three scope areas and given in CO2e metric tons [42].

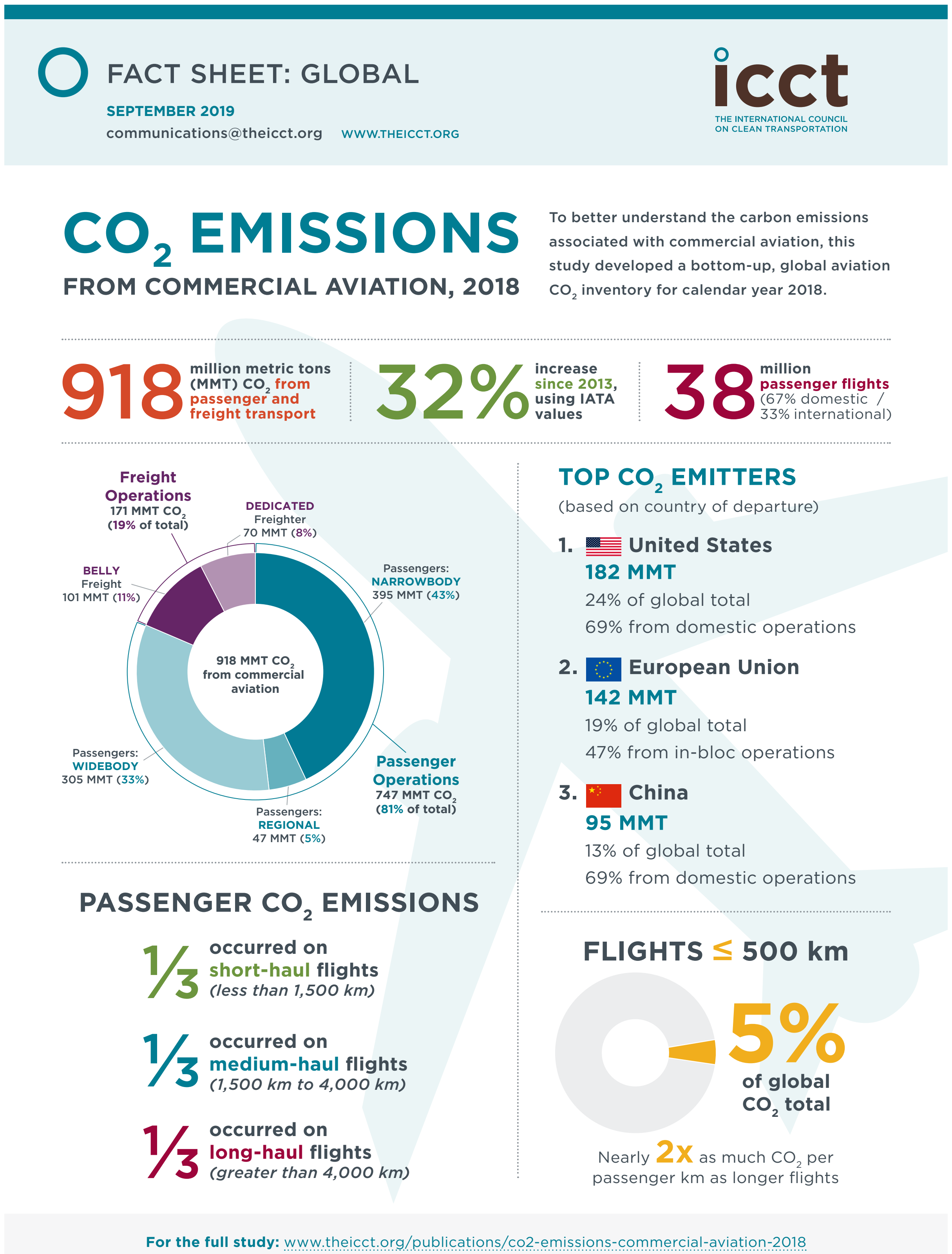



| | FY08 | FY09 | FY10 | FY11 | FY12 | FY13 | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LBNF | | | | | | | | | | | | |
| PIP-II | | | | | | | | | | | | |
| SBN Near & Far Detectors | | | | | | | | | 3942 | 8869.5 | 548.9508 | 521.6047 |
| Mu2e (MC-2) | | | | | | | | | | | 324.825 | 348.5065 |
| Muon G-2 (MC-1) | | | | | | | | | 5080.8 | 5080.8 | 932.8659 | 947.4887 |
| Existing Particle Accelerators HEMSF | 391208.4 | 337149.6 | 390287.5 | 402903.2 | 160678.4 | 94728.3 | 224836.8 | 182507.3 | 203178.3 | 179476.8 | 200217.4 | 189303.5 |
| Existing High Performance Computing HEMSF | 16548.45 | 17215.17 | 17230.22 | 19718.99 | 19542.3 | 18389.43 | 16574.14 | 14742.82 | 14742.82 | 15904 | 15321 | 14334 |
| Site Base | 74689.13 | 75595.25 | 80021.26 | 80555.81 | 85979.34 | 86723.26 | 90333.26 | 83857.44 | 83617.98 | 70310.89 | 69309.99 | 68919.64 |

| | FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29 | FY30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LBNF | | | | | | | | | | 68328 | 68328 |
| PIP-II | | | 61320 | 61320 | 70956 | 70956 | 173448 | 173448 | 173448 | 173448 | 173448 |
| SBN Near & Far Detectors | 669.758 | 700.8 | 700.8 | 700.8 | 700.8 | 700.8 | 700.8 | 700.8 | 700.8 | 700.8 | 700.8 |
| Mu2e (MC-2) | 471.1054 | 1752 | 1752 | 1752 | 1752 | 1752 | 1752 | 1752 | 1752 | 1752 | 1752 |
| Muon G-2 (MC-1) | 1057.261 | 1057.261 | 876 | 876 | 876 | 876 | 876 | 876 | 876 | 876 | 876 |
| Existing Particle Accelerators HEMSF | 133630 | 229464.3 | 242312.3 | 357463.3 | 267470.5 | 172838 | 332149.8 | 432510 | 432866.6 | 433220.6 | 433570.1 |
| Existing High Performance Computing HEMSF | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 | 13131.06 |
| Site Base | 68533.19 | 68150.6 | 67771.85 | 67396.88 | 67025.65 | 66658.15 | 66294.31 | 65934.12 | 65577.52 | 65224.5 | 64875 |

# Why am I here?

# Emissions from travel




- Particle physicists are famous for the amount of traveling they do.
  - Experiment sites, conferences
- Air travel is “only” ~2% of global emissions, but rising rapidly (up 32% in 5 years before pandemic) and hard to de-carbonize.

# Rethinking travel

- The pandemic has taught us a lot about what can be done remotely…and what *can't* be done remotely.
- Can we optimize experiment work so that more of it can be done at home institutions (e.g. remote control rooms)?
- Can we improve meeting technology so that everyone can have the same experience regardless of location?
- Can we rely more on regional centers to reduce travel to the experiment host laboratory?
- What about conferences? Is in-person appearance necessary for career development, or just for fun?
  - Estimate 1 ton $CO_2e$ per conference participant!
  - Improvements: accessible venues, virtual attendance, reduce frequency, multiple regional hubs
- Judicious choices can have an impact.

# European Strategy Update input

**Recommendation 1:**
**As part of their grant-giving process, European laboratories and funding agencies should include criteria evaluating the energy efficiency and carbon footprint of particle physics proposals, and should expect to see evidence that energy consumption has been properly estimated and minimized.**

**Recommendation 2:**
**Any design of a major particle physics experiment should consider plans for reduction of energy consumption, increased energy efficiency, energy recovery and carbon offset mechanisms. Similarly, any design for new buildings associated with particle physics research should consider the highest building and energy efficiency standards.**

**Recommendation 3:**
**European laboratories should invest in the development and affordable deployment of next-generation digital meeting spaces including virtual reality (VR) tools in order to minimize the need for frequent travelling to the laboratory, thereby minimizing the travel carbon and energy footprint of their users.**

# European Strategy Update

- Highlighted in final ESU report:

7

## Environmental and societal impact

A. The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. ***The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.***

# 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**.

# Beyond Snowmass

- The Snowmass study was a huge effort, covering the entirety of particle physics!
  - ~500 white papers → summaries from topical groups → summaries from 10 “frontier” areas → 70 page overall summary report.
- This topic got an entire sentence in the summary!

Finally, **HEP must take greater responsibility for its impacts on climate change** by addressing and mitigating these impacts through DOE project policies and individual community member actions.

- And the topic got a brief mention in the recent Particle Physics Project Prioritization report:

**Area Recommendation 20:** HEPAP, potentially in collaboration with international partners, should conduct a dedicated study aiming at developing a sustainability strategy for particle physics.

- From here, it is in our own hands….

# Outlook

- Human-influenced climate change is real, and particle physics needs to be considered in that context.
- A wide range of our activities can have an outsized impact on carbon emissions.
- But we can take some reasonable steps to mitigate this, and these steps should be integrated into any consideration of new particle physics projects.
  - Funding agencies could allow particle physics sustainability research to count as “normal” particle physics research.
- Optimism:
  - The most recent IPCC report says that it’s not too late to slow the impacts of climate change…but we need to act now.
  - Inflation Reduction Act is actually a climate change bill!
  - A community that can build and operate some of the world’s most complex scientific experiments can address this challenge too!

# My electric car!

# Societal action is needed

RP **Ritchie Patterson**

personal CO2 budgets

To: Kenneth Bloom, Cc: Ritchie Patterson

October 2, 2022 at 11:08 AM

Details

Non-NU Email

Hi Ken,

Inspired by your talk, I set up a spreadsheet to track our family's emissions, and figure out a path to 1t CO2/yr. The results are disturbing ...or I blew my calculation.

For example, a vegetarian produces 17 kg CO2/week (see https://www.bbc.com/future/article/20220429-the-climate-benefits-of-veganism-and-vegetarianism), which amounts to 884 kg/year. So, if I understand right, food alone almost saturates one's CO2 budget of 1 t/year. That's with no clothes, no car, no house, no appliances.

Am I understanding this right? If so, there's no hope unless we grow all of our own food (to avoid food transportation), fully compost waste (since food or plant scraps in landfill produce methane, which is awful), and live naked in caves.

Carwise, our new Tesla is using electricity at a rate of 3600 kWh/year, which with the Tompkins County mix of sources, results in 2.1 t CO2/year. (We have solar panels, which will mitigate this, but still…) I'm going to need to ground my daughter.

So a vegetarian diet for 1 person and car total 3 t. And that's living naked in a cave (with no fires allowed).

Am I missing a big factor here? Have you calculated this?

It was great to see you, and your talk was excellent, and clearly inspiring.

Ritchie