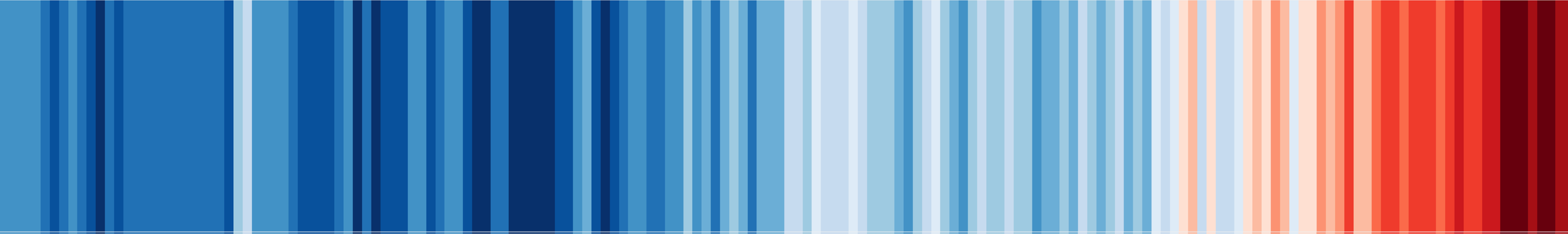


Climate for Change

Discussion starter on how to make our research ~~(more)~~ sustainable

Partikeldagarna 2024

Uppsala

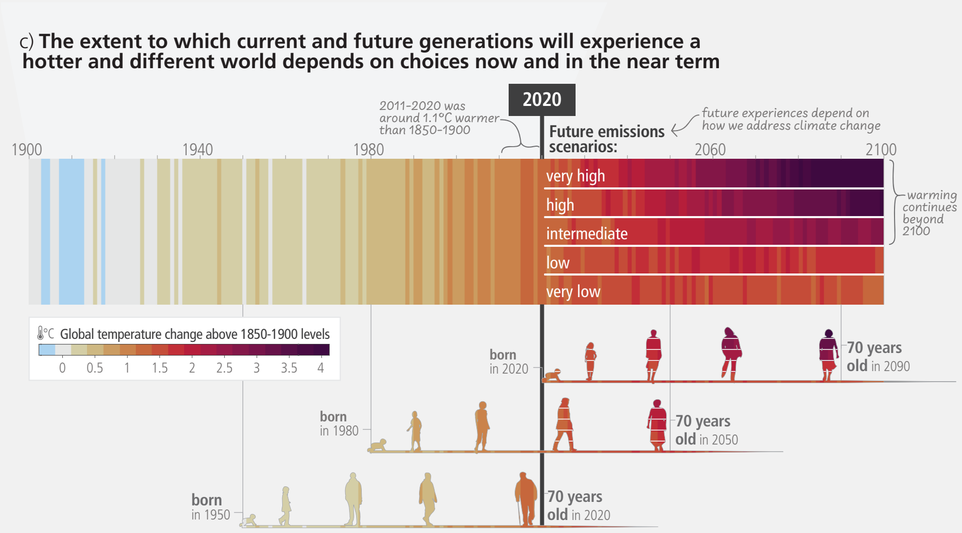
Ruth Pöttgen

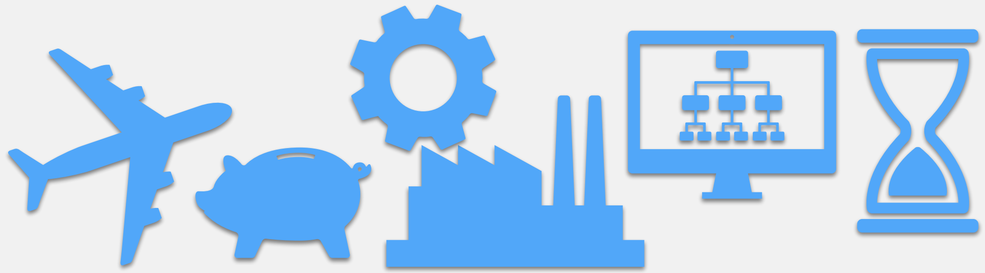
Why this talk? (I am not a climate scientist)

Struggling with discrepancy

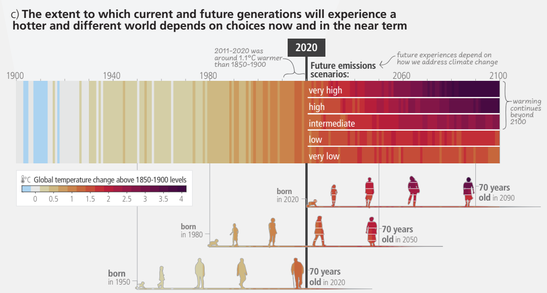
Urgency of climate crisis

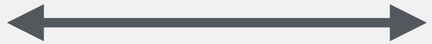
Mainly ‘business as usual’ in academia

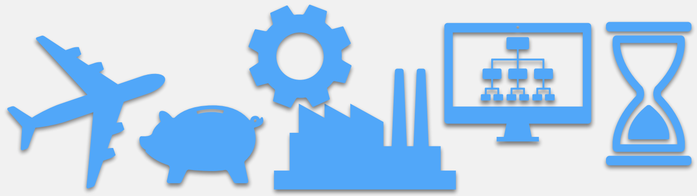




Why this talk? (I am not a climate scientist)







In the following: *Personal selection* from attempts to educate myself

—> There are probably many here that can complement/expand this!

Don’t have all the answers/solutions

—> Start a *common* thought process

—> *Discuss and learn* from each other

—> Please *share* your ideas and experiences!

Why should we care?

IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

Why should we care?

"A.1 **Human activities**, principally through emissions of greenhouse gases, have **unequivocally caused global warming**, with global surface temperature reaching **1.1°C** above 1850–1900 in 2011–2020. […]"

IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

Why should we care?

"A.1 **Human activities**, principally through emissions of greenhouse gases, have **unequivocally caused global warming**, with global surface temperature reaching **1.1°C** above 1850–1900 in 2011–2020. […]"

"B.5 Limiting human-caused global warming **requires net zero CO2 emissions**. Cumulative carbon emissions until the time of reaching net zero CO2 emissions and the level of greenhouse gas emission **reductions this decade largely determine** whether warming can be limited to 1.5°C or 2°C (high confidence). […]"

IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

Why should we care?

"A.1 **Human activities**, principally through emissions of greenhouse gases, have **unequivocally caused global warming**, with global surface temperature reaching **1.1°C** above 1850–1900 in 2011–2020. […]"

"B.5 Limiting human-caused global warming **requires net zero CO2 emissions**. Cumulative carbon emissions until the time of reaching net zero CO2 emissions and the level of greenhouse gas emission **reductions this decade largely determine** whether warming can be limited to 1.5°C or 2°C (high confidence). […]"

"B.6 All global modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot […] involve **rapid** and **deep** and, in most cases, **immediate** greenhouse gas emission **reductions in all sectors this decade**. […]"

IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

Why should we care?

Every ton of CO_2e counts

Anything we do has a potential climate impact, science/research no exception

—> Should **be aware** of the impacts of our research activities, **minimise** them

Why should we care?

Every ton of CO_2e counts

Anything we do has a potential climate impact, science/research no exception

—> Should **be aware** of the impacts of our research activities, **minimise** them

— On *"moral" grounds*: lead by example, raise awareness

— *Justice* with regard to next generations:
Actions we don't take they will have to make up for with even larger efforts

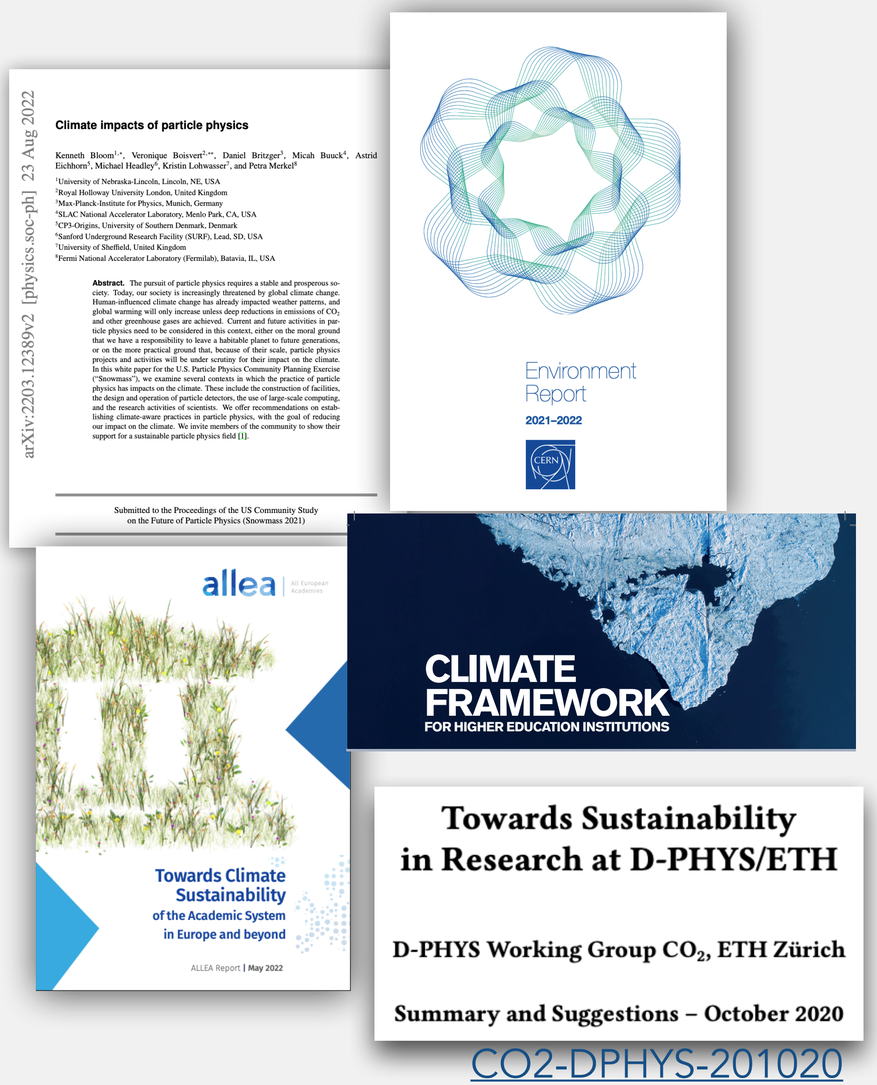
— *Self-interest*: Our activities probably will be scrutinised wrt these aspects in the future, better to be prepared (now, we can do things on our own terms/be proactive)

— *Inevitability*: There is no way around net-zero

Awareness is growing

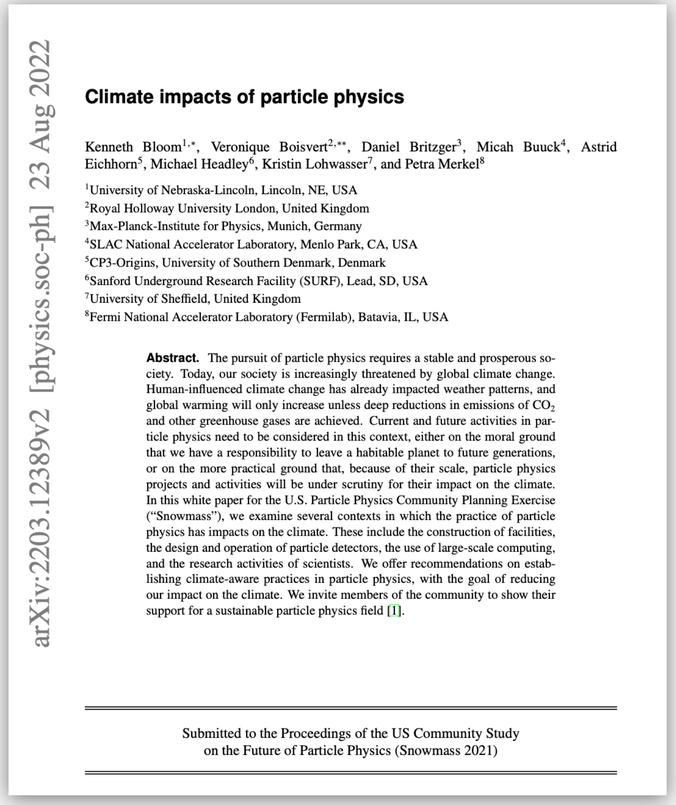
In the field, in Sweden, internationally…

- 2020 Update of the European Strategy for Particle Physics (EPPSU) https://cds.cern.ch/record/2720129
- Recent Snowmass white paper: https://arxiv.org/pdf/2203.12389.pdf
- The CERN environment report: https://e-publishing.cern.ch/index.php/CERN_Environment_Report/issue/view/156
- Case study for an astrophysics project: http://export.arxiv.org/pdf/2101.02049v1
    - Related “manual”: https://www.nature.com/articles/s42254-021-00325-2
- Insititutes’/Experiments’ Sustainability Fora (e.g. DESY, ATLAS)
- Preparations for a submission to the 2025 EPPSU
- ALLEA report (https://allea.org/wg-climate-sustainability-in-the-academic-system/)
- Klimatramverket (https://www.kth.se/en/om/miljo-hallbar-utveckling/klimatramverk/klimatramverket-1.903489)/Klimatnätverk (https://www.slu.se/centrumbildningar-och-projekt/klimatnatverket/)
- …



Example 1: Snowmass Whitepaper

Snowmass: US Community Study on Future of Particle Physics, last round in 2021



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].

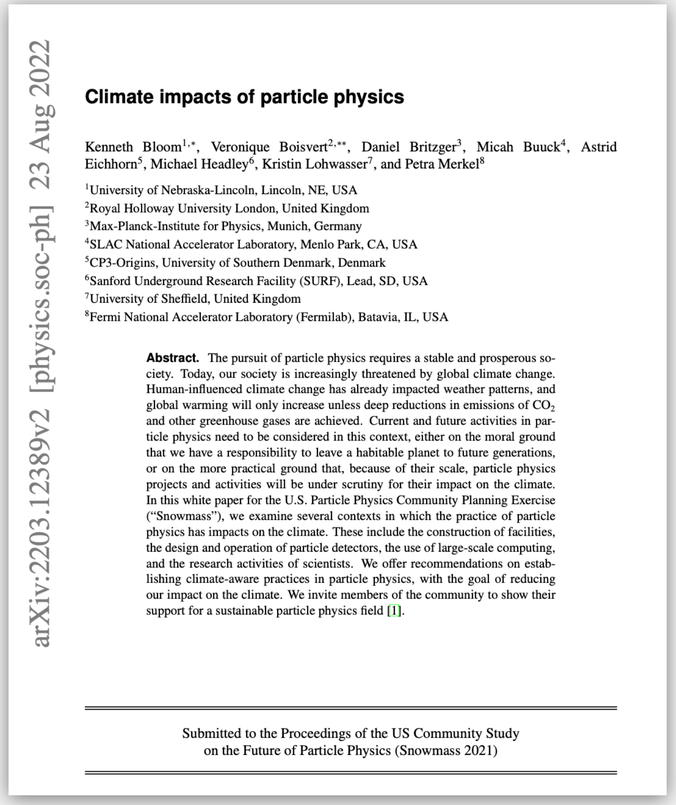
Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

Aspects they look at:

- Facility construction
  - e.g. FCC tunnel ~500 ktons CO_2e, vs ~200 ktons for 1 WTC
- Detector gases
  - Main contribution at CERN, even while LHC running (nuclear power)
- Computing
  - Energy consumption, user code efficiency, hardware…
- Scientists research activities
  - Mainly commute/travel

Example 1: Snowmass Whitepaper

Snowmass: US Community Study on Future of Particle Physics, last round in 2021



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)

Aspects they look at:

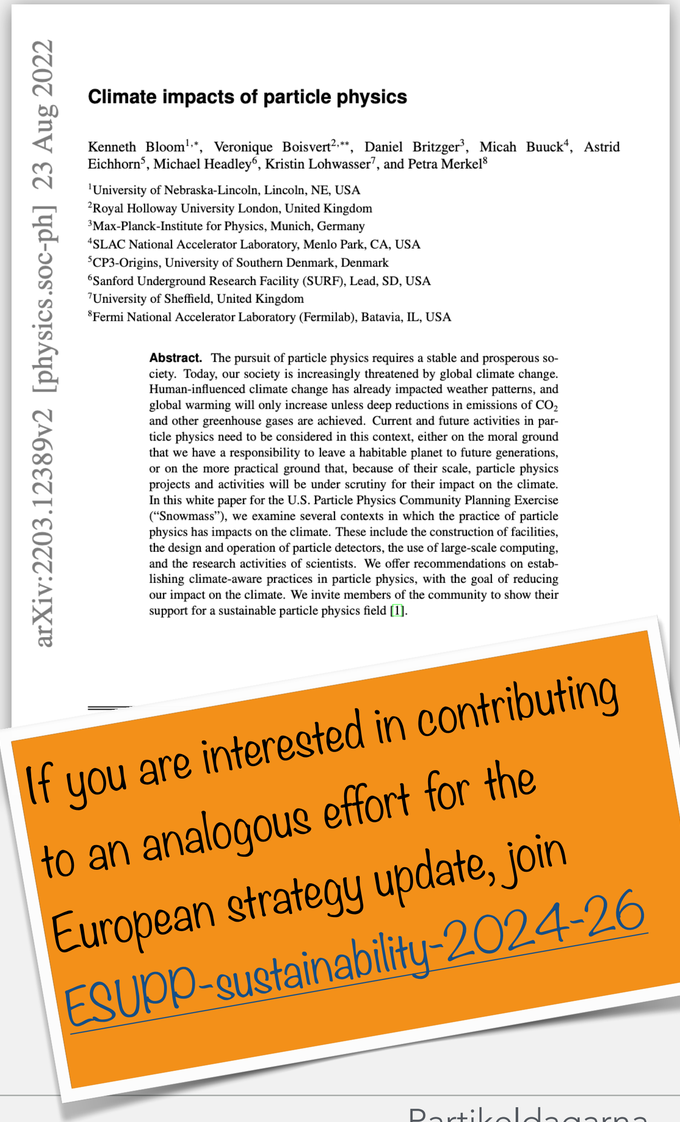
- Facility construction
  - e.g. FCC tunnel ~500 ktons CO_2e, vs ~200 ktons for 1 WTC
- Detector gases
  - Main contribution at CERN, even while LHC running (nuclear power)
- Computing
  - Energy consumption, user code efficiency, hardware…
- Scientists research activities
  - Mainly commute/travel

Recommendations/Suggestions

- Projects report on expected emissions, becomes part of evaluation
- Standardised reporting
- All stakeholders set reduction goals and define pathways to reach them
- Digital meeting spaces
- …

Example 1: Snowmass Whitepaper

Snowmass: US Community Study on Future of Particle Physics, last round in 2021



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].

If you are interested in contributing to an analogous effort for the European strategy update, join ESUPP-sustainability-2024-26

Aspects they look at:

- Facility construction
  - e.g. FCC tunnel ~500 ktons CO_2e, vs ~200 ktons for 1 WTC
- Detector gases
  - Main contribution at CERN, even while LHC running (nuclear power)
- Computing
  - Energy consumption, user code efficiency, hardware…
- Scientists research activities
  - Mainly commute/travel

Recommendations/Suggestions

- Projects report on expected emissions, becomes part of evaluation
- Standardised reporting
- All stakeholders set reduction goals and define pathways to reach them
- Digital meeting spaces
- …

Example 2: GRAND Giant (Radio antenna) Array for Neutrino Detection

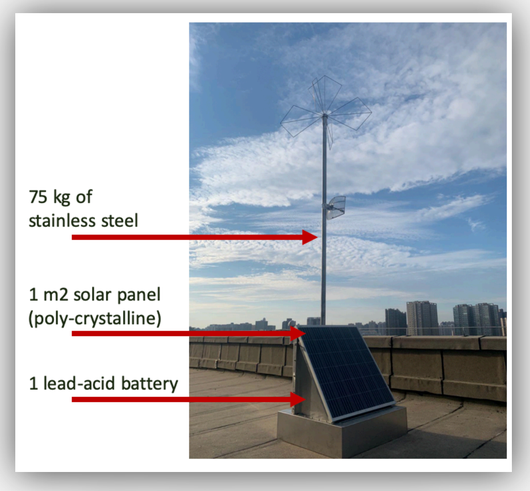
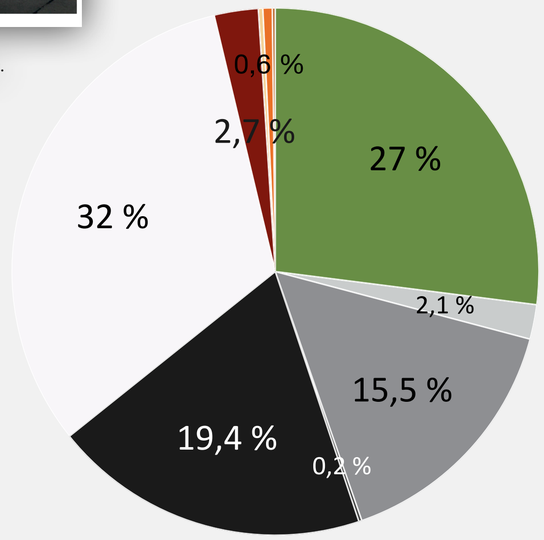


Figure 9: GRANDProto300 prototype antenna.

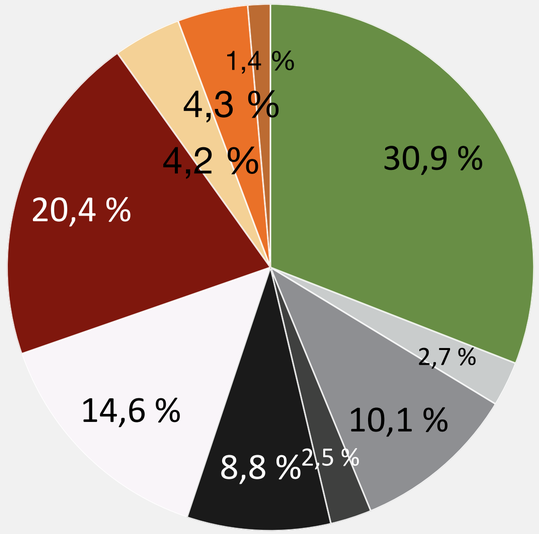
200k radio antennae over 200k km^2
(spread over different sites worldwide)

Astroparticle Physics, 2021, 102587

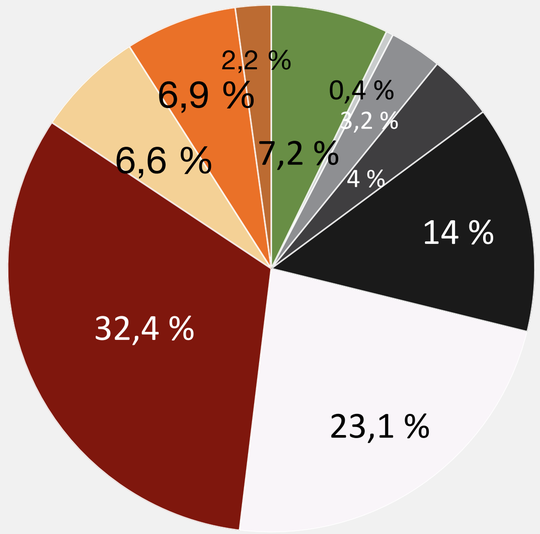
GRANDProto300
482 tCO2/yr

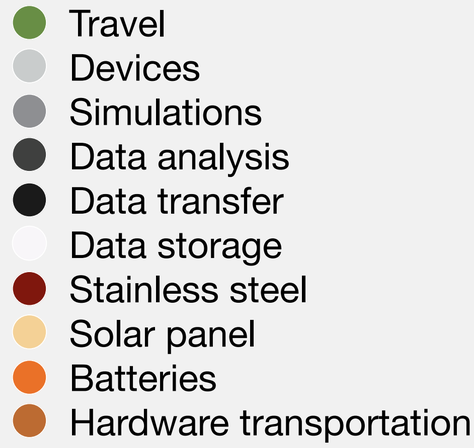


GRAND10k
1061 tCO2/yr



GRAND200k
13385 tCO2/yr



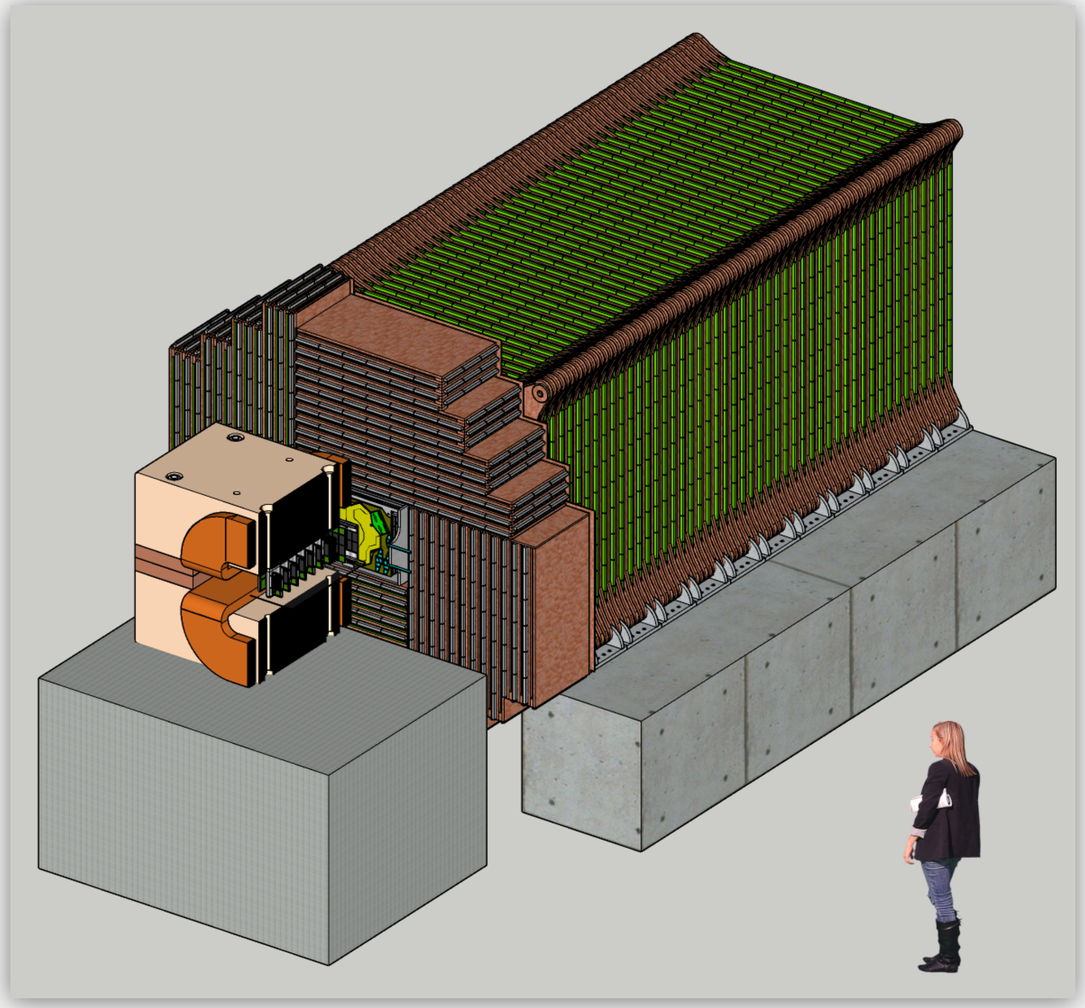


<manufacturing 1000 cars

Fun fact: For them, transporting hard-drives by plane 4 times/year would be orders of magnitudes less carbon emitting than transfering their data online

Example 3: LDMX@SLAC - A First Look

(See yesterday's talks in the DM session)



Areas to look at (eventually):

- Detector materials
- Shipping/Construction
- Computing/Data handling
- Operations (energy consumption)
- Travel
- Disposal
- 'Share' of emissions from accelerator?

Example 3: LDMX@SLAC - A First Look

Disclaimer: I am still learning how to do this!

	Amount	Emission Factor	Total Emissions	Comments
Steel (HCal)	~80t	0.4 - 2.3 [1]	32 - 184 t	Depends on supplier, recycling fraction
Aluminum (HCal)	~3t	14.3 (World Average) 6.5 (North America) [2]	43 t 19.5t	Depends on supplier, recycling fraction
Extruded Polystyrene (HCal)	~8t	6.9 [3]	55 t	Emission factor not exactly for the extrusion process LDMX will use
Silicon (ECal)	~6kg	11.3 (world average) [2]	68 kg	
Energy consumption	2 GWh/ year	220kg/MWh [4]	**440t/year**	Dominated by magnet, based on numbers for CA 2020
LunDMX group's flights to SLAC	10	~5t/ roundtrip [5]	50t/year	

Overall, LDMX ~ GRAND10k

Taking such considerations into account early in the design process could help reducing emissions for new projects

Incentive to **reduce time needed** to collect sufficient data
—> Efficient multi-electron operation!
(see LDMX talk on LU contributions)

Prospects for emission reductions (Not only LDMX specific)

- **Re-use** existing solutions/components

—> Minimise new R&D, material emissions
—> Already done in several places in LDMX
(magnet, some electronics, detector designs…)

- **Choice of material supplier** where possible

(Energy mix, recycling fraction, transport)

- **Minimise long-distance travel**

(Investigate different operational scenarios)

- **Distributed Computing** (send code, not data), optimise computing

- **Minimise runtime** by optimising multi-electron efficiencies

Prospects for emission reductions (Not only LDMX specific)

- **Re-use** existing solutions/components

—> Minimise new R&D, material emissions
—> Already done in several places in LDMX
(magnet, some electronics, detector designs…)

- **Choice of material supplier** where possible

(Energy mix, recycling fraction, transport)

- **Minimise long-distance travel**

(Investigate different operational scenarios)

- **Distributed Computing** (send code, not data), optimise computing

- **Minimise runtime** by optimising multi-electron efficiencies

Energy mix will become more fossil-free until LDMX operations

Prospects for emission reductions (Not only LDMX specific)

- **Re-use** existing solutions/components

—> Minimise new R&D, material emissions
—> Already done in several places in LDMX
(magnet, some electronics, detector designs…)

- **Choice of material supplier** where possible

(Energy mix, recycling fraction, transport)

- **Minimise long-distance travel**

(Investigate different operational scenarios)

- **Distributed Computing** (send code, not data), optimise computing

- **Minimise runtime** by optimising multi-electron efficiencies

Energy mix will become more fossil-free until LDMX operations

Beware Jevons paradox (Efficiency savings eaten up by using more)

Ideas (not just mine!) for HEP (and others)

- Make carbon footprint + reusability a design parameter
- Introduce emission budgets
- Estimate and publish emissions of publications
- More efficient accelerators/detectors/code/computing
  - e.g. emissions monitor for jobs, stricter usage rules, prefer green grid sites…
- Check physics
  - Less systematics? More skimming? Less data reprocessing/rerunning for small improvements?…
- Reduce emissions from travel
  - Less travel, hybrid/remote meetings, sustainable transportation
- Include these discussions in your courses
- …

Ideas (not just mine!) for HEP (and others)

- Make carbon footprint + reusability a design parameter
- Introduce emission budgets
- Estimate and publish emissions of publications
- More efficient accelerators/detectors/code/computing
  - e.g. emissions monitor for jobs, stricter usage rules, prefer green grid sites…
- Check physics
  - Less systematics? More skimming? Less data reprocessing/rerunning for small improvements?…
- Reduce emissions from travel
  - Less travel, hybrid/remote meetings, sustainable transportation
- Include these discussions in your courses
- …

In general: Make sustainability/climate impact part of everyday work life

What I think would be great

- Start talking about what we can do in particle physics/Sweden
    - Are there low-hanging fruits?
    - Where does it make sense to invest efforts?
    - Are there severe conflicts of interest?

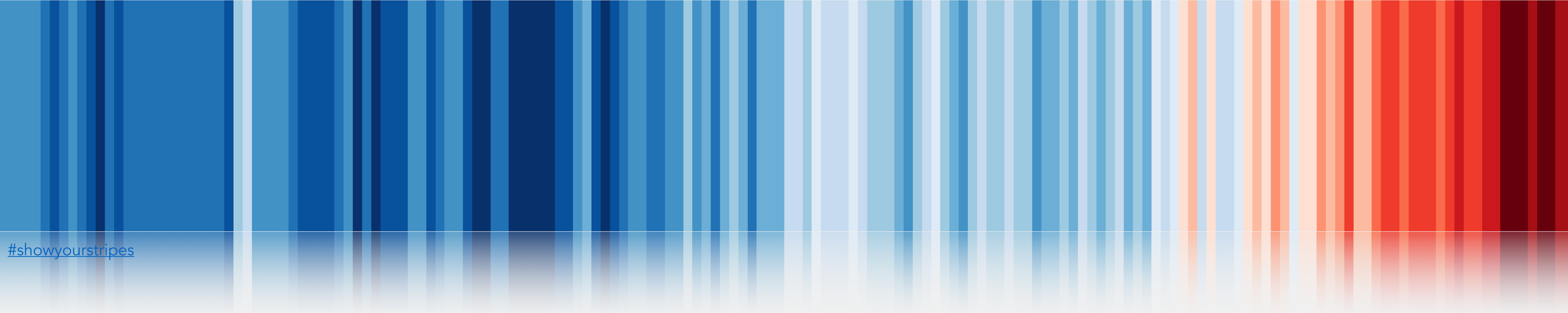
- Can we reduce our footprint by coordinating more, e.g. representation at meetings/conferences?

- Exchange experience from different institutes/experiments/groups

- Lobbying? Opinion pieces?

- Have some kind of **forum** where sustainability can be discussed, resources/information collected

  E-mail list?
  “Green fika” during partikeldagarna?



#showyourstripes

Thank you for listening!

Sources of Emission Factors

This is the difficult part!

[1] https://howbadarebananas.com/

[2] Saevarsdottir, G., Magnusson, T. & Kvande, H. Reducing the Carbon Footprint: Primary Production of Aluminum and Silicon with Changing Energy Systems. J. Sustain. Metall. 7, 848–857 (2021)

[3] https://adapamoulds.com/sustainability/

[4] https://www.eia.gov/electricity/state/california/

[5] https://www.atmosfair.de/en/

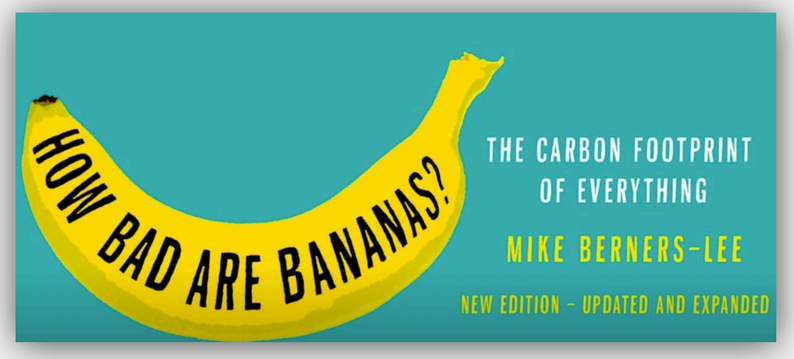
How much left?

IPCC 2021:
Remaining budget until 2050 (for 83% chance of staying below 1.5°C warming): **300 Gt CO_2**

What is 1t of CO_2?

- 4000 km in a car
- 1 one-way flight Paris-NYC (per passenger)
- ~140 meat-based meals
- 2.5 minutes of LHC operation

More examples:



IPCC 2023: Remaining budget (from 2020) for
50% chance of staying below 1.5°C warming: 500 Gt CO_2
83% chance of staying below 2°C warming: 900 Gt CO_2

Emission Counting

Usually split into scope 1, 2, 3

Scope 1: Direct emissions from owned or controlled sources (e.g. a fleet of vehicles)

Scope 2: Indirect emissions from generation of purchased energy (e.g. electricity, heating)

Scope 3: Indirect emissions not in scope 2 (e.g. work travel, commuting, supply chains)

Hardest to estimate, but often dominating

Typical sources (unordered)

Equipment (production and shipping)

Infrastructure and buildings

Operation of labs and experiments

Travel and conferences

Computing and IT

GRAND

Giant (Radio antenna) Array for Neutrino Detection

200k radio antennae over 200k km² (spread over different sites worldwide)

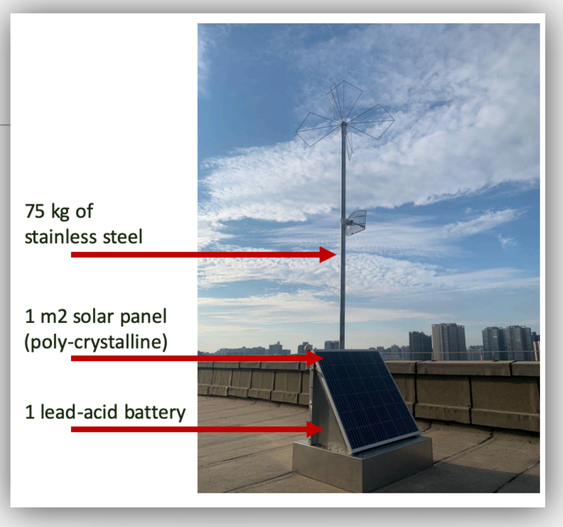


Figure 9: GRANDProto300 prototype antenna.

	2021	2025	203X
	GRANDProto300	**GRAND10k**	**GRAND200k**
Set-up	300 radio antennas over 200 km² in Western China	10,000 radio antennas over 10,000 km² in China	200,000 radio antennas over 200,000 km² ~20 subarrays of 10,000 antennas
People	~70 members (~30% strong involvement)	~100 members (~30% strong involvement)	~400 - 1000 members
Emission [tCO_2e/yr]	Digital: 338 (69%) Travel: 130 (27%) Hardware: 18 (4%) **Total: 486 tCO_2e/yr**	Digital: 422 (39%) Travel: 328 (31%) Hardware: 322 (30%) **Total: 1072 tCO_2e/yr**	Hardware: 6435 (48%) Digital: 6007 (45%) Travel: 965 (7%) **Total: 13407 tCO_2e/yr**