

# CO<sub>2</sub> Emissions from Theoretical Physics Research?

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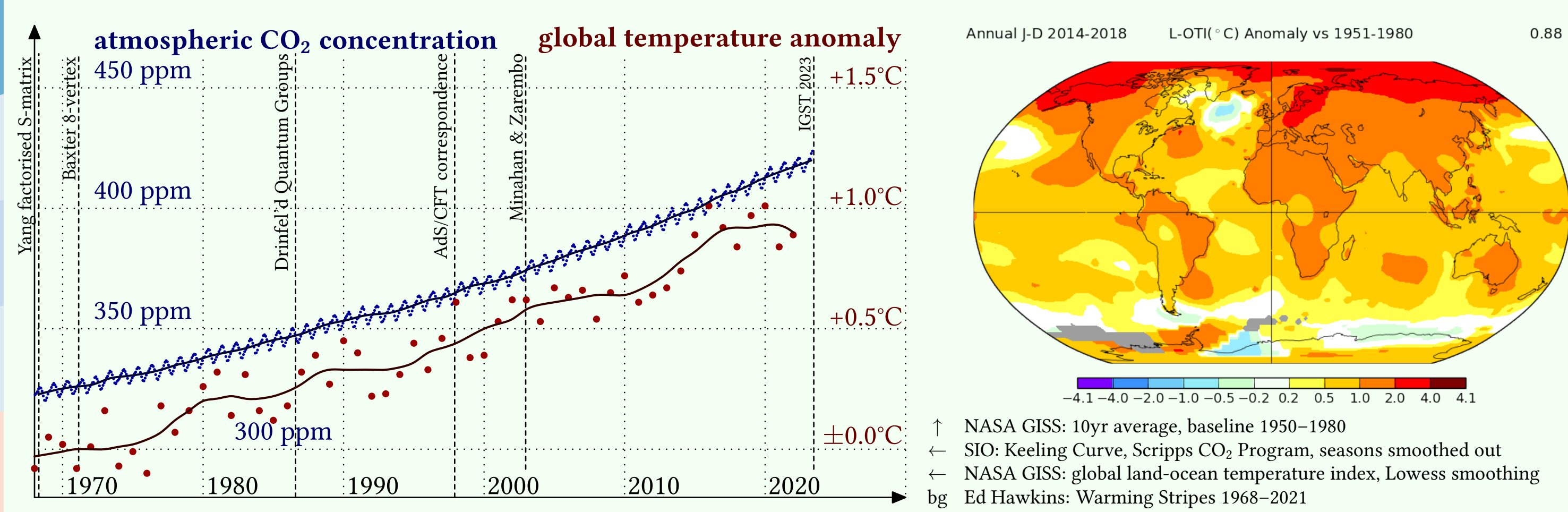
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**Abstract:** Global Warming is a clear and present danger for humankind. Halting it in time will require technological advances and societal changes at impressive scales and rates. Both, Global Warming and mitigation efforts will have an impact on the way we conduct research. What should we do? What will you do?

based on poster by Beisert & Carqueville presented at Strings 2022

## Global Warming (GW) in a Nutshell

**Data:** Keeling Curve, Temperature Anomaly



### Basic Mechanism of Global Warming:

- Combustion of fossil fuels leads to CO<sub>2</sub> emissions (underground → atmosphere).
- CO<sub>2</sub> is long-term stable in atmosphere (integral of emissions matters).
- Greenhouse effect: atmospheric CO<sub>2</sub> (and other greenhouse gases) cause GW.

Other relevant contributions: land use, deforestation, livestock, tipping elements, ...

**Detailed Climate Research, Summary:** IPCC Assessment Reports; latest: AR6 (2021/22)

## Budgeting CO<sub>2</sub>-eq Emissions Towards Net-Zero

**Paris Agreement (2015):** International agreement to take all necessary steps to keep GW below +1.5°C or at most +2.0°C. It is based on negotiations and compromises.

**Climate Impact Research:** IPCC SR1.5 (2018), AR6/WG2 (2022).

Expected consequences: • extreme weather events • infrastructure damage • loss of harvest • mass migration • social unrest • armed conflicts •

GW can be halted by **net-zero emissions** only. 1.5°C / 2.0°C goal still within reach; **requires:**

- immediate emission reductions;
- net-zero by around 2035 / 2050;
- negative emissions: CO<sub>2</sub> capture and storage.

### emission budget figures (CO<sub>2</sub>-eq)

total remaining budget	300–1000 Gt
– per capita (global)	50–150 t
total emission rate	~ 40 Gt/yr
– per capita (Switzerland)	5–15 t/yr

### electricity emission estimates

fossil	500–800 g/kWh
renewable	10–50 g/kWh

### travel emissions comparison

mode	1000 km	annotations
flight	0.2–0.3 t	RFI factor 2
car	0.1–0.2 t	single, fossil fuel
train	0.001–0.08 t	power source

How about **Theoretical Physics research** context?

Some **rough estimates** for emissions (CO<sub>2</sub>-eq):

computer hardware	0.2–1 t
computer operation	0.0002–0.5 t/yr
European return flight	0.3–1.5 t
intercontinental return flight	2–12 t
infrastructure, buildings, catering	...

## If Wishes were Fishes... What are your Suggestions on Sustainability Aspects of Theoretical Physics (TP) Research?

- **Invitation:** Consider and/or discuss with people around you any of the following aspects.
- **Activity:** Write your thoughts or suggestions on a sticky note and paste it into the blanks. Agree / disagree with other notes by adding green / red dots, respectively (max. 3 each).
- **Definitions:** Below, “we”, “our” refers to: scientists in a field of Theoretical Physics (TP) conducting research (including all related activities).
- **Disclaimer:** Provided replies may be reproduced, reused or recycled in aggregated and anonymised form.

### 1. Impact of GW on TP Research

Will progressing Global Warming or mitigating efforts have a detrimental impact on Theoretical Physics research? Why (not)? • Do you consider Theoretical Physics research resilient in this regard?

### 2. Impact of TP Research on GW

Do you think research in Theoretical Physics causes relevant amounts of CO<sub>2</sub> emissions? Why (not)? • Are we on track towards net-zero CO<sub>2</sub> emissions? When and how should this be achieved?

### 3. Realised Steps in TP Research

What steps have you / your group / institution taken to reduce the climate impact of your research? • Do you think the heads, leaders, organisers in our field approach sustainability issues well? Why (not)?

### 4. Sustainable Research Activities in TP

How would Theoretical Physics research be different in a society at net-zero CO<sub>2</sub> emissions? Describe your vision. • What roles do you attribute to change of habits, reduction, compensation and CO<sub>2</sub>-capture? What about scalability and time frames?

### 23. Hybrid IGST 2023

Does the hybrid setup of IGST 2023 achieve in terms of scientific content, social interactions, inducing fewer CO<sub>2</sub> emissions & awareness? • Your wishes for IGST 202X?

### 5. Steps to be Taken in TP Research

What steps are yet to be taken to align our research culture with climate sustainability requirements? • Who should bring forward / impose rules towards limiting CO<sub>2</sub> emissions in our research activities?

### 6. Responsibility to Research and Society

Which CO<sub>2</sub> reduction measures should we not impose on ourselves? Can you provide equally effective alternatives? • What exceptions can we claim to retain / obtain higher than average CO<sub>2</sub> budgets? We would need solid arguments.

### 7. Comments and Feedback

Should sustainability issues play a more prominent role in our professional life? Why (not)? • Do you have any other related remarks?

### References

Selected sustainability references and efforts (further references therein):

- IPCC Reports (e.g. SR1.5, AR6; SPMs)
- Sustainable HEP Workshop 2021
- White Paper: Sustainability in HECAP (in preparation)
- ALLEA: “Towards Climate Sustainability of the Academic System in Europe and beyond” (2022)
- “Towards Sustainability in Research at D-PHYS/ETH”
- “Estimate of the carbon footprint of astronomical research infrastructures”, Nature Astron. 6, 503 (2022)
- “An approach to less climate-impactful conferencing”
- ... many more individual & institutional initiatives.

