v2

Physics, facts and frontiers of climate change science

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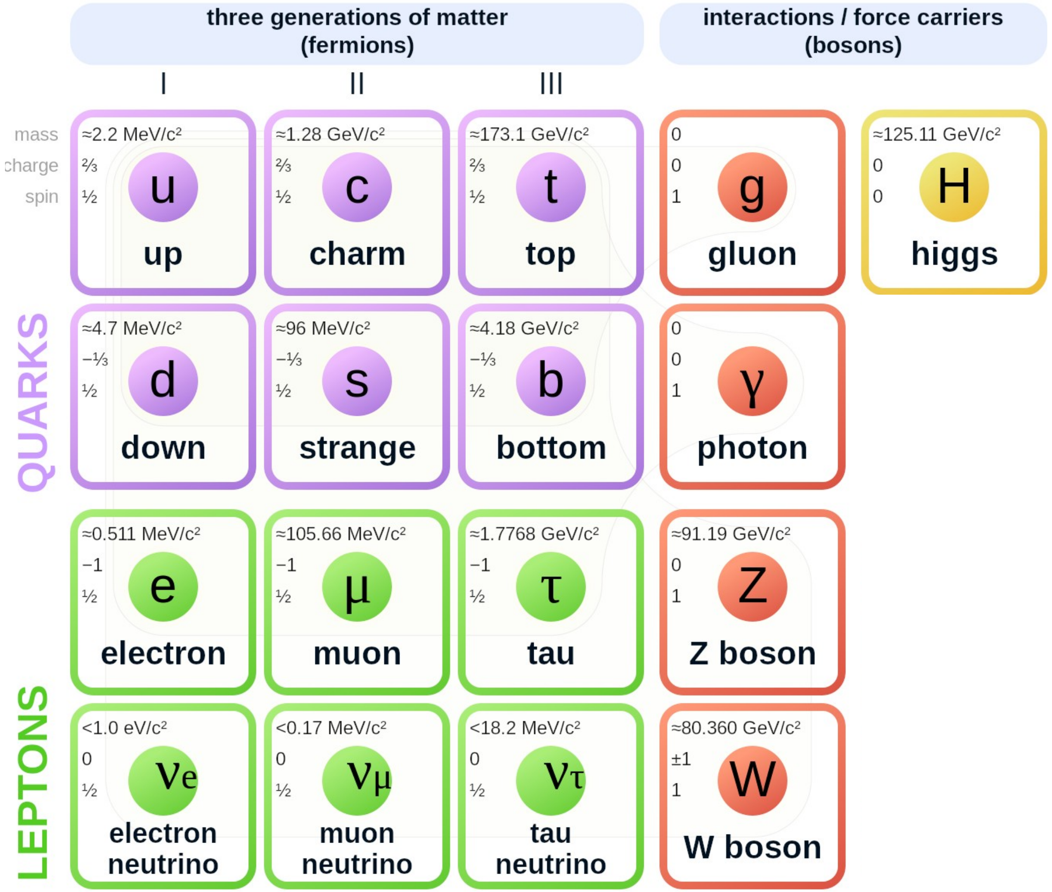
With thanks to Dave Charlton and Jonah Bloch-Johnson

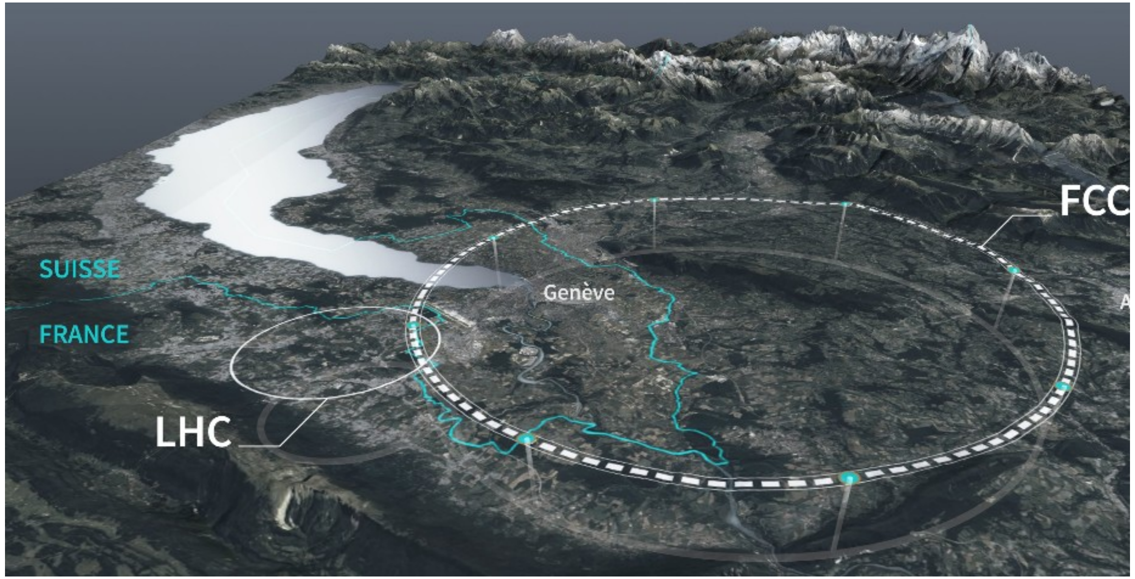
High-energy physics in the present day

Standard model of elementary particles



wikimedia commons, from Particle Data Group 2019

Present and future circular colliders at CERN



CERN

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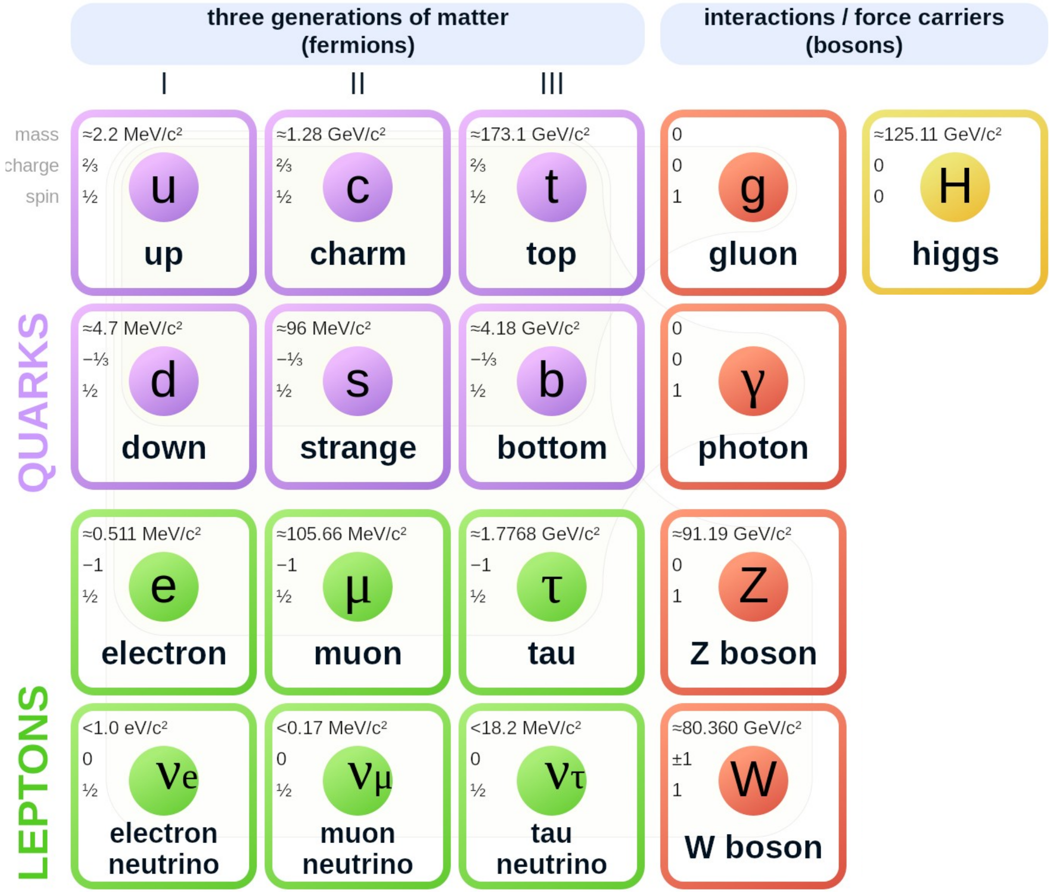

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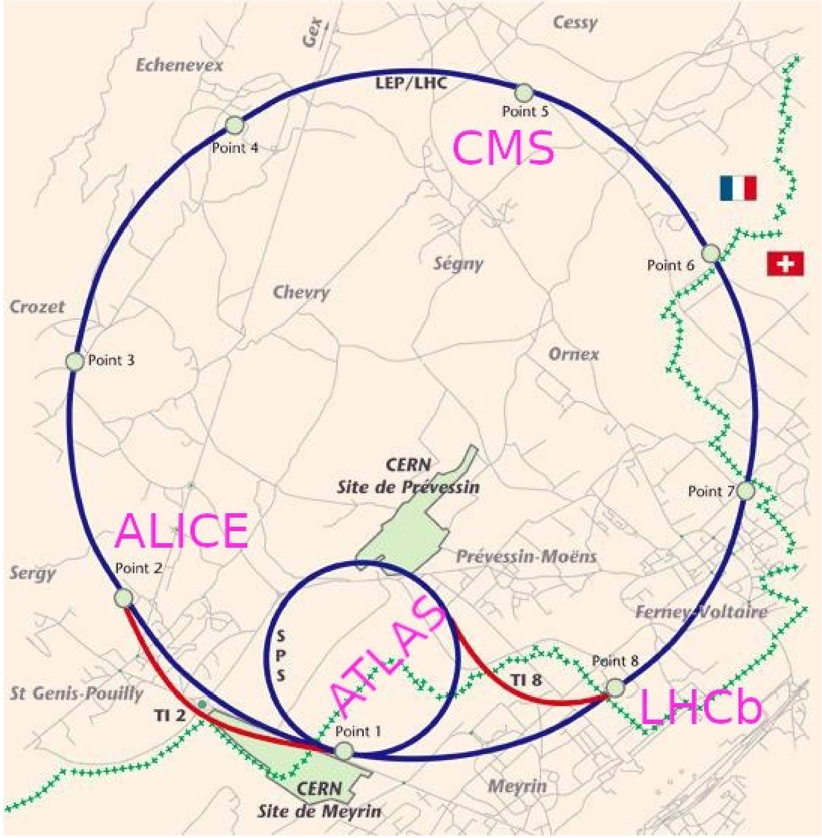
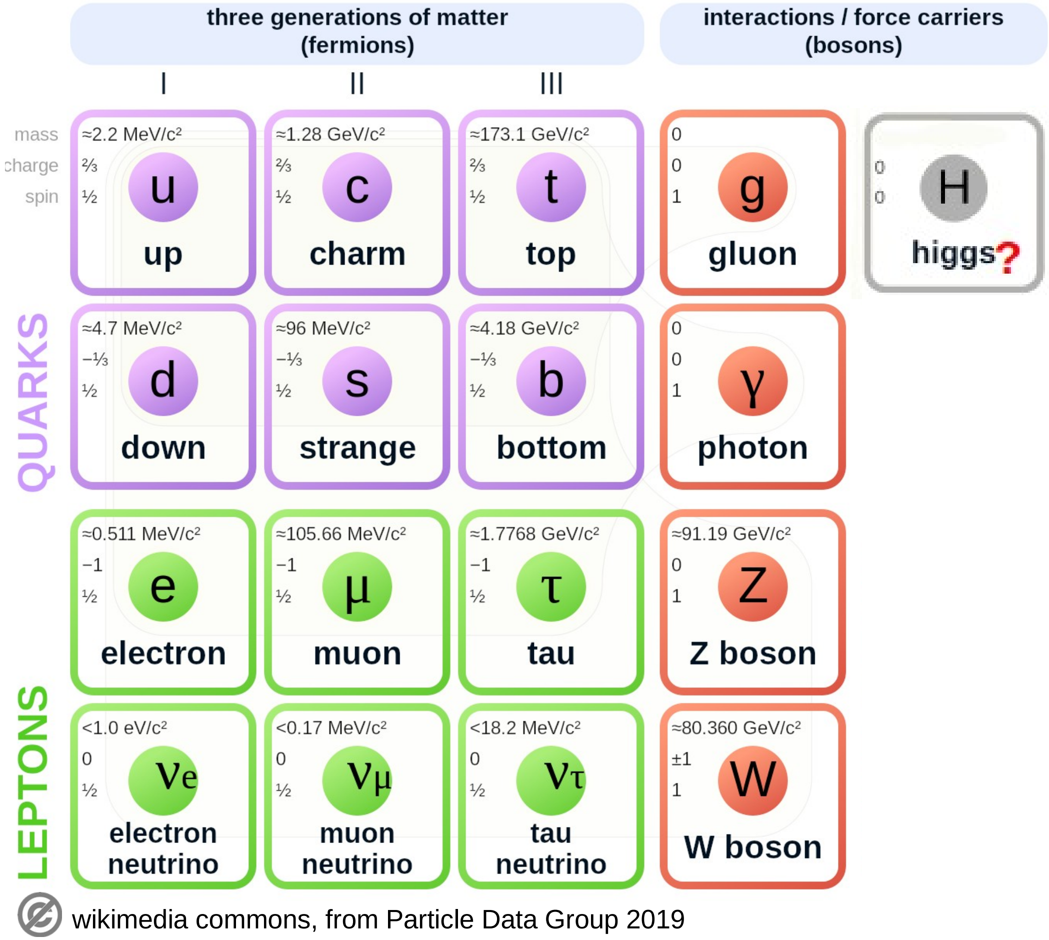
Present (LHC) experiments



CERN, with annotation

High-energy physics in the recent past

Standard model of elementary particles



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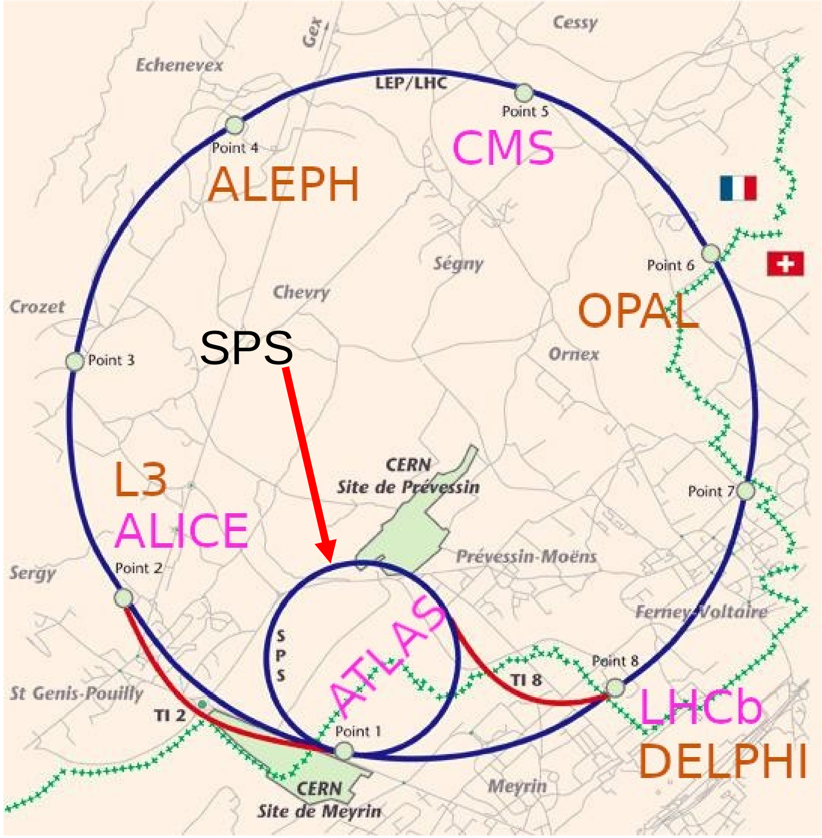
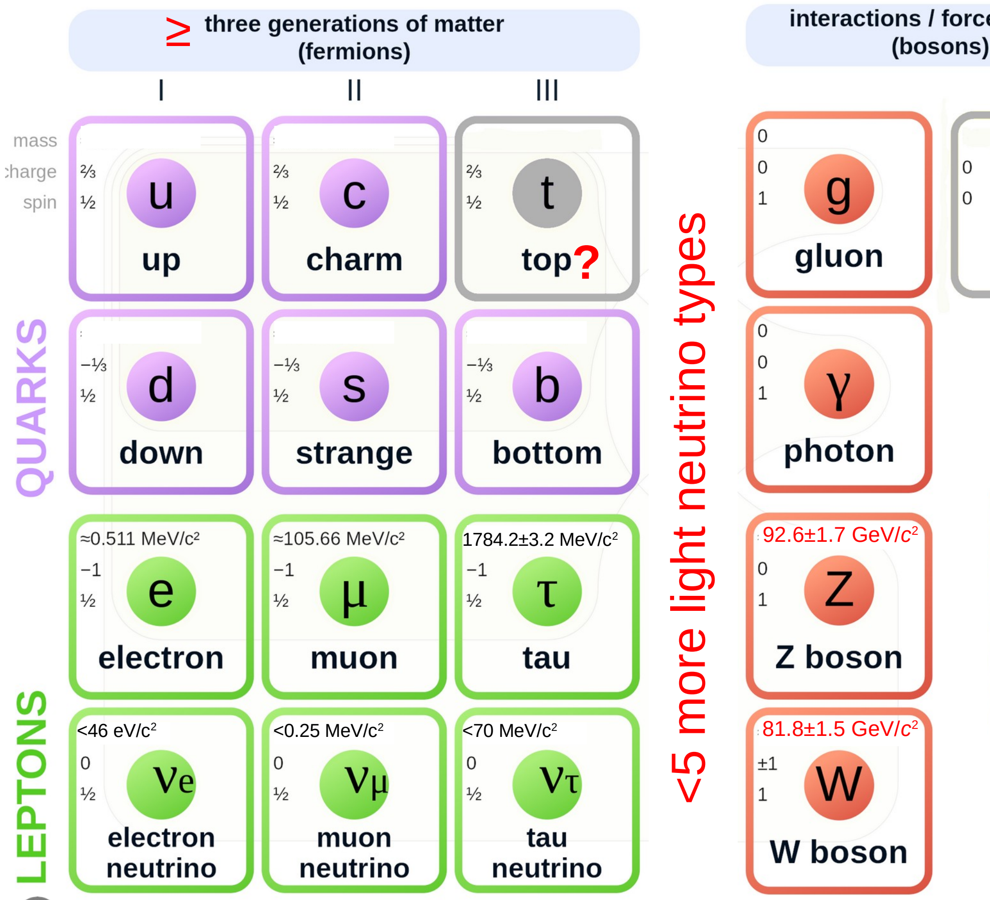
Recent past (LEP) experiments

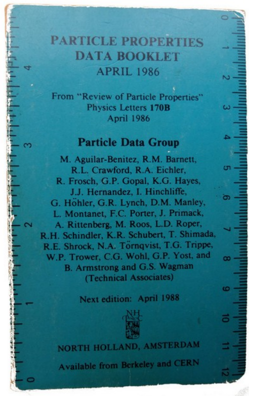


CERN, with annotation

High-energy physics in 1986–1989, when I was a PhD student on experiment UA1

Standard model of elementary particles in 1986





PARTICLE PROPERTIES
DATA BOOKLET
APRIL 1986

From "Review of Particle Properties"
Physics Letters **170B**
April 1986

Particle Data Group

M. Aguilar-Benitez, R.M. Barnett, R.L. Crawford, R.A. Eichler, R. Frosch, G.P. Gopal, K.G. Hayes, J.J. Hernandez, I. Hinchliffe, G. Höhler, G.R. Lynch, D.M. Manley, L. Montanet, F.C. Porter, J. Primack, A. Rittenberg, M. Roos, L.D. Roper, R.H. Schindler, K.R. Schubert, T. Shimada, R.E. Shrock, N.A. Törnqvist, T.G. Trippe, W.P. Trower, C.G. Wohl, G.P. Yost, and B. Armstrong and G.S. Wagman (Technical Associates)

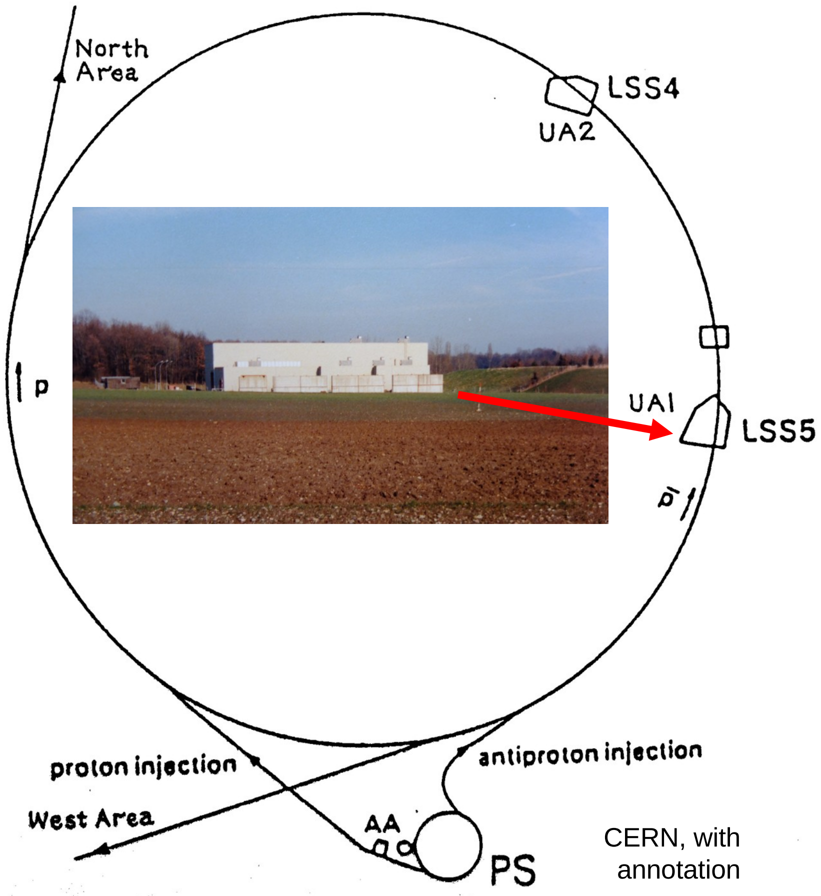
Next edition: April 1988

NORTH HOLLAND, AMSTERDAM

Available from Berkeley and CERN

wikimedia commons, modified

SPS as p$\bar{p}$ collider at 630 GeV



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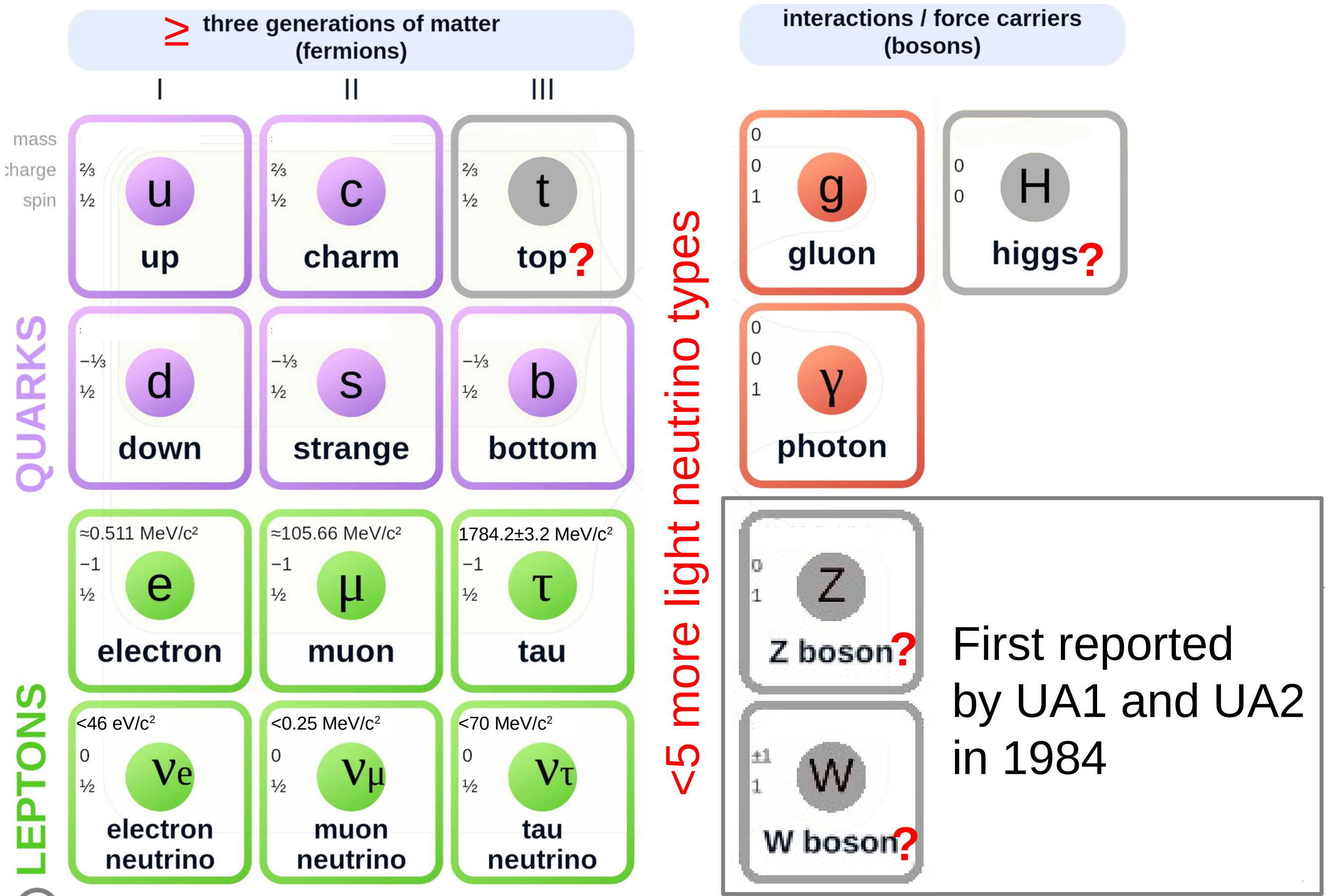

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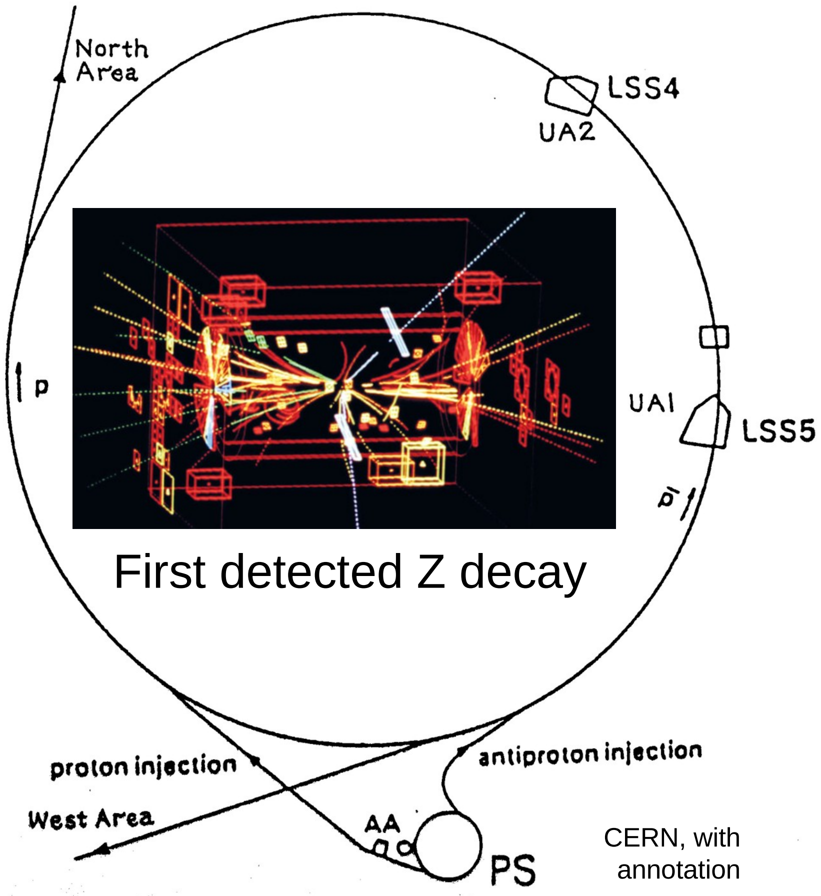
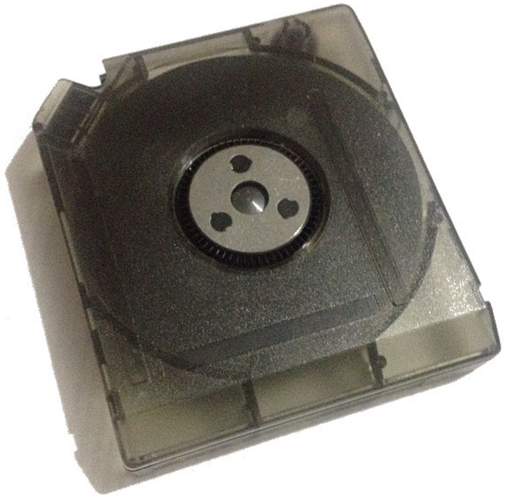
SPS as pp̄ collider at 630 GeV



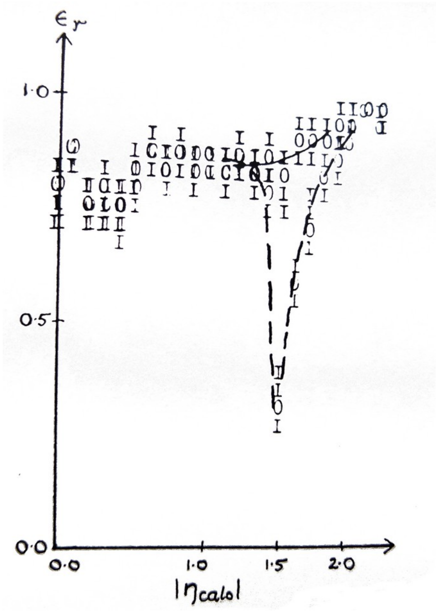
CERN, with annotation

The CERN scientific environment in 1986–1989

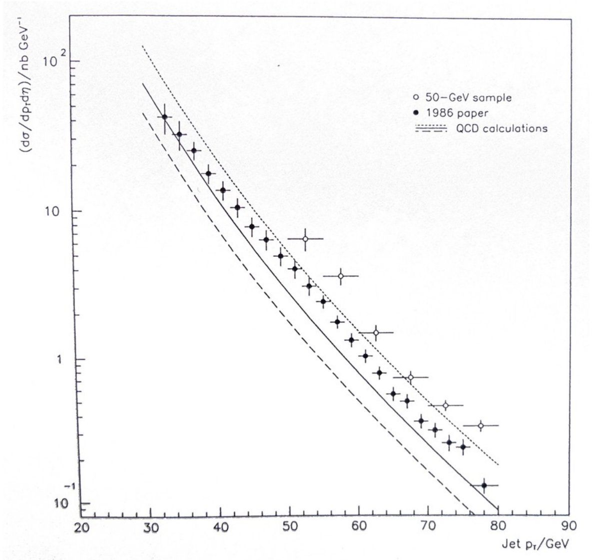
DEC VT220 terminal
12” screen
80 columns, 24 lines



IBM 3840 tape cassette
38k bits per inch
200 Mbyte capacity



HBOOK graphics
from line printer with
lines drawn by hand



HPLOT graphics
from laser printer

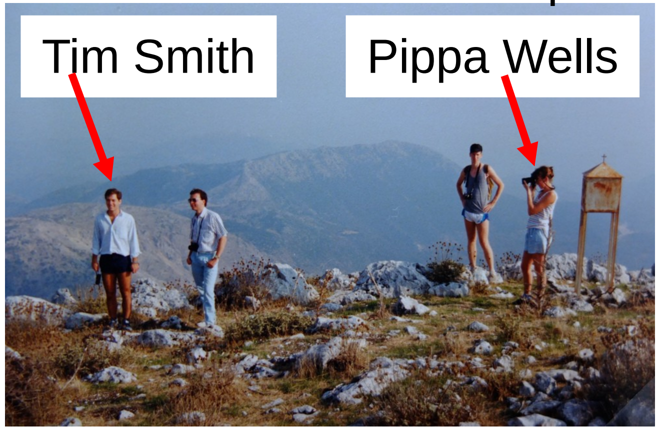
Equipment for preparing presentations
on slides for the overhead projector

My personal environment 1987–1988 while at CERN

CERN visitors car-park

View from my office 1B-09 in Bât 32

Stavrota (1182 m) on Lefkada, Greece
CERN summer school Sep 1988



Mont Blanc
Club Alpin Français course Sep 1988

Why I changed from high-energy physics to climate science after my PhD

- I enjoyed being a particle physicist, especially while at CERN, but
- I wanted to return to normal life, instead of being an expatriate scientist 24/7 non-stop.
- I was discouraged by the separation of experiment and theory in particle physics, by the immense technical complexity of both, and by not properly understanding the theory.
- I wanted to find work of immediate relevance to society, as well as intellectual interest.
- I was attracted by studying and understanding the environment we experience.
- I was concerned about anthropogenic degradation of the natural world.
- I was worried about the greenhouse effect and I supposed a physicist could work on it.

Both subjects involve physics, statistics and computing. A PhD gives transferable skills for research.

How I changed subject

Photo by ChrisO

I took a one-year for a job as a research assistant (not needing a PhD) at the University of East Anglia, Norwich, UK.

My job was analysis of UK daily precipitation records—statistics, not physics.

In May 1990, the Hadley Centre at the UK Met Office was opened by the Prime Minister, Margaret Thatcher (in Bracknell, 60 km west of London).

We shall only be able to deal with the problems by a giant international effort in which we all cooperate. We would be taking a great risk with future generations if, having received this early warning, we did nothing about it. We must take action on CO2 emission: more efficient power stations, cars which use less fuel, better-insulated houses and better management of energy.

On the right, Sir John Houghton,
Director-General of the Met Office and Chair of IPCC WG1

Early experiences of changing from particle physics to climate science

I was one of ~20 new postdoctoral staff recruited in 1990 by the UK Met Office for the Hadley Centre.

We were nearly all physicists and mathematicians, so we had to learn meteorology and climate science.

Today, a relevant MSc would be an advantage in making this transition.

In climate science, small groups can run their own experiments and develop theory by themselves!

Papers have 1–10 coauthors!

The Met Office moved to Exeter in 2003
I have worked 80% at the University of Reading since then

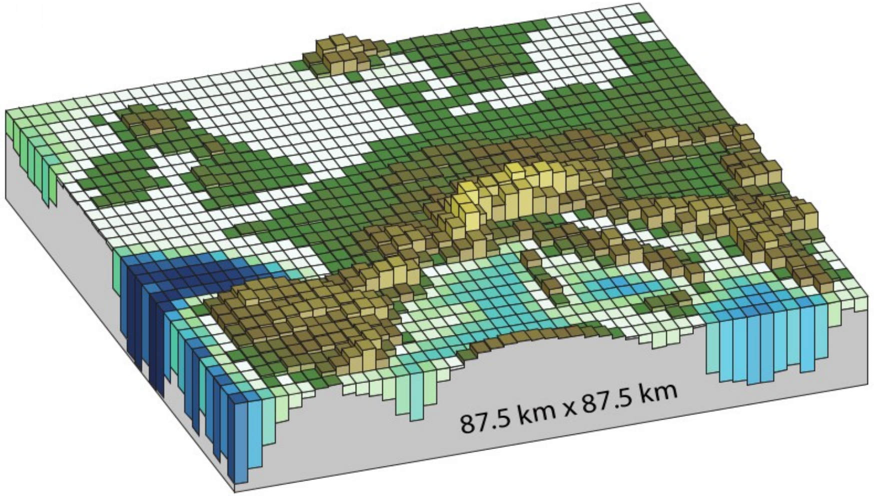
Climate science

Climate is what you expect, weather is what you get

Observations from space, in the atmosphere, at the surface, in the ocean

Partial knowledge of the real world

Simulations of past and future climate by climate models (computer programs)

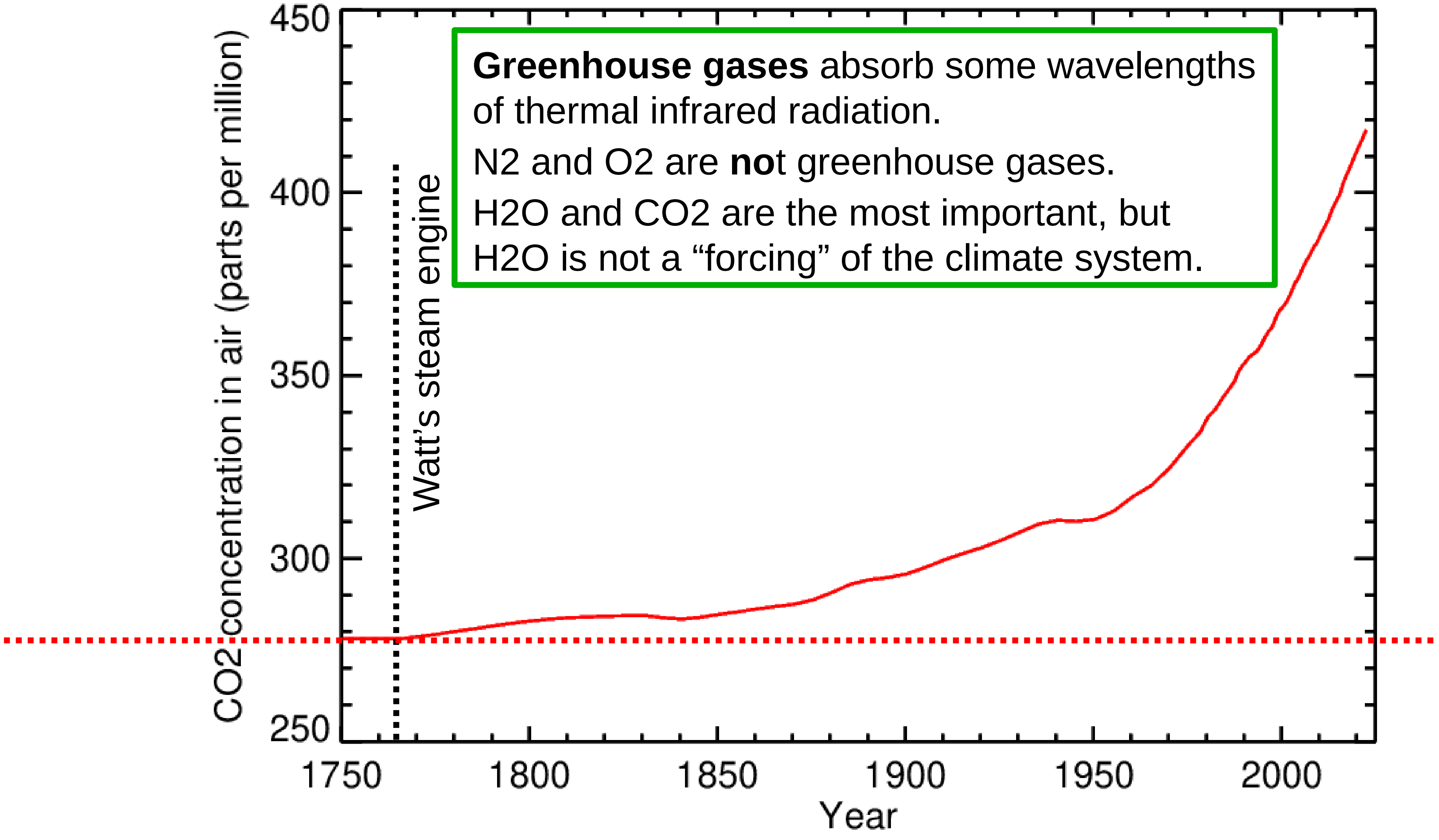


Complete knowledge of an unreal world

Through analysis of observations and simulations ("climate experiments") and physical theory we seek to understand the past and predict the future behaviour of the climate system.

Climate prediction is different from weather forecasting:
For climate, there is only one realisation of the past, and nothing like the future has happened before.

The atmospheric CO_2 concentration has risen by 50% since pre-industrial



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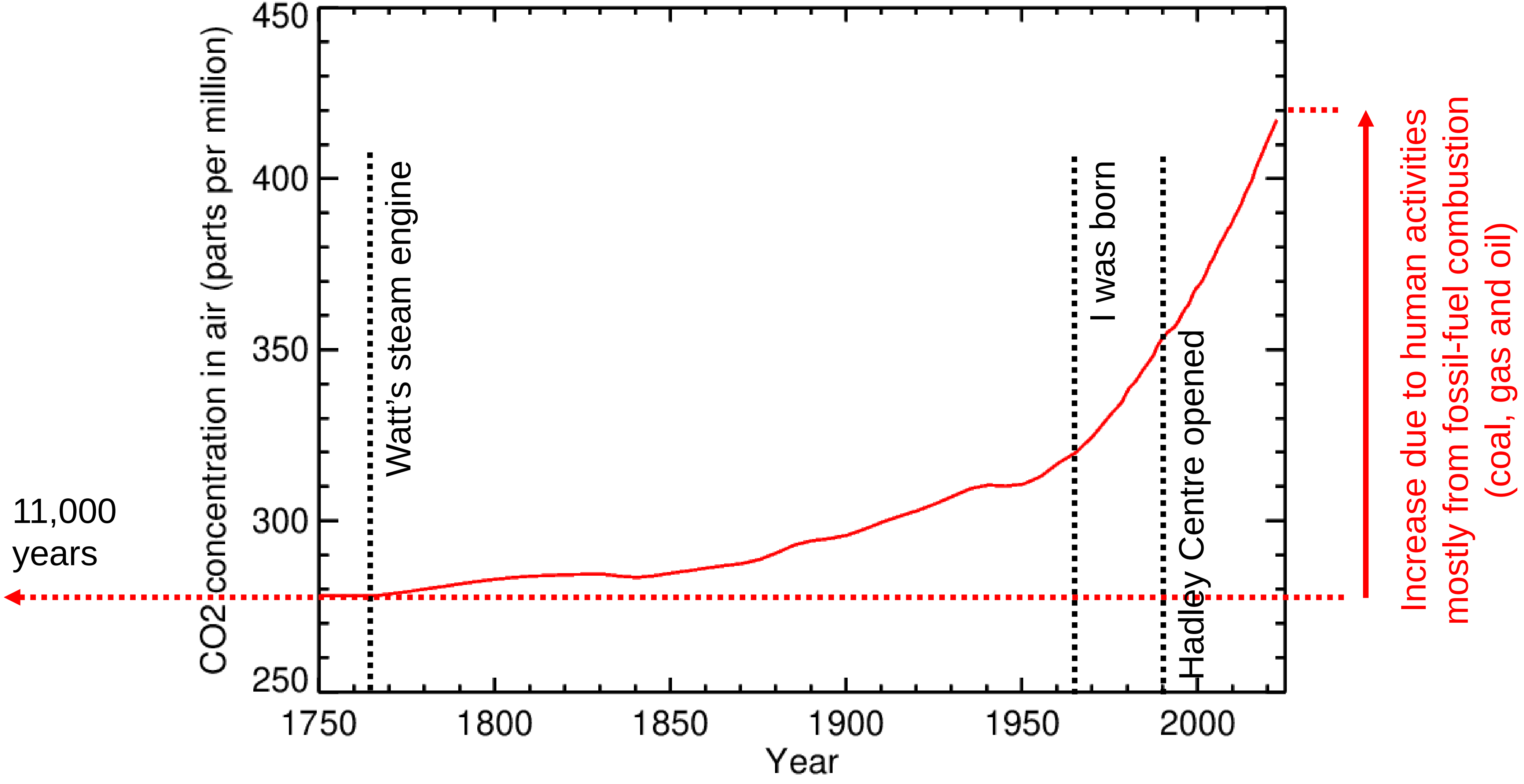


It is unequivocal that human influence has warmed the climate

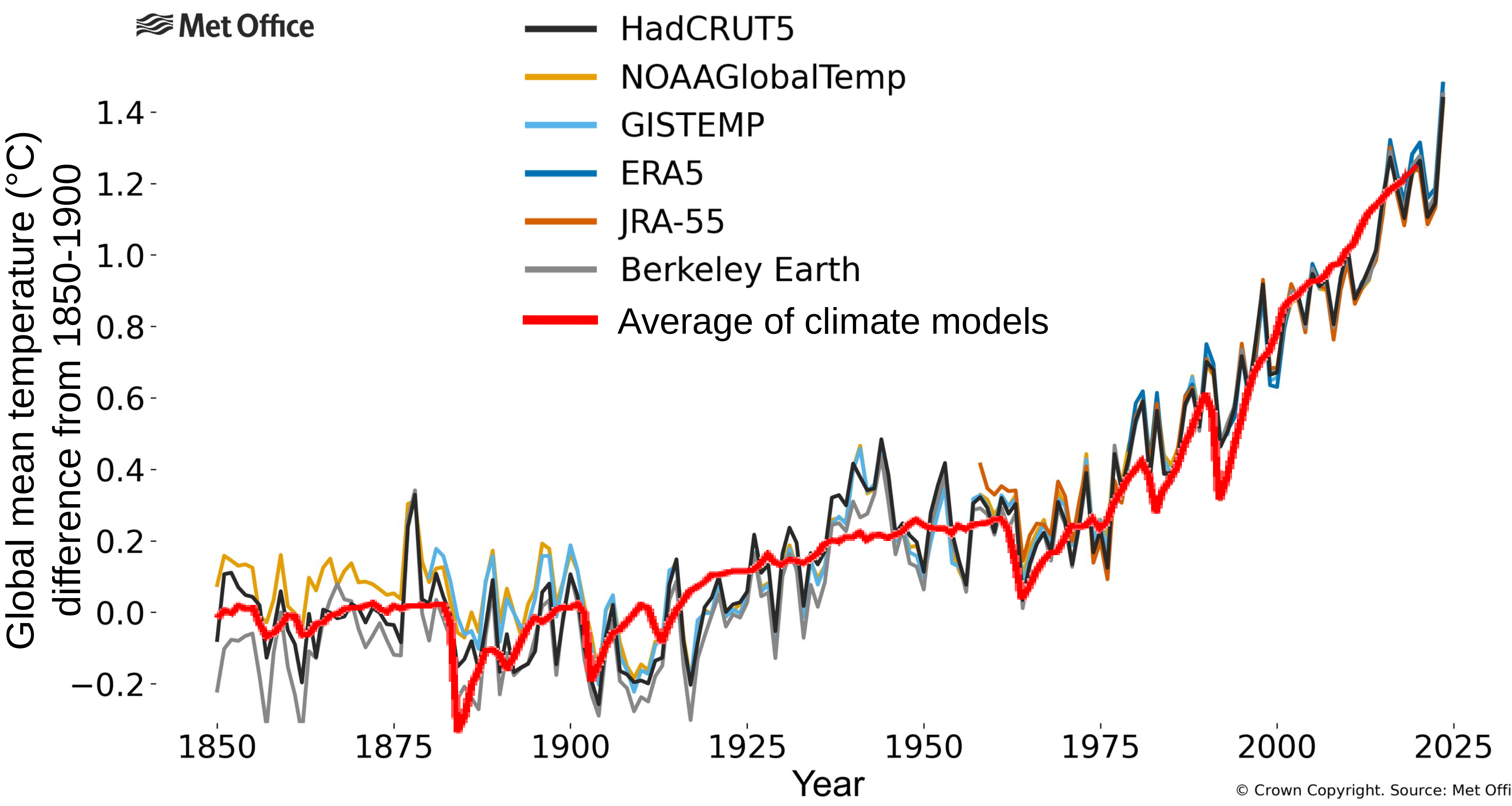
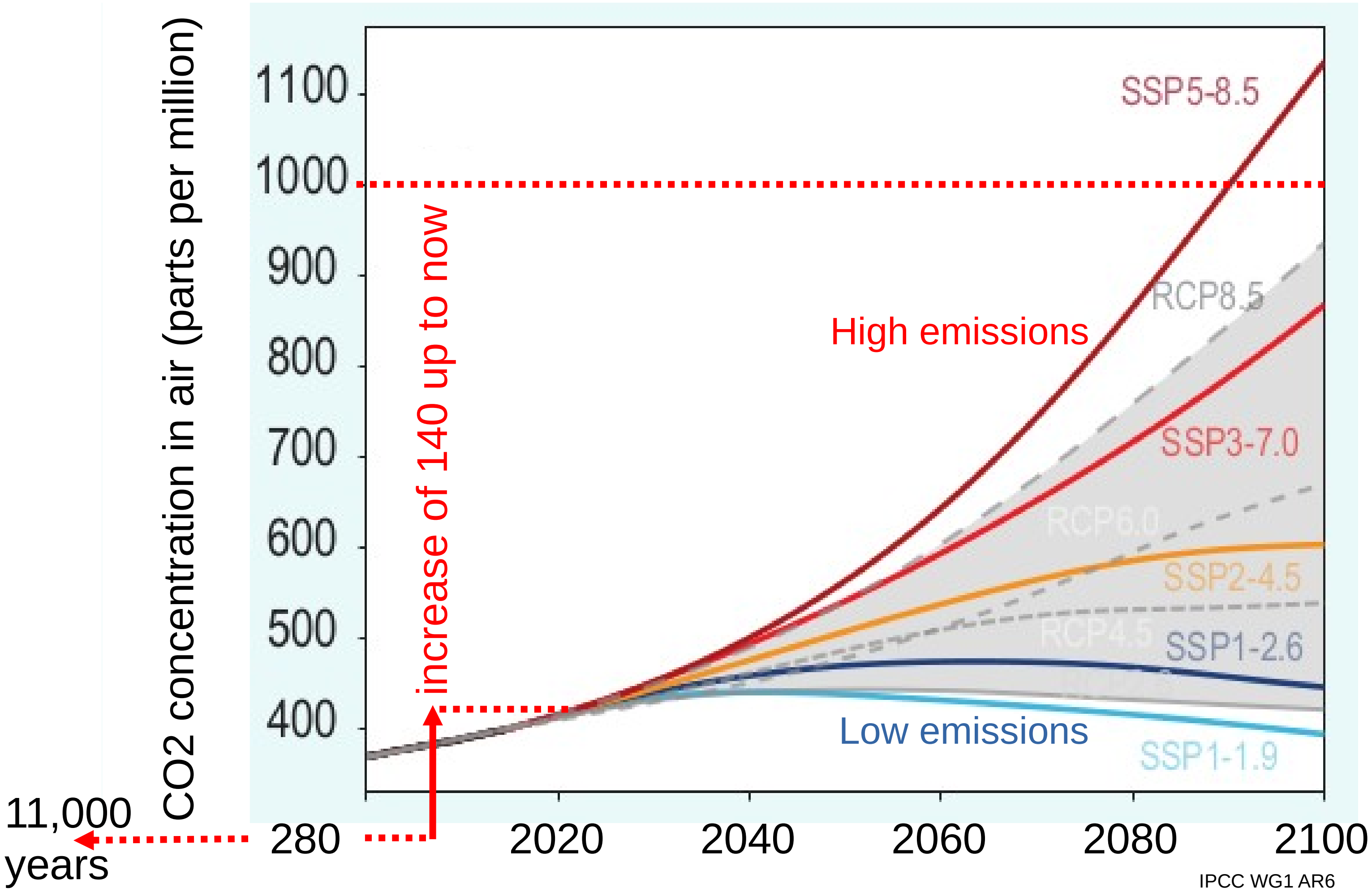


Figure updated: 25/04/2023
Climate model data from IPCC WG1 AR6 Fig 3.4b

Future CO_2 concentration depends on society's choices



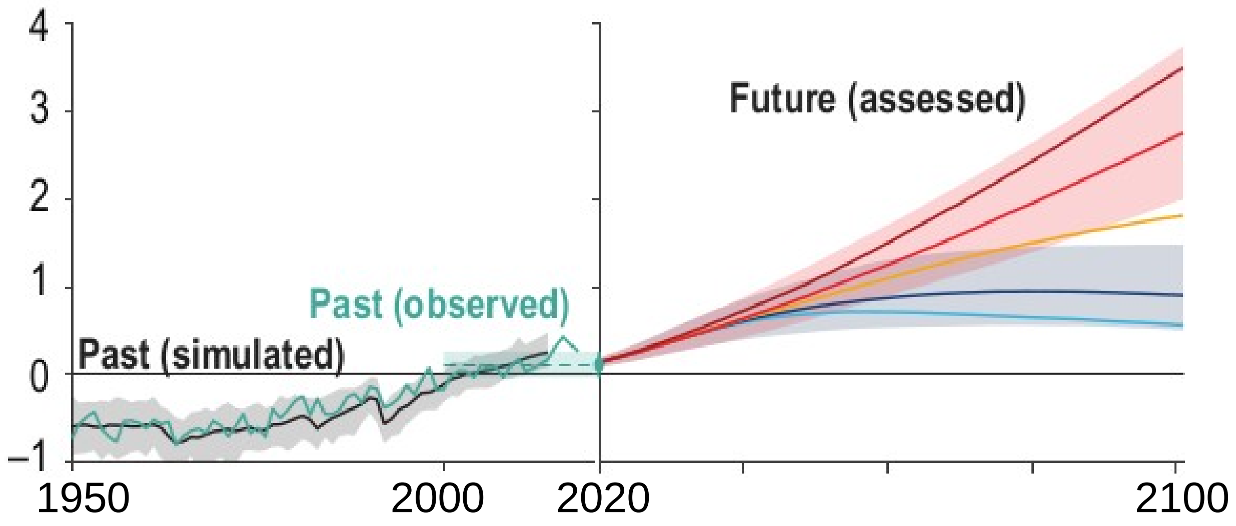
IPCC WG1 AR6

Humans suffer significant cognitive impairment at 1000 ppm CO_2

Future climate change depends on society's choices and the system's response

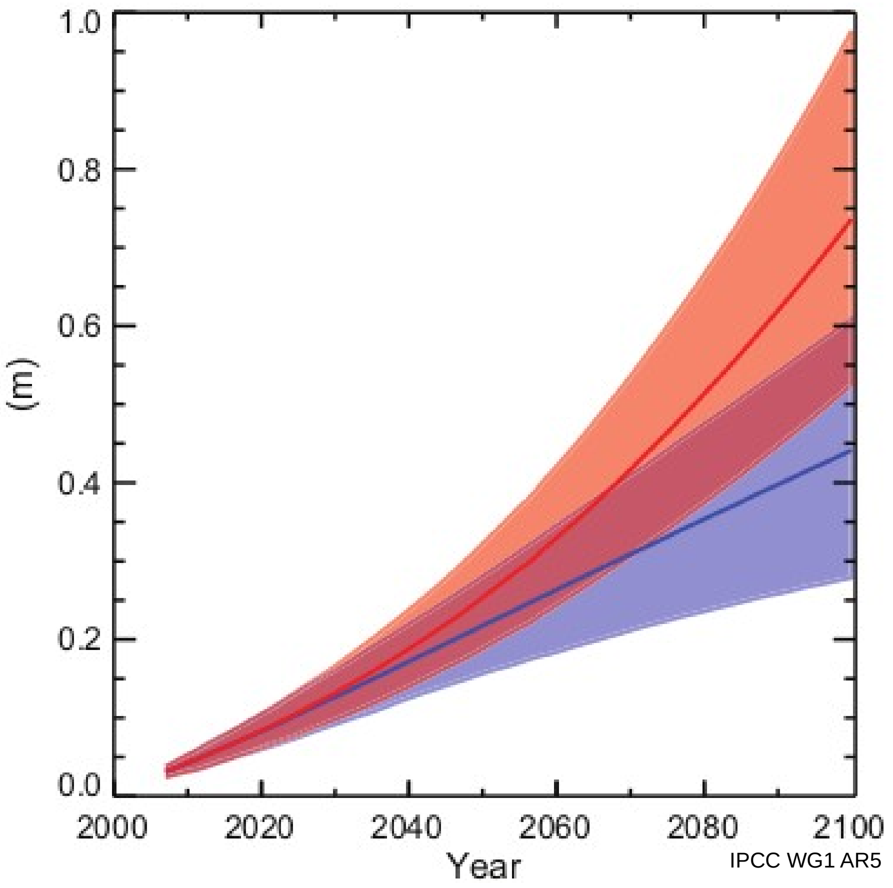
The challenge for climate science is to reduce the uncertainty in projections

Global mean temperature (°C)
difference from 1995−2014



IPCC WG1 AR6

Global mean sea level rise (m)
relative to 1986−2005



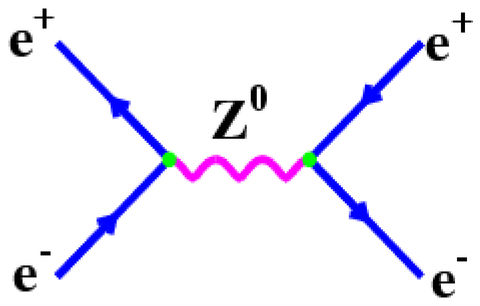
IPCC WG1 AR5

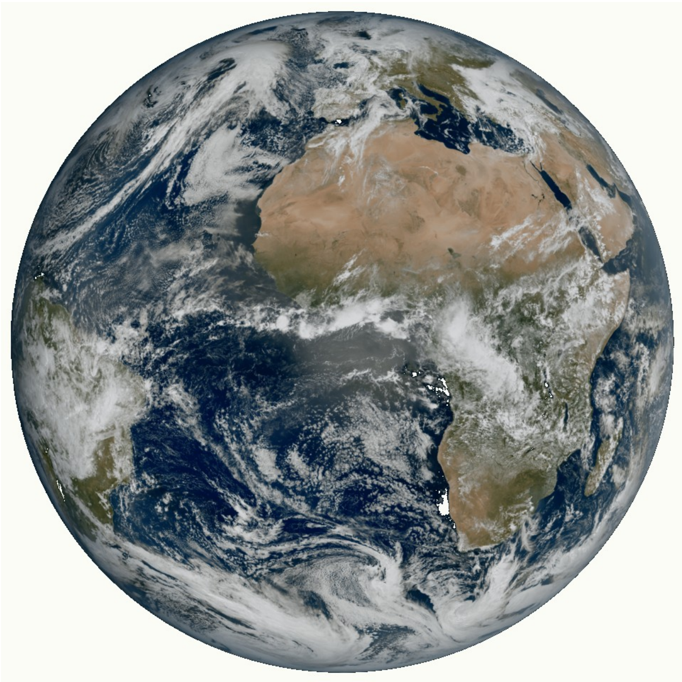
Comparison of particle physics and climate science

Particle physics	Climate science
Understand the nature of the fundamental constituents of matter and their interactions	Understand what determines global and local climate, and how and why they change

1e-17 m   1e-26 s

100 to 1e+7 m   1 to 1e+10 s

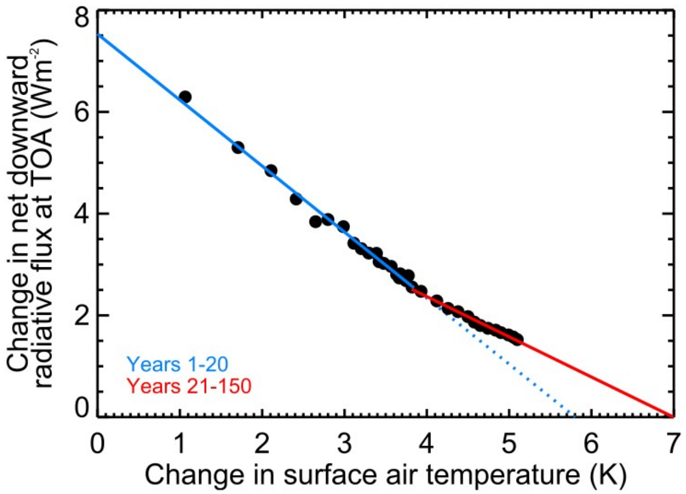




Comparison of particle physics and climate science

Particle physics	Climate science
Understand the nature of the fundamental constituents of matter and their interactions	Understand what determines global and local climate, and how and why they change
Distinct from nuclear physics since ~1940s	Distinct from meteorology since ~1960s
Done by experimentalists and theoreticians	Done by modellers and observationalists
QFT, which is mathematically complex, makes predictions about elementary particle interactions	Simple differential equations of classical physics predict the time-evolution of a huge chaotic system which we try to interpret with simple models

For example



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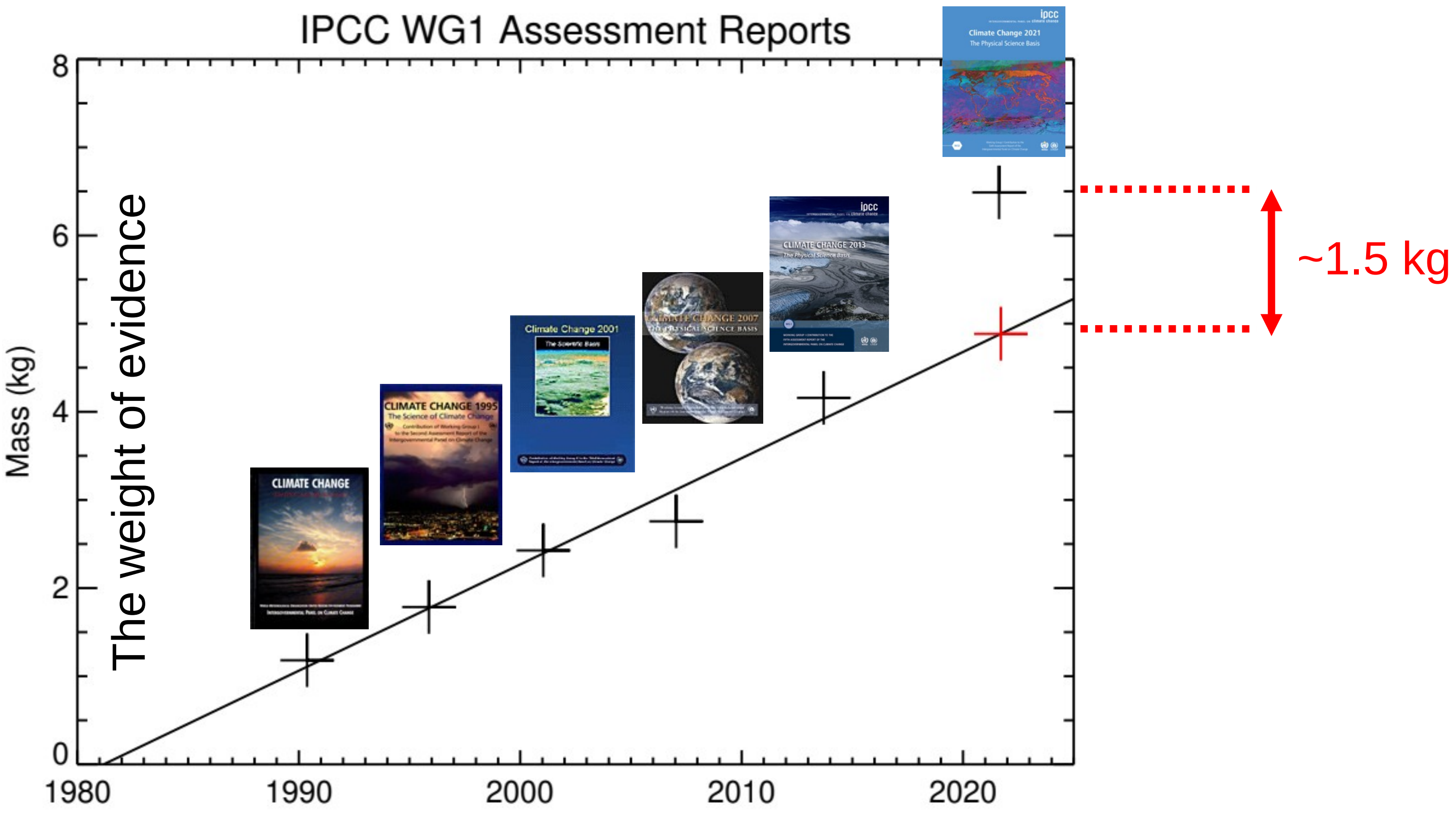
QFT, which is mathematically complex, makes predictions about elementary particle interactions	Simple differential equations of classical physics predict the time-evolution of a huge chaotic system which we try to interpret with simple models
Experiments (hardware and software) take decades to create, involving 1000s of people	Climate models (software only) and datasets take years to create, involving a few 10s of people
Precisely designed experiment repeated 1e17 times, statistics for both signal and background both well-determined by quantum probabilities	One real experiment, which we didn’t design and can’t control, models to evaluate hypotheses and random variation, unquantifiable systematic errors
Advancement of fundamental knowledge, possibly leading to future technological applications	Immediate practical and moral implications for the choices of individuals and society

Intergovernmental Panel on Climate Change (IPCC)

The IPCC was established in 1988. It is an organisation of the UN, with 195 member-countries.
It makes policy-relevant (not policy-prescriptive) assessments of what we know about climate change.



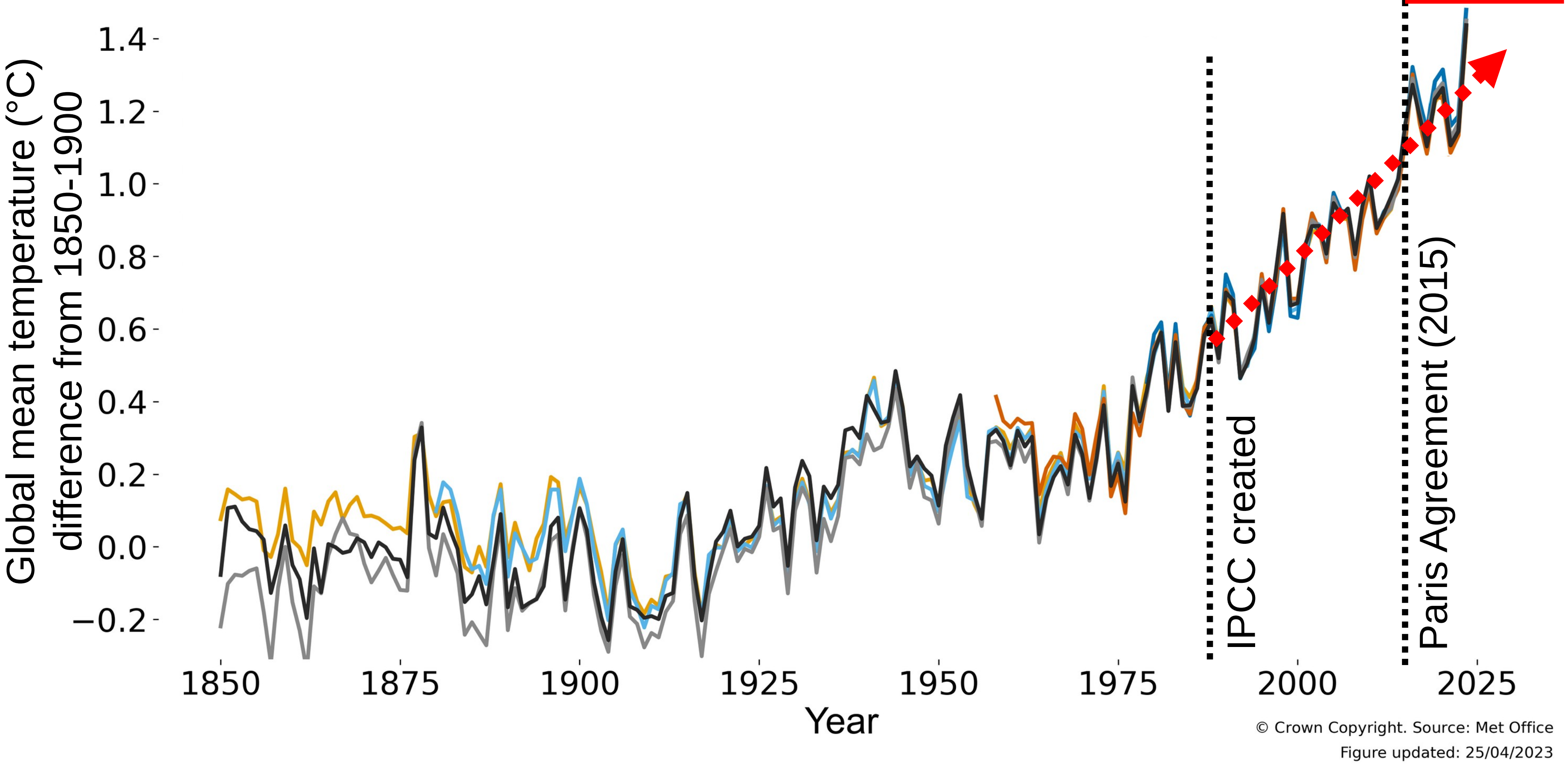
UN Framework Convention on Climate Change (UNFCCC)

The UNFCCC was agreed at the Rio Earth summit in 1992 and signed by 154 countries.

The parties to the UNFCCC agree to stabilise greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system.

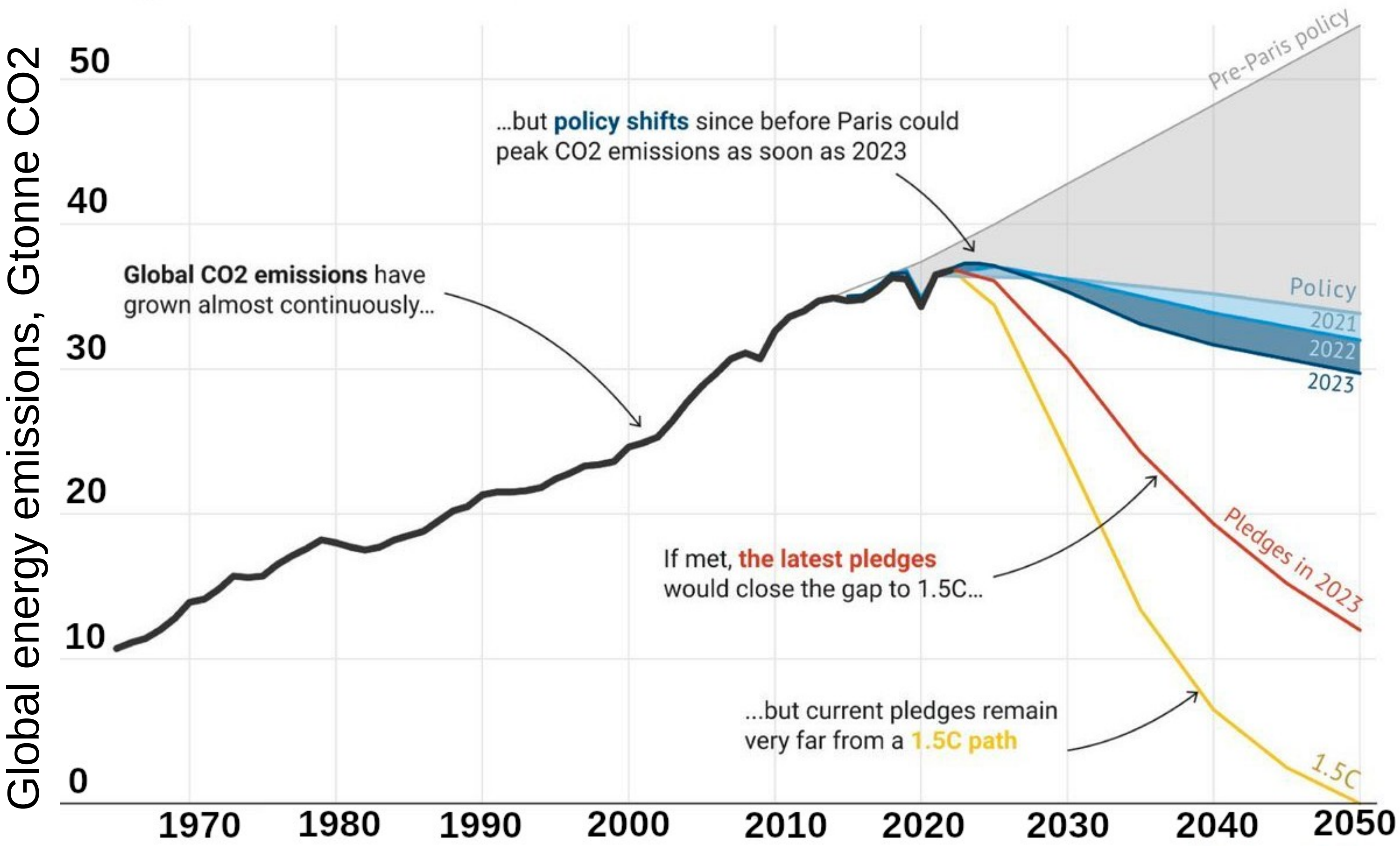
The Conference of the Parties (COP) meets annually: Kyoto 1997, Paris 2015, Dubai 2023.

The Paris Agreement aims to strengthen the global response to the threat of climate change by holding well below 2.0°C and pursuing efforts to limit to 1.5°C



To stabilise the climate, we must stop putting CO2 into the atmosphere

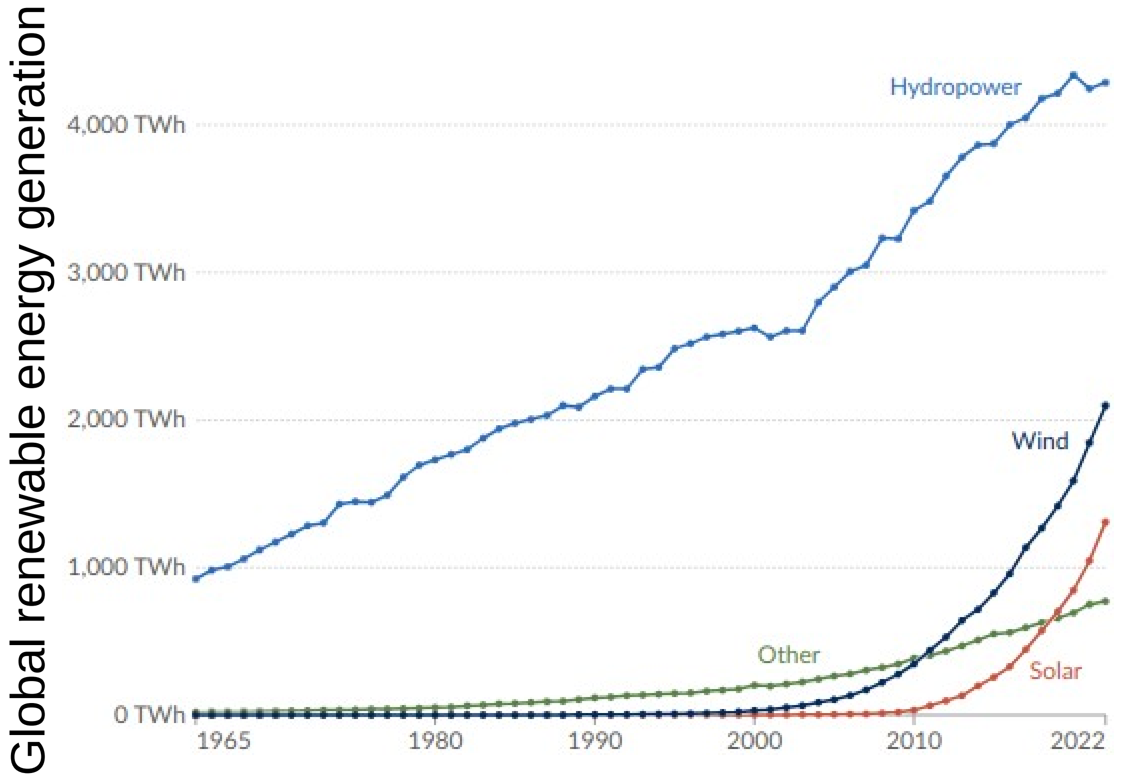
This depends on political will and public policy, not climate science



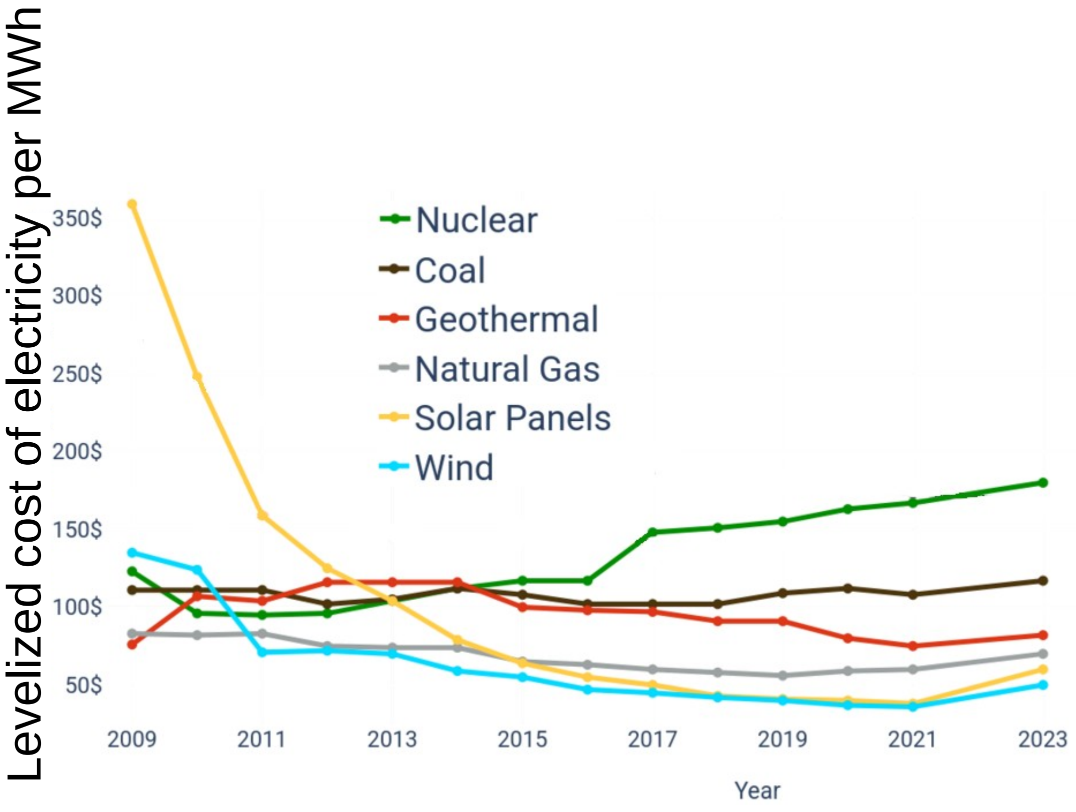
Carbon Brief graphic of IEA data

It requires rapid development of some necessary technologies

This is engineering and economics, not climate science

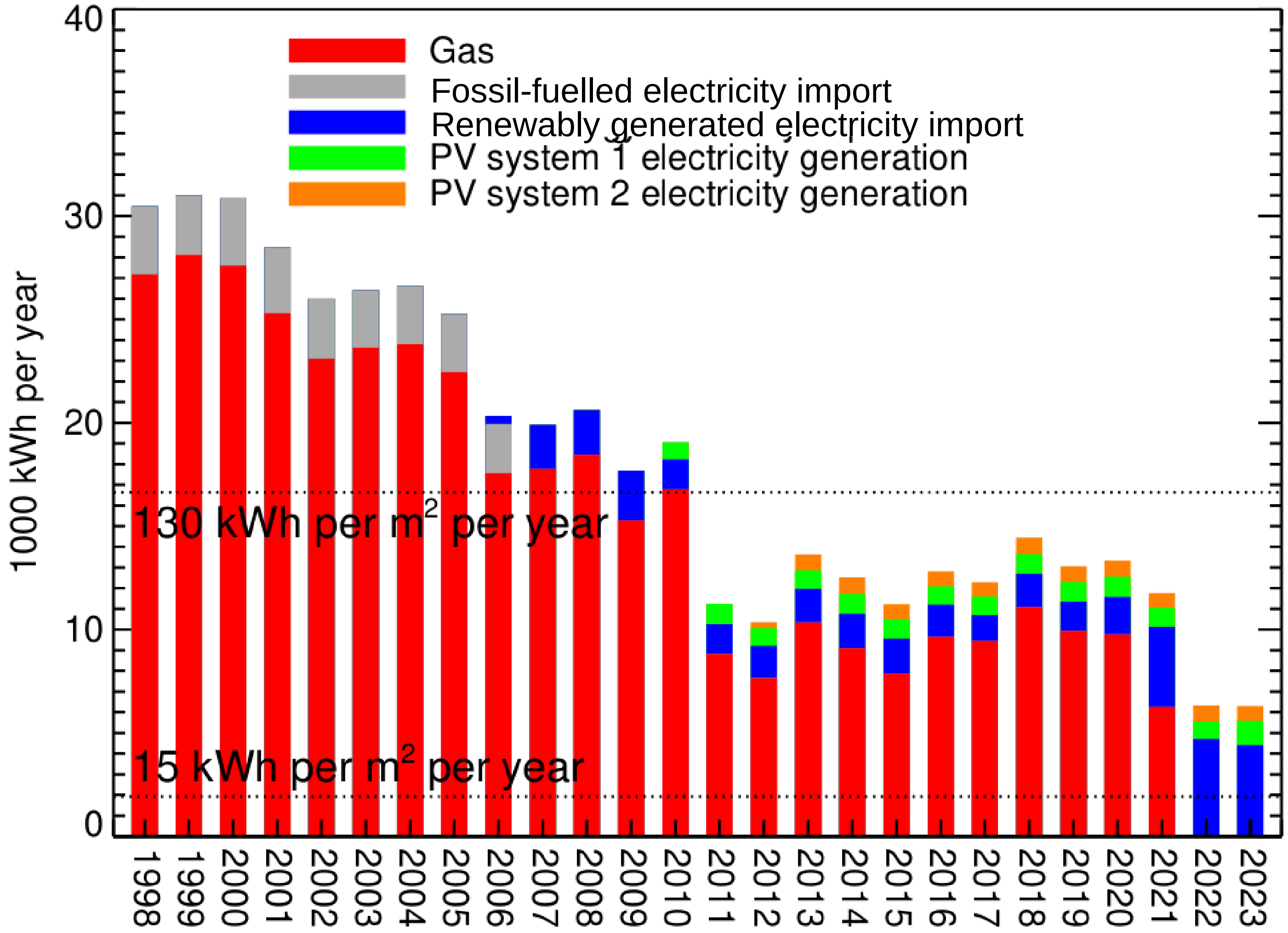


Our World in Data



By Mir-445511 - Own work, CC BY-SA 4.0, simplified, data from Lazard

Energy import and generation at my home



Conclusions

Climate science is practically important and intellectually interesting.

We need more brainpower to make faster progress with advancing the science.

We need more public will to make faster progress towards net zero and below—but it **can** be achieved.

Don't be distracted by the myth that "Every little helps." If everyone does a little, we'll achieve only a little. We must do a lot. What's required are big changes in demand and in supply. (David Mackay)


4 tonnes CO_2 per year per capita, cf. 2 tonnes for flying from Geneva to Chicago and back.

Thanks for invitation to speak and opportunity to visit CERN again.

CERN gave me this award in 2021. It is an honour—but am I an imposter?

Noun Project CC3

CERN and those who work here should be celebrated.