

# Sustainability and Accelerator Operations

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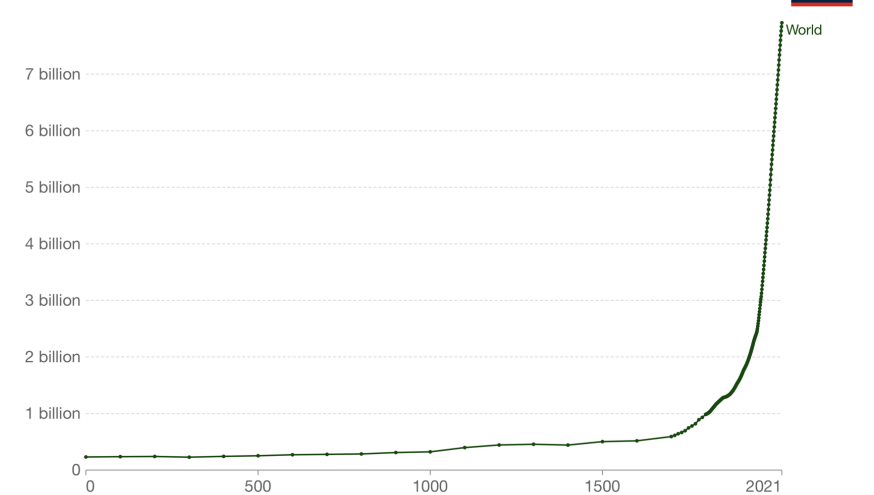
TRIUMF 2023 Science Week Panel Discussion

August 2, 2023

# Our use of energy is unsustainable

- Energy flow and also entropy are the key factors of life on earth. For millions of years, they have been balanced to sustain life on earth.
- Over the last 250 years the availability of essentially unlimited amounts of fossil energy has greatly distorted the way we use energy and led to a profound addiction to this unlimited energy supply resulting in explosive population growth and unsustainable use of fossil energy and other resources.
- The most urgent problem: CO<sub>2</sub> from burning fossil fuels accumulates in the atmosphere and leads to increased global temperatures.
- The threat of catastrophic consequences from possible runaway global warming requires that we stop extracting fossil fuels as soon as possible.

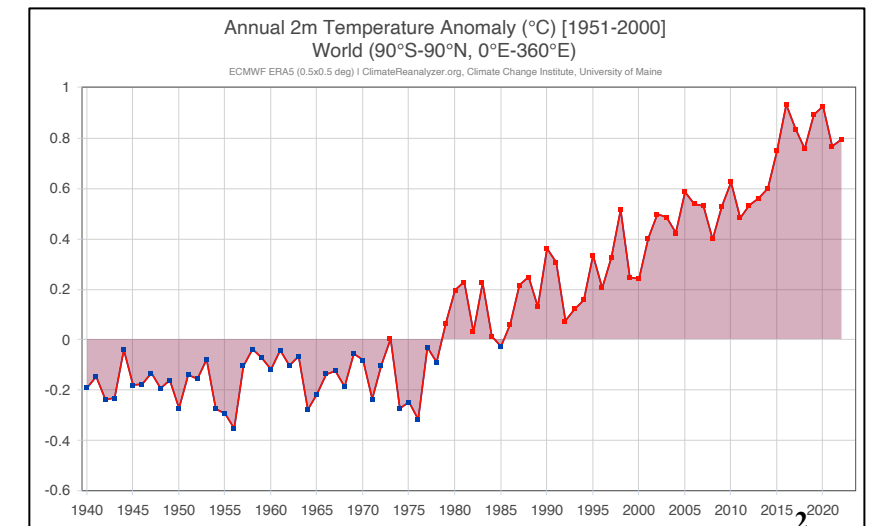
Population, 0 to 2021



Source: HYDE (2017); Gapminder (2022); UN (2022)

Note: Historical country data is shown based on today's geographical borders.

OurWorldInData.org/world-population-growth • CC BY

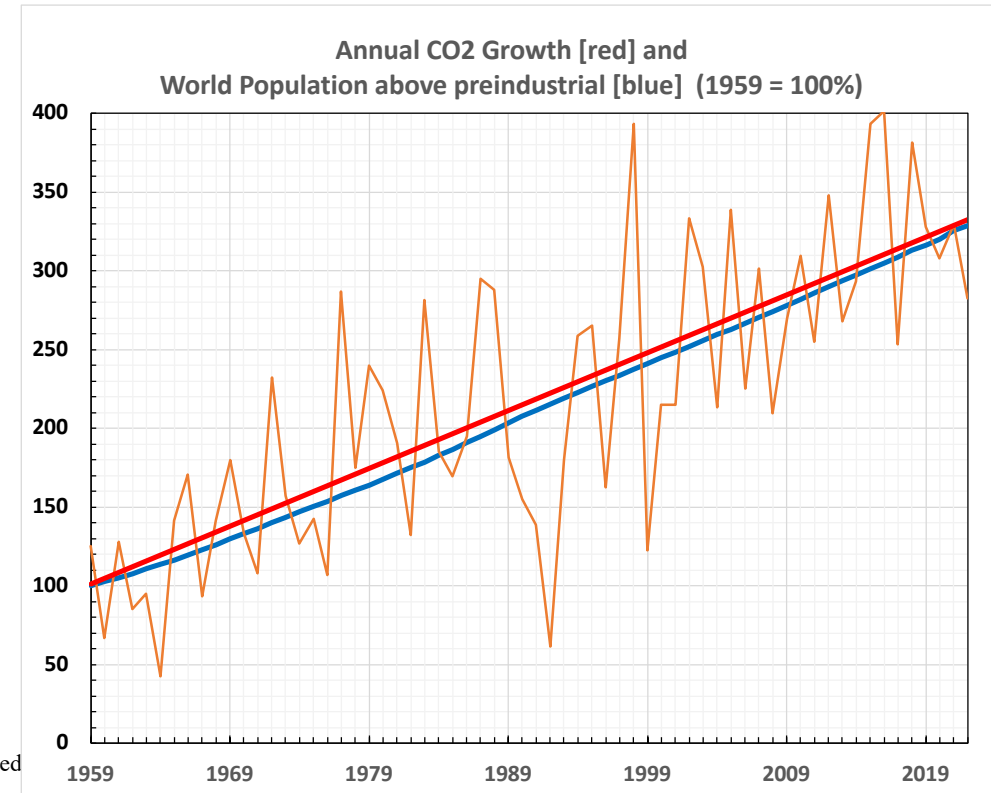
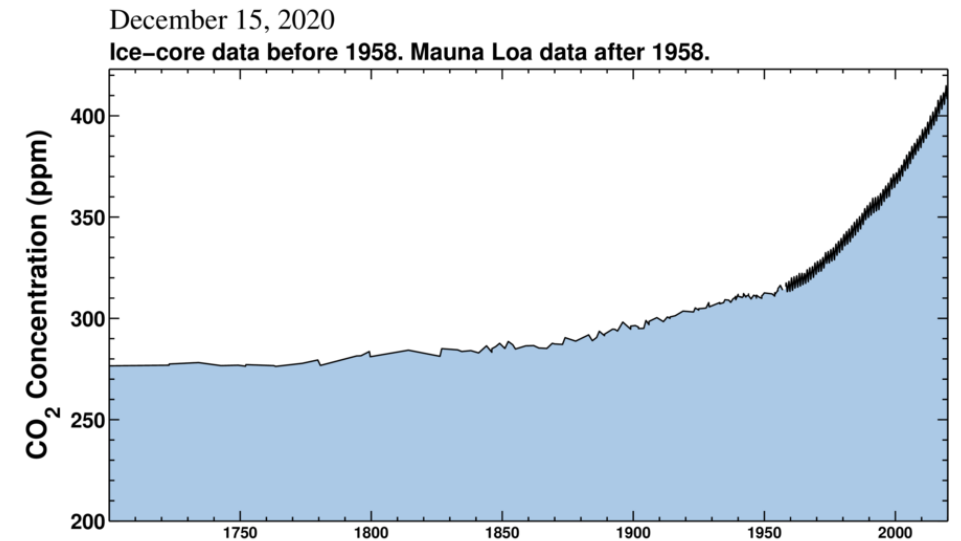


# Are there solutions?

- Climate scientists have established the existence of global warming and its connection to the burning of fossil fuels, based on scientific methods and strict peer review. They were and are attacked for their work.
- Scientists (physicists) and engineers now need to develop and examine global and scalable solutions, also based on scientific methods, fact based, and with strict peer review. This, again, will not necessarily be popular.
- Available energy “sources” principally come in two forms: collecting energy (solar, wind, ...) and liberating stored energy (fossil fuels, fission energy, fusion energy, ...). The energy density of solar and wind is much lower than for fossil energy or nuclear energy.
- Every alternative Carbon-neutral energy source needs to be examined with a complete life cycle analysis of the needed input energy and other resources. A lifecycle analysis of the low-density solar and wind energy is particularly difficult as they need much more hardware per energy produced than the high-density energy sources.
- Finally, we need a realistic model on how to transition to Carbon-neutral energy sources that minimizes the need for fossil fuels.

# How can we verify that our solutions work?

- CO2 emission information is not reliable. Many countries just guess or simply lie. Instead one can measure CO2 concentration in the atmosphere directly. CO2 is quickly distributed around the world.
- Carbon is continuously exchanged between atmosphere, plants, soil, and oceans. However, removal of Carbon from this system is very slow. (~ 100 years)
- Annual CO2 growth in the atmosphere is a direct measure of human-caused CO2 emissions. It shows a continuing acceleration of annual CO2 growth that is closely tracking the world population above preindustrial levels.
- There are significant fluctuations that prevent the detection of annual changes of the world CO2 emissions.
- Since fossil fuels have no C14 measuring C14 deficiency in the atmosphere gives a direct and fast measure of CO2 from fossil fuel burning.



# How can we reduce CO2 emissions?

- Human-caused CO2 emissions are mainly the product of three factors:
  1. Number of people x
  2. Energy consumption per person x
  3. CO2 emission per energy produced.
- There is an urgency to start doing something. Actions on each of these factors are urgently needed:
  1. Reduce and reverse population growth (mainly cultural change)
  2. Reduce energy consumption per person by increasing energy efficiency for all activities (cultural change and technological innovation)
  3. Switch to carbon-neutral energy sources on a large scale. (technological innovation)
- Opposition to this approach:
  - Denial that there is Global Warming (not very widespread anymore as signs of Global Warming are evident)
  - No need to do much because there are future technological fixes such as Carbon capture and geo-engineering (both are completely unproven and quite possibly can not be scaled or maintained), “clean coal” (unproven), and “green hydrogen” (it is energy storage, not an energy source)
  - We already have Carbon-neutral energy sources in the form of solar and wind. They will be abundant, so there is no need to reduce energy consumption. (Solar and wind at the global scale have not been demonstrated. They need enormous amounts of energy and other resources for construction, installation and maintenance.)

# What can the Accelerator Community do?

- **For population growth:** Very little directly. A historically successful approach is supporting women rights and education worldwide.
- **For energy efficiency:** we need to focus on the development of energy efficient accelerator technologies with the same or higher performance. Every new facility should be as energy efficient as possible, even if it means that it is delayed to do the necessary R&D. Accelerator facilities need to produce high energy conditions. This means that energy efficiency often requires some form of energy recovery.
  - More efficient power converters to DC and RF (incremental)
  - More efficient refrigerators (limited by Carnot)
  - Use of process heat using heat pump technology
  - Energy efficient components (Superconducting technology, permanent magnets, HTS, ...)
  - Compact accelerators with high accelerating gradient (Wakefield Accelerators, ...)
  - Energy efficient accelerator concepts (Storage rings, Energy Recovery Accelerators, ...)
  - ...
- **For Carbon-neutral energy source:** Besides hydropower and biomass (wood), which both cannot be expanded significantly, nuclear power is the only proven carbon-neutral energy source that is scalable. The main obstacle is the treatment of the radioactive “waste”. Accelerator Driven Systems (accelerator driven sub-critical reactors) can transmute this waste and also generate more energy. The accelerator has to be highly reliable and very energy efficient. The accelerator community can do this!

# ICFA Panel on Sustainable Accelerators and Colliders

Status, July 16, 2023

## ● Panel members:

- **Europe:** Mike Seidel (PSI, Switzerland), Andreas Hoppe (DESY, Germany), Jerome Schwindling (CEA/IRFU, France), Ruggero Ricci (LNF, Italy), Peter McIntosh (STFC, UK), [Roberto Losito \(CERN, Switzerland\)](#)
- **Asia:** Takayuki Saeki (KEK, Japan), [Yuhui Li \(IHEP, China\)](#), Hiroki Okuno (Riken, Japan), Gwo-Huei Luo (NSRRC, Taiwan), Eugene Levichev (BINP, Russia)
- **America:** John Byrd (ANL, USA), Soren Prestemon (LBNL, USA), Thomas Roser (BNL, USA), Andrew Hutton (JLAB, USA), Robert Laxdal (TRIUMF, Canada), Vladimir Shiltsev (FNAL, USA), [Emilio Nanni \(SLAC, USA\)](#)

## ● Mandate:

- Assess and promote developments on energy efficient and sustainable accelerator concepts, technologies, and strategies for operation, and assess and promote the use of accelerators for the development of Carbon-neutral energy sources. The panel will formulate recommendations on R&D and support ICFA with networking across the laboratories and communications. The membership will ensure a broad regional participation and coverage of accelerator technologies and concepts, relevant in the context of energy consumption and production.
- [Many laboratories are expanding their use of Carbon-neutral energy sources. Whereas this is a highly welcome development it does not replace or obviate the need for increased energy efficiency and reduced energy consumption, which is the focus of this panel.](#)

# ICFA Panel on Sustainable Accelerators and Colliders

Status, July 16, 2023

## ● Activities:

- Members of the panel prepared summary slides of the energy efficiency efforts and plans at their labs for the March 22, 2023, meeting of the sustainability Panel. These summaries will be updated at future panel meetings.
- The panel chair was invited, as a representative of the ICFA sustainability Panel, to join the IOC of the 7<sup>th</sup> WS on Energy for Sustainable Science at Research Infrastructures (ESSRI), to be held in Madrid on September 25-27, 2024. ESSRI is the premier European WS on energy efficiency at accelerator laboratories. Long term, this workshop could either be expanded to be held more internationally or similar workshop series could be established outside Europe.
- Such workshops should be held in a sustainable manner and could serve as a model for sustainable meeting organization. One possibility is to limit in-person attendance to participants that can reach the site without needing a plane ride and offer equivalent participation for remote attendees from overseas. It will require a concerted effort to develop tools and organizations that can make such hybrid meetings successful.