TRIUMF

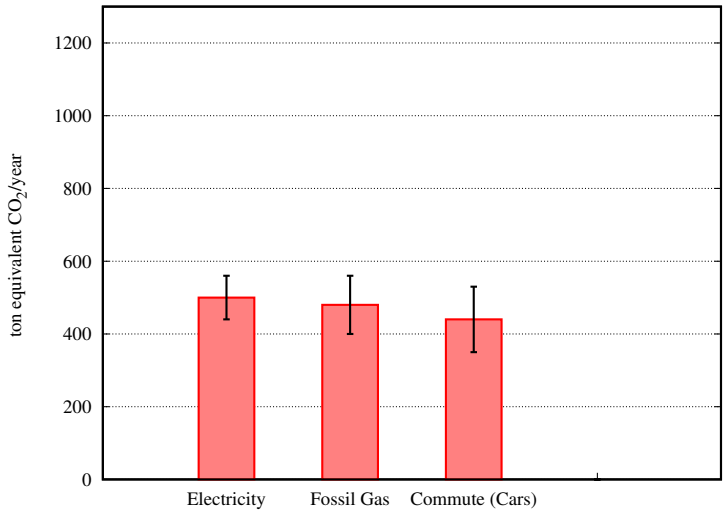
Sustainable Operations of TRIUMF Accelerator Facilities

Thomas Planche, Science Week, August 2023

Outline

- Quick overview of TRIUMF's carbon footprint
- TRIUMF's accelerators: examples of sustainability-driven initiatives
- Ideas to take it further

TRIUMF's Annual Carbon Footprint



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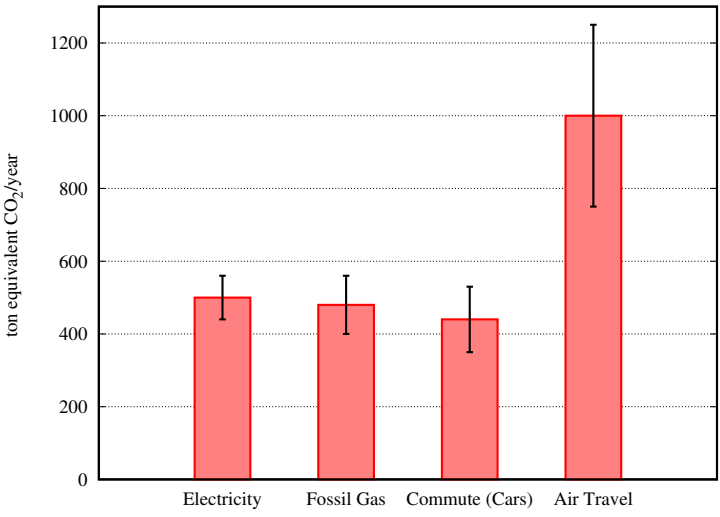
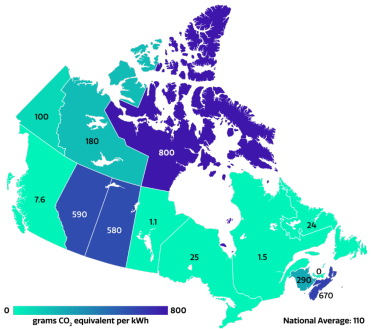


Electrical Power Consumption

TRIUMF consumed 58.3 GWh in 2022 (source: Melchor Almario) $\approx$ the annual consumption of about 1,800 households in BC (source: bcuc). But BC electricity has an astonishingly low carbon footprint (source: cer-rec.gc.ca):



The actual number for $gC0_2eq/kWh$ varies from 7.6 to 9.7 depending on sources (cer-rec.gc.ca, bchydro) which gives us a a total of **500 $tC0_2e$/year $\pm$ 60**

Air travel (for business)

Travel expenses of TRIUMF for 2019 and 2020 are publicly available (source: triumf). In 2019 (pre-pandemic) about $890,000 of that budget was spent on airfare.

Flying from Vancouver in economy class costs in average $\sim$0.17 $/km.[1]

With an average of 200 $gC0_2eq$/passenger/km in economy class (source: gov.uk)[2] we get:

$\$890{,}000/(0.17\$/km) \times 200\, gC0_2eq/km \approx$ **1000 $tC0_2e$/year $\pm$250**

[1] $ = CAD. Average compiled using the lowest prices on Air Canada, leaving Vancouver around September 3 (I compiled the data on July 21) for 4 popular destinations in Canada, 4 in the US, 4 in Europe, and 4 in Asia.

[2] The uncertainty on this number is large, as it is closer to 250 for domestic flights, and closer to 150 for intercontinental flights and it varies somewhat between sources(see for instance ourworldindata)

Ecological Footprint

Site C dam construction site on Peace River (BC) as of April 2017 (credits: wiki commons)

Carbon footprint is a global indicator that is largely oblivious to more **local impacts**: loss of biodiversity, ecotoxicity, sociocultural impacts, loss of agricultural land, etc.

In BC, even though it may not the most effective way to reduce TRIUMF's carbon footprint., saving electricity is still relevant to reduce environmental impacts.

BC Hydro Smart Incentive

2018 520 MeV cyclotron main magnet power supply replacement: the improvement in efficiency was from 80% to about 92%. This led to saving $\sim$1.3 GW.h/year (2.2%).
(source: Franco Mammarella)

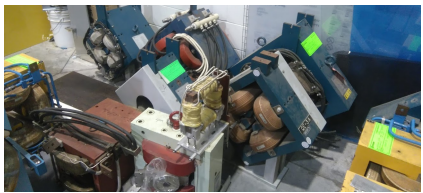
2022 Beamline 1 power supply replacement phase 1&2. Phase 3 planned. Estimated savings: $\sim$0.3 GW.h/year (0.5%).
(source: Arthur Leung)

Circular Economy & Accelerator Hardware

The environmental impact of building new accelerator infrastructure can be reduced by re-using decommissioned hardware. Example: the ARIEL beamline 4N is a 82 m long proton beamline with **64** accelerator magnets (36 quads, 5 dipoles, and 23 steerers) of which **62 are re-used**; 21 of these have been donated by KEK.[3]

This kind of initiative requires:

- To realize that new is not always better
- Long-term storage of equipment marked as re-usable
- Mutualization of resources and equipment data bases between research institutions

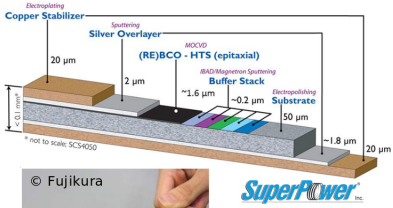


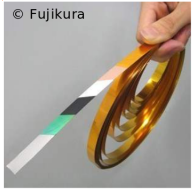
[3] Source: Yi-Nong Rao. For context: this beamline will consume about 400 kW of electrical power.

Superferric Efficient DC Magnets

There is expertise in Canada on high-temperature superconductors. The technology is mature. We could replace the copper coils of our DC magnets with HTS-based coils.

1) REBCO coated conductors





2) Bulk superconductors

More Efficient RF Sources

Example: the e-linac employs 2 Klystrons which have a power efficiency on the order of 50 to 60% (sources: A.K. Mitra et al., A.Y. Baikov)... when they operate close to their maximum power output!

But we currently use them with a power output on the order of 10 kW, where their efficiency is only $\sim$**2.5%**.

We could save over **2 GWh/year**, i.e. 3.4% of the annual consumption, by replacing them with modular solid-state amplifiers.

Thank You

Thank you for your attention

Fossil Gas (for lack of a better word)

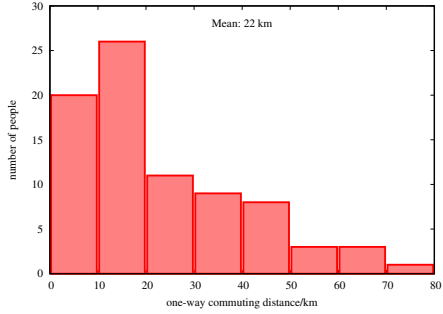
Gas consumption of TRIUMF (heating) is about about 2.8 GWh/year (10,000 GJ/year), (source: Dawn-Marie Barreira, Bill Richert) with a carbon footprint of about 170 $gC0_2eq/kWh$ with a variability of about $\pm$ 30 $gC0_2eq/kWh$ between sources: gov.uk, carbonindependent, usepa.

That gives us a total of **480 $tC0_2e$/year $\pm$ 80**

Commute to TRIUMF (cars only)

Counted between 160 and 180 cars on the parking lot at 10 AM on 3 separate days in July. We estimate the average number of people commuting by car to be $\sim 200 \pm 40$ per business day.

Polled 121 colleagues: 81 declared commute by car at least part of the year, with a mean one-way commute distance of 22 km.



Commute to TRIUMF (cars only)

I did not try to calculate the average based on the make of the cars on the parking lot[4]... but others have done it for the Canadian vehicle fleet (source: nationalobserver) and found $\sim 200\,\mathrm{gC0_2eq/km}$.

Putting everything together gives us:

$250\ \text{business days/year} \times 2 \times 22\,\mathrm{km} \times 200\,\text{cars} \times\ 200\,\mathrm{gC0_2eq/km} \approx$ **440 $\mathrm{tC0_2e}$/year**

With an uncertainty of about $\pm$**90 $\mathrm{tC0_2e}$/year**, if the number of car per day the prevailing source of uncertainty.

[4] If you find the courage to do it yourself here are good sources: carbonfootprint, carboncounter