Carbon Footprint of a Top500 Supercomputer, specifically `Selene`.

Konstantinos Kilmetis

September 2022

Introduction

Much of recent scientific and technological progress is owned to the liberal use of supercomputers. These incredible machines have managed to exponentially accelerate the pace of discovery due to their raw computational power. Said power, has opened new avenues for computation based research since operation that would take years[1] on a personal computers take seconds on a Supercomputer. A common method of measurement of the strength of a supercomputer are the *FLOPS.*

So what's a FLOP?

FLOPS, short for Floating Point Operations Per Second. For our purposes a floating point operation is defined as the as a simple (i.e. one of the classic four: addition, subtraction, multiplications and division[2]) mathematical operation on a pair of floating point numbers. A floating point number is nothing more than a non-integer number, which includes exponentials and decimals. Handling this sort of number is more computationally expensive in comparison to integers. Thus, a *FLOP* is an easy operation done on difficult numbers.

Nowadays, the most powerful supercomputers -as they were documented by TOP500 manage to peak performances in the tens of Penta FLOPS. That is 10^{16} operations per second!

Harder, Better, Faster, Stronger

This is all well and good, but all too often in human history we tend to act as ardent supporters of the modus operandi *move fast and break things.* As one would expect, supercomputer development is no exception to this. We use a lot of money,

[1] and approximately 3-4 ages of the universe on paper!

[2] all of which are just addition with extra steps.

brainpower and energy in the endless race to create the quickest,best and all around better than the last supercomputer. Then, since a supercomputer available we make heavy use of it. After all, it would be a waste to build such a machine only to stare at it.

This takes up energy. Lot's of it, in fact. With a looming climate change on the horizon, public opinion is sluggishly starting to push for sustainability and greener policy on all fronts and supercomputers are no exception. As a result of that, the website which ranks the supercomputers of the world has come up with a new ranking, the Green500. This instead of pure computational power ranks computers on efficiency. That is FLOPS/Power consumed. Usually the same supercomputers top both lists. For example, FRONTIER is currently the most powerful supercomputer in the world and the second most efficient.
This makes sense from an economic perspective. Supercomputers are made by companies. Companies live and die on the free market. Thus, there is an economic incentive to make not only powerful but efficient computers as well.

Devil's in the Details

However, there is no incentive to minimize the environmental impact of a supercomputers. As a case study, we will investigate how the supercomputer `Selene` impacts the environment[3]. `Selene` ranks 8th in the TOP500 and 22nd in the Green500. `Selene` manages an efficiency of 0.024 PFLOPS/KW [1], pretty good right?.

No. This number tells us nothing at all about `Selene's` carbon footprint. In order to find this one out, we have to delve deeper. Specifically on the energy sources that power `Selene`.
`Selene` lives in the Lemont, Illinois, United States. Lemont is a suburb of Chicago. It has a small population and is mostly notable for hosting the Argonne National Laboratory (ANL). `Selene` is one of the ANL's many tools to conduct research, and she[4] currently helps answers questions regarding covid-19, quantum chemistry and protein docking. Lemont, like the rest of northern Illinois is powered by Commonwealth Edinson (ComEd). CoMed, and by extension its parent company Exelon[5], hold a monopoly over the energy supply of northern Illinois. As of such it is safe to assume that ComEd also powers ANL.

It should be noted that since ANL conducts quite a bit of research into nuclear

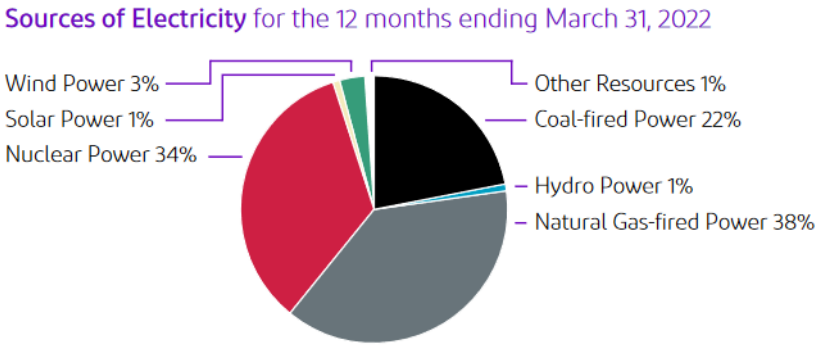
[3]Chosen arbitrarily. 8 happens to be the author's favorite number.

[4]The feminine pronouns are used because Selene is named after the Greek goddess of the Moon, who is female.

[5]A company in the NASDAQ-100. 391 in the Global Fortune 500. Not a small enterprise. Another company, Ameren, has a monopoly on southern Illinois. So much for the free market!

energy there exists a possibility that it has its own internal energy sources. While researching for this report, an attempt was made to reach out to the sustainability office of the ANL in the 7th of September but alas, my query has been so far remained without answer.

CoMed is mandated by law[6] to publicize the distribution of energy sources it uses. The pie chart presented below is taken from their environmental disclosure report for March 2022. It is fair to assume things have been hectic in the energy sector due to the war in Ukraine, so this may not be accurate as of the date of writing (Sept. 2022).



Sources [1] of Electricity Supplied for the 12 Months Ending March 31, 2022	% of Total
BIOMASS POWER	0%
COAL-FIRED POWER	22%
HYDRO POWER	1%
NATURAL GAS-FIRED POWER	38%
NUCLEAR POWER	34%
OIL-FIRED POWER	0%
SOLAR POWER	1%
WIND POWER	3%
OTHER RESOURCES	1%
UNKNOWN RESOURCES PURCHASED FROM OTHER COMPANIES	0%
TOTAL	**100%**

Figure 1: The energy sources CoMed utilizes in order to power the entirety of Northern Illinois[2]

About 60% of the energy `Selene` uses comes from carbohydrates. Illinois actually is a leader in nuclear energy -in no small part due to the ANL- so for a

[6]Section 16-127 of the Electric Service Customer Choice and Rate Relief Law of 1997 and the rules of the Illinois Commerce Commission, 83 III Admn. Code 421

computer in the United States, this is as good as it gets. If we assume that `Selene` works for 24 hours a day, 7 days a week, it consumes 23178960 Kilowatt hours per year.
22% of that value comes from coal (5099371.2 KWhrs). This amount of energy can be extracted from burning about 1100 metric tons of coal. This results in 2200 tons of CO2 released into the atmosphere[3]. 38% comes from natural gas (8808004.8 KWhrs). This amount of energy can be extracted from burning 30054000 cubic feet of natural gas[4]. This results in 3810 tons of CO2 released into the atmosphere[3].

References

[1] PFLOPS and energy consumption usage taken from TOP500.

[2] Comed's Enviromental Disclosure report. Found here

[3] Converted using EPA's greenhouse gas calculator. Found here

[4] Converted using Kyle's Converter. Bit of a dubious source. Found here here