

Energy consumption of facility and non-facility computing equipment used by UKRI researchers

Part of the UKRI Net Zero Digital Research Infrastructure Scoping Project

Wim Vanderbauwhede

School of Computing Science, University of Glasgow

We present an estimate of the scale of the carbon emission of manufacturing and usage of facility and non-facility computing equipment of UKRI researchers. Combined emissions of non-facilities equipment are of the same order of those of UKRI facilities.

The UKRI Digital Research Infrastructure Net Zero Scoping Project aims to deliver carbon neutral computing by 2040 or earlier. A large part of the computing infrastructure is outside of UKRI managed facilities. These is the equipment used by UKRI-funded researchers, usually funded from research grants but also from block grants. This report presents an estimate of the scale of the carbon emission of manufacturing and usage of non-facility computing equipment of UKRI researchers. We also include an estimate for non-UKRI funded clusters as well as for UKRI facilities.

Methodology

Individual devices

UKRI funds 58,000 researchers per year¹. To assess the energy consumption of non-facility computing equipment used by these researchers, we used the following approach:

- We interviewed a variety of researchers and IT managers in the University of Glasgow to assess the variation in use of personal computing equipment in different departments (Physics, Engineering, Maths, Computing Science, Life Sciences). The conclusion of these interviews is that the use of personal computing equipment is similar in all departments, i.e. the ratio of laptops to desktops etc.
- We analysed a database of all personal computing equipment in the School of Computing Science (340 researchers).

¹<https://www.ukri.org/about-us/strategy-plans-and-data/annual-report-and-accounts/>

- The age of the equipment varies. We performed the analysis with a cut-off of 2017 and without it
- The equipment comprised desktops (244-300), laptops (96-123), monitors (264-293) and individual servers (31-34). Clusters were excluded from this database.
- We used average figures for the power consumption of desktops (150W-200W), laptops (30W-50W), monitors (25W-30W) and servers (150W-200W), and also for the average hours per day that these were in use (6h for laptops and monitors, 12h for desktops, 24h for servers). These are conservative estimates because most machines will not be actually off but rather in low-power mode.
- We also inventoried small clusters in the schools in the college, and arrived at an estimated normalised total of 750 servers. These are “virtual” servers based on the core count, assuming 8 cores per server with an estimate power consumption as above. This is likely an over-estimate as most servers have more cores.

Non-facility clusters and server rooms

Based on interviews in the College of Science and Engineering of the University of Glasgow, we conclude that the six schools in the college (Computing Science, Physics&Astronomy, Mathematics&Statistics, Chemistry, Geography & Earth Sciences and Engineering) each have considerable local compute resources. CS and P&A both have about 1000 cores in total across several smaller clusters. The University hosts another 1,500-core HPC cluster which is used by schools with fewer compute needs. Very few of these are funded directly by UKRI, but they are used by UKRI-funded researchers so contribute to Scope-3 emissions. Based on an inventory of such clusters in the College of Science and Engineering of the University of Glasgow, and a count of the number of researchers, we estimate that the number of servers per researcher is 0.5.

Alternatively, we can bound the estimates by assuming that for the entire University, the number of such clusters is twice that of the College of Science and Engineering as this is the most compute-intensive college; this is very likely an over-estimate, but gives an upper estimate of 1,500 servers in small clusters; if we assume this is the case in every research active University in the UK, we arrive at an estimate of 220,000 servers. There are about 200,000 academics, PhD students and postdocs in in research active Universities, so that means about 1 server per researcher. As the uncertainty in this figure is very high, we will bound the estimate as 0.25 to 2 non-UKRI-funded cluster servers used by every UKRI researcher.

Estimated energy consumption of non-facility computing equipment

Individual devices

Using the above estimates, and applying a geometric error margin of 50% to account for the uncertainty on the estimates, we conclude that the power consumption of UKRI funded non-facility computing equipment is between 2MW and 8MW. The estimates above for the power consumption of non-facility computing equipment are already taking into account the numbers of hours the equipment is active, so the energy consumption in GWh/y is simply obtained by multiplying by $24 \times 365 / 1,000,000$. The yearly energy consumption is therefore between 20GWh/y and 70GWh/y.

Non-UKRI clusters used by UKRI researchers

Assuming this type of equipment is always active, so the energy consumption in GWh/y is simply obtained by multiplying by $24 \times 365 / 1,000,000$. The yearly energy consumption is therefore between 10GWh/y and 100GWh/y.

Carbon footprint of non-facility computing equipment

For the emissions from non-facility computing equipment, we used an average CO₂ intensity of 178 g/kWh ².

Individual devices

For individual devices, this results in estimate carbon emissions from usage of between 3 kton/y and 13 kton/y. Based on Freitag citing Malmudin³, for non-facility computing equipment the embodied carbon is about 50% of the total carbon over the typical lifetime. So we can conclude that the total footprint of non-facility computing equipment of UKRI researchers is between 6 kton CO₂e/y and 25 kton CO₂e/y.

These estimates for the compute related footprint only includes embodied carbon of the machines and electricity used by the machines. It does not include scope 3 for use, i.e. internet usage, nor local network power consumption.

As there are 58,000 UKRI-funded researchers we can estimate an individual footprint as between 100 and 400 g CO₂e per year. For comparison, conference travel would result in 500 to 1,500 kg of CO₂e per conference round-trip ⁴.

Non-UKRI clusters used by UKRI researchers

For clusters, this results in estimate carbon emissions from usage of between 2 kton CO₂e/y and 18 kton CO₂e/y. We estimate the embodied carbon for this type of equip-

²<https://data.nationalgrideso.com/carbon-intensity1/historic-generation-mix>

³[https://www.cell.com/patterns/fulltext/S2666-3899\(21\)00188-4](https://www.cell.com/patterns/fulltext/S2666-3899(21)00188-4)

⁴https://link.springer.com/chapter/10.1007/978-981-16-4911-0_2

ment combined with the emissions from the cooling of the server rooms also as 50% of the total carbon over the typical lifetime. So we can conclude that the total footprint of non-facility computing equipment of UKRI researchers is between 5 kton CO₂e/y and 36 kton CO₂e/y. In other words, we estimate that the contribution of such small clusters to the footprint of non-facility equipment is of the same order as that of the personal devices. We can bound the total to between 10 and 60 kton CO₂e/y

Energy consumption and carbon footprint of UKRI facilities

Our basic assumption, corroborated by the evidence from e.g. the Green TOP500⁵, is that the power consumption of UKRI large facilities is essentially Pareto-distributed, i.e. there are few very large facilities, more medium to large ones, and many more small ones. We verified that the distribution of power consumption of supercomputers for several countries (UK, US, Japan, China, Germany) follows this behaviour.

Actual reported energy consumption figures are 25 GWh/y for ARCHER2, 19 GWh/y for DiRAC (all 4 sites), 7.9 GWh/y for all machines located at Daresbury, of which Scafell Pike and Blue Joule are by far the largest, and 2.5 GWh/y for JASMIN⁶. To bound the slope of the Pareto distribution, we bound the number of small machines based on the number of research-active Universities (156 in the REF). We make the assumption that on average, Universities will not have more than 10 UKRI-funded managed facilities (i.e. small supercomputers). Clusters that are not funded by UKRI are not in this estimate, see the above estimate for those. That means there would be about 1,500 of such “small” (order of 50 MW/y in energy consumption) supercomputers funded by UKRI. With this bound, we obtain a total estimate of 200 GWh/y. As the uncertainty is large, we also modeled the scenario where there would be twice as many (3,000) such small supercomputers. This gives an upper estimate of 300 GWh/y; the lower estimate is 100 GWh/y.

Using an average CO₂ intensity of 178 g/kWh and 16% embodied carbon, we can bound again the total emissions of UKRI managed facilities to less than 60 kton CO₂e/y and probably closer to 40 kton CO₂e/y, with a lower bound estimate of 20 kton CO₂e/y.

Conclusion

In summary, we estimate the following for compute equipment used by UKRI funded researchers:

- UKRI facilities: energy consumption 100GWh/y to 300GWh/y; carbon footprint 20 kton CO₂e/y to 60 kton CO₂e/y
- Non-facilities, UKRI funded equipment: energy consumption 20GWh/y and 70GWh/y; carbon footprint 6 kton CO₂e/y to 25 kton CO₂e/y

⁵<https://www.top500.org/lists/green500/>

⁶from consortium project survey, reported 19 Jan 2023

- Non-facilities, not UKRI funded equipment: energy consumption 10GWh/y to 100GWh/y; carbon footprint 5 kton CO₂e/y to 36 kton CO₂e/y

There is a large uncertainty on these figures, but the analysis shows that the carbon footprint of non-facility computing equipment of UKRI researchers is of the same order that of of UKRI managed facilities and therefore both are equally important contributors to emissions from UKRI-funded research.