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The Need for Mandatory Academic Laboratory Sustainability Training – A Fume Cupboard Case Study

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Abstract

While scientific research is paramount to understanding the solar system, ecosystem, human disease and cures (etc) it continues to contribute to human-caused climate change. Scientists are becoming increasingly aware of the carbon footprint associated with their research and recognise the need to work more efficiently with their resource use and laboratory operations.

University laboratories are spaces that allow for research to be carried out safely, however, they consume five times more energy per square meter than office buildings. Fume cupboards are amongst the most energy intensive equipment and thus are a dominant factor when working towards creating safer and greener laboratories. In this paper, we report on the gas, electricity, carbon and financial savings derived by upgrading 105 constant air volume fume cupboards to variable air volume systems. We also report on the frequency of fume cupboard use by research staff, postgraduate students, and their overall understanding of fume cupboard best practice operations. The results reflect that while savings were achieved, they were lower than predicted. A factor to this may be poor student and staff understanding of how fume cupboards work resulting in their incorrect usage, therefore hampering sustainable progression. This study highlights that a major gap exists between laboratory technical upgrades and researcher awareness of proper and safe equipment use and operation. To overcome this, we propose that in addition to health and safety training, mandatory laboratory sustainability operations training should be provided to all laboratory users.

Keywords: fume cupboards, sustainable laboratories, climate change and laboratory research, net zero and laboratory, sustainable labs training

1. Introduction

Over the past decade, higher educational institutions have emerged as the primary contributors to the development of new global discoveries (Silber, 2010). Universities are now at the forefront of some of the world's most important medical and technological advances that are transforming lives around the world (Greever et al., 2020; Silber, 2010). A large proportion of these advancements take place in research laboratories. However, all development comes at a cost, and for a research laboratory the financial and environmental cost is significant (Dittrich, 2015; Skuse, 2019). Across a single university, laboratories collectively can be responsible for 40% of total carbon consumption therefore reducing the positive impact that research strives to have on the planet and contributing to climate change (Greever et al., 2020; Skuse, 2019).

Although the global collective carbon emissions of institutional laboratories have yet to be calculated, in 2015 the pharmaceutical industry was found to have a 55% higher carbon footprint than the automotive industry and in 2018 a study on the annual global emissions from cooling in the health care system was found to be equivalent to the emissions from over 75 million cars on the road or 110 coal power plants per year (Belkhir & Elmeligi, 2019; Greever et al., 2020). Furthermore, 4.4 million metric tons of laboratory plastic waste was disposed from institutions involved in biological, medical, and agricultural research worldwide (Greever et al., 2020; Sawyer, 2019; Urbina et al., 2015). These figures highlight the immense impact scientific research has on the environment and with over 1000 universities worldwide now pledging to cut their net-zero emissions by 2050, it will be essential for laboratories to play a primary role. Not only are scientists in urgent need of acting efficiently and sustainably with their resource use and laboratory operations, universities also have a responsibility to provide green designed laboratories at a building level and to integrate sustainable laboratory educational and training programmes to all laboratory users (Greever et al., 2020).

The University of Strathclyde is the third largest university in Scotland and aims to become Net Zero by 2040 at the latest (Strathclyde, 2022). It has already met its strategic carbon reduction target of a 25% reduction of the 2009-10 baseline surpassing the 2020 target delivery point. Strathclyde laboratories contribute to the top ten of the University's sources of embedded carbon, with laboratory supplies and laboratory consumables being the fourth highest source of procurement-related emissions. To address the environmental impact of its laboratory-based research, the university has used an inclusive approach to encompass behavioural change programmes targeted at all laboratory users, educational tailored PhD credit courses to equip and empower PhD students with knowledge on working more sustainably, the continuous replacement of old energy and water inefficient equipment to higher efficient and safety focused ones such drying ovens, oil baths, water condensers, the reduction in single use plastic items etc.

Over the past six years the university has made efforts to reduce the carbon footprint of fume cupboards; one of the most energy intensive equipment within its laboratories and has successfully upgraded 105 constant air volume (CAV) fume cupboards to variable air volumes (VAV). In this article, we present the gas, electricity and financial savings of this project. Furthermore, as the amount of carbon reduction achieved depends on user operations, we sought to investigate the frequency of fume cupboard use by our research staff and postgraduate students as well as their overall awareness of fume cupboard best practice.

The results show that carbon savings have been achieved by upgrading CAV fume cupboards to VAV ones, therefore transforming labs to greener and safer ones. However, these savings were far less than initially predicted. Furthermore, the survey analysis highlighted that there is a lack of fume cupboard best practice awareness amongst research staff and students which would hamper sustainable progression. This highlights that a link is missing between technical upgrades and relaying information of their best practice to researchers.

2. Fume Cupboards

The primary function of fume cupboards is to physically protect researchers from inhaling air-borne hazardous gases generated during an experiment as well as shielding researchers against spills and explosions (Mills & Sartor, 2005; Tseng et al., 2007). Although they are integral to safety, fume cupboards are one of the most energy intensive equipment commonly found within laboratories (Reiman et al., 1998; Tseng et al., 2007). In spaces and buildings with multiple fume cupboards this is not only a significant operating cost but a worry to global warming contributions (Mills & Sartor, 2005).

2.1 Constant Air Volume vs Variable Air Volume

A typical fume cupboard works by pulling air from inside the laboratory through the open sash and then venting this air externally taking with it any contaminated particles, or the contaminated air can be passed through filters and recirculated back into the laboratory (Aldred Cheek & Wells, 2020; Sharp, 2015).

CAV fume cupboards provide a constant flow of air regardless of the sash position and whether the fume cupboard is in use or not (Aldred Cheek & Wells, 2020). A fume cupboard can exhaust ~ 20-30 m^3 of air per min, this places a significant load on the heating, ventilation and air-conditioning (HVAC) system and as a result a substantial amount of energy is wasted (Reiman et al., 1998). In contrast, a variable air volume (VAV) fume cupboard operates at minimum exhaust volumes when the sash is lowered, this creates a highly responsive energy usage system and the exact savings depends on user behaviour where the lower the sash is closed the greater the energy savings (Aldred Cheek & Wells, 2020; Reiman et al., 1998).

2.2 Fume Cupboard Upgrades

2.2.1 Pure and Applied Chemistry Department

The Thomas Graham building which hosts our pure and applied chemistry department houses 140 fume cupboards and is the most energy intensive building in terms of fume cupboard use on campus. The majority of the ventilation supply serving the laboratories was CV. In 2014, as a pilot study, we upgraded 41 of our CAV fume cupboards to VAV, installed motorised dampers and included auto-sash closures. Then in 2016, we upgraded a further 34 fume cupboards located on one floor from VAV to CAV and introduced auto-sash closures. Figure 1a shows the difference in electricity consumed as a whole building before and after the technical upgrades, overall electricity consumption was reduced by 7% and this is a saving of £21,867 per annum. Figure 1b shows the overall gas consumed before and after the pilot study in 2014, overall gas consumption was reduced by 4.3% giving a financial saving of £2609 per annum.

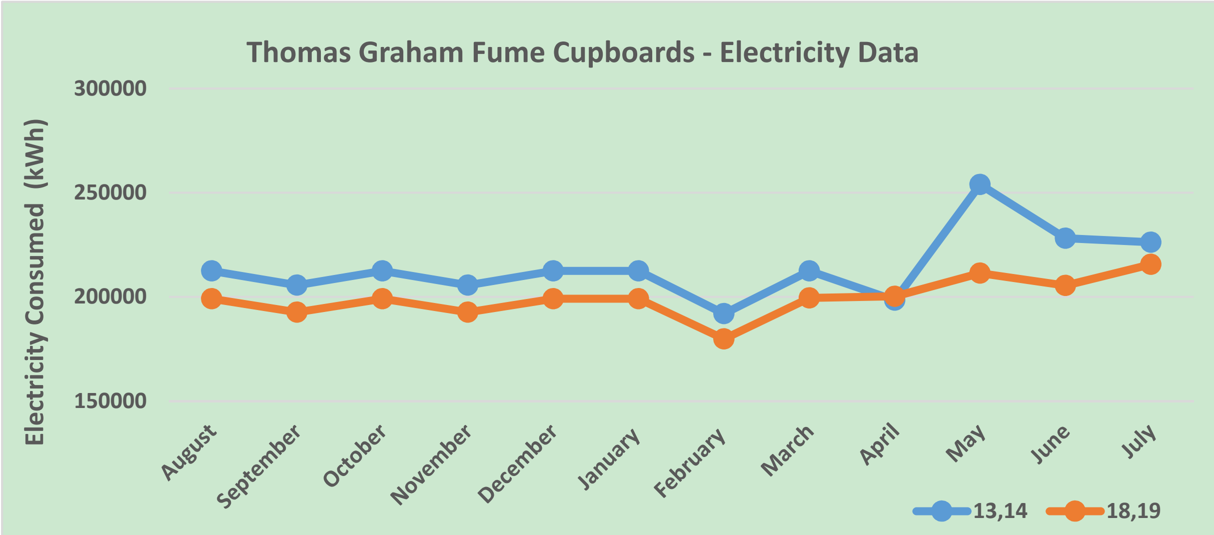

Figure 1a). Electricity savings of upgrading all 71 CAV fume cupboards to VAV ones

In the period 2013-2014 total building electricity consumption was 257,2172 kWh compared to 239,3368 kWh in the period 2018-2019. This is a saving of 178,804 kWh which equates to £21,867 per annum.

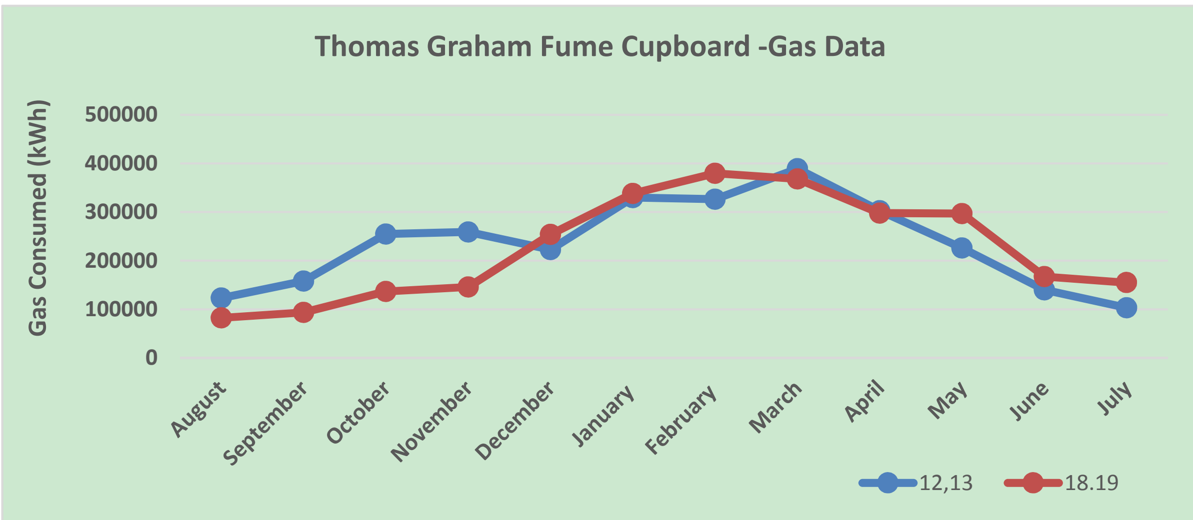

Figure 1b). Gas consumption savings of the initial pilot study of upgrading 41 fume cupboards

The gas savings from upgrading all 75 fume cupboards could not be calculated as there were changes made to the buildings CHP readings for the 2018/19 period. Weather correction was applied to the data to remove gas consumed for heating purposes. The 41 fume cupboards are located on one floor and these are the gas data of that one floor of the building. The overall gas consumed in 2012/13 period is 2836691 kWh and in the period 2018/2019 was 2716990 kWh. This is a saving of 119,701 kWh which equates to £2609 per annum.

2.2.2 Pharmacy and Biomedical Science Department

In 2017, in our institute of pharmacy and biomedical science building [SIPBS] we upgraded a further 30 CAV fume cupboards to VAV and included auto-sash closure. On a building level this reduced electricity consumption by 12% (figure 2a), gas consumption by (figure 2b) and $C0_2$ remission by 12% (figure 2c). This gives us an annual saving of £25,551.

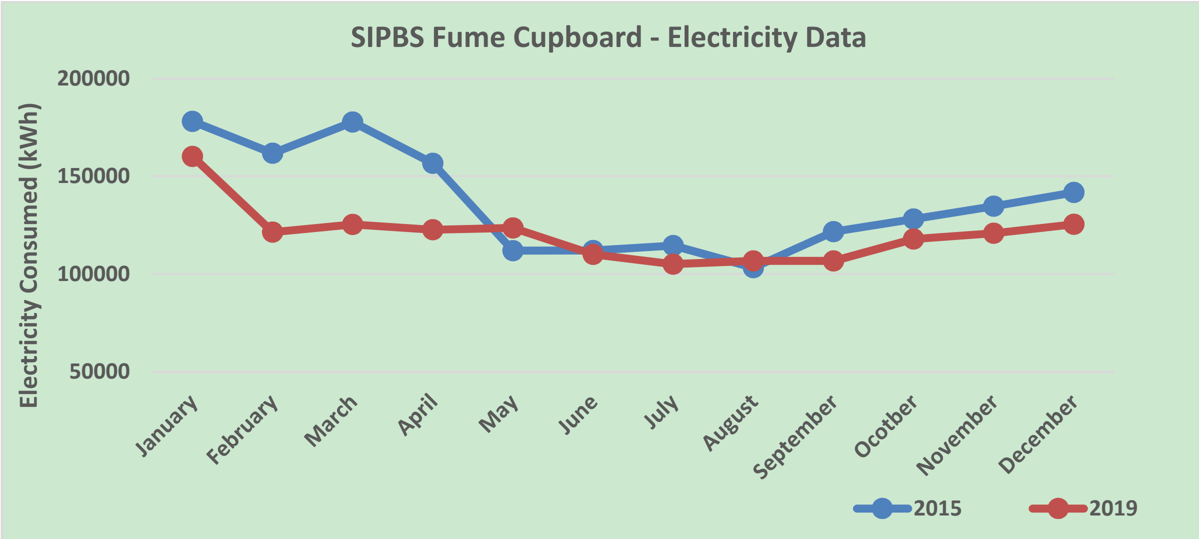

Figure 2a). The electricity savings of upgrading 30 CAV to VAV fume cupboards

Total electricity consumption in 2015 was 1642055 kWh whereas in 2019 it was 1445500 kWh, this is a saving of 196,556 kWh which equates to £24,038 per annum.

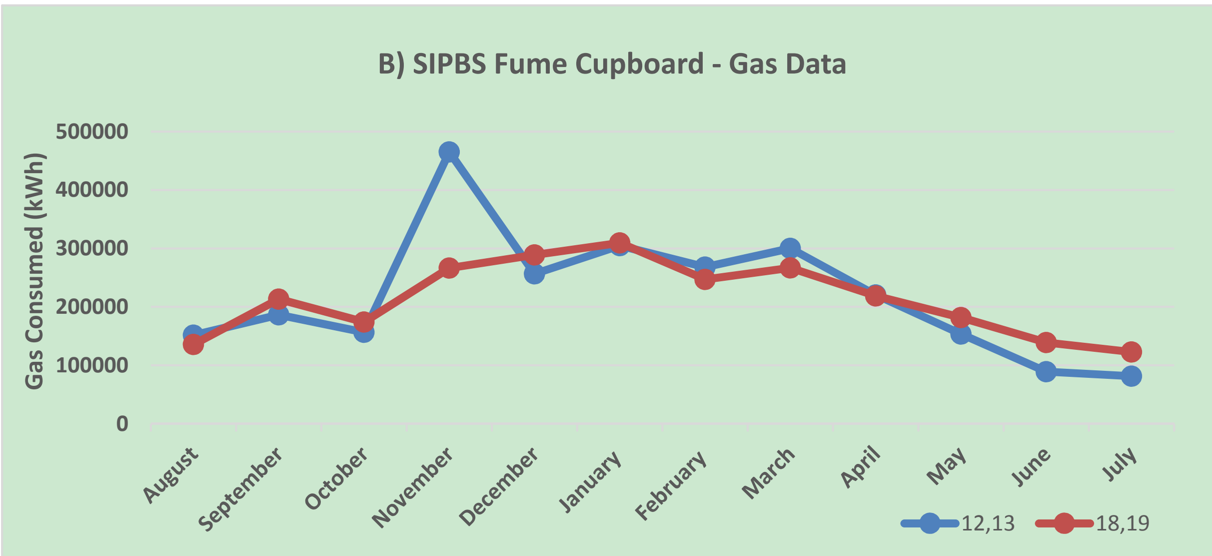

Figure 2b). Gas savings of upgrading 30 CAV to VAV fume cupboards

Weather correction was applied to the data to remove gas consumed for heating purposes. Total gas consumed in the period 2012-2013 was 286,934 and in 2078-2019 was 217,500. This is a saving of 69434.69 kWh and equates to £1513.

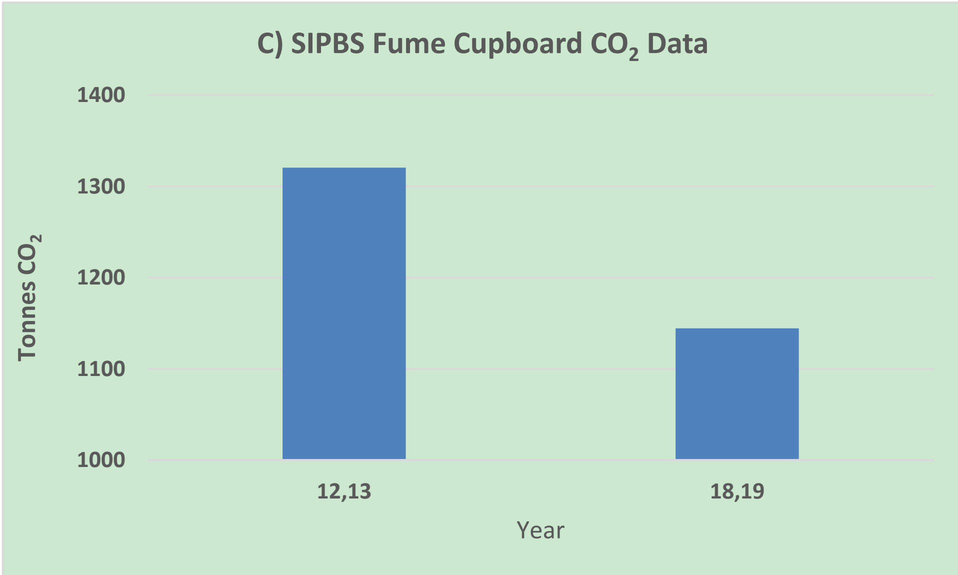

Figure 2c). Amount of CO^2 generated before and after fume cupboard upgrades

In the period 2012-2013 total amount of CO_2 generated was 758,942 tonnes compared to 668,096 tonnes in the period of 2018-2019. This is a saving of 90846 tonnes.

3. The Frequency of Use and Fume Cupboard Sustainability Awareness of Postgraduate Students and Research Staff

To gain an insight into the frequency of fume cupboard use by postgraduate students and research staff and to test their level of awareness of fume cupboards from a sustainable perspective an online questionnaire was conducted. Multiple choice questions that covered aspects of fume cupboard training, frequency of fume cupboard use, sash closure, energy consumption and CO_2 emissions were covered. The questionnaire was sent to three different departments; pure and applied chemistry, pharmacy and biomedical sciences and civil and environmental engineering. In total 161 responses were received of which 97 were postgraduate students and 36 staff.

3.1 Postgraduate Students Fume Cupboard Use and Environmental Issues Awareness

The postgraduate respondents consist of 60 master students and 37 PhD students. Figure 3a shows that 61% of postgraduate students are extensive users of fume cupboards, where 36% use them several times a day followed by 25% that use them 3-4 times a week. Figure 3b shows that 57% received fume cupboard best practice use training prior to use and 53% close the sash after use or have automated sash closure installed. Only 47% of students are aware that fume cupboards are high energy consumers and only 19% are aware that fume cupboards emit CO_2. Finally, only 34% of students were aware of the difference between CAV and VAV fume cupboards.

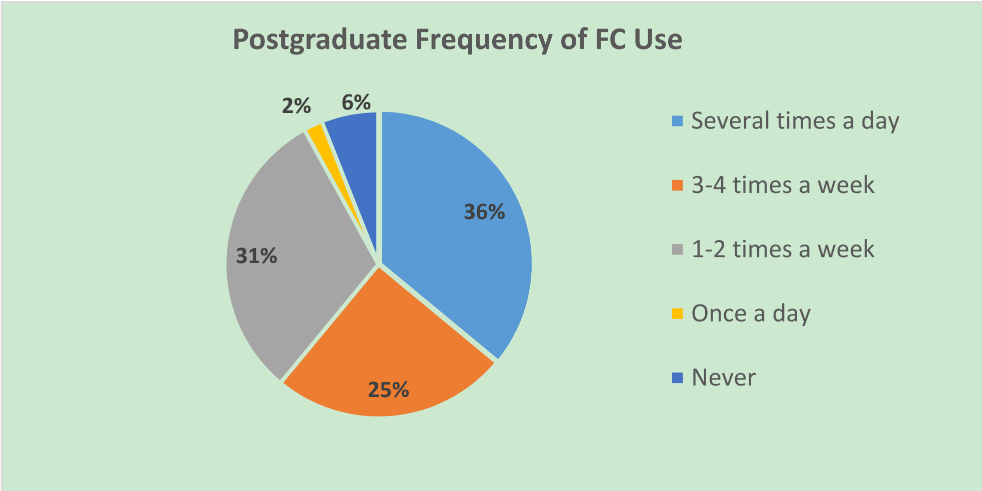

Figure 3a. The dispersion of fume cupboard frequency of use amongst postgraduate students

The questions asked: In 2018-2019 how often did you use a fume cupboard?

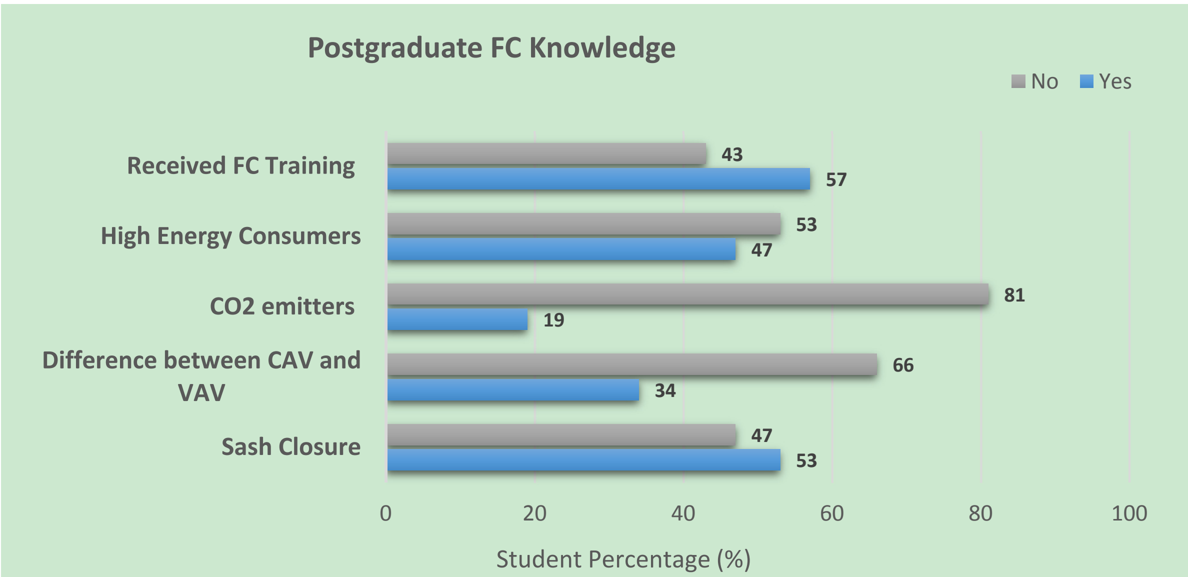

Figure 3b. The level of postgraduate awareness of fume cupboard sustainability related issues

The questions asked: Have you received training on how to use a fume cupboard? Are you aware that FC are amongst the highest energy consumers within a laboratory? Are you aware that FC emit CO_2? Do you understand the difference between a Constant air volume FC and a Variable Air Volume FC? Do you close the sash after using the FC?

3.2 Research Staff Fume Cupboard Use and Environmental Issues Awareness

Figure 4a shows that 38% of research staff use Fume cupboards intensively where 21% use them several times a day followed by 17% that use them 3-4 times a week. Figure 4b shows that 57% have had fume cupboard best practice use training and 54% always close the sash or have automated sash closure installed. Compared to the postgraduate students there is a slightly better understanding of the energy consumption of fume cupboards and their CO_2 emissions with 52% and 29% respectively. However only 27% of staff understood the difference between CAV and VAV fume cupboards.

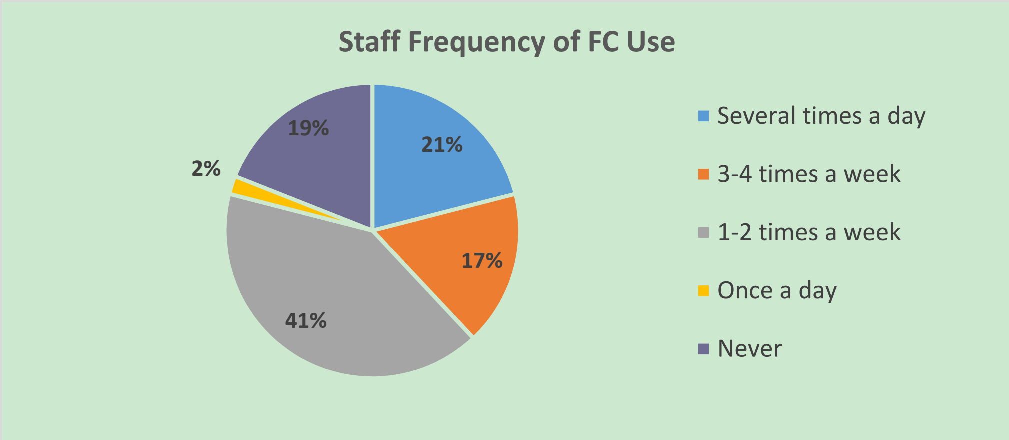

Figure 4a. The dispersion of fume cupboard frequency of use amongst research staff

The questions asked: In 2018-2019 how often did you use a fume cupboard?

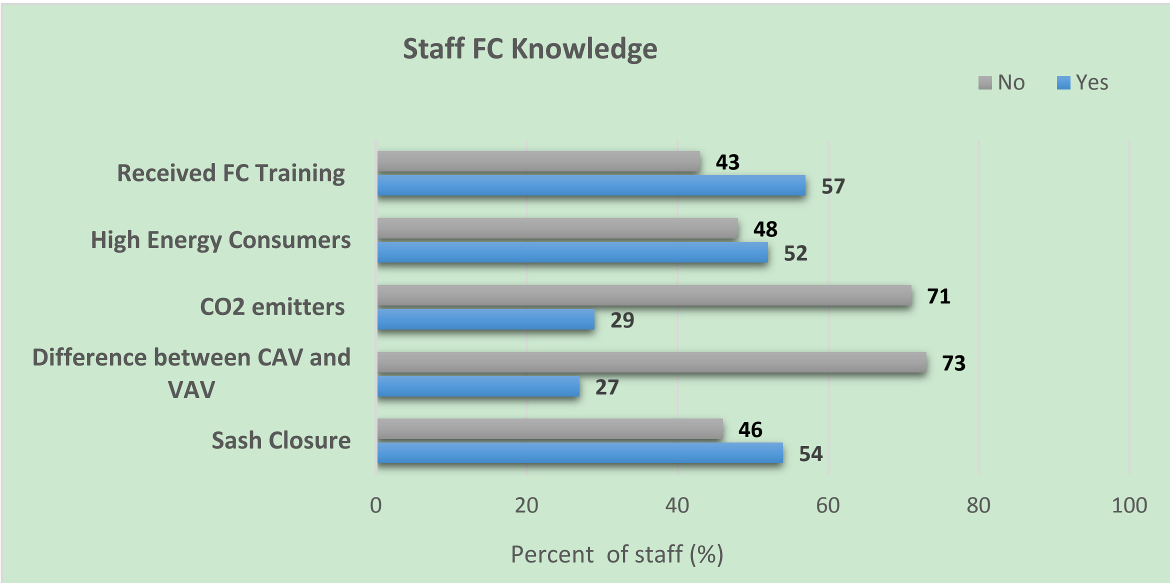

Figure 4b. The level of research staff awareness of fume cupboard sustainability related issues

The questions asked: Have you received training on how to use a fume cupboard? Are you aware that FC are amongst the highest energy consumers within a laboratory? Are you aware that FC emit CO_2? Do you understand the difference between a Constant air volume FC and a Variable Air Volume FC? Do you close the sash after using the FC?

4. Discussion

As the environmental impact of scientific research is becoming apparent across the globe, an increasing number of institutions worldwide are implementing new initiatives to empower researchers with techniques to working more safely and greener (Skuse, 2019). Accredited behavioural change programmes such as "My Green Lab", "Green Impact Labs" and "LEAF" (Laboratory Efficiency Accreditation Framework) work by recommending actions that can reduce waste, water, electricity, plastic and carbon within laboratories (Dittrich, 2015; Sawyer, 2019). LEAF contains an integrated calculator that provides financial and carbon savings when green actions have been taken (Farley, 2022). Other initiatives include global -80°C freezer challenges that run annually; in 2019 over 400 international labs participated with savings of ~2.4 million kWh/year (reduction of carbon emissions by ~1700 metric tons) (SE, 2022). Reducing single use plastic items such as gloves and pipette tips, have also run as successful challenges across many institutions.

At the University of Strathclyde, in order to further help laboratories become greener and safer, we upgraded large amounts of our energy inefficient fume cupboards to more efficient and safer ones. Although savings were achieved, they were not as high as predicted pre-project. Therefore, we sought to gain an insight into the behavioural and operational fume cupboard use by our staff and PhD students. This is because how fume cupboards are operated play a direct factor into achieving maximum efficiency and savings. It was interesting to see that fume cupboards were used intensively with 36% of PhD students and 21% of staff using them several times a day, yet very concerning that nearly half of users were not aware of the high energy intensity of fume cupboards and that only ~ 50% close the sash after use. It was also concerning to learn that only 30% in both cohorts understood the difference between CAV and VAV fume cupboards despite working in departments where both types of fume cupboards are present. These results highlighted a major gap between the use of laboratory equipment and the awareness of their best practice use and their environmental impact. Unless intervention is taken, laboratory equipment will continue being used incorrectly therefore hampering sustainable goals.

5. Conclusion

A middle ground exists between the creation of successful sustainable laboratories from a building and equipment perspective and the correct operations of equipment. It is the norm for students and staff to enter a laboratory and use equipment such as fume cupboards and -80C freezers without being provided with professional training on their best sustainable operations. It is vital that training is provided and made mandatory, this would not only create safer sustainable laboratories but also help reduce the environmental impact of research and help institutions reach their Net Zero goals.

6. Methods

An e-survey consisting of eight fume cupboard use related questions was developed on Qualtrics and sent to all science and engineering departments for postgrad students and research staff to complete. The questionnaire was open for three weeks and all results were collected anonymously. Results were then analysed on Microsoft Excel. A copy of the e-survey questions can be found in the appendix.

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