THE BARTLETT

BARTLETT IAQ ENERGY REPORT

How can reducing energy demand improve Indoor Air Quality

CONTENTS

ABSTRACT

This report will investigate the reduction of energy consumption to improve indoor air quality. Aiming to directly reflect upon the energy usage consumption in UCL Bartlett Institute and report findings on optimising air ventilation and energy efficiency. Through analysing the Bartlett Building's 2020-2021 energy usage during the months of January to December, more time and energy was spent inside in 2021, compared to the activity in the year of 2020.

According to the research, there is a high recommendation of installing natural ventilation, such as opening windows in summer. Though natural ventilation and passive approaches are good they are not always available. The solution is to combine strategic engineering ventilation system as well as including vegetation. This is called the hybrid ventilation system, as it uses mechanical and natural methods in combination.

Through this study it is shown that to reach lower energy usage and increase ventilation in the Bartlett building, architects and engineers must manage air exchange between the inside and outside to bring in fresh air while reducing excess heat or heat loss. Natural and mechanical ventilation have various airflow rates and directions. Also, after SARS-Cov-2, Bartlett must address the indoor air quality (IAQ) to increase cleanliness norms. By monitoring the indoor air quality and employing green spaces to improve visual, thermal, and auditory comfort, a low-energy IAQ programme can be designed. This can be achieved through planting trees and bushes to minimise CO_2 emissions. Plants promote thermal comfort by altering wind direction and speed. Primary studies may reveal which Bartlett rooms have the poorest ventilation conditions. The net-zero carbon initiative may benefit from statistics about Bartlett's energy consumption.

Keywords: IAQ [Indoor Air Quality], CO_2 [Carbon Dioxide], HVAC [Heating, Ventilation and Air Conditioning: 'climate control'], SARS-Cov-2 [Covid]

INTRODUCTION

This report follows a precise methodological approach on how to increase energy efficiency in the Bartlett Building whilst increasing the indoor air quality. First, we must examine the Bartlett Building's energy usage from 2020 to 2021, by using an online engine for viewing energy consumption in UCL's buildings to identify power consumers (fabriq.space, n.d.). Through the conducted examination, 2021 used more energy than 2020 and it was the indoor activities that contributed to energy usage (Gul & Patidar, 2015). As past March 2020 to December 2020, activities were remote due to the covid-19 pandemic.

Heating, Ventilation, and Air Conditioning (HVAC) systems contribute significantly to a building's energy usage. Ventilation is vital to maintaining a healthy interior atmosphere (Chenari, et al., 2016), the publications examined suggest using natural ventilation, such as opening windows in the summer to promote airflow (Schulze & Eicker, 2013). Natural ventilation and passive techniques are beneficial, but not always accessible (Chenari, et al., 2016). A hybrid ventilation system considers the pros and cons of mechanical and natural systems. For instance, an office building's air, floorings, sunlight hours, and daily cooling uptake temperatures all performed similarly. Determining success was more dependent on control settings than on strategy.

To strengthen this statement, architects must regulate the pace of air exchange between inside and exterior to bring in fresh air while removing surplus heat during the winter season or limiting heat losses during the summer season. Natural ventilation requires a different method than mechanical ventilation since flow velocity and direction are unknown (Chenari, et al., 2016). Moreover, IAQ must be addressed at the post-pandemic Bartlett Institution due to increased sanitary standards after SARS-Cov-2. Through monitoring interior environmental quality and deploying green areas to promote auditory, visual, and thermal comfort to the building's occupants, a healthy and low energy wastage IAQ programme may be developed. Adding greenery to Bartlett to reduce CO2 emissions is one approach to use natural ventilation (Sun, et al., 2021). This is possible due to the natural photosynthetic reaction that occurs within plants which naturally removes CO2 from the air.

Finally, vegetation can be one of the many solutions to cooling indoor spaces. Putting plants inside or around a structure may improve thermal comfort, depending on wind direction and velocity. To establish which Bartlett rooms utilise the most energy and have poor ventilation, primary research whilst be undertaken to ascertain the average occupancy level of each room (Gul & Patidar, 2015). Data from research should be maintained as a case study to evaluate the Bartlett building's energy usage and move forwards to the goals for net-zero carbon program.

METHODOLOGY

Utilising the keywords to search in Google Scholar to form the methodology. A range of 20 research papers were analysed. Furthermore, to ensure the relevance of this investigation, that this report will start by analysing the Bartlett Building energy consumption of electricity, fuel, and heat in the years 2020 and 2021 to determine how much energy is used in tandem with the ventilation system and indoor air quality will be investigated in order to further the Bartlett net-zero by 2030 goal.

1. **BARTLETT INSTITUTE CASE STUDY 20/21':** Investigating energy consumption within the Bartlett building in the 2020/21 academic year through looking into information on how much energy was consumed. Ongoing human activities throughout the year will be analysed with respect to months in which the most energy was consumed.
2. **INDOOR AIR QUALITY AND SYSTEMATIC VENTILATION PROGRAM:** Evaluation of the main characteristics of a building life cycle. This is followed by assessing ventilation programs and systems that can be of use to the sustainable program, and exploring how to improve indoor air quality within the Bartlett.

Data collection and configure sourcing type is conducted this research, as there are minimal hours on this report. The research is diluted into summaries that assist in forming a feasible means of improving air quality and ventilation within the Bartlett building. This report focuses on the monthly energy consumption to determine which month uses the least energy or the most to deploy the 'hybrid ventilation' programme.

1. BARTLETT BUILDING ENERGY CONSUMPTION YEAR 2020/21'

Starting off with a review of the overall energy consumption of the Bartlett Building (22 Gordon Street) from the year 2020 to 2021, using the online engine, Fabriq, to pinpoint a demographic of electricity usage (fig. 1).

At beginning of 2020, it can be seen that there was a high usage of electricity, with emissions at *26,172.6 kgCO2*. However, due to covid forcing a remote working environment, there was a decrease from January to April, represented by the reduction in emissions to *9,079.36 kgCO2*, a considerable drop of *17,093.24 kgCO2*. From May to September, emissions did not exceed 15,000kgCO2. Although from October of that year, energy consumption did reach *15,209.79 kgCO2* but afterwards decreased to the 12,000kgCO2 mark in December. This may be due to the initial easing of covid lockdown regulations and subsequent second lockdown, forcing another remote learning environment, reducing human activity in Bartlett. This analysation concluded that there was higher human activity within the building at the beginning and the end of the year 2020.

In 2021, energy consumption was fairly stable from January until June, staying under 15,000 kgCO2 mark. However, there was a jump to 19,000 kgCO2 in July as the pandemic regulations eased, in which emissions nearly reached 20,000 kgCO2 with *19,997.68kgCO2* in October. Energy consumption then slowly decreased to 12,000 kgCO2 in December. In comparison, it can be seen that there was less energy consumption in the year 2020 than 2021. Thus there is evidence that indoor activities contribute to electrical energy consumption (Gul & Patidar, 2015).

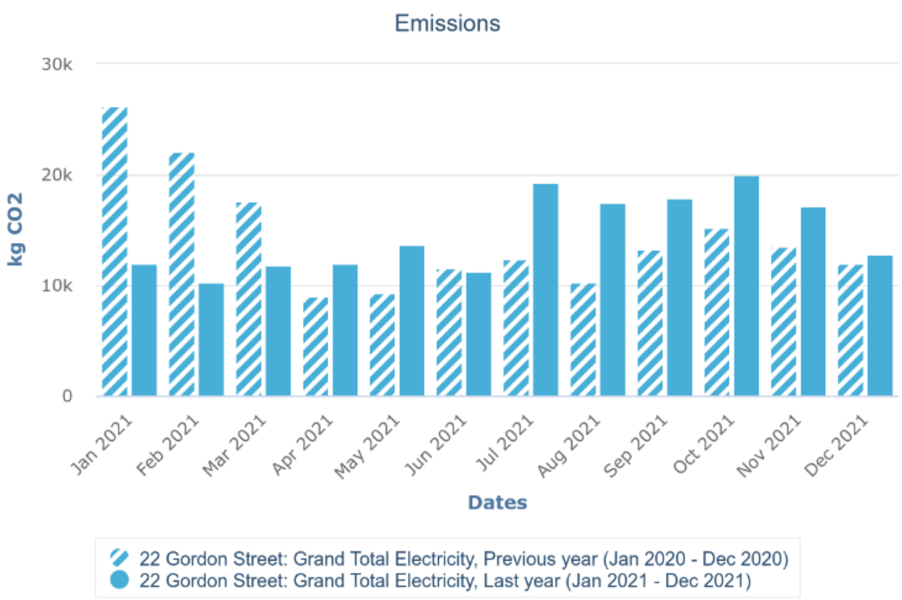

***Figure 1**: Electrical usage (per kg CO2), 2020-2021 comparison (fabriq.space, n.d.)*

Analysis of three major sectors: industry, transportation, and service may be done through the Bartlett building electrical energy consumption case study, however, the data may be deemed too broad and general to achieve this (Pérez-Lombard, et al., 2008). The majority of the energy used by Bartlett's building was generated by human activity within the facility throughout the course of the school hours (Gul & Patidar, 2015). This overall data from Chapter 1 to 1.1 will aid in the investigation of Bartlett's building's air quality and ventilation.

1.1 ENERGY CONSUMPTION WITHIN BARTLETT BUILDING OVERVIEW

By using the Bartlett building's electricity, heat and fuel data as a case-study, major trends and patterns in energy consumption can be discovered and determine an overall energy usage with regard to the efficiency of the ventilation within the building. This will then be implemented through the method adapted from secondary researches (Gul & Patidar, 2015). Firstly, focusing on the term dates of the year 2021 (UCL, 2017):

Term 1 [27/09/21 – 17/12/21], Term 2 [10/01/22 – 25/03/21], Term 3 [25/04/22 – 10/06/21]

The Bartlett Building has *8,454.00 m2* of total floor space, although with time constraints there was not primary research conducted, fuel and heat data from the year 2020 to 2021 is shown in figure 2 below.

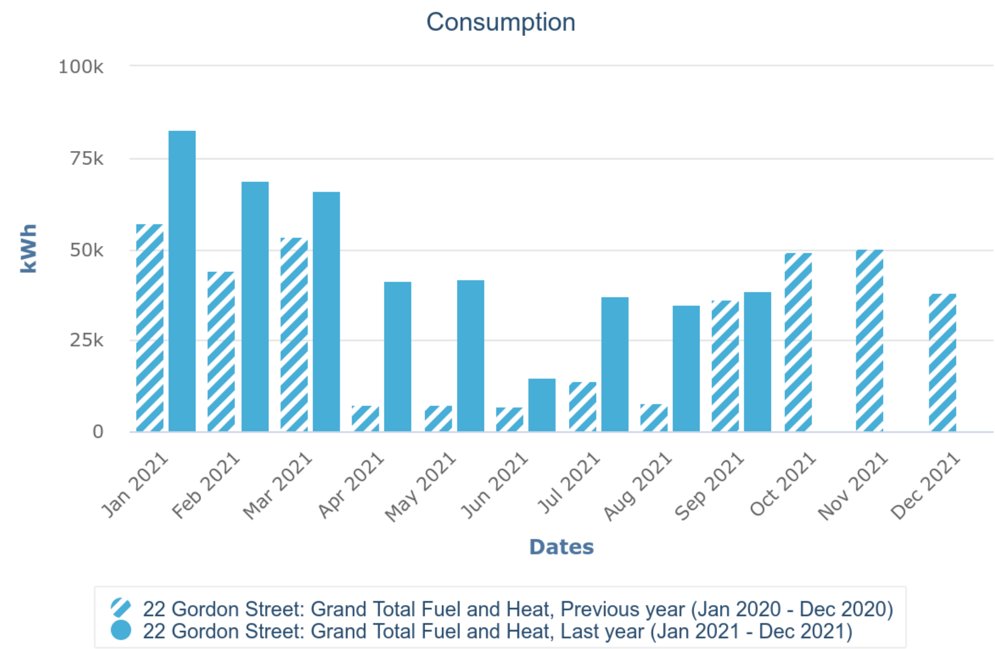

***Figure 2**: Grand Total of Fuel and Heat consumption, 2020-2021 (fabriq.space, n.d.)*

It can be deduced that from the months of January to March, both years had a high usage of total fuel and heat energies, with the year 2020 reaching highest at *57,300.29 kWh* and the year 2021 sored highest at *82,923.43 kWh* respectively. Those months occur in Term 2, thus it can be inferred that in the years 2020 to 2021, Term 2 has the highest human activity within the building.

Further studies towards the evaluation of climate change pathways through the Dynamic Life Cycle Assessment (Negishi, et al., 2019) can be used to determine the amount of overall energy consumption within Bartlett. Data on fan power input and cooling energy usage is essential and can be deduced from the DLCA method in order to improve indoor air quality (IAQ). As evidenced from figure 2, during the time periods from January to March and October to December 2021, time periods are known for the cold winter temperature. Hence more energy is needed to heat the building, and insulation is maintained, leading to potential IAQ concerns as traditionally, air will be circulated within the building. In contrast, during the months between April and September, the weather was hotter, allowing for a lower usage of energy in the building. Additionally, air conditioning, fans, and ventilation will be used, reducing IAQ concerns, but still using excessive energy. In both cases, the ventilation and temperature control must be further optimised to have a year-round good IAQ and low carbon footprint.

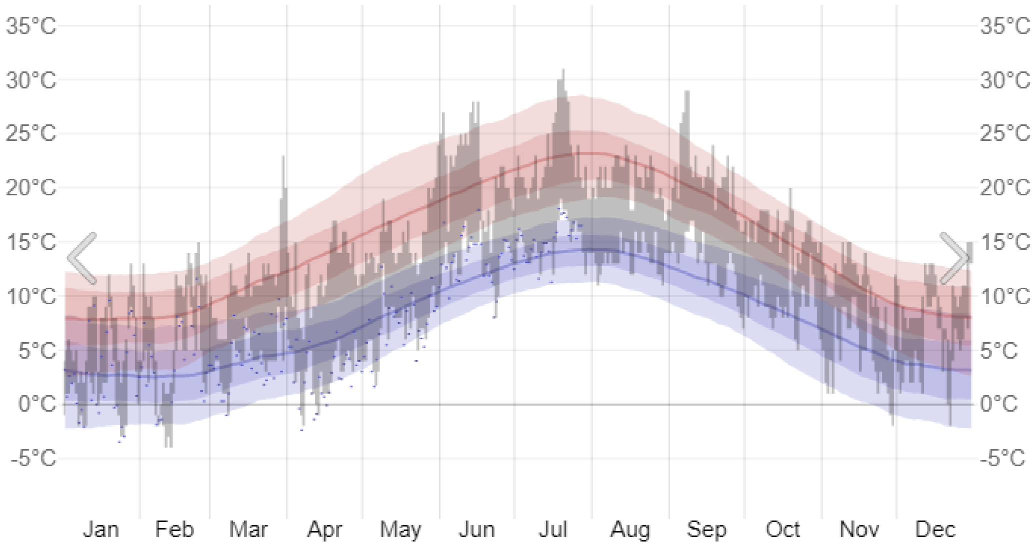

Figure 3: *The daily range of reported temperatures (gray bars) and 24-hour highs (red ticks) and lows (blue ticks), placed over the daily average high (faint red line) and low (faint blue line) temperature, with 25th to 75th and 10th to 90th percentile bands (Weatherspark.com, 2019).*

2. HVAC & VENTILATION SYSTEM EVALUATION

The HVAC systems, namely: Heating, Ventilation and Air Conditioning systems are a substantial contributor to a building's energy consumption. However, ventilation is a critical component of HVAC systems when it comes to maintaining a healthy indoor environment and good IAQ (Chenari, et al., 2016). Focusing on case studies evaluated from cited articles, a systematic approach can be drafted to implement on Bartlett's net-zero carbon goal to reach by the year 2030. The main findings from the articles researched point towards one approach; natural ventilation systems. For instance, in the summer, windows can be opened to increase airflow (Schulze & Eicker, 2013). What can be analysed from the energy consumption in chapter 1-1.1 is that natural air ventilation is feasible during the summer periods, as in the winter, the building will undergo an increase in the case of heating systems. This chapter will focus on the available articles that provide insights on the many ways to reduce energy demand, to increase IAQ and to immediately and effectively improve the ventilation systems.

Whilst natural ventilation and passive approaches are effective, they are not always available nor appropriate (Chenari, et al., 2016). A hybrid ventilation system on the other hand, identifies the disadvantages of mechanical and natural ventilation systems while keeping their benefits in mind. Hybrid ventilation systems for new and refurbished office and educational buildings were the focus of IAEA Annex 35, a project of the United Nations agency for energy policy. It is possible to adjust natural ventilation openings in accordance with IAQ, free cooling mode temperatures, or a combination of both. Controlling temperature set points for room air, controlling floor slab temperatures, controlling internal sunlight exposure hours through windows, and daily cooling energy usage set points were all compared for an office building and found to be very similar in terms of performance. It was found that defining control parameters was more significant than the strategy itself in determining success. The primary goal was to keep internal temperature gains to a minimum while also providing enough air flow rates for appropriate ventilation. The researchers proposed that buildings are not to be overcooled, especially in the transition months of May, June, September, and October, and according to another study conducted in the UK, it was found that sophisticated algorithms for temperature control are to be no better than simple ones (Schulze & Eicker, 2013). Thus, simple strategies can be implemented to produce a high effect.

It is essential that designers consider the issue of determining how to manage the rate of air exchange between inside and out so that fresh air may be brought into an area while also eliminating excess heat during the cooling season or reducing heat losses during the heating season. Since the flow velocity and direction at the apertures are not known in advance, natural ventilation needs a different technique than mechanical ventilation. With regard to how air flows in and around a building, the design decisions that are made have a significant impact on the dynamics of the interior and exterior environments (Chenari, et al., 2016).

As seen in figure 4, it is possible for air to be exchanged between the interior and outdoor environments without the need of mechanical equipment at all. This is also referred to as the movers and shakers of natural ventilation. Because of temperature changes, the density differential between inside and outside air causes thermal buoyancy driven ventilation (Chenari, et al., 2016).

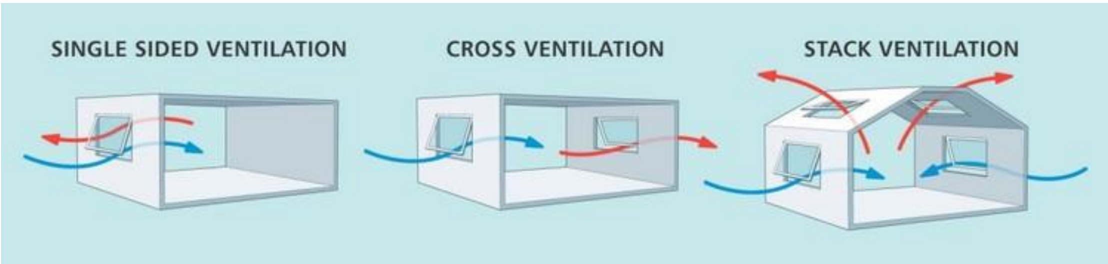

Figure 4: *Natural Ventilation systematic review (ArchDaily, 2021).*

Another concern to pinpoint is that the HVAC system should integrate a monitoring level of CO2 levels, if possible, as one study shows that high concentration of CO2 does impact human decision-making performance (Satish, et al., 2012). Only 5% of the recorded peak indoor CO2 concentrations surpassed 1,000 ppm (parts per million), assuming an outside concentration of 400 ppm, in a representative survey of 100 U.S. workplaces. CO2 concentrations may rise as high as 1,900 ppm during 30- to 90-minute sessions in business conference rooms. In addition to this, a similar experiment has concluded that the higher the CO2 concentration, the higher the indoor air temperature, in contrast to the lower indoor air temperature condition which potentially achieves energy saving of 15% for the acceptable thermal comfort level (Cao & Deng, 2019).

2.1 VENTILATION & INDOOR AIR QUALITY STRATEGIES

Factoring in the fact that there has been an increase in the cautiousness for sanitary requirements within buildings following the Coronavirus Pandemic (SARS-Cov-2), IAQ must be improved and prioritised through strategies that are able to be deployed within the post-pandemic Bartlett Institution. Looking at the main strategy, ‘Hazard Controlling’ (Megahed & Ghoneim, 2020), through monitoring indoor environmental quality and deploying green spaces to increase acoustic, visual, and thermal comfort to the building’s occupier, a healthy and minimal energy wastage IAQ program can be implemented (Song, et al., 2021). The idea of an environmentally friendly strategy is well-known and eco-friendly enough, basic implementation of this system is, for instance; adding vegetation into Bartlett as a way to tackle CO_2 emission is one way of deploying the natural ventilation method (Sun, et al., 2021).

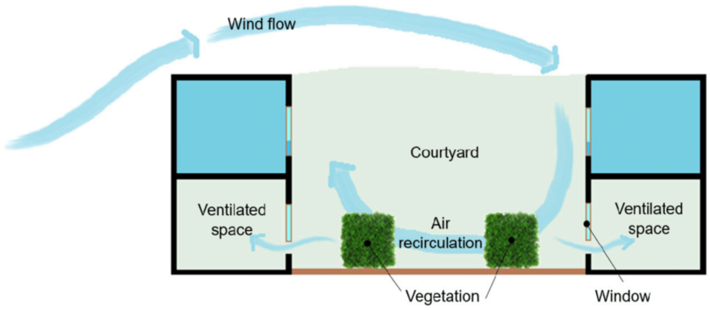

Figure 5: *Stimulation of natural ventilation in a courtyard (Sun, et al., 2021)*

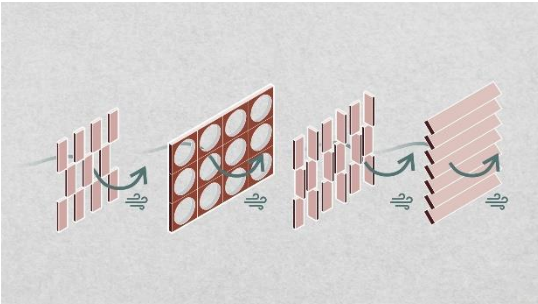

Figure 6: *Partitioning as a method of controlling ventilation motion (ArchDaily, 2021)*

In figure 5, the vegetation resulted in a cooler temperature in both rooms that has the window opened (Sun, et al., 2021). This study indicates that thermal comfort can be enhanced through implementing and installing vegetation within the building or around it, depending on the wind direction and velocity, further research must be conducted to fully grasp how to manipulate this to the highest effect. Furthermore, to gain a better understanding of which rooms within the Bartlett uses the most energy and poor ventilation, primary research can be conducted to determine and pinpoint the specific rooms that can be used as samples and cases of the average occupancy level (Gul & Patidar, 2015). In which the data can be directly stored as case study for further evaluation of the amount of energy used within the Bartlett building. Spacious and wide areas within the building can be enhanced with just a simple installation of a partition that is solely designed to control ventilation, as seen in figure 6.

As a further discussion, the presented diagram (figure 7) is presented to allow for a better understanding of how this hybrid ventilation system can be used to its full potential, this diagram is deducted from the overall research from available articles.

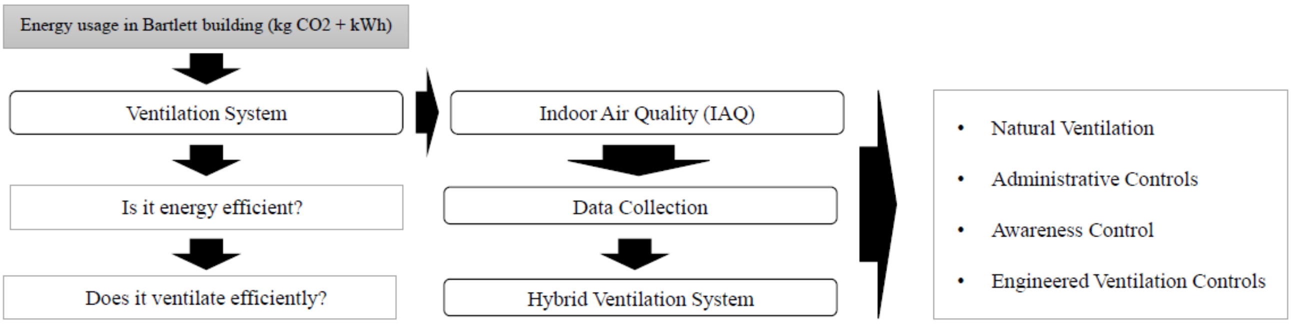

Figure 5: *Analytical Diagram to visualise the process to determine the best way to reduce energy emission and increase IAQ.*

Additionally, administrative and awareness control is also one way to promote reducing energy emissions within the building and allow for a better understanding of the ventilation system in Bartlett, as greater awareness will result in more individuals within the building reducing their contribution to Bartlett's emissions. Strategies in raising awareness on how to increase IAQ can be utilised, also another way is to create and organise design activities for students and staff to participate in envisioning a more sustainable approach to Bartlett, in order to increase awareness of the subject. Activities such as designing indoor structures to install vegetation for ventilation (e.g., wall planters) to increase the purification of air could be one of the many simple ways in raising awareness throughout the building (Susanto, et al., 2020).

CONCLUSION

Energy savings are examined as a means of both reducing Bartlett's overall carbon footprint and a means to effectively improve indoor air quality in this paper's conclusion. Energy-saving improvements at UCL Bartlett Institute from January through to December in 2020-2021, shows that in 2021 the Bartlett Building used more energy as people spent more time within the faculty than in 2020, due to covid remote-working environments. It is also strongly advised that windows be opened to allow natural ventilation, such as in the summer, which will also reduce the need for cooling energy.

A combination of mechanical ventilation and vegetation is proposed, mechanical and natural techniques for ventilation are combined in a hybrid ventilation system. This Research demonstrates that architects and engineers must design and articulate structures that can regulate air exchange between the inside and outside of buildings to bring in fresh air while minimising heat gain or loss from the exterior. Natural and artificial ventilation have different airflow rates and directions, and the interaction between these must be understood in order to design efficient, effective, and functional ventilation.

Some Bartlett rooms may be under-ventilated, according to an investigation. Internal air conditioning, free-cooling mode temperatures, or a combination of both, may be used to modify natural ventilation apertures in a building. Maximum air flow rates for night ventilation were sought while minimising internal gains. Buildings should not be overcooled during the transition months of May, June, September, and October based on a study in the UK.

Hence adaptation of minimal-effort IAQ measures may be accomplished via the use of green spaces. The planting of trees and bushes can help decrease CO2 emissions. Also, to achieve the sustainable criteria, Bartlett must enhance the indoor air quality. Planting vegetation will increase the visual, thermal, and acoustic comfort, and through administrative and awareness raising methods, as well as a more thorough knowledge of the building's energy use, Bartlett's overall carbon footprint and IAQ can be at a more ideal level.

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