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Decarbonising Universities: Case Study of the University of Exeter's Green Strategy Plans Based on Analysing Its Energy Demand in 2012–2020

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Abstract: This study investigates the carbon footprint of the University of Exeter by analysing its energy consumption between 2012 and 2020 to assess its current standing in the process of achieving carbon neutrality. The study then explores the possible methods of reaching this target in line with the University of Exeter's Environment & Climate Emergency Policy Statement. The leading part of the statement is as follows: "All Campus activities/operations shall have a carbon net zero impact and or result in environmental gain by 2030 and aims to be carbon net zero by 2050 (accounting for all associated activities and Scope 3 footprint)". Using methods of energy consumption reduction, a new carbon footprint for Scope 1 and 2 emissions was calculated for the year 2030, which included phasing out oil and gas and swapping out inefficient systems, such as old heating or lighting. This reduced the emissions from 17.24 ktCO_2e to 3.34 ktCO_2e also greatly helped by the reduction in electricity grid conversion factors. The remaining emissions would be reduced further to net zero by on site solar and offsite wind investment.

Keywords: decarbonisation; cleaner production; university; renewable energy; net zero

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1. Introduction

Climate change is arguably the biggest issue faced by mankind today. The release of carbon caused by humanity can be referred to as the carbon footprint that a person, process, institution, or area may have. Following a worldwide effort, countries and individual institutions have made a start towards carbon neutrality, whereby their carbon emissions or footprint is offset by non-carbon emitting energy production, or carbon capture, to become carbon net zero. Carbon neutrality has been a widely discussed phenomenon for some time. The first world climate conference was held in 1979, by which time the physics behind greenhouse warming had long since been understood [1]. Since then, the climate has become significantly worse and with it, the problem has been made more public and efforts to counteract it have taken off. Nowadays it is one of the most spoken about issues concerning the environment, and it has become part of nearly every school's curriculum to allow the future generation to have the best chance at tackling climate change [2]. Countless projects and works have been carried out and written on the phenomenon, and the focus falls on those that relate to universities. Universities have the responsibility to lead the way towards carbon neutrality due to them being significantly energy intensive institutions and as they have significant research capabilities. Most articles state that universities are struggling to stay on track for their proposed emission goals due to their energy intense facilities, and many say Scope 3 emissions are causing many issues given the high density of campus users and as Scope 3 emissions are practically immeasurable, and therefore, difficult to control [3,4]. Out of 20 UK's Russell Group universities, emissions increased for all but two compared to their self-set targets [4]. The whole investigation undermines the effort that universities claim to have made on emission reduction. This helped spark an initial interest in investigating UoE's progress on this matter; 11% of the carbon emissions in the public sector are released by higher education institutions and the governing bodies of HEIs have 'underestimated the challenge of carbon emissions reduction' [4]. There is an irony within the targets set by universities; if low, realistic and achievable targets are set for emissions reduction, the governing bodies are reprimanded for not setting higher goals, yet the institutions that set higher goals have not managed to achieve them [4].

Other than research purposes, universities also create future generations of leaders who will be responsible for putting sustainable change into practice and education [5]. Universities and similar institutions should, therefore, be looking to achieve more impressive targets than those set by the global carbon budget, such as becoming net zero by 2030 rather than 2050 and acting as an example to other institutions.

The energy demand of the University of Exeter is considered as the largest carbon release for which the University is directly responsible. More specifically it covers Scopes 1 and 2 carbon emissions, with Scope 1 being the direct emissions from within the University's boundaries from owned sources and Scope 2 being indirect emissions, largely from purchased electricity. Scope 3 includes indirect emissions that result from the operation of the institution [6]. This can include anything from waste produced by the site, to the emissions released by the manufacture of goods used on site, to emissions released by commuters travelling to the University site. The difficulty with managing Scope 3 emissions is that the University often cannot directly control them but only encourage their reduction. Furthermore, they are often unquantifiable. Therefore, this study concentrated to a greater extent on investigating Scope 1 and 2 emissions and how to reduce them by analysing available data, and for Scope 3, discuss incentives for reduction. This is designed to show whether and how the University is able to complete its goals of becoming operationally net zero by 2030 by reducing Scope 1 and 2 emissions and net zero including associated and Scope 3 emissions by 2050.

Investigated areas and associated data will fall within certain boundaries. The first boundary is created around Streatham Campus as shown by the campus map in Figure 1. The University of Exeter (UoE) has three main campuses, however, in this study, only the Streatham Campus will be considered as it covers over 85% of University ground and consumption, with the smaller two campuses sharing the other 15%. The breadth of the data set available in relation to the Streatham Campus data make the analysis of this campus more accurate and realistic. The second important boundary surrounds Scope 1 and 2 emissions data. In order to conduct the most accurate study, only buildings and operations run directly by the University will be considered, as available data is more reliable where it has been collected and made available by persons or teams associated directly with the University. This, therefore, excludes INTO and UPP run and owned buildings. INTO is a joint venture with the UoE to aid international students integrate into English speaking programmes and UPP is a partnership programme that constructs and operates residential buildings for universities. They are both separate entities to the University. Often when considering the most recent data, 2018/19 will be used as 2019/20 was affected by COVID and does not represent a realistic normal functioning year. The reason for referring to years in such a way as 2018/19 is to show the academic year, starting in August 2018 and ending in July 2019.

In analysing the data, several clear errors were evident, especially in the gas and electricity data. These were clear anomalies with a few possible causes. The University relies on multiple methods of data collection, manual reading per day, per month, per year, or automated readings using different systems. This allows for a systematic error at times. For example, there have been errors of factors of ten larger than mean results which might be human error or technological error, and there have also been results in data showing zero, which could either be readings being missed (not taken by a person) or a meter fault. To overcome the issue that these errors cause, anomalies were discussed with relevant University persons and when confirmed. Zero errors have often happened more recently, suggesting that COVID may have had an impact on readings being taken. COVID has impacted the University's usage of energy and carbon footprint, showing an unrealistic recent year. As COVID subsides, usual usage of energy will resume, therefore, findings purely found upon investigations based on the 2019/20 year (the most recent in data sets) have not been solely used. When the 'most recent year' is discussed, it will be based on 2018/19 to prevent COVID from having an impact on conclusive results. A better energy consumption monitoring system is needed and will aid future research.

Figure 1. University of Exeter's Streatham campus map.

The Literature Review will portray the reasons behind the study including researched theories of decarbonisation and carbon free generation. The Methodology will summarise the process of the project and give an insight into how data were collected. The Analysis section will show data and findings from UoE, while the Results section will display possible reductions in data introduced in the Analysis section. The Discussion will show compiled reductions with the results overview part acting as a conclusive section for the Results and Discussion. The Conclusion will provide the suggested answers to whether and in what manner the UoE might achieve its goals by summarising the aims and findings.

2. Literature Review

2.1. Scope 1: Direct Emissions Reductions (Burning Fuel for Heat or for Vehicles)

2.1.1. Gas

The main consumers of gas at universities are the systems used to heat their extensive building area. Using gas for heating is beginning to become unnecessary given that it is a fossil fuel, and other methods of heating buildings now exist, such as ground or air source heat pumps and infrared heaters. These use considerably less energy to heat the same amount of space and as the grid increases its portion of carbon free electricity generation, it seems best to turn to electricity for heating in the future. Gas as of 2025 will also be banned from use for heating in new homes, and gas-fired boilers will be largely phased out by 2033 in all homes [7,8]. Gas boilers are around 85% efficient, which suggests that if 100 kW of gas is burnt then around 85 kW of heat will be produced, whereas heat pumps are 300% efficient, 100 kW of electricity (to pump the air or coolant) would produce 300 kW of heat [9]. Grid generated electricity currently produces 0.23314 $kgCO_2e/kWh$ and grid gas 0.20374 $kgCO_2e/kWh$ [10]. These conversion factors are from June 2020 and since then, the carbon free portion of the grid has continued to increase and is forecast to increase further [11]. Using the data from above:

$$1\text{ kWh heat (gas boiler)} : \frac{0.20374}{0.85} = 0.2397\text{ kgCO}_2\text{e} \quad (1)$$

$$1\text{ kWh heat (heat pump)} : \frac{0.23314}{3} = 0.0778\text{ kgCO}_2\text{e} \quad (2)$$

$$\frac{0.2397}{0.0778} = 3.08 \quad (3)$$

This shows that the heat pumps emit 3.08 times less CO_2 than the gasfired boiler shown in Equation (3), by Equation (1), for the emissions of a gas boiler, being divided by Equation (2), emissions for a heat pump. The heat pump, running on electricity, is clearly a cleaner method of producing heat due to its enormous efficiency. This is possible as the only fuel (electricity) it requires is consumed to pump the air or coolant medium through the system and into the building. The air gains energy (heat) from a coolant being pumped through a low-grade source of thermal energy, such as the ground, air, or water [9]. Gas boilers, on the other hand, burn gas to acquire all the necessary energy. Infrared heaters are growing in popularity due to their relatively low cost and high efficiency. Heating solid objects or people instead of the air in a space, which may escape, trumps the efficiency of a standard convection wall heater. An infrared panel is generally 40% of the size of a convection heater, and therefore, 250% efficient in comparison [12]. Infrared heaters also heat up quickly which would suggest further saving in electricity and carbon emissions. Infrared heaters are efficient but not as much as heat pumps. They are, however, far cheaper. Heat pumps can cost around £20k depending on their size and are difficult to install in already standing buildings [13]. Infrared heaters are, therefore, very useful in quick and cheaper renovations. Heat pumps can, however, also be combined with current water heating systems, and heater size will have to increase to allow for a larger transmission of heat energy within the building, but the majority of in-building heating infrastructure can stay in place [14].

2.1.2. Vehicle Fleet

The other Scope 1 emission that an institution is directly responsible for is that of its vehicle fleet. Most institutions, and certainly universities, have a fleet of vehicles that aid the day-to-day operation of the site. Reducing vehicle emissions has been a focus for some time as road transport accounts for nearly 30% of all emissions in the UK [15,16]. The vehicle industry has always been under fire from lawmakers. The EU emissions target of 90 g/km for 2021 is putting automotive companies under great pressure to develop and build EV versions of their flagships [17]. There are, therefore, countless models of vehicles of all classes, other than those that include specialised equipment or machinery, such as tractors that can replace current diesel or petrol vehicles. Universities have already begun to adopt EVs and, as of 2018, the average proportion of EVs in a university vehicle fleet has increased to 14.9% [18]. Given the variety of EVs on the market, there is scope to increase this percentage significantly.

2.1.3. Oil

Oil is beginning to be considered an unnecessary fuel for energy production or domestic use: all its uses can be met using cleaner methods. According to renewable heating suppliers, oil, like gas, will most likely be banned from heating use in new build homes from 2025 [19]. However, according to fuel distributer CPS, these are false claims [20]. There appears to be a disparity between what is being said about the future of oil boilers. The difficulty comes for homes and buildings that do not have the correct infrastructure or funds to install more capital-intensive alternative options, yet a university with the ability to step away from oil should do so. Only 6% of UK homes now use oil boilers [21], suggesting that it is very much possible for an institution with advanced infrastructure to remove oil as a fuel.

2.2. Scope 2: Reductions Downstream Activities' Emissions

There are many ways in which electricity is consumed in an institution, such as UoE. Unfortunately, many of them are required for the function of a university and are, therefore, impossible to phase out. There are, however, some areas that should be looked at. Unnecessary use of electricity includes outdated technologies, such as electric storage heaters and incandescent bulbs [22]. Further improvements can be made, such as close control of lighting timetabling or controls and voltage optimisation for building and building standards [23]. Introducing smart meters or technologies that turn off appliances, such as fridges, at peak grid consumption times will aid the grid shift usage away from traditional peak times, which are often aided by fossil fuel electricity generation.

Buildings Standards

The quality of a building plays a large role in its consumption of energy, causing both Scope 1 and 2 emissions. According to the World Watch Institute, buildings are responsible for 40% of world energy consumption [24]. This includes the whole life cycle of a building, including construction and demolition. Buildings are often graded on their sustainability or efficiency: one used at the UoE is known as the BRE Environmental Assessment Method (BREEAM). It includes management, energy, health and wellbeing, innovation, land use, materials, transport, pollution, waste, and water. Many of these have a direct impact on carbon emissions. The system grades a building with a certain status, for example, BREEAM Excellent status is the top 10% of buildings [25]. Another popular standard used is the Passivhaus standard. Passivhaus requires a building to be completely insulated; heat loss through surfaces (walls, doors, windows, roofs, and floors) costs a building a lot of energy. If not insulated properly, windows and doors can be responsible for the loss of 40% of a building's heat, walls 35% and roofs 25% [26]. Buildings built before 1990 can be as little as 50% as efficient as ones built today [27].

2.3. Scope 3: Reductions Upstream Activities' Emissions

Scope 3 is considered the most difficult to manage due to the issues of procurement and is, therefore, also difficult to reduce. This is especially noticeable on a university campus used by a huge number of people, all of which have a Scope 3 impact in some way. The only emission that can be procured accurately, by using respective tonnage and disposal methods, is waste.

Managing waste is a frequently disputed topic among the public [28]. There are many forms of waste, which mainly fall into the two categories of recyclable and non-recyclable. Recycling initiatives have existed for a long time and will continue to grow and become more refined, such as aiming for closed loop recycling to decrease remanufacturing. The more recently defined problem arises from waste that cannot be recycled. Every person can envisage landfill sites crawling with bulldozers and swarmed by birds or incineration plants feeding billowing black smoke into the atmosphere. These were serious issues that needed to be overcome as the world grew in population and in turn waste and associated CO_2 emissions. Waste to energy plants (WtE) or energy from waste (EfW) offers a disposal method that claims to have a negative carbon footprint [29,30]. WtE plants operate by collecting, drying and incinerating waste in a furnace that heats a water jacket for steam turbine or direct heat use. Waste gases are physically and chemically filtered so that the only released gas is water vapour. Leftover ash and filtrates are used in different applications, such as building blocks [31]. The other method is using anaerobic digestion plants (AD plants), which operate by breaking the waste down using bacteria into biogas. The leftover sediment is often used as fertiliser, and the gases produced are not released into the atmosphere, but are used to generate electricity or are fed into the gas grid. Theoretically, only incombustible substances and non-foodstuffs are an issue if everything else can be converted into energy when disposed of with very low emissions.

2.4. Alternative Generation (Carbon Negative)

To this day many renewable or carbon neutral methods of generating power have been created and put into use. All these methods, however, require the fabrication of materials and construction, all of which still release emissions. A study published by Nature Energy states that only three methods have very low life-cycle emissions: nuclear, wind and solar. They project that by 2050 the aforementioned will have life-cycle emissions of 3.5–12 gCO_2e/kWh unlike hydropower and bioenergy, which have much higher emissions of ~100 gCO_2e/kWh [32]. This may be hard to fathom, however, wind and solar require little construction and generate an average amount of electricity, and nuclear has a large carbon emission cycle due to construction, material requirements and maintenance but generates a huge amount of carbon free energy, which offsets the carbon emissions. Hydropower and bioenergy do not create as much energy compared to their material, construction, and maintenance impact. Of the three low life-cycle emitters, solar and wind are considered the better options due to the controversy over nuclear power. This includes scepticism over its safety, as history would support, which includes operational danger, nuclear waste, and their huge cost of construction and upkeep [33].

2.4.1. Wind

Wind power generation has increased significantly over the last ten years. Table 1 below shows the increasing share of electricity that it provides the grid.

Table 1. Wind generation as percentage of grid electricity [34].

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Onshore	1.9%	2.9%	3.4%	4.7%	5.5%	6.7%	6.1%	8.5%	9.1%	9.9%
Offshore	0.8%	1.4%	2.1%	3.2%	4.0%	5.1%	4.8%	6.2%	8.0%	9.9%
Total	2.7%	4.3%	5.5%	7.9%	9.5%	11.8%	10.9%	14.7%	17.1%	19.8%

Studies show that in 2020, 24.8% of UK electricity was produced by wind [35]. The UK clearly has the ability to harness a huge amount of wind [36]. Figure 2 shows vast areas of high yearly mean wind speed; onshore and especially offshore surrounding the UK. Figure 3 shows the mean wind speeds surrounding Exeter (marked with a black star). Mean speeds of approximately 8 m/s can be seen on the coast, which quickly climbs to over 9 m/s offshore. This suggests a possible wind intensity of 650–950 W/m^2 (the availability of energy at a location for conversion by a wind turbine) [37]. Wind will continue to play a major role in UK renewable generation and offers a great carbon free option (offsite) for the UoE, with only one setback. The UK grid will struggle to cope with intermittent power generation, which is the case unfortunately with energy generated by the natural surroundings. If the UoE were to be completely reliant on such a resource it might have to invest in onsite energy storage to store energy at times of peak generation to be used during lulls in generation.

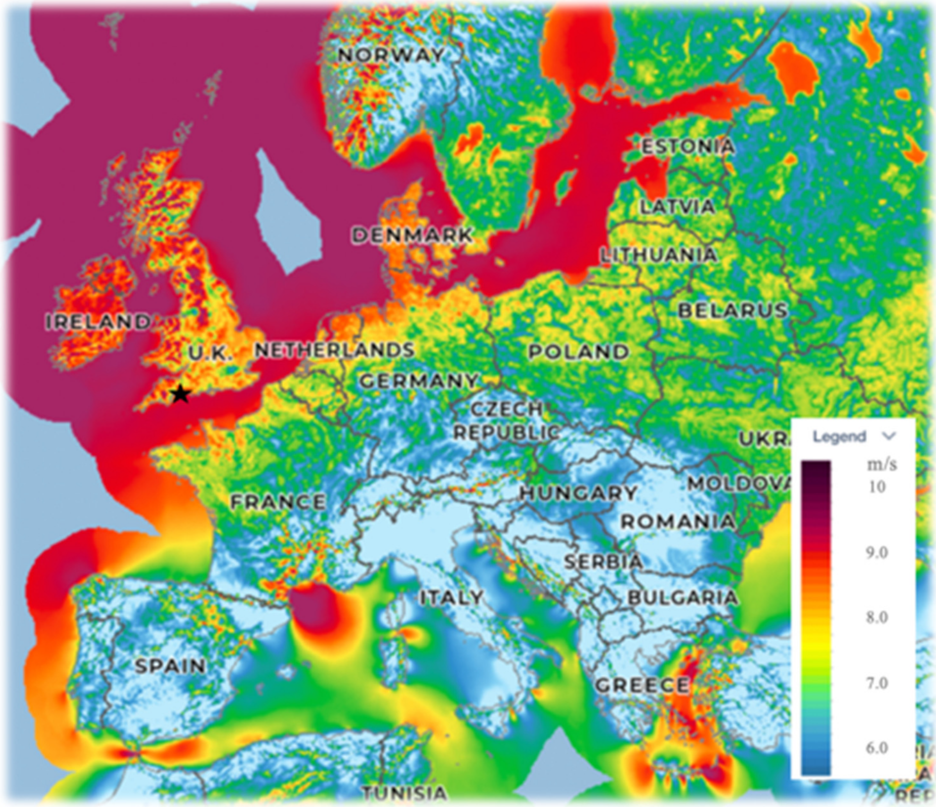

Figure 2. Mean wind speed Europe [38].

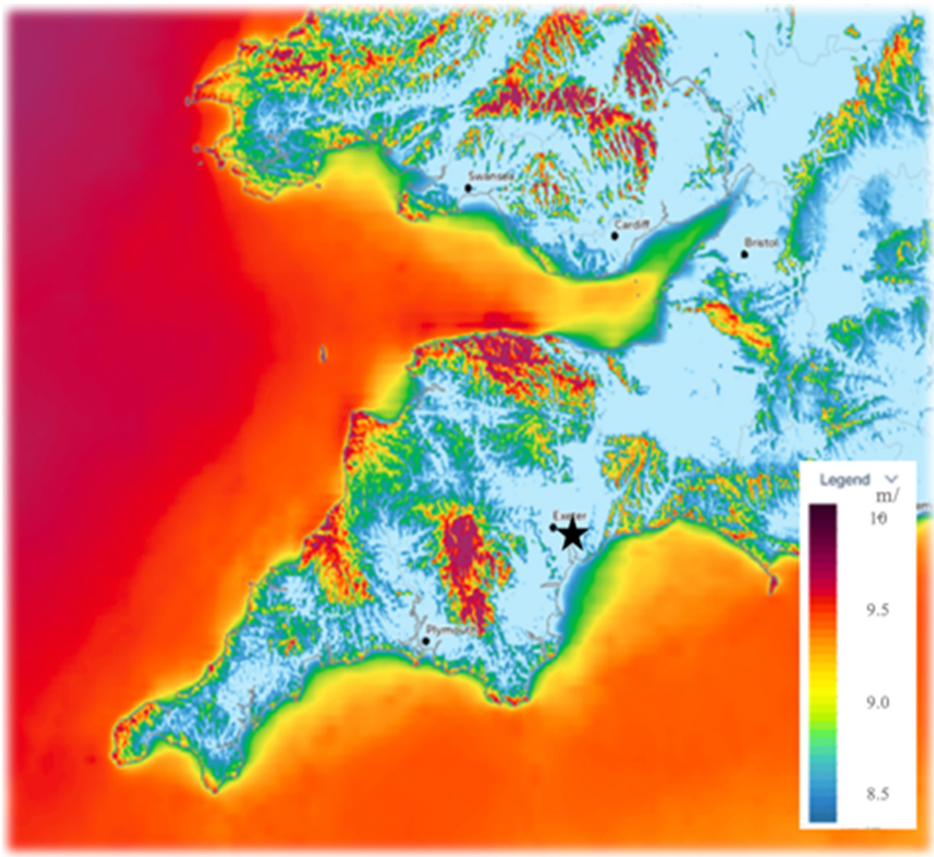

Figure 3. Mean wind speed of the South West UK [38].

2.4.2. Solar

Solar is not as productive in the UK as wind, providing under 4% of grid electricity as of 2019 [39]. This is made clear by the solar intensity maps shown in Figures 4 and 5. The legend suggests intensities of approximately 1000 kWh/kWp around Exeter, which is at the top end in the UK, but very little compared to the rest of Europe and indeed the world. Solar has, however, become very cost effective and is viable for implementation on Streatham Campus, unlike other renewable and carbon free methods of electricity generation. Due to the high building density at universities, roof space is plentiful, and therefore, many universities have already adopted large scale solar projects. The University of Sussex now has over 3000 panels, which provides them with 5% of their required electricity (777,000 kWh of electricity per year), and they are also looking to continue expanding further in the short-term [40]. Companies, such as Solarsense are encouraging universities to partner with them through a power purchase agreement, which has the potential to reduce the cost of the panels, as they have done for Nottingham with a 203,000 kWh/year installation and others [41]. Like wind, PV generation is dependent on the weather and does not generate after dark in winter meaning, therefore, that storage would be recommended for spells of low generation or peak demand.

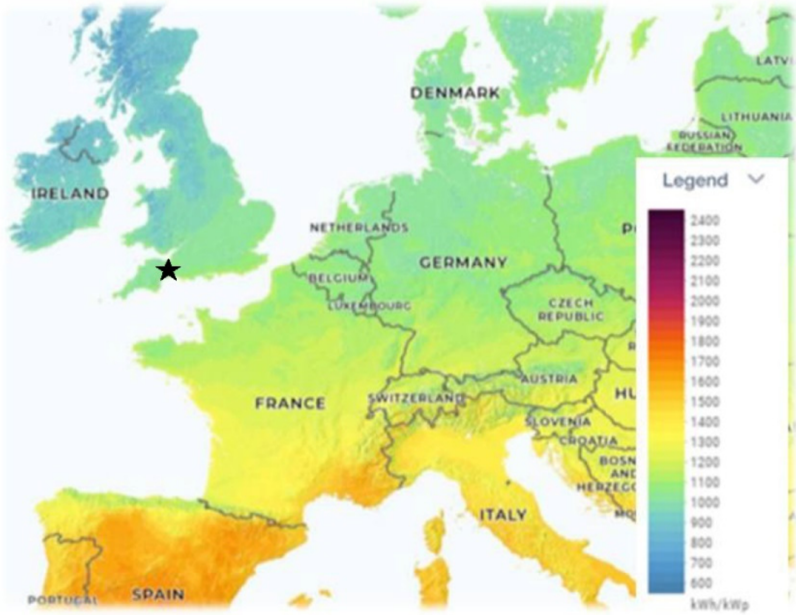

Figure 4. Solar intensity Europe [42].

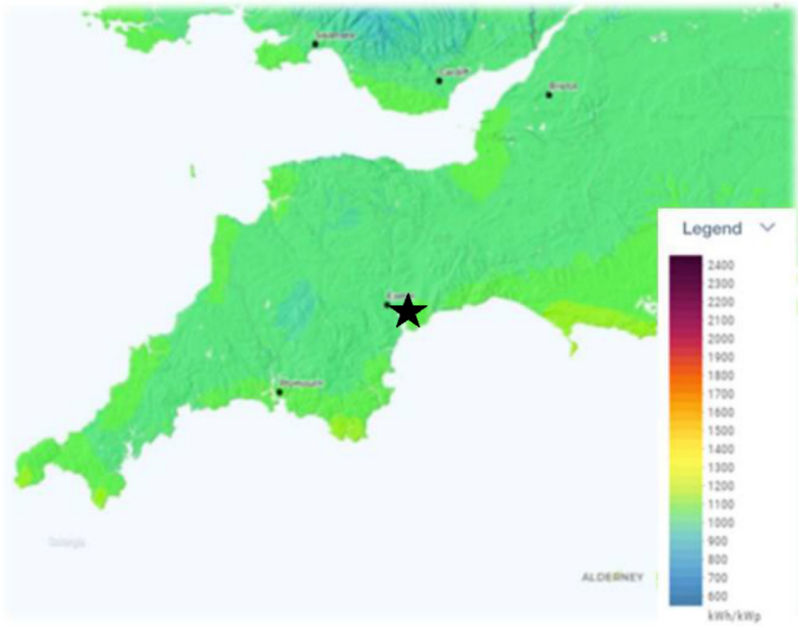

Figure 5. Solar intensity South West UK [42].

3. Methodology

Data Collection and Compilation

The energy consumption data of the University of Exeter were acquired (responsible for Scope 1 & 2 emissions) between the start of the 2012 academic year to the end of the 2019 academic year (2020). Raw monthly data were collected for the gas and electricity consumption of the whole university and of each individual building. Regarding Scope 3 emissions, data on waste was available, however, due to procurement issues, data for other types of Scope 3 emissions were not available. Pure consumption data were not of great use as buildings differ in size and use, and therefore, could not be fairly compared. Further research was conducted into the building types and gross internal areas (GIA), so as to better compare and investigate energy consumption. Residences were analysed by GIA alongside buildings and on their own by number of residences. The following formulae were used to compare buildings.

$$\text{Residence Comparison (kWh/person)} : \frac{\text{Consumption}}{\text{Number of Residents}} \tag{4}$$

$$\text{Building Comparison } \left(\text{kWh/m}^2\right) : \frac{\text{Consumption}}{\text{GIA}} \tag{5}$$

When showing data graphically these are shown either per year or per month. Using the above, it could be deemed whether or not buildings are efficient or need refurbishment or change. It also allowed the smaller but less efficient consumers to be highlighted, unlike graphs of gross consumption which would only show the largest buildings. The highest consumers were shown graphically to show past trends, which meant the graphs were clearer due to fewer data sets. The remaining consumers were shown in tabular form in order of energy intensity (per m^2) in 2018/19, and past data were also investigated to validate that the 2018/19 data was a usual year, as anomalies had been found.

The vehicle fleet could be investigated to obtain emissions for each vehicle model but due to the lack of data on the distance the fleet drives in the certain time period, total emissions per unit time could not be calculated, and therefore, emissions per km were shown then compared to a potential new fleet with EVs in place of emitting vehicles. It was, therefore, possible for a percentage reduction to be formulated. Regarding Scope

3 emissions, data for waste was shown in chart form. This clearly demonstrated not only the greatest tonnage of waste by type but also what caused the largest release of CO_2 emissions.

With data on buildings compiled, the results had to be discussed, which required further research into each building (including residences). This included finding construction dates, refurbishment history, heating type, faculty type and condition. This information was made available by members of the UoE energy team and by the University website. This helped explain the results and directed the next step of reducing consumption. This would be most relevant for inefficient buildings; buildings that have no reason to have such a large consumption per m^2 or per resident. Buildings with poor insulation for example would fall into this category as they would consume significantly greater amounts of energy to create sufficient heat. Some buildings on the other hand are fully dedicated to research and lab space which house energy intensive equipment, and such spaces with high consumption are understandable and acceptable. Areas of poor efficiency or unnecessarily high consumption were brought to light, and methods of reduction were researched that were applicable to said locations. These reduction methods included phasing out gas and oil for heating and implementing carbon free heating methods, regulating temperature, improving buildings standards, such as insulation, introducing LEDs and removing any unnecessary consumption. For the most part of Scope 3 emissions, the only way to reduce their amount is by raising awareness so that the users of the campus have a smaller carbon footprint. The UoE has some direct control over Scope 3 including methods of waste disposal, and associated data have been acquired and shown. Alternative generation included researching viable options for either onsite renewable generation of electricity or investment into or partnering with offsite renewable generation. The reason for looking into renewable generation was to offset the remaining carbon emissions from purchased electricity and Scope 3 emissions. The UoE's Streatham campus could never be carbon free as it will always require electricity and its users will always have a carbon footprint, however, small that may be. The research was, therefore, conducted into the amount necessary to offset remaining emissions using wind generation and PV generation.

4. Analysis

4.1. Scope 1

Figure 6 shows yearly gas consumption per m^2 for the University of Exeter buildings. To increase clarity only the top quartile of consumers are shown in order of the highest consumers in 2018/19 as shown in Table 2. Cornwall House pool is not shown in Figure 7 as it significantly decreases clarity due to its consumption being so high. The outdoor pool cannot meet Passivhaus standards for insulation, and its consumption, therefore, does not come as a surprise, however, the efficiency of the current system should be inspected. Given water is much more efficient to heat than space (air), heat pumps for swimming pools can in fact reach higher efficiencies up to 500%, and therefore, such an installation should be considered [43]. Indoor pools should always be considered too as they have twice the efficiency [44]. The 2018/19 spike in orange occurs in Hope Hall. The data for Hope Hall is an anomaly as monthly readings show no data for the entries leading up to the spike and too little data afterward. Other than the anomaly, the consumption of Hope Hall has dropped to 100 kWh/m^2 since being retired as a residence in 2014. The remaining buildings all consumed over 200 kWh/m^2 in the academic year 2018/19, many of which may need attention or renovation. Estates Service Centre uses significant amounts of gas per m^2 as it includes heated greenhouses. The centre, according to information from the UoE, was built in 1960 and is in poor condition, which suggests that the building may be very inefficient to heat, hence the high load of gas that is required. The next highest is Lafrowda House, which has a dip due to zero consumption between July 2015 and September 2016, which suggests the metering method needs to be updated. Data from 2018/19 onwards also seems to have decreased, most likely due to COVID and reduced use. The building is in good condition, however, was built in 1890, and therefore, may have an inefficient boiler and most likely poor insulation. Geoffrey Pope follows with yearly totals fluctuating around 500 kWh/m^2.

This is a large amount but the building houses 4800 m^2 of lab space, much of it equipped with gas taps. Yet the building is old, having been built between 1960 and 1979 and is in average condition, so should be investigated more closely, especially as the building uses the most gas overall as it is one of the largest. Hatherly has been quite consistent over the last 8 years and is among the highest consumers, most likely as it was built in 1952 suggesting poor insulation; its condition as of 2013 was considered average. This should be updated although unfortunately it is locally listed, therefore, changes to the building are more difficult. Biosciences Greenhouse consumes a great deal of gas as it requires constant climate control, including high temperatures and consistent ventilation. Its use should be investigated, perhaps resulting in downsizing. The Peter Chalk Centre was not expected to have such a high intensity as it was built in 1998 and houses mainly lecture theatres. However, it does also contain a café which may consume a significant amount of gas. Unfortunately, specific data for the café was not available. Cornwall House is host to numerous different areas including a nightclub, a diner and study space, yet it was built in 1971, therefore, may contain inefficient heating or ventilation systems and have poor building standards. Reed Hall was constructed in 1867 and is primarily used for hosting events. Its early construction and large open areas surrounded by large windows suggest the building may require high gas intensity to remain warm. Unfortunately, as a Grade II listed building, extensive renovation may be difficult, however, improvement of building standards should be investigated. The remaining buildings are shown below (excluding residences), in Table 3. The last building shown is the Harrison building, which consumes a significant amount of oil for heating: 110,157 litres. Using conversion factors this would be the equivalent of 183.78 kWh/m^2/a, which would put the building among the leading buildings for energy consumption intensity. The Harrison is an old building constructed in 1968 with poor building standards. The building needs immediate attention, first to stop the use of carbon intense oil and to improve building standards, such as insulation.

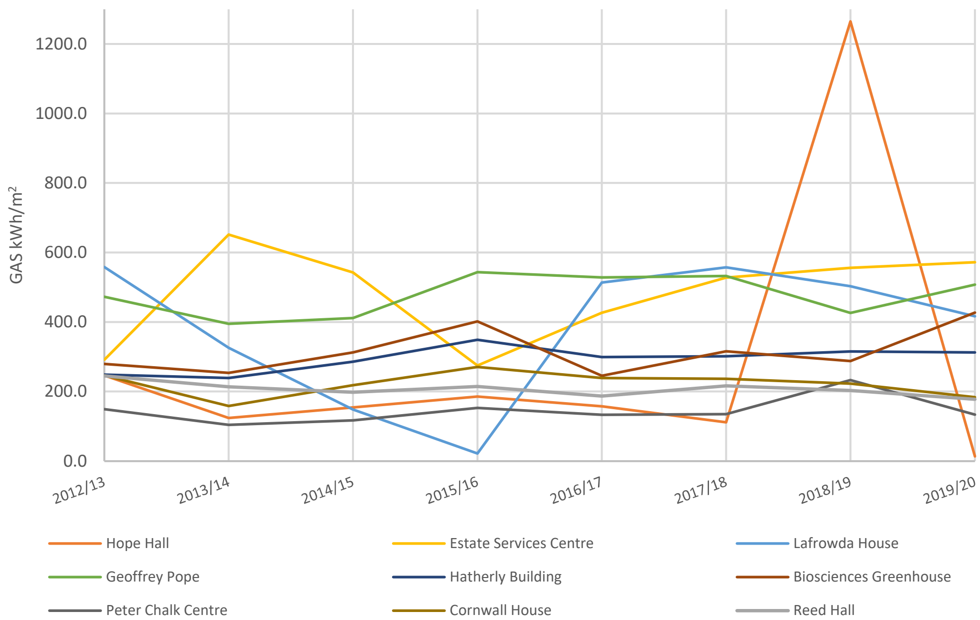

Figure 6. Yearly gas consumption in UoE buildings.

Table 2. Electricity intensity, 2018/19.

Building Name	Gas Intensity 2018/19 (kWh/m^2/a.)
Cornwall House Pool	2012.4
Hope Hall	1265.1
Estate Services Centre	555.9
Lafrowda House	502.7
Geoffrey Pope	426.3
Hatherly Building	315.4
Biosciences Greenhouse	287.6
Peter Chalk Centre	233.1
Cornwall House	222.9
Reed Hall	203.1

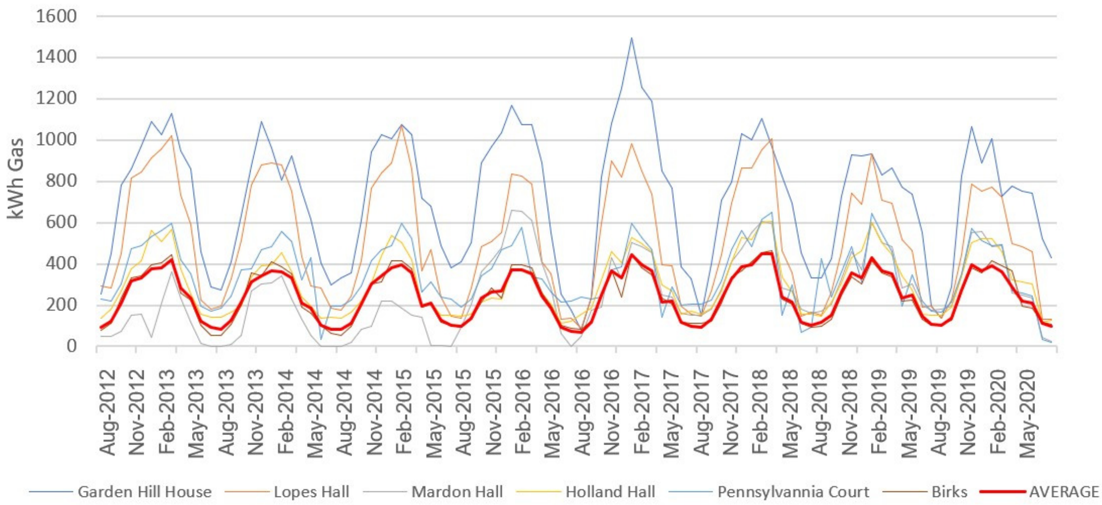

Figure 7. Gas per capita per residence (highest consumers).

Table 3. Gas intensity among University of Exeter's buildings.

Building Name	Gas 2018/19 kWh/m^2/a.	Building Name	Gas 2018/19 kWh/m^2/a.
Henry Welcome Building for Biocatalysis	156.5	Queen's Building	83.8
Newman Building	145.8	Xfi Building	70.8
Living Systems Building	140.6	Streatham Court	70.1
Forum and Forum Library	138.3	Building: One	66.0
Changing Pavilion (Hockey Pitch)	135.9	Clayden	65.4
Washington Singer	120.2	Kay House	62.4
Alexander Building and Thornlea Complex	108.5	Sports Hall	60.8
Knightley	108.1	Old Library	60.4
Amory Building	106.9	Lazenby	56.7
Clydesdale House	105.7	Russell Seal Fitness Centre	50.8
Devonshire House	100.8	Institute of Arab and Islamic Studies	47.7
Reed Mews Wellbeing	100.5	Great Hall	35.8
Physics Building	93.5	Sir Christopher Ondaatje Devon Cricket Centre	35.2
Laver Building	90.7	Higher Hoopern Farm	33.2
Roborough	86.9	Northcote House	29.4
Byrne House	85.8	Harrison Building	3.8

Due to available information from the university on inhabitants [45], it was possible to compare residences per capita. Raw data of monthly consumption were acquired, and non-university run residences were omitted. Figure 7 shows the gas consumption per capita of the residences, showing intensities above the average in red.

Garden Hill House was built in 1920 and was reported to be in average condition in 2013. The building is clearly in poor order and in need of improvement. Part of the issue is that it is a house as opposed to 'halls', and therefore, contains more area per resident. The use of houses should be carefully considered as residences as they are far less efficient than apartments or halls. Lopes Hall was built in 1890 and has poor standards, low levels of insulation and single glazing. Efforts should be made to lower the intensity as much as is allowable by the Grade II listing. Mardon Hall, built in 1930, suffers for similar reasons to Lopes. Pennsylvania Court and Holland Hall were both built in 2005 but have a large area per resident. Birks is also a modern build but is high standard accommodation and perhaps offers slightly larger areas per student. The remaining residences and associated intensities are shown below in Table 4.

Table 4. Gas consumption intensity 2018/19.

Residence	Total Gas 2018/19 kWh/r/a.	Residence	Total Gas 2018/19 kWh/r/a.
Garden Hill House	8224	Old Lafrowda	2809
Lopes Hall	6006	Nancherrow	2537
Pennsylvania Court	4408	Ransom Pickard	2495
Mardon Hall	4086	New Lafrowda	2224
Holland Hall	4035	Duryard T&Y	2068
Birks C	3407	Rowe House	1640
St Germans	3182	Nash Grove	1594
Rowancroft	3067	Clydesdale Rise	1070
Birks	2907	James Owen Court	66

Figure 8 depicts the total gas consumption on the campus to show monthly trends for the years in question and listed in the legend. It clearly shows a seasonal trend due to heating load. Heating is switched on after September and continues to increase consumption towards the peak in January. The gas consumption then decreases as cold weather ends and consumption troughs during the summer months. The 2018/19 line shows unusually high consumption data: January and February 2018/19 are higher than expected due to anomalies caused by Hope Hall, where gas consumption increases by a factor of 20. The data set resumes its usual course in March, as is visible in the graph. March 2017/18 has a potential anomaly suggested by the fact that only one building had a significant increase, namely the Amory building, having consumed over twice as much gas as in the previous colder month of February.

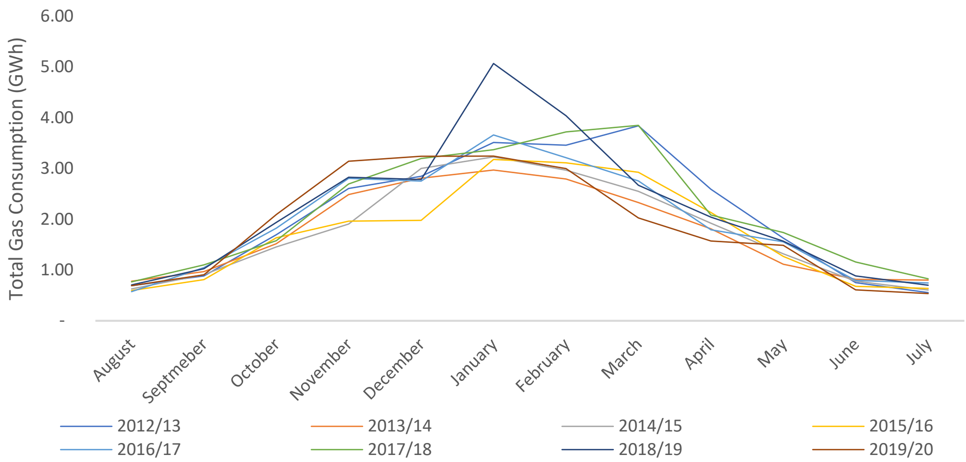

Figure 8. Monthly total gas consumption by year in GWh.

4.2. Scope 2

Scope 2 emissions are produced by the generation of purchased electricity. Data made available by the UoE were used to compare different buildings' consumption. The upper quartile of consumers as of the year 2018/19 is shown above in Figure 9. The Computer Building has been removed from the graph for clarity due to its significantly larger intensity. The intensity as shown in Table 5 is 1879 kWh/m^2/a. This is an invalid result as according to the UoE Energy Department, the metering was discontinued during that year and not refitted due to COVID.

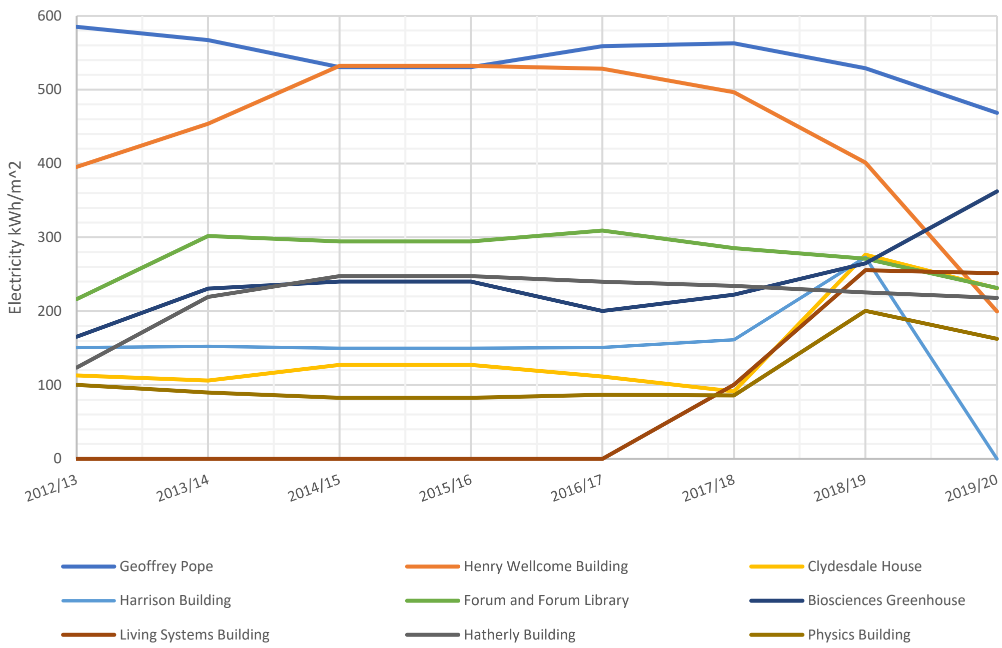

Figure 9. Electricity intensity, upper quartile 2018/19.

Table 5. Electricity intensity, 2018/19.

Building Name	Electrical Intensity 2018/19 kWh/m^2/a.
Computer Building	1879
Geoffrey Pope	529
Henry Welcome Building	401
Clydesdale House	277
Harrison Building	273
Forum and Library	271
Biosciences Greenhouse	265
Living Systems Institute	256
Hatherly Building	225
Physics Building	201

Previous results show a stable intensity of over 3500 kWh/m^2/a. This building houses the computing hub for the UoE, which requires not only extensive power but also intensive cooling. It may not be possible to change the amount of energy required, however, the electricity consumed could be reduced if exchanges were made, for example, if heat exchangers were built between areas that need cooling, and areas that need heating. Geoffrey Pope has by far the largest net consumption but also has a very large area of 6889 m^2, which results in an intensity of 529 kWh/m^2/a. The building has a very particular and energy intensive use, biosciences, and as mentioned above houses 4800 m^2 of lab space. The building is, therefore, used around the clock for energy intensive activities. According to the University website, the facility includes aquaria rooms, a bioimaging unit, a centre for cytomics, environment-controlled grow rooms with a greenhouse facility, a mass spectrometry facility, and other analytical facilities. The Geoffrey Pope building also holds the MRC Centre for Medical Mycology. All the aforementioned facilities require high levels of energy to run. These facilities, unless currently poorly managed, will unlikely be able to decrease their electricity consumption used for specific functions, that is to say, not including nonspecific electricity uses, such as lighting. The reasons for the Henry Welcome building being an intense electricity consumer are similar to those of Geoffrey

Pope: it contains multiple state of the art facilities, such as bio behavioural laboratories. Clydesdale House is a postgraduate centre that contains catering facilities and a bar. It was built in 1989 and has been reported to be in good condition as of 2013. As seen in the graph above, it suddenly increases in intensity in 2018/19 after having remained consistently at a lower intensity in previous years. This may be the result of new facilities or more events, but metering should be investigated to assess whether this amount is real and might continue to remain overly large. The Harrison building runs on gas and oil for heat, and therefore, its high electricity intensity is purely controlled by its appliances. The Harrison is home to Engineering, Mathematics and Physical Sciences which run many electrically intensive areas, such as computer rooms, workshops, and laboratories. Data in 2019/20 are incorrect due to failed meters. The Forum and Library include study space, lecture theatres, social spots, shops and more. It is the most used area on campus and is also used for long hours during the day. The Biosciences greenhouse requires constant climate control, which should be reviewed to assess its necessity. The Living Systems Institute is a state-of-the-art facility that merges medicine, biology, and physical sciences. Its sole need for electricity is to run its impressive resources. The use of such resources must be monitored to reduce unnecessary use. As can be seen in Figure 9, it was built in 2016, the start of data collection for this building. Hatherly represents lab space run by the Medical School, which runs intensive research. It is also a very old building, built in 1938, which may be host to inefficient lighting. The Physics building is also an electricity intensive faculty due to its required equipment and computing. Like Hatherly, it is an older building that may contain inefficient lighting. Table 6 shows remaining buildings and their electricity intensities, all of which were under 200 kWh/m^2/a.

Table 6. Building total electricity 2018/19 per square meter.

Building Name	Electricity Intensity 2018/19 kWh/m^2/a.	Building Name	Electricity Intensity 2018/19 kWh/m^2/a.
Peter Chalk Centre	191.2	Washington Singer	71.0
Kay Building (Labs)	169.3	Newman Building	66.4
Mary Harris Memorial Chapel	167.7	Amory Building	64.3
Cornwall House	142.9	Laver Building	60.3
Devonshire House	138.7	Byrne House	60.1
Cornwall House Pool	136.7	Lafrowda House	59.0
Clydesdale Rise—Blocks A–C	125.2	Hope Hall	58.8
Changing Pavilion (Hockey Pitch)	124.9	Streatham Farm	58.5
Reed Mews Wellbeing	123.1	Kay House	56.2
Building:One	108.8	Knightley	54.3
Xfi Building	105.4	Great Hall	53.9
Russell Seal Fitness Centre	103.1	Queen's Building	53.2
Reed Hall	98.4	Alexander Building and Thornlea Complex	49.6
Sports Hall	94.5	Ransom Pickard—Blocks A–B	47.7
Old Library	87.2	Lazenby	44.3
Clayden	79.6	Estate Services Centre	38.5
Streatham Court	75.9	Higher Hoopern Farm	37.8
Institute of Arab and Islamic Studies	75.6	Roborough	19.6
Northcote House	75.4	Sir Christopher Ondaatje Devon Cricket Centre	4.4
Sir Henry Welcome Bdg for Mood Disorders Research	72.3		

In this study, halls were compared by resident as well. Figure 10 shows electricity consumption in halls per resident. There is a clear trend due to heating over the winter months. King Edward Court is a 1990 building that runs on electric heaters and storage heaters. These methods of heating are extremely inefficient, which causes a vast amount of electricity to be consumed. Clydesdale Rise, Nash Grove, Clydesdale Court, Llewellyn Mews and Cook Mews are the same, built around 1990 and all running on electric panels or storage heaters. Rowancroft is heated by a mixture of gas water heaters and electric panel heaters, which is why the residence is at the better end of the most inefficient. An old residence mainly built around 1960 suggesting poor insulation may also be present. Most remaining halls run heating on gas, explaining their lower electricity consumption per capita. The 2018/19 data is shown in Table 7.

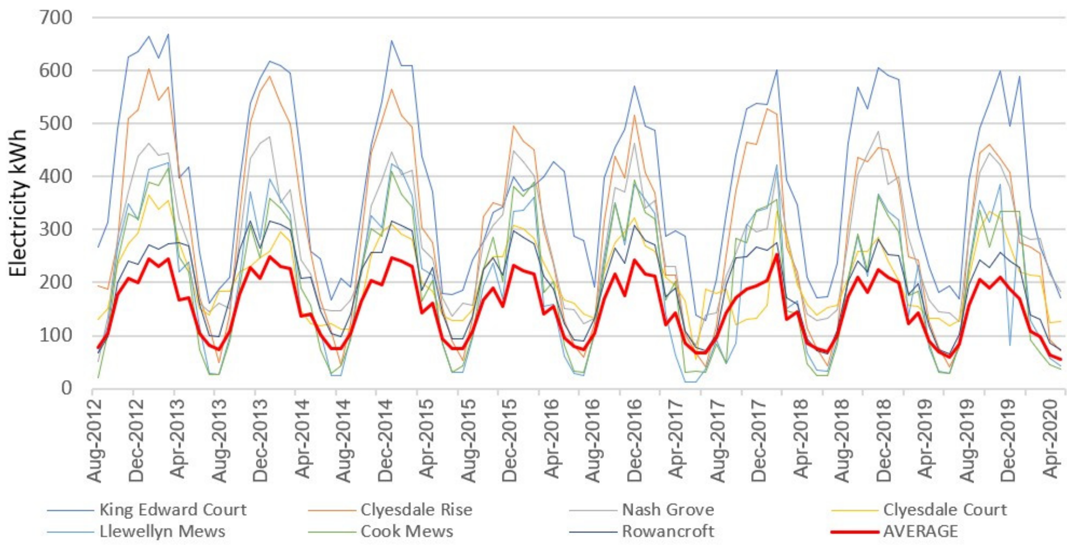

Figure 10. Electricity consumption in halls per resident (upper quartile), (kWh/month/capita).

Table 7. Residence total electricity 2018/19 per resident.

Residence	Total Electricity 2018/19 kWh/r/a.	Residence	Total Electricity 2018/19 kWh/r/a.
Holland Hall	2489	Brunel Close	1223
Lopes Hall	2302	New Lafrowda	851
Nancherrow	2214	Ransom Pickard	885
James Owen Court	1964	Mardon Hall	745
Rowe House	1864	Duryard	697
Birks	1541	Garden Hill House	572
Pennsylvania Court	1400	Birks	376
Kingdom Mews	1313	Old Lafrowda	344
Merrivale	1230		

Figure 11 shows the total electricity consumption by month from the academic years 2012/13 to 2019/20. There is a clear outlier in June 2019 (dark blue) which from investigating the raw data was caused by the Harrison building showing a result too large by a factor of approximately 30, which may have been caused by malfunctioning metering, accounting for multiple months; 2017/18 shows higher consumption which is caused by the surges in multiple buildings between January and April 2018, the most likely cause being that the average temperature was lower in those months than in other years; 2019/20 (brown line) shows lower consumption from March to July 2020, which shows the effects of COVID as the campus had very little use during the pandemic.

The remaining results show clear trends of increasing from October with a slight fall in December. The October rise will be due to heating turning on in electrically heated buildings, the December dip due to a reduction in appliance use over the holidays. The lowest consuming months, June, July and August, are also the result of holidays.

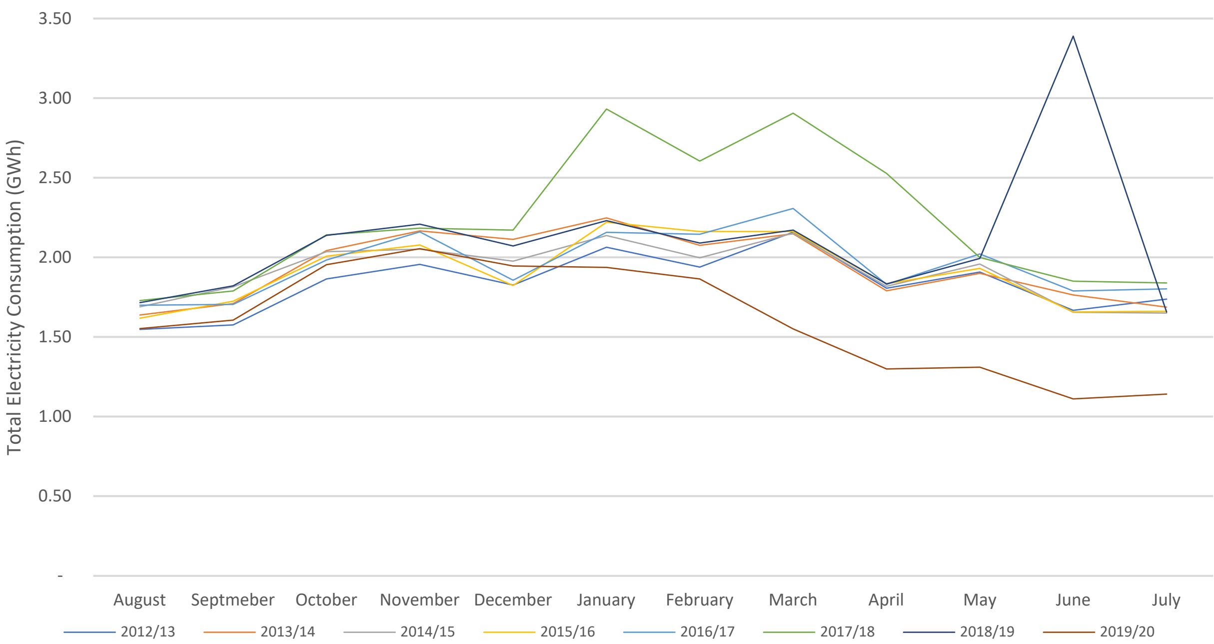

Figure 11. Total monthly electricity consumption on Streatham Campus.

4.3. Scope 3

Waste plays a large part in the release of Carbon Dioxide and other harmful substances. Regarding Scope 3, it may be the largest at UoE. Waste at UoE is managed in the following ways: it is either disposed of and converted into energy using either combustion or anaerobic digestion or it is recycled; closed loop or open loop. The aforementioned methods are very effective at releasing little CO_2. However, the amount of waste should and can still be reduced. Below is a condensed version of the waste data report pre-COVID (August 2018–July 2019), shown in Table 8, in order of highest to lowest CO_2 emitter.

Table 8. Emission types and amount in tonnage.

Waste Type	tCO_2e	% tCO_2e	Tonnes	% Tonnes
Food and Drink	275	24	67.4	5%
Glass (Mixed)	152	13.3	166	11%
Metal (Mixed Scrap)	139	12.1	36	2%
Metal (Mixed Cans)	133	11.6	20.2	1%
Plastic (Mixed)	127	11.1	40.5	3%
Paper	116	10.2	119	8%
Cardboard	103	9.01	119	8%
Food Waste	48.9	4.26	12	1%
WEEE (Small)	23.6	2.06	13.2	1%
Municipal (Mixed)	14.3	1.25	671	45%
Wood	8.27	0.72	19	1%
General Waste (non-recyclable)	3.02	0.27	141	10%
Dry Mixed Recyclables	1.13	0.13	53.1	4%
Total	1144.22	100%	1477.4	100%

The difference between CO_2e and tonnage by waste type is clearly visible in Figures 12 and 13 suggesting that different waste types release significantly different amounts of CO2e on disposal. Even though municipal leads the raw tonnage of waste, it only makes up a tiny percentage of the overall CO_2 emission. This is most likely due to the low carbon method of disposal. Food and drink are the most significant contributor of CO_2. This result seems odd as it was expected that food and drink would release little CO_2 if disposed of at an AD plant.

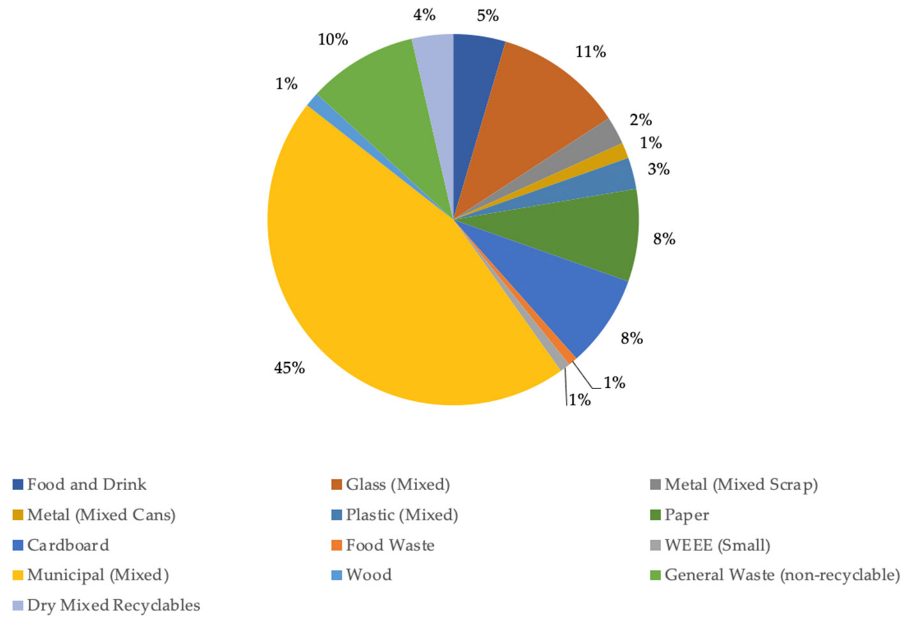

Figure 12. Breakdown of tonnage of waste types.

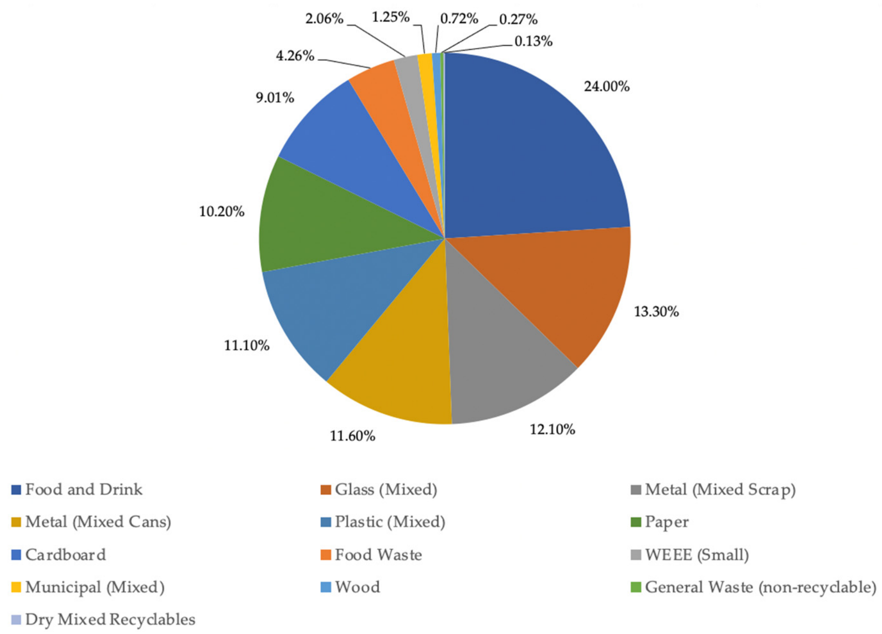

Figure 13. Respective carbon dioxide emission per waste type.

5. Results

5.1. Scope 1

5.1.1. Heating/Hot Water

Before COVID, in the year 2018/19, a total of 26.179 GWh of gas were consumed, of which 23.046 GWh were used for heating and hot water, 88.4% of the total consumption, as shown above in Figure 14.

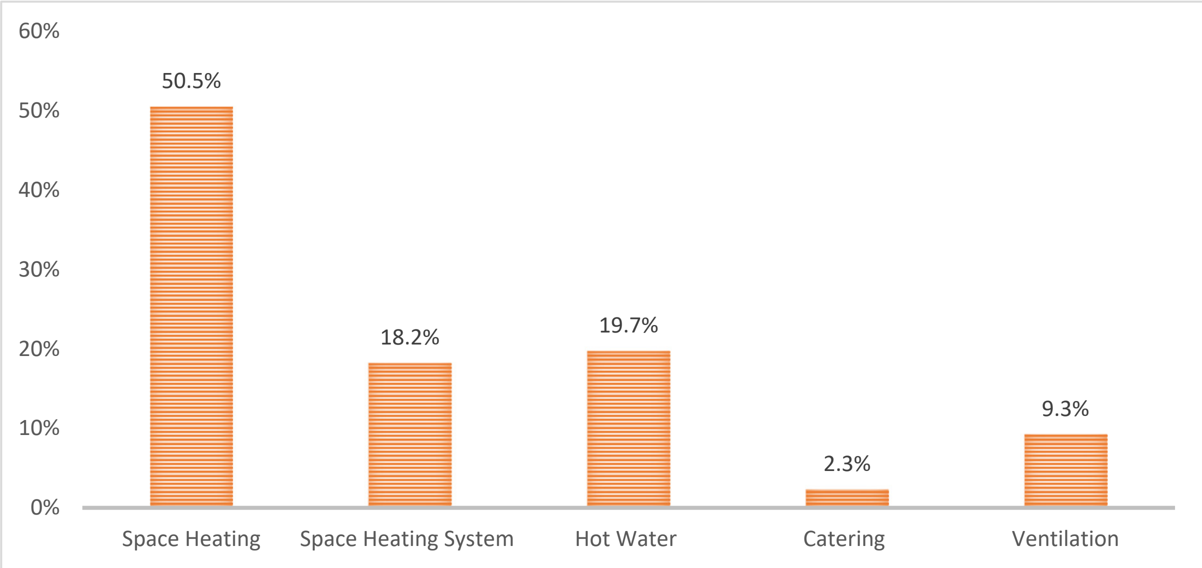

Figure 14. Breakdown of gas consumption 2018/19.

Given that gas boilers are also to be phased out, the levels of gas would be reduced up to the year 2030, with only required gas remaining, such as for labs and fume cupboards. Using the efficiencies of heating types and conversion factors, the following reduction could take place shown in Equation (6):

$$\begin{gathered}\text{Heat Pump Power} = \text{Gas Consumption } \times \text{efficiency ratio}\\ \text{Required Heat Pump Power} = 23,286,215 \times \tfrac{9}{30}\\ \text{Required Heat Pump Power} = 6,985,864.5 \text{ kWh}\\ \text{Saving in 2030} = \text{kWh gas} \times 0.1838 - \text{kWh electricity} \times 0.1016316\\ = 3,570,018.94 \text{ kgCO}_2\text{e}\end{gathered} \quad (6)$$

In places where heat pumps are not possible or do not suffice considering requirements, the addition of modern infrared heating should be considered. The Forum/Library has introduced them already. They are among the most efficient forms of heating where electricity is directly transformed into heat (unlike heat pumps). They are the perfect cheaper and efficient option to fill the gaps not filled by ground or air source heat pumps. Given that ground source heat pumps have a small temperature difference, they often struggle to get buildings to exactly the required temperature. They do, however, form an excellent base load, albeit at times requiring extra methods.

The UoE has incorporated a small number of solar heating systems, though these are not particularly effective in the UK. However, they will still reduce emissions due to heating, especially before the grid becomes carbon zero. New buildings and large renovations should aim to include solar heating so as to have the best possible chance of being carbon net zero on their own.

5.1.2. Ventilation

Ventilation consumes 9.3% of the UoE's gas, due to fume cupboards and AHUs [46], which can run on electricity. Therefore, that switch could be made that would increase the electricity emissions, albeit by a small amount compared to the savings induced. AHUs will always be required to help air exchanges occur and to back up heat pumps in larger spaces, however, there are also more efficient ways of using them. Mechanical heat-recovery systems can be included to take the heat out of vented air and reapply it to air moving into the room. Eighty-four percent of vented heat is recoverable according to Vent Axia. Redistribution of air between areas requiring heating and cooling and vice versa is a very efficient way of regulating temperature and keeping air exchanges high. For example, institutions, such as universities will have computer processing centres or areas that need significant cooling and of course, there are areas that need heating.

5.1.3. Vehicle Fleet Changes

As shown in Table 9, the University already operates many EVs, however, more should be introduced. Assessing the list of different departments and their vehicle requirements, alternative EVs can be suggested. For all departments that need small vans, the obvious choice was the Nissan eNV200 EV or the Renault Kangoo ZE, of which the UoE already own multiple and have no direct carbon emissions.

Table 9. List of vehicle models and associated emissions owned by UoE as of October 2020.

Model	Quantity	Emissions (g/km)	Total per Model (g/km)	Replacement
Nisssan eNV200	17	0	0	-
Renault Kangoo ZE	1	0	0	-
VW Transporter	3	160	480	eTransporter
Vauxhall Vivaro	1	180	180	eTransporter
Peugeot 207	1	133	133	many options
BMW 730ld	1	167	167	many options
BMW 520d	1	127	127	many options
Ford Transit	11	200	2200	Nissan eNV200
Volkswagen Caddy	4	161	644	Nissan eNV200
Citroën Berlingo	1	148	148	Nissan eNV200
Vauxhall Combo	1	150	150	Nissan eNV200
Peugeot Partner Combi	1	140	140	Nissan eNV200
Land Rover Defender	2	255	510	no alternative
IVECO Daily Luton	1	300	300	no alternative
Toyota Hilux	3	242	726	no alternative
Nissan D22	1	180	180	no alternative
Nissan Navara	1	180	180	no alternative
Tractor	11	400	4400	no alternative
IVECO Minibus 17 seat	4	200	800	Transit SE Concept
TOTAL	66	3323	11,465	
Remaining Emission g/km			7096	
Reduction			38%	
New Average Emissions			107.5	

If a larger van is required examples, such as the Volkswagen eTransporter have been recently released. Between the eNV200 and the eTransporter, the following vehicles could be replaced: Citroën Berlingo, Ford Transit, Volkswagen Caddy, Volkswagen Transporter (non-EV), Peugeot Partner Combi, Vauxhall Combo & Vauxhall Vivaro. There are also electric minibus options available on the market, such as the Transit Smart Energy Concept [47]. The Peugeot 207, and the two BMWs have many carbon free potential replacements, and therefore, these could also be removed. The vehicles that have no alternative are specialist vehicles, such as 'pickups' or tractors that are not readily available in EV form. The Land Rover Defender listed has a service arm that may not be adaptable to an EV. The total emission from all vehicles came to 11,465 g/km. Removing the emissions from all replaced vehicles has a potential saving of 38%. The average emissions would become 107.5 g/km, which is close to the EU 2021 target of 90 g/km for 2021, which considers only new build cars [17]. Given tractors are involved in the findings in Table 8, the fleet would have very respectable total emissions if these changes were to happen.

5.1.4. Oil

Oil is currently responsible for 1.19% of emissions due to energy consumption (gas, electricity), and in 2030 will be expected to be responsible for 1.64% due to reductions in electricity and gas emissions. It is currently used for one remaining heating system which should be substituted immediately. Otherwise, it is still used for backup generators, which are not often necessary, however, they are run and tested approximately once a month. The use of fossil fuel generators is no longer necessary. Alternatives now exist mainly in the form of onsite batteries that can be charged by solar or be topped up with the grid supply, and can be used to run the key elements of the campus if grid power were to be lost. This would allow all oil to be phased out and a further drop in carbon emissions could be possible. In 2018/19, 517,963 kWh of oil were consumed, which has the equivalent carbon emission of 132,961.1 kgCO_2e [48].

5.2. Scope 2

Electricity, unlike gas, will be impossible to phase out and does not need to be, as CO_2 is not emitted when electricity is used; it is theoretically 100% efficient. Despite it being of renewable generation at the UoE, electricity should still be reduced as the grid is not yet powered by only renewable or non-carbon emitting resources; other consumers are still using carbon emitting electricity. Data from the grid over the last year show that 25.9% of generated electricity was renewable with a further 17.7% being produced by nuclear, totalling 43.6% of electricity generation being produced by non-carbon emitting sources [49]. This will continue to increase: by 2025 the grid is to operate at zero emissions [50]. Given that there is a 56.4% reduction in emitting sources yet to happen, using past data for a breakdown of grid energy sources and past conversion factors, the current emissions for the grid (0.2331 gCO_2e/kWh) were decreased to yield a 2025 estimation of 0.1016316 gCO_2e/kWh [51].

5.2.1. Heating

The campus uses 16.2% of its electricity for heating and hot water. Some of this is from ground source heat pumps, however, a large amount is from electric storage heaters and panel heaters, which at their best could theoretically reach 100% efficiency. However, this is not always the case. This suggests that heat pumps will remain a minimum of three times as efficient. Currently, around 5% of the required heat load is supplied by heat pumps. This suggests that the other 95% of that load can be decreased by a factor of three if heat pumps were to take over. This would yield a potential reduction of 1.325 GWh. Given that by 2030 the aim is to run heating solely on electricity, savings due to improvements on insulation were applied to the electricity values. As stated in Section 2.2, buildings built before 1990 may have the potential to halve their energy consumption for heating with better insulation. Using available heating data from the UoE, total energy consumed for heating pre-1990 buildings adds up to 10.95 GWh. Taking 50% of this and converting it to equivalent electricity consumption using the difference in efficiencies gives 1.64 GWh. This value was added to the savings and will be used to further offset emissions.

5.2.2. Lighting

As shown below in Figure 15, lighting accounts for 19.4% of the UoE's electricity consumption, which is similar to the UK average of 20% [52]. This amounts to 5.36 GWh, a substantial amount. There are two ways in which lighting should be reduced: the method of producing light and the amount used. Currently, the campus has a mixture of different types of bulbs: LED, fluorescent, halogen, or incandescent. Good quality LEDs use a mere 20–25% of the energy that original incandescent bulbs use and 25–30% of that of halogen incandescent [53]. CFL and fluorescent lights are on average 50% the efficiency of LEDs due to their omnidirectional output [54]. The change to LED is an obvious decision. The initial cost is more expensive, however, LED lifetime spans from 25,000 to 200,000 h. The best of CFL have a maximum of 15,000 h life and incandescent far less than that. There would, therefore, be a short repay period. According to the UoE Energy Manager Andy Seaman, an estimated 60% of lighting is yet to be changed to LED on the campus. The majority of the lighting is fluorescent, which suggests that 60% of the current lighting consumption can be reduced by at least 50%. Changing all lights on the campus to LED would save 1.608 GWh per year. Regulating the amount of light used can be conducted using control switches, sensors, timers, or dimmers. Currently, buildings tend to always run as if full during the day, and rooms are often fully lit without any users present. Introducing timers and sensors would only allow the lights to be on with no occupancy for a very short period and most importantly would not let lights remain on overnight. Dimmers should also be installed as modern lightbulbs respond well to dimming without losing efficiency, unlike incandescent bulbs [55].

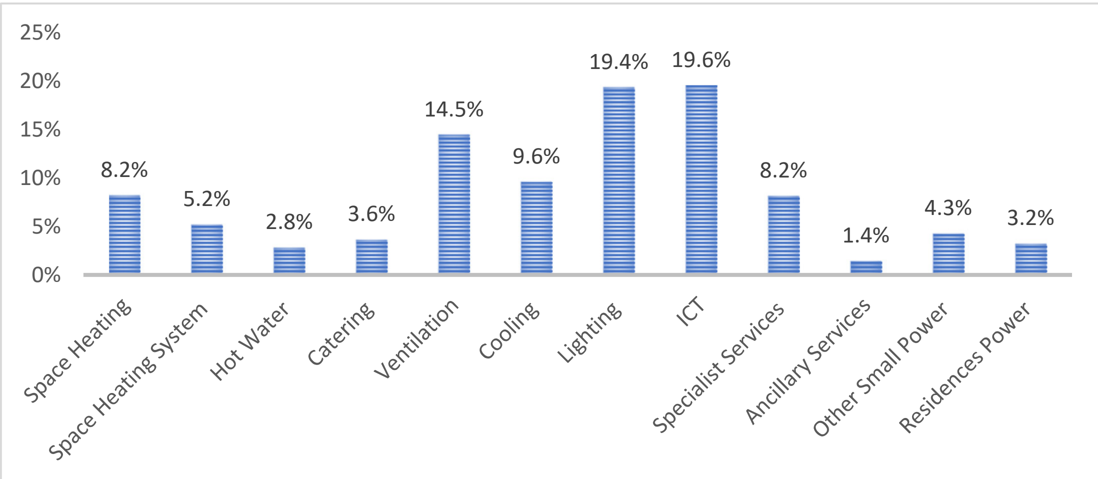

Figure 15. Breakdown of electricity consumption 2018/19.

5.2.3. Cooling

Cooling uses a significant portion of electricity (9.6%), which is unexpected in a country with a mild climate. However, universities run a significant amount of energy intensive areas that require cooling to operate efficiently and safely. A clear example of this is the Laver Annexe computer building, as shown in the Analysis section. It has significant electrical consumption to cool the computer processors, 3500 kWh/m^2 per year, seven times that of any other buildings and over 20 times that of a Passivhaus building. The system will always consume a significant amount of electricity, especially as the computing power of the UoE will no doubt continue to increase as the capacity of the University increases. The distribution of heat should, therefore, be utilised. The heat that is produced by the processors should be taken into a different building demanding heat, which would both reduce cooling consumption and heating load in the two buildings.

5.2.4. EV Chargers

Data acquired between October 19 and January 21 shows that a total of 3.366 MWh was used. Figure 16 shows pods and electricity in use and the relationship between the two. Table 10 shows the monthly totals and pods used. This data is unfortunately unreliable due to COVID, and this is visible in the number of pods (charge points) used after March 2020 when the first COVID lockdown began. The energy used was expected to continue increasing as more staff became aware of the charging location.

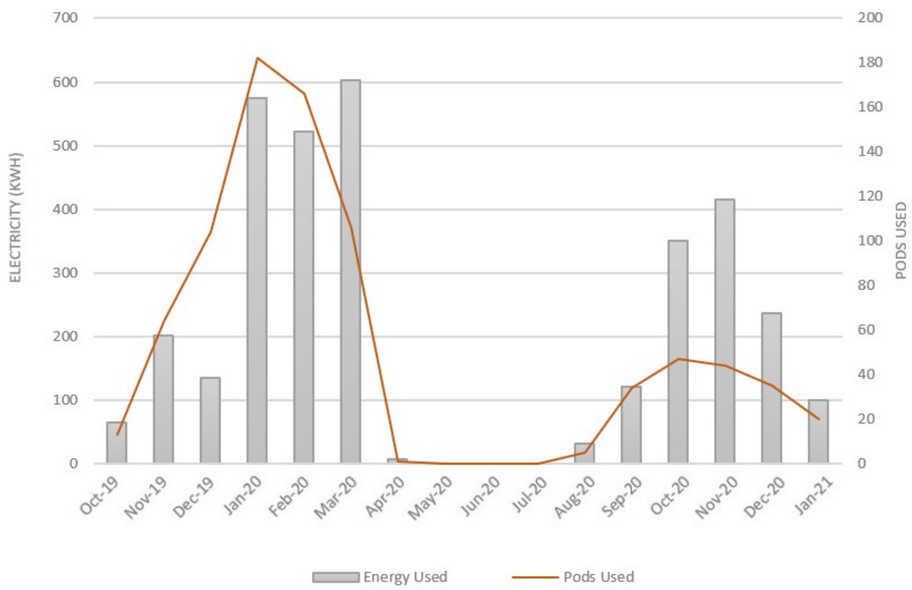

Figure 16. Electricity and pods used by EVs.

Table 10. EV charging data by month.

Month	Energy Used (kWh)	Number Pods Used
Oct-19	65	13
Nov-19	201	64
Dec-19	136	104
Jan-20	574.76	182
Feb-20	522.6	166
Mar-20	602.3	106
Apr-20	8	1
May-20	0	0
Jun-20	0	0
Jul-20	0	0
Aug-20	31.8	5
Sep-20	121.6	34
Oct-20	349.8	47
Nov-20	416.1	44
Dec-20	236.6	35
Jan-21	100.6	20
TOTAL	3366.16 kWh	

However, as the Streatham campus was deemed nearly out of use, popularity never rose. As can be seen from the graph in Figure 17, the levels of usage from August onwards are not as high as expected, however, the usage per pod has increased suggesting people are charging their vehicles for longer durations. Raw charging data from PodPoint shows customers have only been charging their vehicles for short durations.

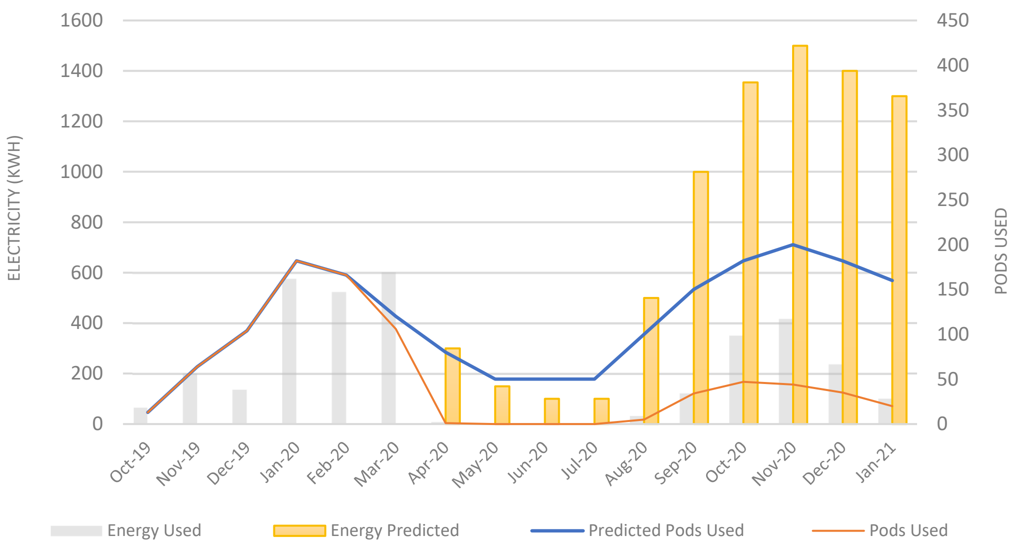

Figure 17. Electricity and pods used by EVs.

According to PodPoint, this is because the first 14 min are free and require no login, and this will be the cause of the high pod usage to total electricity used a comparison that was visible pre-COVID. The latter half of the graph shows customers have been charging their vehicles for longer periods, which hopefully suggests that when normal campus timetables resume the rest of the customers will follow suit. To simulate 2020 prediction without COVID, the Pods used were replicated from pre-COVID and copied to the beginning of the 2020 academic year in September, and then the total electricity transferred was calculated accordingly using the energy per pod from October 2020 onwards. A shallow trough was added to represent the little usage throughout the summer. Following these parameters, the graph in Figure 18 was created. The new results show a total of 7.705 MWh of electricity used. This would have the equivalent CO_2 saving of 4.316 tonnes. Introducing a greater number of EVs is not a process that the university can directly begin, as the idea must be instilled into the users of the campus. Like all Scope 3 emissions, they are difficult to control and must be reduced by encouraging the users of the institution. Once more EVs are employed, the UoE will also have a better understanding of the effect that vehicles have on the campus by monitoring their electrical consumption from onsite charging points.

5.3. Scope 3

UoE has schemes in place to encourage and enable recycling as much as possible. WARPit is a scheme where departments may give away unwanted items that would otherwise be disposed to departments that might make use of said items, which may also include loaning of surplus items. Such a scheme both encourages recycling and discourages the unnecessary purchase of surplus items between departments. Changes to the campus involve removing all office bins from buildings and installing centralised recycling including plastics, cans and paper. This also includes introducing food waste bins in all centralised open kitchens. The UoE online sustainability pages also explain in detail how to recycle or dispose of all types of items, which guides the users to part with their items in the most sustainable (and where applicable, low carbon emitting) way. 'Moving on' is another recycling scheme to reduce unnecessary disposal of reusable goods, which involves the students donating unwanted goods, such as kitchen appliances, bedding, books and more, for other students to inherit. Schemes, such as the aforementioned provide a good basis for improving the 'reuse, recycle' initiative. Like other Scope 3 emissions, the most realistic method of reduction relies on the awareness of the users of the campus. Between the University website and onsite means to raise awareness, the University has a good basis from which to encourage the correct disposal of waste to minimise the respective carbon footprint. To further reduce the emissions of waste management, current efforts must be heightened to further encourage the correct disposal of waste and to improve recycling methods by making clear to students and other users of the campus exactly where to dispose of each waste type. Following that, the remaining 'destroyable' waste must continue to be processed as efficiently as possible by methods, such as WtE and AD plants.

The UoE and its management only have so much control over the emissions that the University might release. Scope 1 and 2 emissions are more controllable to an extent, especially with climate control, lighting, and computing power. However, these are also controlled by students or other users on campus. Starting with residences, a huge consumer of heat energy all rooms can turn their heating down from the set temperature, instead of, for example, utilising the opening of windows to release heat. It is also the responsibility of students to switch off unnecessary appliances including lights when not in use. Regarding Scope 3 emissions, much of the control is in the hand of users. This includes means of transport, use of materials, waste disposal, and any other associated activities. Scope 3 emissions must be acted on by everyone in the institution—its managers, and its users—as methods of procurement and more importantly reduction are extremely difficult to act on. Generating renewable energy onsite must happen to offset inevitable emissions and Scope 3 emissions that may be out of the control of the University. The University will always emit, as it will always require electricity, goods and services that emit carbon, and its users will always have a carbon impact. The reason for the previous analysis is to reduce the carbon footprint, not fully remove it, as that is unrealistic. Hence, renewable energy production must be used to offset the remaining carbon emissions to achieve 'net zero' carbon emissions. There are of course multiple ways to generate renewable energy, however, not many are viable on a campus, such as the UoE's Streatham campus.

5.4. Solar

Integrating solar to the campus has started and plans for further development are in place. Solar is a great way to associate individual buildings with having net zero emissions. Table 11 shows the total PV energy generated onsite every year.

Table 11. Current Solar energy generation from the PVs within the University of Exeter.

Year (August to July)	Electricity Generated on Site from Photovoltaic Panels (kWh)
2012/13	0
2013/14	12,570
2014/15	29,119
2015/16	41,855
2016/17	34,182
2017/18	58,442
2018/19	153,852
2019/20	158,746

The recent total of 158,746 is in no way comparable to the total electricity consumed by the University and plans to continue the growth of PV have been made by the university. A detailed summary of all the potential areas and their potential annual yields shows that there are nearly 200,000 m^2 of feasible area, roof mounted or ground mounted, on and bordering Streatham Campus. This scale of application is no quick process and has, therefore, been broken down into 5 phases, with the 1st phase being the most immediate to go into development. Each phase contains several applications and their forecasted annual yield is shown in Table 12. As can be seen, the total potential yield is over 14 GWh per year. This would have a serious impact on the amount of purchased energy the University would require. The UoE aims to have 50% of planned PV built in 5 years, amounting to 7.06 GWh production per annum, and by 2030 an estimated potential of 11.1 GWh per annum.

Table 12. The University of Exeter's plans to maximise solar energy generation by 2030.

Phase	Total Annual Yield (kWh)
1	1,454,736
2	682,949
3	1,573,113
4	1,924,561
5	8,485,451
TOTAL	14,120,810

5.5. Wind

Generation from wind is responsible for the majority of clean energy generation in the UK. Using compiled data and graphs, the remaining emissions were calculated as 2.13 $ktCO_2$. This yearly amount was to be offset by wind energy investments. Using the final figure for remaining emissions, the following calculations were made using Equation (7) to find the required rated power for the wind turbines.

$$\text{Required Total Rating of Wind Turbines} = \frac{\text{e} \times \text{con.f}}{365 \times 24 \times \text{cap.f}} \tag{7}$$

where:

$$\text{e} = \text{remaining emissions (kWh)}$$
$$\text{con.f} = \text{conversion emissions : electricity}$$
$$\text{cap.f} = \text{avg. capacity factor of UK turbines}$$
$$\text{Required Total Rating of Wind Turbines} = \frac{20.92 \times 10^6 \text{ kWh}}{365.25 \times 24 \times 0.427}$$
$$\text{Required Total Rating of Wind Turbines} = 5.59\text{MW}$$

This required rating is smaller than the average offshore single wind turbine and the equivalent of approximately two onshore wind turbines.

6. Discussion

6.1. Building Trends & Reductions

By showing building data for large consumers per m^2, the buildings that may be inefficient were singled out. This was more so the case with gas, as gas is used almost completely for heating only, suggesting that if a specific area uses a significant amount, then it may be using more than necessary and thus be inefficient. Gas consumption is very seasonal, given the space heating that it must run. There does, however, remain a baseload that runs catering, ventilation, and hot water. This remains at approximately 1 GWh per month, as shown in Figure 8. The buildings that have a significant heating intensity are often older buildings, which was expected given that they have poor levels of insulation, whether that be in walls, windows, or doors, old heating systems and overworked AHUs.

Electricity has proven a difficult area to reduce usage unless it is electricity that powers heating. All buildings have their own legitimate reasons for using a certain amount of electricity per square metre due to their faculty and uses. As expected, the buildings using the most are those that run electricity intensive tasks. Further down the order, however, are buildings that should not be as thirsty as they are, and it is these buildings that are using electric storage heaters. They may well emit less carbon in the future due to the use of electricity and not gas, however, they are inefficient. This has been found to be visible in the older buildings, which makes matters worse given that they are likely to have poor insulation and system technology. This became significantly clearer when the residences were compared. They contain no electrically intensive facilities, and only their heating could cause such high levels of electrical consumption.

Two trends were investigated: yearly and monthly. The yearly data, as shown in Figures 6 and 9, showed how buildings have behaved in the past in comparison to each other and validated the data that was being acted on (2018/19), as multiple data sets contained anomalies. It also showed the effect that COVID had on consumption. COVID did not have a great effect on gas consumption—in some areas a slight increase was visible due to the increase in room temperature, as heightened ventilation measures were required against the virus. Electricity use did fall, as fewer people used the campus and several facilities were closed. The monthly data (shown in Figures 9 and 12) allowed seasonal trends to be identified. As expected, this applied mainly to heated months. The trend was clearer with gas, as 68.7% of the gas load fuelled space heating in 2018/19. Fast consumption increases around October, peaks in January and falls until April. Electricity use showed a slight increase due to the few buildings that are heated by gas and small dips were visible during holiday times.

The intense energy consumption of some buildings has been mitigated by their intense facilities. Unfortunately given that there is no data on the breakdown of energy between the equipment and the building itself, the standards of the intense buildings need thorough investigation.

6.2. Consumption & Emissions Results Overview

Figures 18 and 19 show the changes that are to be implemented between 2018/19 and 2029/30 specifically in the UoE's consumption of electricity and gas. Electricity is shown to have increased its heating and hot water load by 84.8% due to taking on the load from gas.

Ventilation has also increased by 51% for the same reason. The extra load due to heating on electricity would be much higher had it not been for improvements in heating systems and insulation. Lighting decreases consumption by 30% due to changes in lighting types. Overall changes to consumption and emissions of fuel types from 2012/13 to 2029/30 are shown in Figures 20 and 21. To give more clarity on the changes made and highlighted throughout Section 5 and Figures 18 and 19, details of the changes have been summarised below in Table 13. As seen in Figure 21, the total electricity consumption has increased by 13.9%, gas has decreased by 96.2% and oil has been completely phased out. The total demand of the University has fallen by 41.6%, from 54.8 GWh per annum to 32.02 GWh per annum.

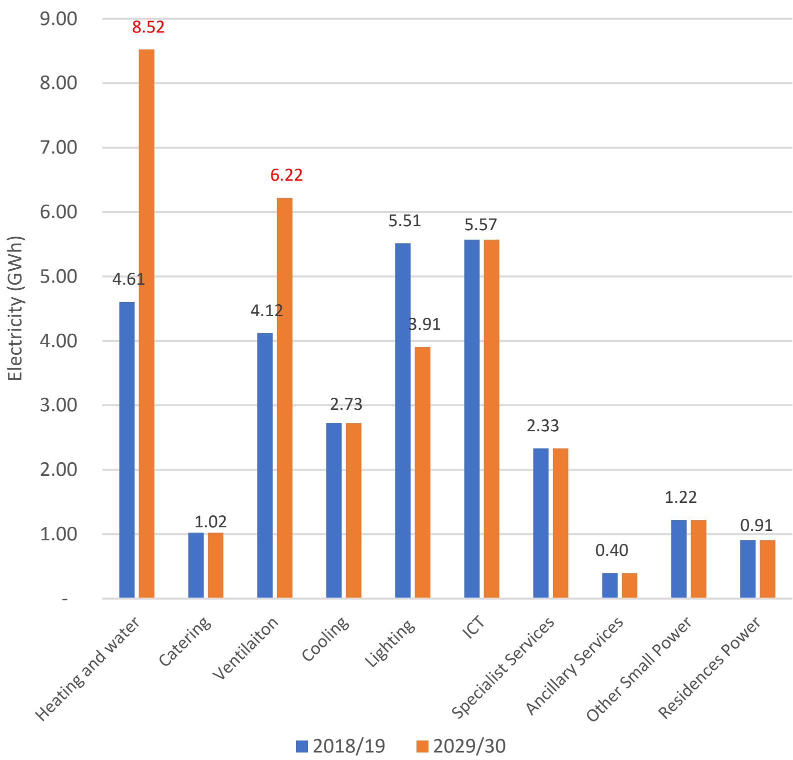

Figure 18. Breakdown of electricity consumption.

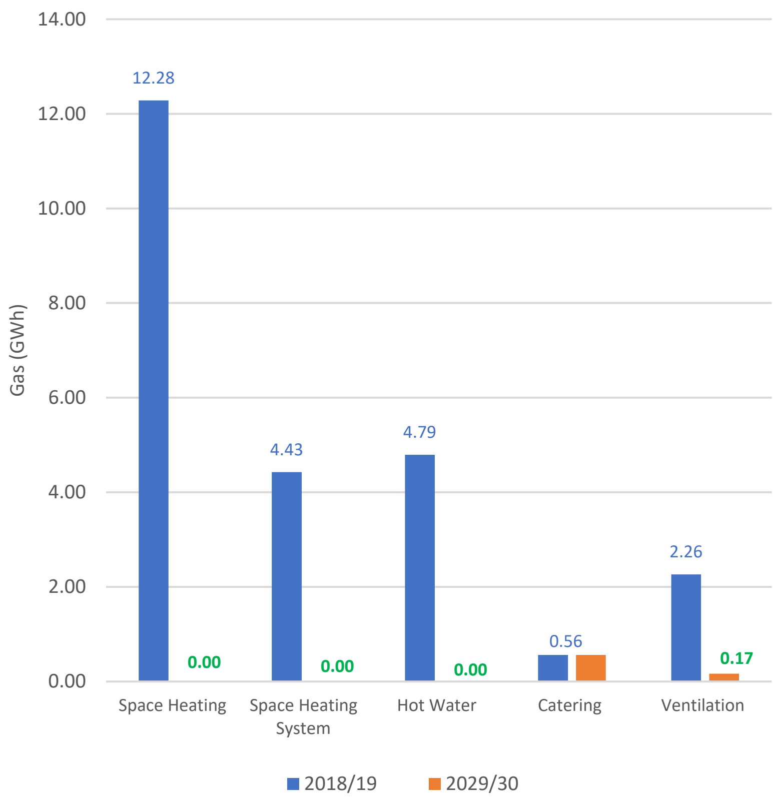

Figure 19. Breakdown of gas consumption.

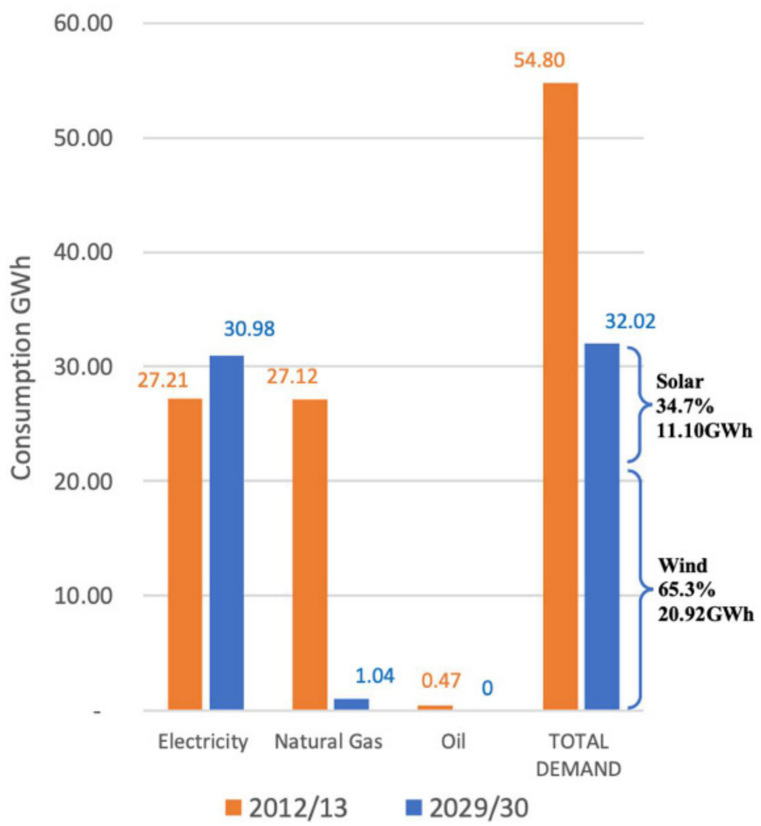

Figure 20. Total consumption vs generation (GWh).

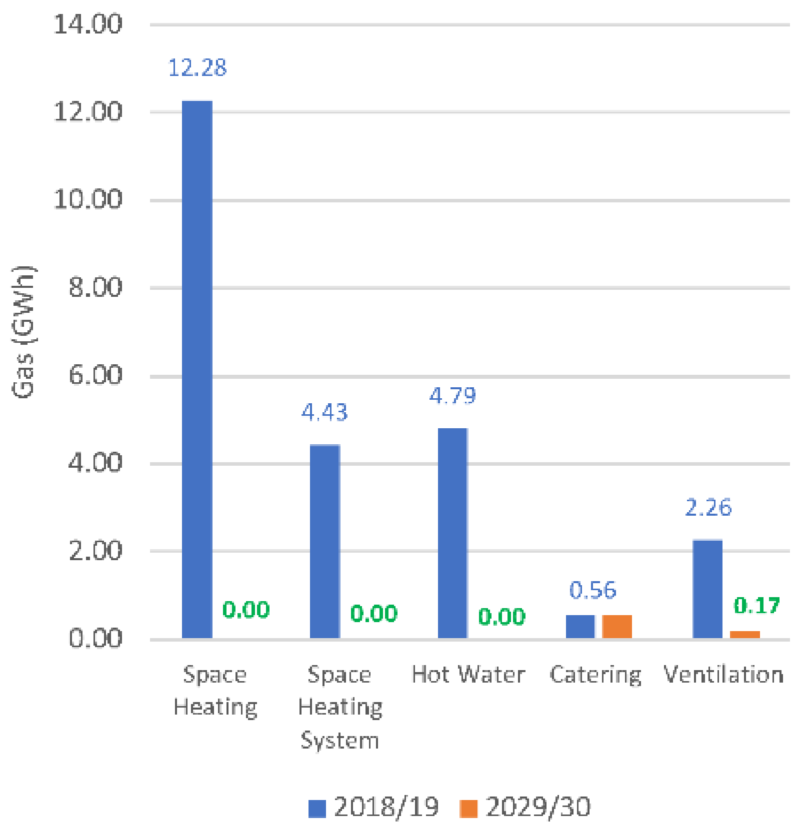

Figure 21. Emissions by fuel type (ktCO_2e).

Table 13. Methods and amounts of emission reductions.

Method of Decrease	How	Amount GWh	Emissions ktCO_2e
PV	Introduction of 75% of solar plans	11.1	1.118
Phasing out gas	Phasing out all 96% of gas, transferring to electricity	16.3	3.570
LED	30% reduction in lighting consumption	1.608	0.163
Insulation	Reducing heating load of pre-1990 buildings by 50%	1.642	0.167
Phasing out oil	All oil use to be discontinued	0.518	0.133
Old electric heating	Heat pumps swapped in, saving 70% of electric heating load	1.325	0.135
Grid Reduction	Conversion factor falls by 77% since 2012/13	-	8.508
	TOTAL Reduction	32.493	13.9

These are significant changes. However, these changes are heightened by the falling carbon conversion factor of grid electricity, which is demonstrated in Figure 21, which shows the total annual emissions in the years 2012/13 and 2029/30. Given that the carbon conversion factor for electricity generation is forecast to fall by 77.2% between 2012 and 2030, the total reduction in carbon emitted from the University was found to be 80.6%, from 17.24 ktCO_2e to 3.34 ktCO_2e. The remaining carbon emissions are shown below in Figure 22, showing the difference in total emissions and savings due to changes in efficiency and an increase in PV generation. It was decided that the gap, 2.21 ktCO_2e, would be offset by wind generation. A required 20.92 GWh per annum would need to be met by wind. Required wind and solar are shown against the Total Demand in Figures 22 and 23. The capacity of wind turbine(s) was calculated as 5.59 MW, as shown in Equation (7).

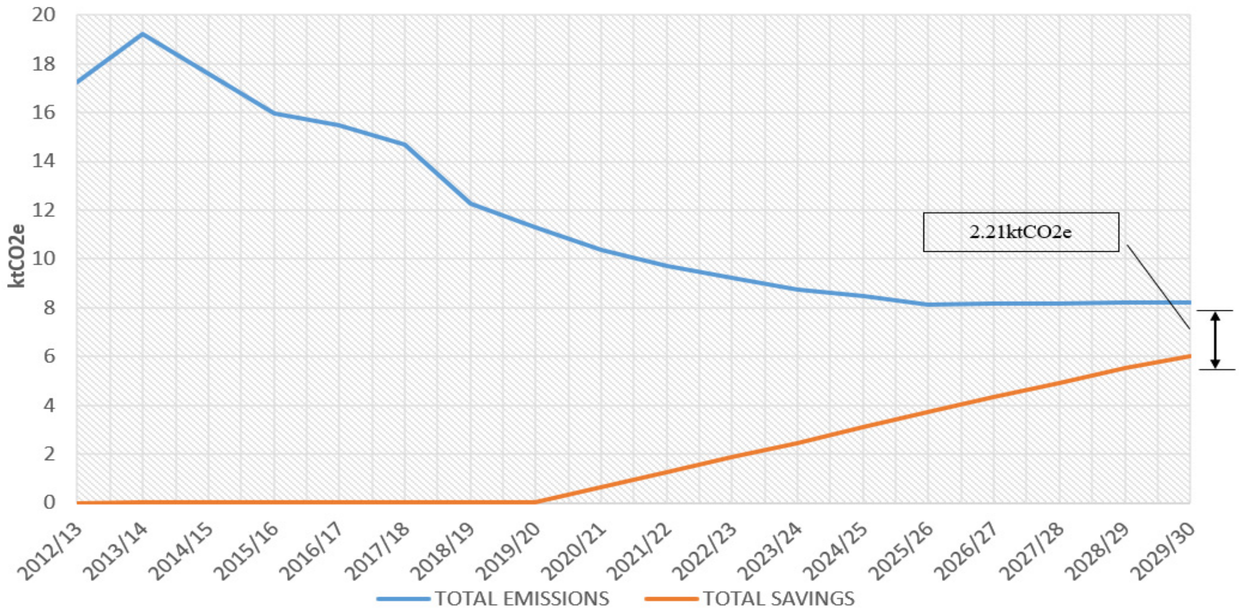

Figure 22. Total falling emissions vs rising savings in emissions.

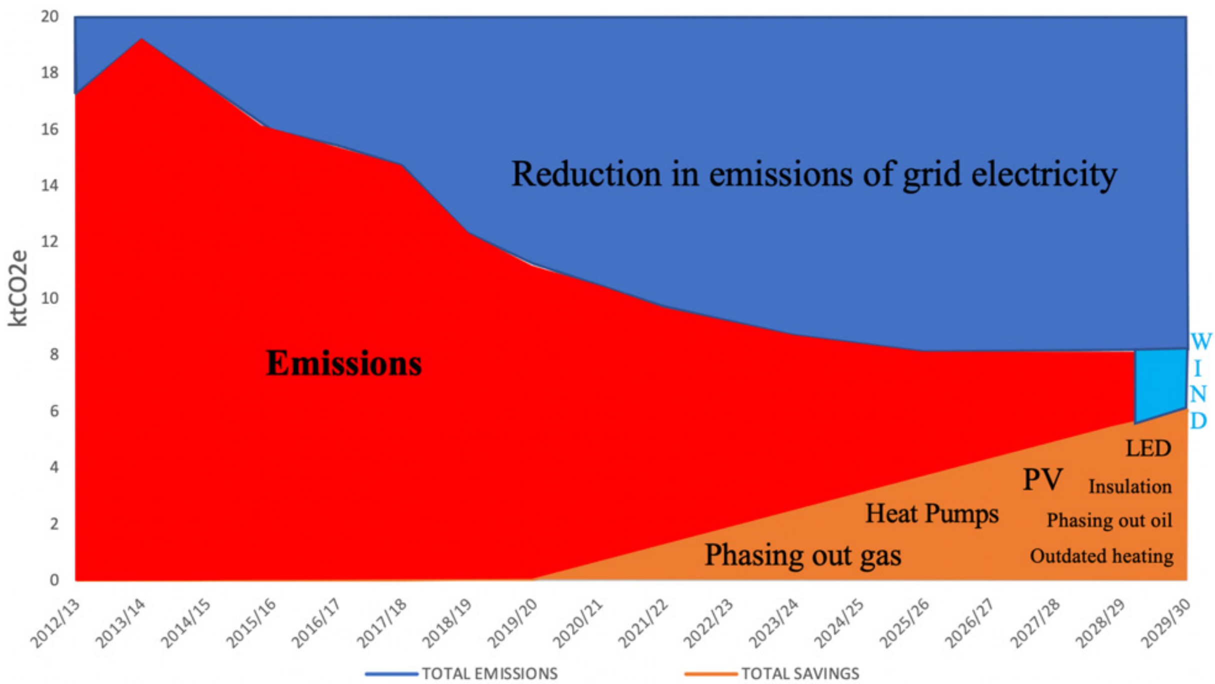

Figure 23. Visual aid for timeline and methods of reaching carbon neutrality, (ktCO2e) for the University of Exeter.

7. Conclusions

Universities are institutions of great energy consumption and will always remain that way. The University of Exeter has made it clear that it is attempting to reduce its carbon footprint within a certain time frame. The most immediate target of becoming operationally carbon net zero has been found to be achievable by changes in energy usage types, consumption loads, and additional electricity generation. The method used to reach the goal of becoming operationally carbon net zero included reducing current consumption as much as possible by 2030 and then offsetting remaining emissions by investing in carbon free electricity generation in the forms of either onsite solar installations or offsite wind.

Possible reductions were applied to the data from the 2018/19 academic year, as they were the most recent reliable set of data because of COVID during the 2019/20 academic year. The emissions path to 2030 was mapped from the academic year starting in 2012 to the year ending in 2030. The overall emissions from energy consumption were reduced from 17.24 ktCO_2e in 2012/13 to 3.34 ktCO_2e in 2029/30. The most beneficial change was the phasing out of gas, as it caused the heating to rely on electricity, thus enabling the use of the more efficient heat pumps. Electricity emissions are forecast to drop to approximately 0.1 kgCO_2e/kWh, which allows the effects of switching from gas to electricity to be all the more beneficial. Oil was phased out in a similar fashion. Further consumption reductions were made by improving building standards, such as insulation improvements and lighting replacements. Reductions in consumption will not deliver zero emissions if the grid still has a carbon footprint. The renewable generation sources mentioned were, therefore, used to offset the remaining emissions. Possible PV was to be built onsite and the remainder was to be offset by offsite wind, either through direct power purchase agreements or direct investment. This resulted in PV covering 34.7%, and wind 67.3% of the remaining demand forecast for the academic year 2029/30. If the planned reduction in energy consumption is not met or the level of PV has not been achieved by 2030, further investments in wind should be made.

Building consumption was analysed between 2012 and 2030 to show which buildings operated inefficiently. Without acting on these buildings, the reduction in emissions concluded above would not be possible. Ground and air source heat pumps require a high level of insulation as they rely on a natural source of energy for heat exchange. Buildings that do not meet high standards of insulation may have to incorporate AHUs or infrared heaters to lift the temperature to the required setting. Inefficient buildings have been singled out for further investigation, potentially involving renovation, by showing their consumption per metre squared—and in the case of the accommodation, consumption by residents also—to facilitate comparison. For further and more reliable building analysis, consumption monitoring must be improved. An integrated automated metering system should be installed to reduce the instances of failed or incorrect readings, of which there have been many.

Unfortunately, vehicle emissions could not be numerically added to the emissions due to lack of data on exact mileage, however, their emission per unit distance was found, which allowed for the equivalent reduction to be calculated following proposed EV substitutions.

Considering the target of becoming carbon neutral by 2050 (including associated emissions and Scope 3), the users of the campus must also change their behaviour. Given that Scope 3 emissions are controlled mostly by an overwhelming number of users, awareness of the damages of carbon emissions and global warming must be increased, and this also includes what more can be conducted by users in their everyday lives. This includes encouraging the correct disposal of waste so that the University can fully dispose of it in the correct way, encouraging the saving of electricity by controlling lighting and appliances, avoiding incorrect use or overuse of materials, and encouraging the withdrawal of petrol or diesel cars from the campus. This should be conducted by publicising the existence of the vast and underused EV charging sites and increasing the number of alternative electric modes of transport, such as e-bikes. A further increase in renewable generation will also likely be necessary, which would be achieved by installing more PV arrays and greater investment in wind energy.

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Nomenclature

AD	anaerobic digestion
AHU	air handling unit
CO_2	Carbon Dioxide
DBEIS	Department for Business, Energy, and Industrial Strategy
ECEPS	Environment & Climate Emergency Policy Statement
EfW	Energy from Waste
EV	electric vehicle
GIA	gross internal area
HEA	Higher Education Academy
HEI	higher education institution
$ktCO_2e$	kiloton Carbon Dioxide equivalent
kWh	kilowatt hour
$kWh/m^2/a.$	kilowatt hour per metre squared per annum
kWh/r/a.	Kilowatt hour per person per annum
NUS	National Union of Students (UK)
PPA	Power Purchase Agreement
PV	photovoltaic
UoE	University of Exeter
UPP	University Partnership Programme
USDE	U.S. Department of Energy
WtE	Waste to Energy

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