DCU Campuses
Carbon Footprint 2019 Report

Sustainability DCU
October 2020

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Acknowledgements

We wish to acknowledge all university staff who assisted with data collection. We wish to acknowledge those individuals in industry who helped inform our research. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

1. Executive Summary

The term carbon footprint refers the measure of the total amount of greenhouse gases (GHGs) emitted across all the activities of an organisation (Carbon Trust 2012). A carbon footprint is calculated by constructing a GHG inventory, in which organisations quantify, report and manage their GHG emissions. This study constructs a GHG emissions inventory for the Dublin City University (DCU) for the 2019 calendar year and thus estimates its carbon footprint using the internationally recognised methodology 'Greenhouse Gas Protocol Corporate Standard'[1]. The final figures are presented as tonnes of carbon dioxide equivalent (tCO_2e). This is the 2019 report of the DCU Carbon Footprint using the GHG Protocol and, as can be seen from table 1 below, there has been a significant increase in reported GHG emissions over the reporting periods since 2015. There was a large increase (~45%) growth in student numbers between 2015 and 2018 (although this has since dropped by ~17% of 2018 numbers as of 2019) and an over 150% increase in campus size due to incorporation with St. Patrick's College, Mater Dei and Church of Ireland Institute of Education. However, the majority of the increase in reported GHG emissions is due to improved measurement i.e. additional categories have been included in the scope of calculations, particularly procurement.

Table 1: Summary 2015, 2017, 2018 and 2019

	Scope 1 & 2 tCO2e	All Scopes (1,2 & 3) tCO2e	tCO2e/FTE	tCO2e/m2
2015	13,337	21,652	1.65	0.11
2017	13,865	24,659	1.40	0.04
2018	17,286	66,321	3.54	0.11
2019	15,300	52,362	2.33	0.06

Table 2: Staff and student numbers and total campus area for 2015, 2017, 2018 and 2019

	Staff (FTE)	Students	Campus m2
2015	1,315	11,820	202,343
2017	1,553	16,080	578,701
2018	1,360	17,396	578,701
2019	1,656	14,358	578,701

[1] http://www.ghgprotocol.org/standards/corporate-standard

Figures 1 and 2 below presents the CO2 footprint for the Dublin City University for 2018 and 2019 respectively, identifying emissions sources and their % contribution to the total university carbon footprint.

A key objective of DCU in the completion of this Carbon Footprint report is to demonstrate the GHG Protocol methodology and promote it as a proposed methodology for all Higher Education Institutions (HEIs) in the measurement of their carbon footprints. To aid this discussion DCU has made the data from the 2019 CO2e Report open source and is open to sharing this with those who may be interested. DCU have also submitted their 2019 data to the CDP for external validation of the methodology used.

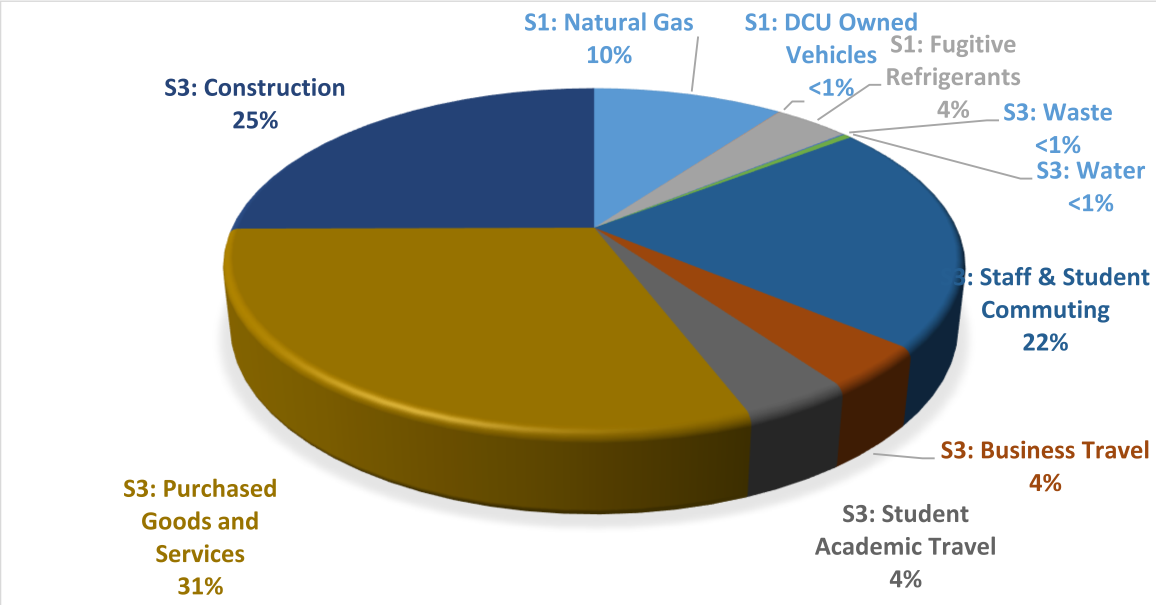

Figure 1: DCU Campus total carbon footprint 2018 (66,321 tCO2e)

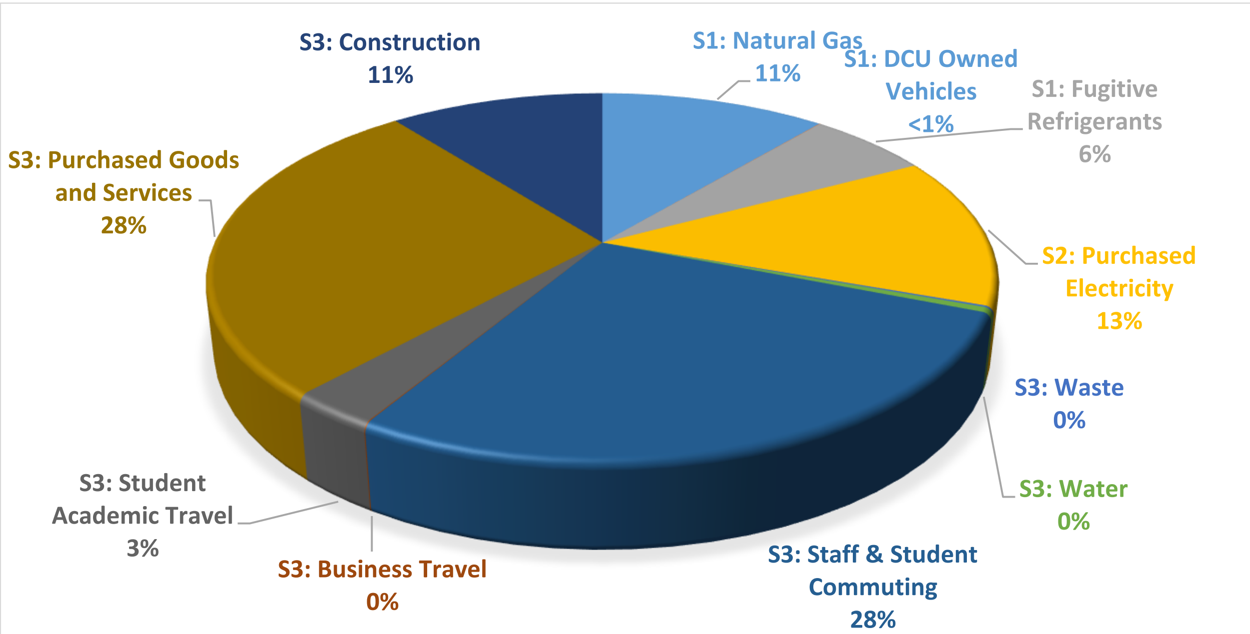

Figure 2: DCU Campus total carbon footprint 2019 (52,632 tCO2e).

This report will focus on the 2019 report – for information on the previous report please see the DCU website (https://www.dcu.ie/ocoo/sustainability.shtml)

2. Introduction

Climate change has been recognised by the United Nations (UN) as one of the biggest challenges today facing humankind (UN, 2017). The recent dramatic rise in global temperatures is due to increased anthropogenic emissions of greenhouse gases (GHG's) from activities such as fuel combustion from energy production and transport, industrial processes, solvent/product use, agriculture and waste (IPCC, 2018a) (UN, 1998). Globally policymakers and scientists alike have agreed that the average global temperature needs to be limited to around 1.5°C above pre-industrial times to keep the risks and impacts of climate change at a manageable level (UN, 2015; IPCC, 2018b). The average global temperature reached 1°C above pre-industrial levels in 2017, meaning there is a limited amount of time to act before we reach these agreed thresholds (IPCC, 2018a). The impacts of global warming are already in effect with increased frequency and intensity of heatwaves, droughts and precipitation events across the globe (IPCC, 2018a). In order to ensure global warming does not exceed 1.5°C, anthropogenic emissions need to be reduced urgently with CO_2 emissions to reach net zero by 2050 (IPCC, 2018a).

The life cycle assessment (LCA) of a product identifies the environmental impacts of a product during production, transportation, use and disposal over its entire life cycle, as outlined by The International Council of Chemical Associations (ICCA, 2012). The application of LCA has broadened in recent decades and is no longer limited to products (Guinée *et al.*, 2011). LCA can now be used to measure the impacts of systems, events, organisations and sectors, among others (Guinée *et al.*, 2011). Performing a full LCA on an organisation can be time, cost and data intensive (ICCA, 2012). However, the pressing environmental concern of climate change has meant the introduction of emission trading schemes and mandatory GHG monitoring for many organisations (EU, 2012). Legislative action such as this has sent a focus in recent times towards the single LCA indicator of a Carbon Footprint (Navarro, Puig and Fullana-i-Palmer, 2017). Various methodologies branching from this LCA indicator have been developed with the intent to simplify the process of an organisational Carbon Footprint while still retaining the integrity of data (Navarro, Puig and Fullana-i-Palmer, 2017).

The term Carbon Footprint (CF) has now come to generally mean the full amount of GHG emissions that are directly and/or indirectly caused by an activity, product life cycle or organisation (Wiedmann, 2009; Alvarez *et al.*, 2016). An organisation's reported emissions can be separated in to three categories or "scopes" (WBCSD and WRI, 2004). Scope 1 emissions are all direct GHG emissions that occur from sources owned/controlled by an organisation (WBCSD and WRI, 2004). Scope 2 emissions are all GHG emissions that occur as a result of the electricity an organisation purchases (WBCSD and WRI, 2004). Scope 3 emissions are all other GHG emissions that may occur as a result of an organisations activities, though the organisation may not own the source of emissions (WBCSD and WRI, 2004).

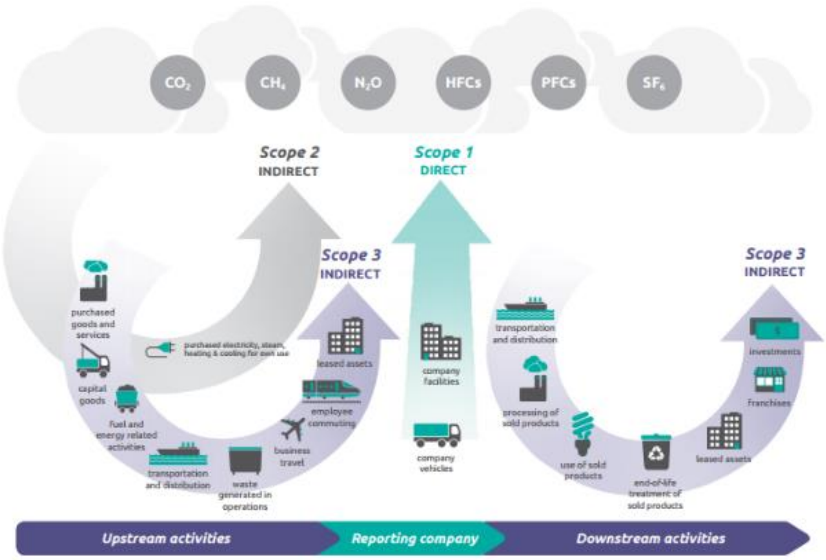

Figure 3. Image of Scope 1, 2 and 3 emission sources (WBCSD and WRI, 2011).

Higher education institutes (HEI's) and universities have a prominent influence on societal problems and attitudes (Arizona State University, 2009). Universities are hubs of innovation and research where solutions to worldwide problems, such as climate change, can be developed (Arizona State University, 2009). Universities also contain some of the future leaders of society and thus find themselves in a unique position to influence the future global attitude of sustainability and climate change impacts (Arizona State University, 2009). In recent years, there has been an increased demand of HEI sustainability accountability (Brusca, Labrador and Larran, 2018). Most universities who are taking their sustainability pledges seriously aim to reduce GHG emissions, with a CF being the first step to this (WBCSD and WRI, 2004). Universities often conduct a CF as a means to inform the ethical and altruistic responsibilities they perceive themselves to have regarding sustainability and GHG mitigation (Robinson *et al.*, 2018). A CF's strength lies in the fact that it has scientific legitimacy, is globally communicable and is easier to implement than a full LCA (Alvarez *et al.*, 2016).

However, there are limitations and issues associated with university carbon footprints (Alvarez *et al.*, 2016). Although quantifying Scope 3 emissions is necessary for most organisations to report a complete GHG inventory and make effective mitigation strategies, there are difficulties surrounding Scope 3 quantification (WBCSD and WRI, 2004; Patchell, 2018; Robinson *et al.*, 2018). There is a lack of guidance on what activities should clearly be included or excluded, leading to either an incomplete picture of an organisations GHG inventory or double counting of emissions (Robinson *et al.*, 2018). There is also the perception that because what is included in Scope 3 emissions is at the discretion of an organisation, that if an organisation is to include a complete quantification of Scope 3 emissions they will be perceived negatively by the public (Robinson *et al.*, 2018). If only reporting Scope 1 and 2 emissions (as is typically all that is mandatory by most standards) a university cannot effectively implement strategies to reduce Scope 3 emissions over which they have control (Patchell, 2018; Robinson *et al.*, 2018). However, if a university that was previously only reporting Scope 1 and 2 emissions were to start including Scope 3 emissions it would increase their total tCO_2e reported per year, which may be viewed negatively by the public who may not understand this nuance (Queen's University, 2018; Robinson *et al.*, 2018). The collection of data for calculation can also be fraught with difficulty as often times guidance on data collection methods are not clear and guidance is often sufficient only in areas where reliable data collection is easily obtained (Robinson *et al.*, 2018).

This study aims to do a comprehensive quantification of a HEI's emissions with the inclusion of all Scope 1, 2 and 3 emissions. This will identify key emission hotspots for HEI's and show the significance for organisations to account and report their Scope 3 emissions. This study will also offer a carbon footprinting methodology for HEI's and in particular offer a methodology for quantifying Scope 3 emissions, which organisations can often find challenging.

3. Methodology

This study will use the methodology outlined in The Greenhouse Gas Protocol Corporate Accounting and Reporting standard (The GHG Protocol standard) and The Greenhouse Gas Protocol Corporate Value Chain Scope 3 Accounting and Reporting standard (The GHG Protocol Scope 3 standard) (WBCSD and WRI, 2004, 2011).

This methodology will be used to quantify the emissions of the HEI Dublin City University (DCU). DCU is a comprehensive university based in North Dublin, Ireland. DCU offers a range of third level programmes in their Faculty of Business, Faculty of Humanities and Social Science, Faculty of Engineering and Computing, Faculty of Science and Health and Institute of Education as well as online distance education programmes. DCU has a population of over 16,000 students and 1,500 staff.

3.1. Organisational Boundary

A Financial Control approach was used to set organisational boundaries. The university directs the financial and operating policies of three main campuses; Glasnevin, St. Patrick's and All Hallows. In keeping with the guidance of The GHG Protocol, all group companies and subsidiaries consolidated into DCU's annual Financial Statement were also deemed to be under the university's Financial Control and thus were also included within the organisational boundary (WBCSD and WRI, 2004; DCU, 2016). The spatial boundary of DCU is outlined in Figure 4 and Table 3.

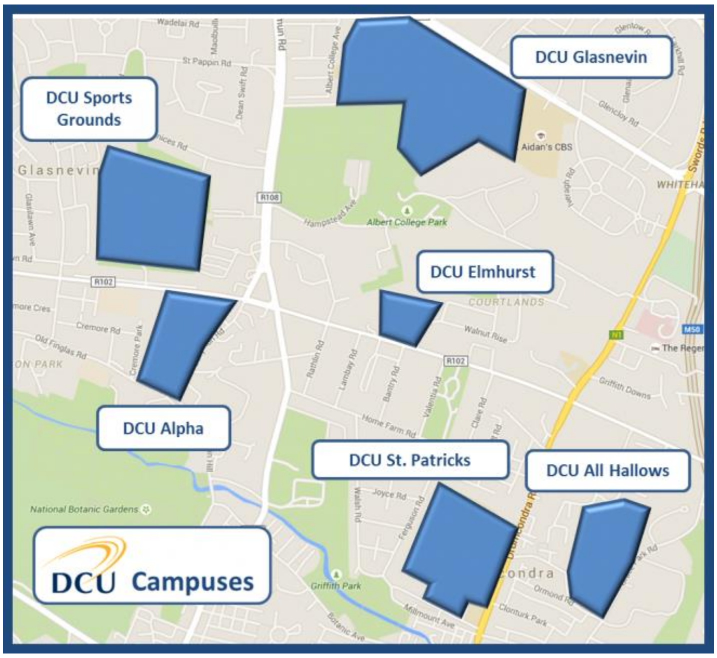

Figure 4. Map of DCU Campuses (Dublin City University, 2019).

Table 3. DCU campus and building area.

Campus	Campus Space (ac)	Building Space (m^2)
DCU Glasnevin	50	170,000
DCU Sport’s	30	1,500
DCU St. Patrick’s	28	40,000
DCU All Hallow’s	16	12,150
DCU ALPHA Innovation	9	18,600
DCU Elmhurst	10	0
DCU in the Community, Ballymun	0	170
DCU Ryan Academy, Citywest	0	800
Total:	143	243,220

Note: total campus area for 2019 estimated at 578,701m2

The temporal boundary chosen was the calendar year of 2019 (1st January – 31st of December). The six Kyoto Protocol gases of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC’s), perfluorocarbons (PFC’s) and sulphur hexafluoride (SF_6) were the greenhouse gases accounted for, as specified by The GHG Protocol (WBCSD and WRI, 2004).

3.2.Operational Boundary

All Scope 1 and Scope 2 emissions were quantified and reported as was mandatory by The GHG Protocol standard (WBCSD and WRI, 2004). Identified Scope 1 emission sources were the stationary combustion of Natural Gas for heat and energy generation, mobile combustion of diesel from the operation of DCU Owned Vehicles and the Fugitive Refrigerants from air conditioning and refrigeration within the university. Emissions from DCU Owned Vehicles and Fugitive Refrigerants were not included in DCU carbon footprints previous to 2018 (Fahy, 2018). Purchased Electricity was the only Scope 2 emission source identified. These emissions were a result of stationary combustion at the site of electricity generation.

The inventory also quantified all Scope 3 emissions, which were optional to quantify and report under The GHG Protocol standard (WBCSD and WRI, 2004). Identified Scope 3 emission sources were the mobile combustion of motor fuel and indirect emissions from electricity used for Staff & Student Commuting, the mobile combustion of aeroplane fuel and indirect emissions from the Hotel sector for Staff Business Travel and Student Academic Travel, methane production and indirect processing emissions from Waste and indirect supply and treatment emissions from Water. Emissions from Purchased Goods & Services were also included. As defined by The GHG Protocol Scope 3 standard, the boundary set for emissions from Purchased Goods & Services was “Cradle to Gate” meaning all emissions generated from extraction until arrival at DCU was included (WBCSD and WRI, 2011). Emissions from Student Academic Travel and Purchased Goods & Services were not included in DCU carbon footprints previous to 2018 (Fahy, 2018). A summary of emission sources within each scope can be seen in Table 4.

Table 4. Summary of identified emissions.

	Emission Source	**Nature of Source**
Scope 1	Natural Gas	Stationary combustion of natural gas
	DCU Owned Vehicles	Mobile combustion of diesel
	Fugitive Refrigerants	Leakage of refrigerants
Scope 2	Purchased Electricity	Indirect stationary combustion
Scope 3	Staff & Student Commuting	Mobile combustion of motor fuel, indirect stationary combustion
	Staff Business Travel	Mobile combustion of aeroplane fuel, indirect hotel sector emissions
	Student Academic Travel	Mobile combustion of aeroplane fuel
	Waste	Methane production, process emissions
	Water	Indirect supply and treatment emissions
	Purchased Goods & Services	Cradle to gate emissions

3.3.Selected Quantification Tools

Emission factors were used to quantify the majority of emissions as, given that direct monitoring of emissions was not available and what activity data could be feasibly collected, this methodology was deemed to be the most accurate. Total emissions from an activity are calculated by multiplying the relevant activity data by an appropriate emission factor (Eq.1). An emission factor is a calculated ratio relating GHG emissions to a measurement of activity; for example, using electricity emissions data from a national inventory and total electricity consumed nationally, an emission factor for emissions per kWh of electricity consumed within that nation may be calculated (WBCSD and WRI, 2004). Emissions were calculated as carbon dioxide equivalent (CO_2e), which is a common unit for greenhouse gases. Emission factors that were as regionally reflective as possible were chosen to improve accuracy in this present study.

$$\textit{Emission Factor } (CO_2e/x) \times \textit{Activity Data } (x) = \textit{Total Emissions } (CO_2e) \qquad \text{Eq.1}$$

Natural gas and diesel Sustainable Energy Authority Ireland (SEAI) emission factors were used to calculate emissions from Natural Gas and DCU Owned Vehicles. SEAI are Ireland's national energy authority (DCCAE, 2020). These emission factors are based on information from the Irish Environmental Protection Agency's (EPA) annual National Inventory Report for Ireland, as confirmed in personal communication via email with SEAI (16th April 2019) and EPA (17th April 2019). The Irish EPA is an independent public body responsible for national environmental protection and policing (EPA, 2020).

Purchased Electricity was calculated using an SEAI electricity emission factor instead of the Energy Elephant Realtime Management System tool that the university currently uses to report emissions. The Energy Elephant Real Time Management System monitors emissions from the national electricity grid in real time and takes in to account that 37.5% of energy bought by DCU is from renewable sources, compared to the national standard of 25% (DCU Estates Officer, personal communication, 15th April 2019). However, DCU did not receive a Certificate of Origin (CoO) for their purchased renewable energy to guarantee this energy was from renewable sources (DCU Estate Officer, personal communication via email, 16th April 2019). As this renewable energy purchase was a national requirement of public bodies its credibility was governed by the Office of Public Procurement and only those who purchased 100% renewable energy received a CoO (DCU Estate Officer, personal communication via email, 16th April 2019). Therefore, Purchased Electricity emissions were calculated using SEAI factors as the value may be reflective of DCU's true purchased electricity emissions.

Emission factors from the UK Department for Environment, Food and Rural Affairs (DEFRA) were used to calculate emissions from Staff & Student Commuting, Waste and Water. The Irish Department of Communications, Climate Action and Environment or any other national body (such as the EPA) has yet to calculate and publish emission factors for these categories. Thus, in the absence of Irish emission factors DEFRA emission factors were deemed to be the most regionally reflective. Diesel, petrol and electric vehicle emission factors were based on the New European Driving Cycle (NEDC), although International Council on Clean Transport (ICCT) data was used to reflect real world vehicle use rather than laboratory testing values (UK Department for the Environment Food and Rural Affairs, 2019). This data was adjusted using information from the Society of Motor Manufacturers and Traders (SMMT) and the UK Department for Transport (DfT) to reflect to age and activity distribution of UK vehicles (UK Department for the Environment Food and Rural Affairs, 2019). For the taxi emission factor used is based on NEDC data and Transport for London (TfL) black cab data (UK Department for the Environment Food and Rural Affairs, 2019). Bus emission factors were derived from UK DfT average distance, occupancy and fuel consumption statistics (UK Department for the Environment Food and Rural Affairs, 2019). The Clear road test database and UK DfT licence statistics were used to derive the motorbike emission factor used (UK Department for the Environment Food and Rural Affairs, 2018). The national rail emission factor used was based upon the reported average electricity and diesel consumption per average passenger kilometre (km) in the most up to date UK Office of the Rail Regulators National Rail Trend (UK Department for the Environment Food and Rural Affairs, 2018). The light rail emission factor chosen to calculate Irish Luas emissions is derived from TfL and UK DfT statistics on electricity consumption per average passenger km (UK Department for the Environment Food and Rural Affairs, 2018). The van emission factor chosen was based on UK National Atmospheric Emissions Inventory (NAEI) emission data, with SMMT Motor Vehicle Registration Information System (MVRIS) and UK DfT data used to make assumptions about van size and uplift factors respectively (UK Department for the Environment Food and Rural Affairs, 2018).

Water UK reports on all UK water suppliers GHG emissions and these data are where the water supply and treatment emission factors were derived from (UK Department for the Environment Food and Rural Affairs, 2018). Waste landfill emission factors are based on the UK Methane Emissions Landfill Modelling (MELMod) report (UK Department for the Environment Food and Rural Affairs, 2018). All waste emission factors chosen use data from the Waste Resource Assessment Tool for the Environment (WRATE) about waste transport and preparation emissions (UK Department for the Environment Food and Rural Affairs, 2018). DEFRA recycling and recovery emission factors do not take emissions from the processing of these wastes in to account (UK Department for the Environment Food and Rural Affairs, 2018). Although this is not in keeping with The GHG Protocol Scope 3 standard, which sets a minimum boundary of Scope 1 & 2 emissions for any waste disposal processing emissions from other facilities, these emission factors were chosen due to a lack of alternative emission factors deemed to be regionally reflective (WBCSD and WRI, 2011; UK Department for the Environment Food and Rural Affairs, 2018).

DEFRA's Global Warming Potential (GWP) of refrigerants were used to calculate emissions from Fugitive Refrigerants. These GWP's were extracted from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (UK Department for the Environment Food and Rural Affairs, 2018). Some of the refrigerants used by DCU were not Kyoto gases and thus were not mandatory to report. However, these refrigerants were still quantified separately following guidance from The GHG Protocol (WBCSD and WRI, 2004). The GHG Protocol indicates this may improve the accuracy of any future reports, as a future change of refrigerant with a lower GWP may otherwise appear as an increase of emissions if moving from a non-Kyoto gas to a Kyoto gas (WBCSD and WRI, 2004). The GWP of R170 (ethane) was sourced from Linde as it was not included in DEFRA's emission factors (Linde, 2020).

AerClub Travel emission factors were provided from the Climate Policy section of the Department of Environment, Community and Local Government (DECLG) in 2016 (ClubTravel, personal communication via email, 16th April 2019). These emission factors were chosen to quantify and report Staff Business Travel and Student Academic Travel flight emissions as they were provided from an Irish national body and likely best reflect national flight activity emissions. However, due to political restructuring, this department no longer exists and as such information regarding the underlying methodology or data used to derive the AerClub Travel emission factors was unavailable (ClubTravel, personal communication via email, 16th April 2019). AerClub flight emission factors include the effects of radiative forcing (ClubTravel, personal communication via email) (UK Department for the Environment Food and Rural Affairs, 2018).

Emission factors for Staff Business Travel hotel stays were derived from the Cornell Hotel Sustainability Benchmarking (CHSB) tool, which contained annual emission reporting data from thousands of hotels internationally as produced by International Tourism Partnership (ITP) and Greenview (UK Department for Environment Food and Rural Affairs, 2018; GreenView, 2020). There were some limitations with using these hotel emission factors. Not every country was represented. For any country not included, the geographically closest country's emission factor was used. Furthermore, the data on which the emission factors were based upon may not be accurate. Most hotels included in the underlying CHSB tool data were high end and thus report a high carbon intensity. Not all data within the tool was independently verified which may compromise the emission factors' reliability.

The GHG Protocol Scope 3 Evaluator tool was used to quantify emissions from Purchased Goods & Services (Quantis, 2019). This was a spend based Environmentally Extended Input Output (EEIO) tool based upon the World Input Output Database (WIOD); a global multiregional estimate of average environmental impact by economic region-sector (Quantis and The Greenhouse Gas Protocol, 2017). As this database was constructed in 2009, The GHG Protocol Scope 3 Evaluator tool adjusts price indices by applying WIOD Socio-Economic Accounts factors up to 2014 (Quantis and The Greenhouse

Gas Protocol, 2017). As such, a limitation of this chosen tool was that it was based on outdated data. WIOD data also only includes emissions from the GHG's CO_2, CH_4 and N_2O, meaning not all Kyoto gases are included in Purchased Goods & Services reported emissions data (Quantis and The Greenhouse Gas Protocol, 2017). Another limitation of the tool chosen is that it is not regionally reflective. The tool chosen aggregates world data and does not take in to account an organisation's location. An EEIO tool is also not able to take in to account subtle value chain differences compared to a process-based approach. For example, changing suppliers of a product may reduce emissions due to lower emissions during production, but this won't be captured in an EEIO tool who will classify both supplier's product as the same (WRI and WBCSD, 2013). However, given the data available and time constraints for this project, The GHG Protocol Scope 3 Evaluator tool was used.

A summary of quantification tools used for each emission source can be seen in Table 5. Table 5 also shows the underlying methodology or data that each tool is based on. A full list of emission factors used is provided in the supplementary data.

Table 5. Summary of quantification tools used for identified emission source and underlying basis of tools

	Tools Used	Basis of Tool
Natural Gas	SEAI Natural Gas Emission Factor	EPA National Inventory Report
DCU Owned Vehicles	SEAI Diesel Emission Factor	EPA National Inventory Report
Fugitive Refrigerants	DEFRA GWP of refrigerants	IPCC Fifth Assessment Report
Purchased Electricity	SEAI Electricity Emission Factors	EPA National Inventory Report
Staff & Student Commuting	DEFRA Car/Taxi Emission Factors	NEDC, ICCT uplift data, SMMT and DfT databases, TfL data
	DEFRA Bus Emission Factor	UK DfT statistics
	DEFRA Motorbike Emission Factor	Clear database, UK DfT statistics
	DEFRA Van Emission Factor	NAEI emissions data, SMMT MVR Information System
	DEFRA Rail Emission Factors	UK Office of Rail Regulator's National Rail Trend data, UK DfT and TfL data
Staff Business Travel	AerClub Emission Factors	Provided by Climate Policy section of former DECLG
	DEFRA Hotel Emission Factors	CHSB Tool Data
Student Academic Travel	AerClub Emission Factors	Provided by Climate Policy section of former DECLG
Waste	DEFRA Waste Emission Factors	MELMod report, UK Environment Agency WRATE data

Water	DEFRA Water Supply/Treatment Emission Factors	Water UK data
Purchased Goods & Services	The GHG Protocol Scope 3 Evaluator	WIOD

3.4. Activity Data Collection

Once quantification methodologies and tools were chosen the corresponding activity data was collected. It should be noted that in some cases the direct activity data was not available and had to be derived from other data available. In keeping with The GHG Protocol principle of Transparency, all assumptions and extrapolations are disclosed (WBCSD and WRI, 2004). (See supplementary data).

Activity data was collected from a number of different offices across DCU, which have different roles. The Estates Office is responsible for building maintenance, grounds maintenance, campus security and the provision of health and safety (DCU, 2020a). The Sustainability Office is responsible for university sustainability across a number of criteria such as transport, waste, water, biodiversity, energy etc. The Finance Office oversees all financial activities of the university (DCU, 2020b). The International Office is responsible for recruiting, managing and representing DCU international students and domestic students international experiences (DCU, 2020c). The Quality Promotion Office promotes, supports and facilitates continuous quality improvement activities across academic and administrative units throughout the University (DCU, 2020d).

The activity data needed to quantify emissions from natural gas was kWh of natural gas consumed. This was obtained from the DCU Senior Management Energy Review 2019 (Raftery *et al.*, 2019). Diesel consumed in kWh was not included in this review and instead a figure of 60,000 kWh was provided by the Estates Office of DCU (DCU Estate Officer, personal communication via email, 16th April 2019). Electricity consumed in kWh was obtained from the DCU Senior Management Energy Review 2018 (Raftery *et al.*, 2018). Tonnes of each waste type and water supplied to each campus in m^3 were also obtained from the DCU Senior Management Energy Review 2018 (Raftery *et al.*, 2018).

The amount of refrigerant leaked in kg from air conditioning units and cold rooms was obtained directly from the Estates Office, who provided a register of all units which are serviced annually. For stand-alone fridges/freezers an inventory was done according to the DEFRA Screening Method guidelines (UK Department for the Environment Food and Rural Affairs, 2019). The refrigerant type and charge capacity (kg of refrigerant used within a unit) was collected for each stand-alone fridge/freezer unit. Where the refrigerant or charge capacity was unknown, an assumption was made based on similar fridges of the same model or description. Due to health and safety rules, access to restaurant units was restricted and models were instead assumed based on information given from restaurant staff about units. Retail staff on campus provided the global warming potential of units rather than refrigerants used. Charge capacity was then multiplied by an annual leakage rate of 0.3% to estimate the amount of refrigerant leaked from these units in kg (UK Department for the Environment Food and Rural Affairs, 2019). It was recognised that a limitation to this data collection method is that some units may have been overlooked.

Data regarding the daily distances commuted by staff and students and their chosen mode of transport for their commute was obtained from DCU's Sustainability Office 2019 travel survey, which was circulated to all DCU staff and students in December 2019 via email. Since travel survey distance responses were within a range, the mid interval or upper limit was assumed as the respondent's distance. To calculate the total distance for each mode of transport the mean daily one way distance for each mode was multiplied by the total number of commuting days for the year (220 for staff and 160 for students), the percentage of staff/student that used each mode of transport, the total Full Time Equivalent (FTE) staff/students during 2019 (1,656 FTE staff and 14,358 FTE students) and then doubled to reflect a return journey.

The DCU Finance Office provided information on flight class and distance flown in km. Data on hotel stays was not directly available. It was assumed from the information the DCU Finance Office gave that any staff member that spent one night or more in a country stayed in a hotel during that time. The number of passengers (pax) was multiplied by nights spent in a country to get the total number of nights spent in a hotel for that country.

The DCU Quality Promotion Office provided data on the number of incoming students on exchange and their domicile. The DCU International Office provided information on the destination country and number of outgoing DCU students on exchange. The International Office also disaggregated incoming student information further. Information on the university's partner institutions was then used to proportionally represent student start/end points (DCU International Office, 2020). An online map tool was used to calculate distances "as the crow flies" (Free Map Tools, 2019). The closest airport to each institution and Dublin Airport was assumed as the start/end point for all flights. It was assumed that all students made one return flight per semester. For students on a year-long exchange it was assumed that the 2019 calendar year contained only one semester of their exchange, as a year-long exchange typically falls within the academic year as opposed to the calendar year. For students on a two year long exchange, it was assumed that two semesters of this exchange fell within the calendar year.

DCU Finance office supplied spend data on the top 20 suppliers of all DCU companies. This spend data was provided in euro, included Value Added Tax (VAT) and a supplier category/description accompanied each supplier. The only data available was from the financial year (October 2018-September 2019) which does not align with the 2019 calendar year. However, this data was still used as it was assumed to be a reflection of the spend within the 2019 calendar year. These suppliers typically accounted for 80% or higher of the campus companies spend. The exception to this was the DCU main account where the top 190 suppliers were provided, accounting for 80% of the spend. As this data was not the full spend amounts, spend in euro was divided by the relevant percentage of spend and multiplied by 100 to make data proportional. Euro amounts were then multiplied by the WIOD Ireland 2014 conversion rate to convert euro spend to American dollars (USD) as price indices within the tool were normalised up to 2014 (Timmer *et al.*, 2015). Based on supplier descriptions/categories provided, VAT amounts were assigned to each supplier's spend using a revenue VAT database (Revenue Irish Tax and Customs, 2019). VAT of each spend was then calculated and subtracted from spend to calculate basic price in USD. Each basic price value was categorised into a GHG Protocol Scope 3 Evaluator sector of purchase based on supplier descriptions/categories provided and using the United Nations International Standard Industrial Classification of All Economic Activities Revision 3.1 (ISIC Rev.3) (United Nations, 2002; Quantis, 2020). Fifteen out of thirty-five possible categories were identified for the DCU's spend. Basic price values were further sub categorised as a good or service.

A summary of the activity data needed for each emission source quantification and the source of this data can be seen in Table 6. Activity data can be seen in the supplement data.

Table 6. Summary of activity data needed for each emission source quantification and source of activity data.

	Activity Data Needed	**Unit**	**Source of Activity Data**
Natural Gas	Natural gas consumed	kWh	Senior Management Energy Review 2019
DCU Owned Vehicles	Diesel consumed	kWh	Estates Office
Fugitive Refrigerants	Amount of refrigerant leaked	kg	Estates Office Register, DEFRA Screening Method Inventory
Purchased Electricity	Electricity consumed	kWh	Senior Management Energy Review 2019
Staff & Student Commuting	Total distance travelled for mode of transport	km	Sustainability Office Transport Survey
Staff Business Travel	Flight class and distance flown, country of hotel stay	km, number of nights	Finance Office
Student Academic Travel	Flight class and distance flown	km	Quality Promotion Office, International Office
Waste	Weight of waste type	tonnes	Estates Office

Water	Water supplied	m^3	Senior Management Energy Review 2019
Purchased Goods & Services	Basic price spent in each GHG Protocol sector purchase category	$ (USD)	Finance Office

4. Results

4.1. Absolute Emissions

A summary of 2019 emissions for each emission source can be seen in Table 7. As is required from The GHG Protocol standard, a base year was chosen (1st January 2018 – 31st December 2018) to meaningfully compare emissions over time (WBCSD and WRI, 2004). A summary of available 2018 emissions for each emission source can also be seen in Table 7.

Table 7. Results of 2019 emissions versus 2018 emissions.

	Scope	Total Emissions 2019 (tCO_2e)	Total Emissions 2018 (tCO_2e) (Base Year)
Natural Gas	1	5567.8	5739.36
DCU Owned Vehicles	1	13.5	15.83
Fugitive Refrigerants	1	3024.1	2265.77
Purchased Electricity	2	6694.28	9264.98
Staff & Student Commuting	3	13,841	12,291.23
Business Travel- Flights Only	3	1873.3	1893.40
Business Travel- Hotels Only	3	563.7	391.06
Student Academic Travel	3	1,549	2300.37
Waste	3	66.1	52.22
Water	3	210.72	236.70
Purchased Goods & Services	3	19,228.74	31,851.28
Total:		**52,632**	**66,302.20**

The above figures for Purchased Goods and Services include Construction-based emissions. As Construction-based emissions are subject to higher levels of fluctuation from year to year than other sources of emissions, it was decided to compare the total emissions excluding Construction to the total emissions, which can be seen in Table 8.

Table 8. Comparison of the different scopes with and without Construction

	Scope 1 & 2 tCO_2e	All Scopes (1,2 & 3) including Construction tCO_2e	All Scopes (1, 2 & 3) excluding Construction tCO_2e	Scope 3 excluding Construction tCo2e
2018	17,286	66,321	52,004	34,717
2019	15,230	52,632	47,341	32,042

Upon guidance from The GHG Protocol, emissions from non-Kyoto refrigerants were calculated but not included in the overall emissions total (Table 9).

Table 9. Surplus calculation.

	Total Emissions 2019 (tCO_2e)	Total Emissions 2018 (tCO_2e)
Fugitive Refrigerants (Non-Kyoto Refrigerants)	872	550.60

4.2. Emission Intensity

As universities can differ significantly in size or population, carbon intensities may be used to meaningfully compare university emissions. The carbon intensity of tCO_2e/FTE reflects the emissions associated with individual full time equivalent (FTE) staff and students. The carbon intensity tCO_2e/m^2 reflects the emissions associated with the university's campus area. Carbon intensities for both Scope 1 & 2 emissions and overall emissions were calculated for broader external comparison, as it is recognised that some institutions may only report Scope 1 & 2 emissions currently.

Table 10. Carbon intensities for DCU's 2019 population and campus area.

	tCO_2e/FTE	tCO_2e/m2
Scope 1 & 2	0.96	0.03
All Scopes	3.29	0.09
All Scopes (Excluding Construction)	2.96	0.08

Table 11. Carbon intensities for DCU's 2018 population and campus area

	tCO2e/FTE	tCO2e/m2
Scope 1 & 2	0.92	0.03
All Scopes	3.54	0.11
All Scopes (Excluding Construction)	2.77	0.09

5. Discussion

5.1. Breakdown of Overall Emissions

Total emissions for DCU during the 2019 calendar year was 52,632 tCO_2e. As can be seen in Figure 5, Scope 3 emissions accounted for the majority of emissions (70.9%). Scope 1 emissions accounted for 16.5% of overall emissions and Scope 2 emissions accounted for 12.9% of overall emissions. The single largest contributor to emissions was Purchased Goods & Services, closely followed by Staff and Student Commuting (26.5% and 26.3% of overall emissions respectively) with construction related procurement accounting for 10.1% of overall emissions. Scope 1 & 2 emissions increased from approximately 26% of overall emissions in 2018 to 29% of overall emissions in 2019.

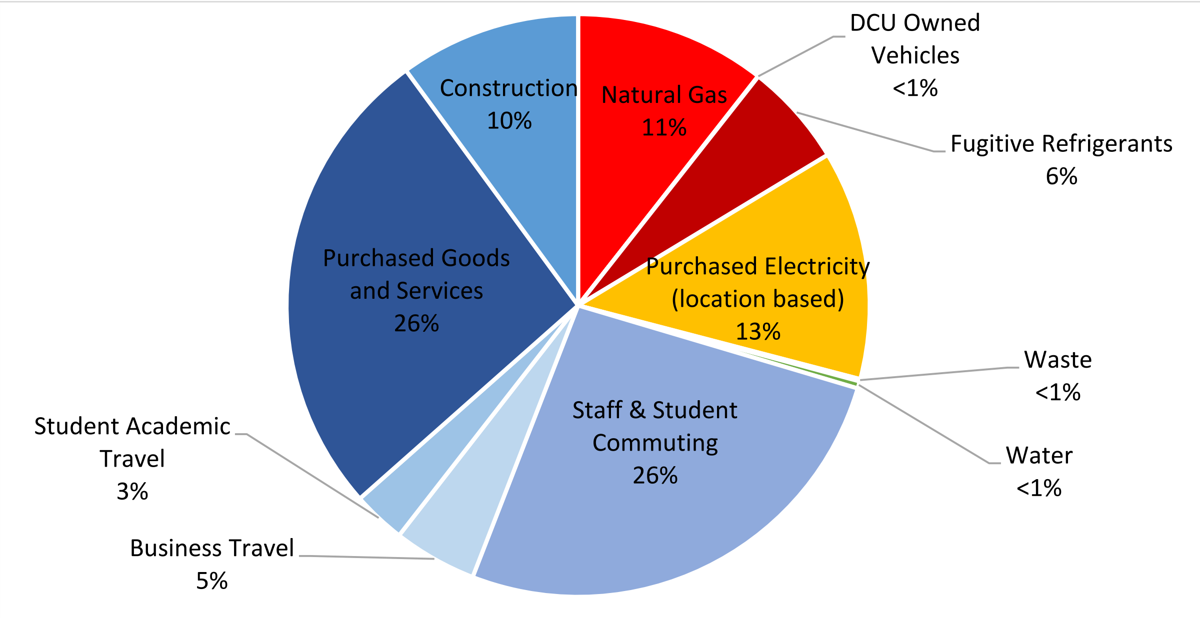

Figure 5. Percentage breakdown of DCU emissions by scope and category. Scope 1 emissions are in red, Scope 2 emissions are in yellow and Scope 3 emissions are in blue.

There is a lack of published literature regarding HEI emissions that includes Purchased Goods & Services related emissions. This may be due to the complex nature of quantifying these emissions or an ignorance of the significance of emissions from this category. However, applicable literature that was found supported findings on the portion of DCU's overall emissions attributed to Purchased Goods & Services (Doyle, 2012; Alvarez, Blanquer and Rubio, 2014; Woodhouse *et al.*, 2014). University of Cambridge, who also quantified Purchased Goods & Services emissions using a spend based EEIO system, found procurement related emissions to be 51.4% of the university's overall emissions with construction related procurement being 14.6% of overall emissions (Woodhouse *et al.*, 2014). It should be noted that University of Cambridge did not include emissions from Fugitive Refrigerants, Student Academic Travel and University Owned Vehicles (Woodhouse *et al.*, 2014). The University of California, Berkeley (UC Berkeley) calculated procurement related emissions to be 39% of the university's overall emissions using a more advanced hybrid method (Doyle, 2012). Construction related procurement equated to 24% of procurement related emissions (Doyle, 2012). It was difficult to meaningfully compare results from the University of Madrid as their carbon footprint did not capture emissions from Staff & Student Commuting, Student Academic Travel and Fugitive Emissions (Alvarez, Blanquer and Rubio, 2014). However, the university reported Scope 3 emissions to be 59% of their overall emissions using an EEIO tool (Alvarez, Blanquer and Rubio, 2014). As the university did not include the Scope 3 emission contributing category of commuting, it may be expected that actual Scope 3 emissions would be higher for the university (Alvarez, Blanquer and Rubio, 2014). It was difficult to directly compare results from these three universities with DCU's results as quantification methods, operational boundaries and countries of origin differed (Doyle, 2012; Alvarez, Blanquer and Rubio, 2014; Woodhouse *et al.*, 2014). However, these universities results were at the very least an indication that DCU's large Purchased Goods & Services emissions were not unusual and should be taken into serious consideration for future carbon footprints and mitigation measures.

5.2. Significance of Results

When comparing the total emissions between 2018 and 2019, there was a significant drop of 21% in total emissions. However, a large percentage of this drop in emissions was due to a change in Construction-based emissions, which fell from 22% (14,317 tCo2e) of DCU's total emissions in 2018 to 10.1% (5,290.6 tCo2e) of DCU's total emissions in 2019. This was due to the construction of the U Student Building, which was completed in September of 2018 (Dublin City University, 2020), as well as the expansion of the existing Stokes Engineering Building, which was completed in July 2018 (Fitzpatrick, 2020). There were no building projects of a comparable scale taking place in 2019, which led to the major decrease in Construction-related emissions.

When Construction-based emissions are removed from the comparison, there was a decrease of 9% of 2018 emissions between 2018 and 2019. While there was still a decrease in total emissions excluding

Construction, it is notably lower than the percentage drop in total emissions and is more indicative of DCU's reduction in emissions due to changes in university policy.

Although it is only mandatory to report Scope 1 & 2 emissions with The GHG Protocol Standard, these results highlight the importance of including Scope 3 emissions to effectively inform future HEI mitigation strategies (WBCSD and WRI, 2004). The inclusion of four emission sources since DCU's 2018 CF showed a dramatic shift in the university's Scope 1 & 2 portion of overall emissions (55% in 2017 down to 26% in 2018). These categories, which had previously been omitted due to their assumed insignificance or difficulty in quantification, meant DCU's Scope 3 emissions increased from 45% of overall emissions in 2017 to 76.34% of overall emissions in 2018, and have remained above 70% of total emissions into 2019.

Even when HEI Scope 3 emissions are accounted for, a HEI may believe they have limited ability to reduce these indirect emissions as they are out of the HEI's control (Horan *et al.*, 2019). However, previous organisational CF case studies may show that this thinking may be too limiting. After completing a CF in 2010 to quantify their 2007 emissions, the UK's National Health Service (NHS) found that Scope 3 emissions accounted for the majority of their emissions, with emissions from Procurement being 59% of their overall emissions (NHS Sustainable Development Unit, Stockholm Environmental Institute and ARUP, 2010). The implementation of carbon reduction measures by the NHS resulted in a 16% absolute reduction of 2015 Procurement carbon emissions from the base year of 2007, despite an increase in activity during that time (NHS Sustainable Development Unit, 2016). The NHS is an example of how an organisation's influence over categories such as Purchased Goods & Services emissions can have an impact if monitored and tackled

5.3. Higher Education Institute Carbon Footprint Methodology

The CF methodology used in this paper may adopted for the use of any Higher Education Institute. An outline of the methodology is summarised below.

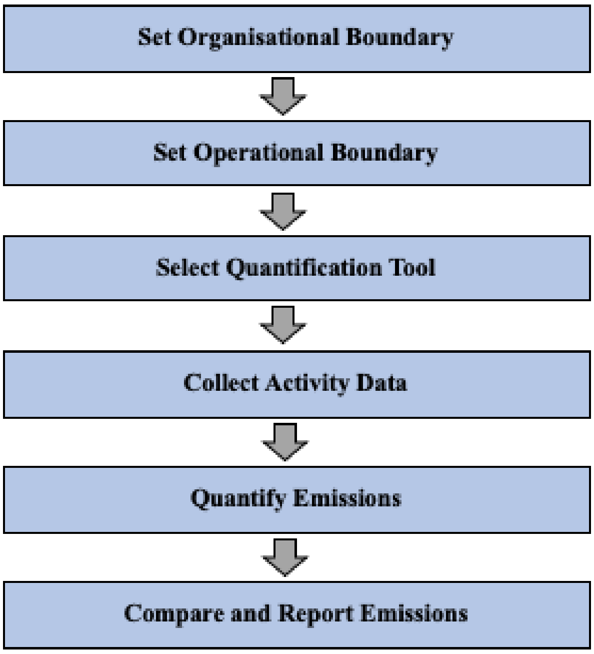

Figure 6. Carbon footprint methodology flowchart.

- **Set Organisational Boundary:** Using the financial control approach outlined by The GHG Protocol standard, boundaries for a HEI should be set (WBCSD and WRI, 2004). HEI's should include any operation over which it (a) has the ability to direct financial/operating policies with the view to gaining economic benefits from its activities or (b) considers as a group company or subsidiary for the purpose of financial consolidation and is therefore consolidated in financial accounts (WBCSD and WRI, 2004).
- **Set Operational Boundary:** All possible emission sources within all three scopes should be identified and included. HEI emission sources are not limited to those included in DCU's carbon footprint and care should be taken that any additional sources for a university are identified. Boundaries for emission sources (e.g. cradle to gate rather than cradle to grave for purchased goods) should be in keeping with The GHG Protocol standard and The GHG Protocol Scope 3 standard (WBCSD and WRI, 2004, 2011).

- **Select Quantification Tool:** Quantification tools that directly monitor emissions from an emission source (e.g. the Energy Elephant Real Time Management tool used to quantify DCU's purchased electricity emissions) are preferable as uncertainty surrounding quantification and data collected is reduced. Where these are unavailable, emission factors may be used. Although it is more preferable to use national emission factors (e.g. SEAI and AerClub) as they will reflect HEI emissions more accurately, it is recognised these may not always be available. In these cases, non-national emission factors that are reliable and regionally reflective (e.g. DEFRA) may be used. Some emission sources, such as Purchased Goods & Services, may be too complex or not have the correct activity data available to quantify emissions using emission factors. In these cases, other tools may be used (e.g. The GHG Protocol Scope 3 Evaluator).
- **Collect Activity Data:** In all cases, activity data should be sourced directly from source. Where this is not possible, activity data may be extrapolated from data that is already available. Where activity data is unreliable or difficult to obtain, a new quantification tool requiring different activity data may be necessary.
- **Quantify Emissions:** Using selected quantification tools and activity data collected, quantify emissions for identified emission sources.
- **Compare and Report Emissions:** All emissions that have been quantified should be reported. A base year should be chosen to compare emissions to. Carbon footprint reports should be transparent in the manner in which emissions were quantified.

This methodology can be compared to the HEI carbon footprint methodology proposed by Robinson et al. in their paper. The essence of both methodologies' content is very similar and both include the processes of setting organisational and operational boundaries, collecting activity data and quantifying emissions and reporting results. The main difference of both methodologies is the structure. Robinsons et al.'s approach may be more high level; Robinsons et al.'s study shows these processes outlined under the overall arching processes of "Scoping", "Conceptualising" and "Communicating". In comparison, this study's methodology (see Figure 7) may be seen as more practical as these processes are further segregated and laid out consecutively step by step. In addition, the actual process of quantifying and reporting DCU's carbon footprint in this study is an example of the methodology and offers further technical guidance on this methodology. Robinson et al. also discuss the possibility of having a cut off criteria and recommends HEI's do two separate carbon footprints: a minimum Scope 1 & 2 CF and a comprehensive CF including Scope 3 emissions. It is thought that all HEI's have the resources to conduct a minimum CF with the aspiration to complete a comprehensive CF (Robinson *et al.*, 2018). The methodology in this paper does not make this distinction. It is assumed all identified emissions sources from each Scope is included, including Scope 3 emissions. The results from DCU's carbon footprint shows the significance of including all emissions within an organisation's CF as Scope 3 emissions may be the vast majority of HEI emissions (see Figure 5).

5.4. Future Improvements

A number of measures could be taken to improve future DCU carbon footprints using this methodology. Firstly, improvements could be made to improve the quality of activity data. The travel survey used to collect Staff & Student Commuting data could include more specific distance responses (i.e. smaller distance interval choices or ask respondents to manually input distances), or ask respondents to input their start and end journey points, in order to increase the accuracy of total distances travelled. Future carbon footprints may also wish to conduct a survey with incoming and outgoing exchange students and garner information on flight frequency and class to increase the accuracy of flights calculated for Student Academic Travel. More detailed data about the exact university or city of exchange origin/destination would also improve the accuracy of calculated flight distances for Student Academic Travel. It is recommended future carbon footprints communicate further with the DCU International Office and Quality Promotion Office to resolve how this data can be obtained in a manner that is sufficiently anonymised for data restriction purposes. It is also recommended that DCU seek a CoO for renewable energy bought from the Office of Public Procurement to ensure that emissions quantified including this portion of renewables is reflective of DCU's actual Purchased Electricity emissions.

A number of improvements can also be made to improve quantification tools chosen in future carbon footprints. Future carbon footprints should seek recovery and recyclables Waste emission factors that include the minimum boundaries specified by The GHG Protocol Scope 3 standard. Methodology for the derivation of AerClub emission factors should be sought and compared against other flight emission factors to determine which factors are more reliable and reflective of DCU's flight emissions. Emission factors for hotel stays in countries not covered by DEFRA's emission factors should be sourced. All quantification tools, specifically all emission factors, should be reviewed with every carbon footprint as the science and data these tools are based on is constantly improving and evolving

It is apparent that the emissions quantified for Purchased Goods & Services have a high level of uncertainty and should be viewed as a screening of the general magnitude and sources of procurement related emissions within the university, rather than a reliable result. DCU's emissions from the GHG Protocol sector of purchase Agriculture highlight a limitation with the tool used to quantify Purchased Goods & Services emissions. Though not a big contributor due to low spend in the sector, agriculture proved to be the most emission intensive sector. At only 0.65% of spend it accounted for 3.51% of emissions. This means spend within this sector emitted roughly 2.09 $kgCO_2e/\$$ compared to 0.69 $kgCO_2e/\$$ for construction and 0.21 $kgCO_2e/\$$ for business activities. Spend is categorised in to the tools sector of purchase categories using ISIC Rev.3, an economic classification system (United Nations, 2002). Using this system all landscaping activities were classified under an agricultural sector of purchase. However this sector also includes all farming activities, a huge contributor to anthropogenic emissions globally (Wollenberg *et al.*, 2016). Thus, emissions calculated for the university's landscaping activities using this tool likely did not reflect the actual emissions of these activities. Any activity within a sector of purchase was generalised to the same emissions despite the nature of that specific activity, meaning any emissions from purchases may be under or over estimated.

Emissions also reflect general emissions for sectors of purchase globally and may not be specific enough to each region to accurately reflect emissions. For example, general emissions surrounding restaurant activities may vary from country to country based on that country's typical diet, GDP, food availability or predominantly used cooking fuel, among other factors. The activity data required for this tool (basic price in USD) was another limitation of this tool. Converting currency may have further compromised results as there was no specific guidance on what currency exchange rate to use although exchange rates are continuously changing. Given the order of magnitude of spend data, results could vary significantly if the euro activity data is converted by a different exchange rate. Getting activity data in basic price was also a challenge, as university accounts do not typically have a financial or administrative reason to separate VAT price from overall spend with the majority of purchases and so VAT data was not directly available. The tool also may not quantify emissions within sectors of purchase that are reflective of today's emissions within that sector, as the tool only corrects data up to 2014 (Quantis and The Greenhouse Gas Protocol, 2017). The tool also doesn't include emissions for HFC's, PFC's and SF_6, meaning it does not cover the entire boundary of Kyoto gases included in this inventory (Quantis and The Greenhouse Gas Protocol, 2017).

If using an EEIO tool to quantify emissions in the future, the university could increase accuracy by sourcing a tool that is regionally reflective (based on national or European sector of purchase emission data), up to date (based on emission data within the period of the temporal boundary), uses price including VAT in euro as it's activity data and is inclusive of all Kyoto gases. A more specific EEIO tool that recognises different activities within each sector of purchase would also increase accuracy.

However, it is recommended that the university moves away from a solely spend based method of quantification for this category of emissions in order to increase accuracy (WRI and WBCSD, 2013). Sourcing supplier specific emission data directly from suppliers would be the most reliable method of quantifying Purchased Goods & Services emissions (WRI and WBCSD, 2013). However, recognising the high time and cost investment that may be involved in sourcing this data from all of the university's suppliers, a move towards a hybrid method may be more feasible (WRI and WBCSD, 2013). This would involve sourcing supplier specific emission data from some suppliers and calculating the remaining suppliers emissions using an EEIO tool (WRI and WBCSD, 2013). A hybrid method would allow for procurement related reduction efforts to be captured in future carbon footprints, as the generalisation of an EEIO tool does not take into account suppliers emission reduction efforts in comparison to other suppliers within that sector. As it has been identified as DCU's largest source of purchased goods and services emissions, it is recommended that construction suppliers are the first approached for supplier specific emission data. Aside from getting a more accurate quantification of construction emissions, this may also begin communication between suppliers and the university on how to reduce emissions. Future growth policies within the university may also endeavour to make use of existing structures within the university rather than construct new ones to mitigate future construction emissions.

6. Conclusion

The results from this study outlines the need for HEIs to include scope 3 emissions within their greenhouse gas accounting for effective emission mitigation. Although typically omitted by HEIs and other organisations during carbon footprint calculations due to the complex nature of calculating these emissions, indirect emissions contribute over 70% of DCU accounted emissions. Mitigation measures targeting reduced consumption, better use of available space and sustainable transport will be more effective at reducing a HEI's annual emissions than energy efficiency measures targeting only scope 1 & 2 emissions.

This study also effectively lays out an organisational carbon footprinting methodology that may be useful for other HEIs. However, future CFs may be wise to take measures discussed to improve quantification tools or activity data collection for greater accuracy. This current methodology may be used as a way to highlight emission hotspots to inform HEI mitigation strategy.

7. Summary of Limitations and Assumptions Made

There is a higher degree of uncertainty when using emission factors in comparison to direct monitoring. In the majority of cases, DEFRA emission factors were used in the absence of Irish national emission factors. Waste emission factors do not cover the minimum boundaries outlined in The GHG Protocol standard. The underlying methodology for AerClub Travel emission factors is unknown. Where hotel emission factors didn't exist for a country, the geographically closest country's emission factor was used. The GHG Protocol Scope 3 Evaluator tool used for Purchased Goods and Services may be based on outdated data, is not inclusive of all six Kyoto gases and may not be regionally reflective.

Where the refrigerant or charge capacity for stand-alone refrigeration units was unknown, an assumption was made based on similar fridges of the same model or description. Due to health and safety rules, access to restaurant units was restricted and models were instead assumed based on information given from restaurant staff about units. An annual leakage rate of 0.3% for stand alone refrigeration units was assumed. A limitation to the DEFRA Screening Method is that some units may have been overlooked. Since travel survey distance responses were within a range, the mid interval or upper limit was assumed as the respondent's distance. It was assumed all staff and students travelled each commuting day of the year. It is assumed that respondents to the travel survey were representative of the entire university. As data on hotel stays was not directly available, it was assumed that any staff member that spent one night or more in a country stayed in a hotel during that time. As exact institution names couldn't be provided due to data protection reasons, destinations of partner institutions were equally distributed within each country. It was assumed that all students on exchange made one return flight per semester. Finance data was based on the financial year, which does not align to the calendar year. As this finance spend data was not the full spend amounts, spend in euro was divided by the relevant percentage of spend and multiplied by 100. Purchased Goods & Services activity data may vary based on which euro to USD conversion rate is used. As they are qualitative processes, errors may have been made assigning VAT to spend and assigning spend to sectors of purchase.

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