UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENGINEERING AND THE ENVIRONMENT

Centre for Environmental Science

A universal method for accounting greenhouse gas emissions from the activities of higher education institutions using a hybrid life-cycle approach

by

Oliver James Robinson

Thesis for the degree of Doctor of Engineering

2017

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UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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A UNIVERSAL METHOD FOR ACCOUNTING GREENHOUSE GAS EMISSIONS FROM THE ACTIVITIES OF HIGHER EDUCATION INSTITUTIONS USING A HYBRID LIFE-CYCLE APPROACH

Oliver James Robinson

Organisations of all types are significant contributors to international greenhouse gas emissions and the business case for supporting low-carbon practices is gathering pace. Three noteworthy barriers to reporting greenhouse gas emissions in a Higher Education context, namely, time resources, financial resources, and data quality, were found to hinder the production of full greenhouse gas emission assessments encompassing all Scope 1, 2 *and,* 3 value chain sources.

Higher Education Institutions are chosen for study due to their positioning as key components of education systems across the globe. Transcendent of international borders, socio-political regimes, and economic systems, the sector is a significant actor on climate issues. Overseeing education and research activities, institutions are often likened to towns in their size and operational scope. The carbon reduction targets of institutions in the United Kingdom are assessed for pragmatism and were deemed overambitious. Furthermore, they do not account for Scope 3 sources, often the largest proportion of the carbon footprint.

A critical assessment of common organisational greenhouse gas assessment methodologies was undertaken and a gap in knowledge highlighted. Whilst theoretical environmental standards are designed to be universally applicable, their practical application to higher education is little explored and in practice, debatable. A theoretical methodology, sympathetic to university environmental practitioners' requirements was proposed to bridge this gap. Clear and unambiguous guidance that avoided assumptions was developed. Among the numerous benefits, the use of external data sources was reduced and the potential for double counting was eradicated through the use of cut-off criteria, which excluded all paid-for Scope 3 services.

The methodology performed favourably against three baseline test parameters: a baseline of 150 hours to complete the emissions assessment, corresponding to financial costs of £24,200 and to satisfy the requirements of the verification standard, ISO14064-part 3. A series of potential strategies, incorporating the use of the proposed methodology (verifiable using industry verification standards) were outlined: whilst the sector should make ambitious pledges to decarbonise along the trajectory set by the Paris agreement, it should not be at the expense of quality research and teaching.

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Contribution to the Field

The following publications have been produced:

Robinson, O., Tewkesbury, A., Kemp, S., & Williams, I., 2017. Towards a universal carbon footprint standard: a case study of carbon management at universities. *Journal of Cleaner Production*.

Robinson, O., Kemp, S. & Williams, I., 2015. Carbon management at universities: a reality check. *Journal of Cleaner Production*, 106, pp.109–118.

The following book chapters have been produced:

Robinson, O., Kemp, S. & Williams, I., 2017. Consumption, Production… or perfection? Exploring approaches to carbon footprinting in higher education institutions. In: W. Lead Filho et al. (eds.), Handbook of Theory and Practice of Sustainable Development in Higher Education, World Sustainability Series. Vol 2. Ch. 31. pp. 441-452.

The following conference papers have been presented:

Robinson, O., Tewkesbury, A., Kemp, S., & Williams, I., 2016. Consumption, Production… or perfection? Exploring approaches to carbon footprinting in higher education institutions. In: 3rd World Symposium on Sustainable Development at Universities, Boston, MA, 14-16 September 2016.

Robinson, O., Tewkesbury, A., Kemp, S., & Williams, I., 2015. Carbon management at universities: towards a universal method for calculating scope 3 emissions. In: 19th Annual Conference of the Environmental Association of Universities and Colleges, Leeds, UK, 24-25 March 2015.

Robinson, O., Kemp, S., & Williams, I., 2013. *Comparing the carbon management activities of the University of Southampton to the nineteen English Russell Group institutions.* In: 16th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP) and 7th Conference of the Environmental Management for Sustainable Universities (EMSU), Istanbul, Turkey, 4-7 June 2013.

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DECLARATION OF AUTHORSHIP

I, Oliver James Robinson declare that this thesis and the work presented in it are my own and have been generated by me as the result of my own original research.

A universal method for accounting greenhouse gas emissions from the activities of higher education institutions using a hybrid life-cycle approach

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;

2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;

3. Where I have consulted the published work of others, this is always clearly attributed;

4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;

5. I have acknowledged all main sources of help;

6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;

7. Parts of this work have been published as:

Robinson, O., Tewkesbury, A., Kemp, S., & Williams, I., (in press) Carbon management at universities: towards a universal carbon footprint standard. *Journal of Cleaner Production*.

Robinson, O., Kemp, S. & Williams, I., 2015. Carbon management at universities: a reality check. *Journal of Cleaner Production*, 106, pp.109–118.

Signed: ....

Date:...

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being too busy because of ‘writing up’; they can all be rest assured that I won't need that excuse any more.

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On Saturday 12th December 2015 in Paris, 196 countries agreed to limit anthropogenic-induced climate change to +2°C above pre-industrial levels, with an aspiration of +1.5°C. The talks in Paris were seen as the final opportunity for the UN process to reach a deal on the succession plan to the Kyoto Protocol adopted in 1997. The deal is criticised for not being legally binding. The deal is described as exploitive of developing nations. The deal is seen as expensive to developed nations. Whilst these statements are somewhat true, compromises were made and mechanisms implemented to continually review the agreement’s process and the intended decarbonisation contributions of its signatories. What is important is that for the first time, collective political momentum has culminated in a *global* and *unanimous* agreement.

A few months before Paris, in March 2015, the concentration of carbon dioxide recorded at NOAA’s Mauna Loa observatory exceeded 400ppm. For some, this was an inconsequential milestone, however this was in fact the first time Earth had experienced such a concentration in *four million years*. It is clear that Humans have a profound effect on the Earth; in 2016, as the Paris Agreement entered into force after ratification by the EU, Canada, India and Nepal, the International Geological Congress declared the Earth had entered a new geological epoch aptly named “The Anthropocene”.

During my time writing this thesis, war has ravaged Syria and the Middle East. Compounded by the most severe drought in the region in 900 years, the alarming number of casualties and refugees from this crisis and others attest to the frightening, tangible and contemporary impacts of a changing climate. Coincidentally, the Paris talks were marred by attacks linked to this conflict two weeks before negotiations began. The rise of populism in Europe and America, embodied in the UK’s vote to leave the EU and the election of Donald Trump as the 45th President of the United States epitomise the uncertain and tempestuous future in store for us in the West. What should be remembered is that in working together, Humanity can and will overcome the impending existential climate threat. It is my firm belief that a fundamental shift to a low-carbon economy is possible by the end of the 21st Century and I am deeply hopeful that the Paris Agreement represents the start of a revolution towards equitable sustainability.

Oliver J. Robinson

Friday 18th August 2017, Greenwich, London

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Definitions and abbreviations

AASHE	Association for the Advancement of Sustainability in Higher Education
ACU	Association of Commonwealth Universities
ACU	Air-conditioning Unit
ACUPCC	American College and University President's Climate Commitment
AFOLU	Agriculture, forestry and other land-use
AMS	Automatic Metering System
APUC	Advanced Procurement for Universities and Colleges
AUDE	Association of University Directors of Estates
BAU	Business-as-usual
BECCS	Bio-energy with Carbon Capture and Storage
BEIS	Department for Business, Energy and Industrial Strategy
BIS	Department for Business, Innovation and Skills
BMS	Building Management System
BMW	Biodegradable Municipal Waste
BSI	British Standards Institute
CCA	Climate Change Act
CCAs	Climate Change Agreements
CCAR	Californian Climate Action Registry
CCC	Committee on Climate Change
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CDSB	Carbon Disclosure Standards Board
CEO	Chief Executive Officer
CIF	Capital Investment Framework
CMP	Carbon Management Plan
COPERNICUS	Co-Operation Programme in Europe for Research on Nature and Industry through Coordinated University Studies
CRC	Carbon Reduction Commitment
CSR	Corporate Social Responsibility
Defra	Department for Environment, Food and Rural Affairs
DJSI	Dow Jones Sustainability Index
DMU	De Montfort University
DUKES	Digest of United Kingdom Energy Statistics
EAUC	Environmental Association of Universities and Colleges

ECA	Enhanced Capital Allowances
EEA	European Economic Area
EEIOA	Environmentally Extended Input-Output Analysis
EF	Emission Factor
EoL	End-of-life
EMR	Estates Management Record
EMSU	Environmental Management for Sustainable Universities
EPBD	Energy Performance of Buildings Directive
EPR	Extended Producer Responsibility
EPSRC	Engineering and Physical Sciences Research Council
ESD	Education for Sustainable Development
ESG	Environmental, social, and corporate governance
EU ETS	European Union Emissions Trading Scheme
FSB	Financial Stability Board
FTE	Full-time equivalent
FTSE	Financial Times Stock Exchange
GHESP	Global Higher Education for Sustainability Partnership
GHG	Greenhouse Gas
GIA	Gross Internal Area
GIS	Geographic Information Systems
GO	Guarantee of Origin
GRI	Global Reporting Initiative
HE	Higher Education
HEA	Higher Education Authority
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
HEI	Higher Education Institution
HEICC	Higher Education Institution Carbon Calculator
HEIDI	Higher Education Information Database for Institutions
HESA	Higher Education Statistics Agency
HGV	Heavy Goods Vehicle
HMRC	Her Majesty's Revenue and Customs
ICAO	International Civil Aviation Organisation
ICE	Internal Combustion Engine
INDC	Intended Nationally Determined Contribution
IOA	Input-output Analysis
IPCC	Intergovernmental Panel on Climate Change

IPPC	Industrial Pollution Prevention Control
IPIECA	International Petroleum Industry Environmental Conservation Association
ISO	International Standardisation Organisation
JI	Joint Implementation
KPI	Key Performance Indicator
LCA	Life-cycle Assessment
LCI	Life-cycle Inventory
LPG	Liquefied Petroleum Gas
LSE	London School of Economics
LULUCF	Land use, land-use change and forestry
MACC	Marginal Abatement Cost Curve
MOOC	Massive Open Online Course
MRF	Materials Recovery Facility
NMT	Non-motorised transportation
NOAA	National Oceanic and Atmospheric Administration
NOC	National Oceanography Centre
OECD	Organisation for Economic Co-operation and Development
OLEV	Office for Low Emission Vehicles
PA	Process Analysis
PAS	Publicly Available Standard
PE	Person Equivalent
PLC	Public Limited Companies
QCA	Qualitative Comparative Analysis
RCP	Representative Concentration Pathway
REF	Research Excellence Framework
REC	Renewable Energy Certificate
ROI	Return-on-investment
SBTI	Science Based Targets Initiative
SDA	Sectoral Decarbonisation Approach
SDG	Sustainable Development Goals
SFC	Scottish Funding Council
SMBM	Simplified Material Balance Method
SME	Small-medium Enterprise
SOC	Soil Organic Carbon
SS	Staff and Students
SSSI	Site of Special Scientific Interest
SUPC	Southern Universities Purchasing Consortium

SUS	System Usability Score
SUSU	Southampton University Students' Union
TCFD	Task Force on Climate-related Financial Disclosures
UCL	University College London
UK	United Kingdom
ULEV	Ultra-low emission vehicle
ULSF	Association of University Leaders for a Sustainable Future
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UoS	University of Southampton
US EPA	United States Environmental Protection Agency
USM	Universal Standardised Methodology
VBA	Visual Basic for Applications
WBCSD	World Business Council for Sustainable Development
WEEE	Waste Electrical and Electronic Equipment
WRI	World Resources Institute
WWF	World Wildlife Fund

Chapter 1: Introduction

1.1 Context: Global climate change

The end of the pre-industrial era was marked by the development of the steam engine (*ca.* 1870). The technological advancements this fostered enabled a fundamental shift from hand production methods to machine-based production. Through rapid industrialisation, the human experience of life on the planet was changed forever and as a result, population rose rapidly (Cohen, 2003). The transition from wood-derived energy to energy from coal allowed for electrification (Hughes, 1993) and the greatest technological revolution in human history. Empirical measurements (in ice core records and in modern times, empirical atmospheric sampling) show a significant causal link between rapid global industrialisation and climatic perturbations (Ramanathan *et al*., 1985; Intergovernmental Panel on Climate Change (IPCC), 2013). Significantly rising concentrations of greenhouse gases (GHG) present in the Earth's atmosphere as a result of human activity is directly responsible for the largest shift in atmospheric conditions for at least 800,000 years (Petit *et al.*, 1999), which is projected to increase the stress on scarce resources (Kerr, 2007), reduce crop yields (Parry *et al*., 2004) and accelerate both habitat migrations and species extinctions (Pimm *et al.*, 1995).

The rate of emission releases grew exponentially in the 20th Century as economies prospered after two global wars. The emergence of capitalism and an economic shift towards neoliberalism resulted in the sustained exploitation of Earth's natural resources still occurring into the 21st Century. The main GHGs, CO_2, CH_4 and N_2O, increased from ~280 parts per million (ppm), 722 parts per billion (ppb) and 270 ppb, respectively, prior to the industrial revolution in 1870 to contemporary levels of 399.5ppm, 1834ppb and 328ppb, respectively (Tans & Keeling, 2016). In March 2015, the global monthly average CO_2 concentration surpassed 400ppm for the first time (Le Quéré *et al*., 2015). The effect these increases have had on the climate system act to enhance the naturally occurring 'greenhouse effect' and increase surface temperatures; global sea surface and land surface temperatures have increased by 0.85^{o}C [0.65 – 1.06^{o}C] (Intergovernmental Panel on Climate Change, 2013) in the intervening period.

Today, global GHG emissions equate to 49 ± 4.5 $GtCO_2e$ *per annum (p.a.)* (IPCC, 2014) and the highest four emitting countries/regions represent 59*%* of emissions, namely, China (27%), USA (14%), EU28 (10%) and India (7%). Primarily, GHG emissions are attributed to the burning of fossil fuels and land-use change (particularly for agricultural process, human settlement and deforestation) (Le Quéré *et al.*, 2015). The publication of the IPCC's fifth assessment report (AR5) in 2014 warned that unless mean human-induced warming is limited to 2^oC[1] (relative to 1861-1880) and imminent action is taken, catastrophic and runaway climate change may be inevitable. Despite this goal, the global carbon 'allowance' is rapidly diminishing and, therefore, under all scenarios, time is limited for the world to react. Numerous models have shown that in order to reach this goal (with a probability of >66%), it is imperative that anthropogenic GHG emissions since 1870 are to remain below 2900GtCO_2. By 2011, two-thirds (1900GtCO_2) of this budget had been already been released. Additionally, some authors are advocating reaching carbon neutrality by 2026 in order to avoid overshooting this threshold (Höhne *et al*., 2014; CCC, 2016). The cost of limiting climate change to the global economy has been estimated at between $350 billion - $1.1 trillion *p.a.* by 2030 (Stern, 2006), although the consequences of runaway climate change are incomprehensible.

As a result of the threats from climate change, reducing carbon emissions has become a persistent, yet divisive issue for politicians and policymakers to address. The publication of the Brundtland report in 1987 and the establishment of the IPCC in 1988 created the political momentum for the establishment of the United Nations Framework Convention on Climate Change (UNFCCC). As the foremost mechanism for states to agree on national emission reduction targets (agreed upon at the 1992 Earth Summit in Rio de Janeiro), the UNFCCC has been instrumental in the formulation of climate policy over the last 25 years. The first UNFCCC Conference of the Parties (COP) was held in Berlin in 1995 and established the procedures for the subsequent milestones *i.e.* the adoption of the Kyoto Protocol[2] in 1997, the agreement of the Marrakesh Accords in 2001[3], the Bali Roadmap in 2007[4], the Copenhagen Accord in 2009[5], the 2010 Cancun Agreement and, 2012 Doha Amendment[6] (Gupta, 2010). The culmination of these efforts came at the 21st Conference of the Parties (COP) in December 2015. After limited successes and negotiations, 195 nations adopted a partially voluntary and partially legally-binding multilateral post-Kyoto agreement to limit climate change to 1.5^oC above pre-industrial levels

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[1] This figure, for all intents and purposes, is cited as the threshold for 'runaway climate change'. Originating from Nordhaus (1975), the reality of intricate and little-understood climate feedbacks means that whilst this value is a tangible target for policymakers, it is criticised as being neither a panacea for climate change or a goal, after which, humanity can denounce all responsibility (Knutti *et al.*, 2015).

[2] Entered into force in 2005, set a 5% reduction on a 1990 baseline by 2008-2012 for six GHGs: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.

[3] Advised detailed rules on the implementation of Kyoto, including Joint Implementation (JI), emissions trading (ET), and the Clean Development Mechanism (CDM).

[4] Official launch of the climate adaptation fund, roadmap to signing a climate agreement laid out to Copenhagen in 2009.

[5] A pledge that temperature increase must be limited and that a goal of $100bn for developing nations by 2020 must be set.

[6] Amended the Kyoto Protocol to include an additional GHG (NF_3) and approved an extension to 2020.

(UNFCCCe, 2015)[7]. Ratification by 55 parties accounting for 55% of global emission is needed for entry into force (UNFCCC, 2015).

Historically, the major setbacks for the UNFCCC process have been attributed to the disparities in global development rates. Less economically developed countries (LEDCs) desire to protect their right to economic development (much in the same way more economically developed nations (MEDCs) did previously). In recent decades, the shift of manufacturing to the East and the population growth for many has meant that the trend of highly carbon-intensive developed economies is being challenged. For instance, China overtook the USA as the largest emitter in 2007 and developing nations look set to become the dominant contributors to anthropogenic GHG emissions (Vidal & Adam, 2007). Developed nations typically have the physical infrastructure, academic expertise and political will to advance emission reduction policies. Authors such as Yandle *et al*. (2004) predict that the environmental Kuznets curve (a bell-shaped relationship between *per capita* income and environmental degradation) for developing nations will be different to that demonstrated by MEDCs which emerged in the 20th Century. Clean technology that didn't exist during the first wave of economic development can now be used by LEDCs to reduce environmental degradation at lower income levels (Stern, 2004). Others state that when accounting for international trade, the curve is shifted to the left for carbon exporting countries and shifted to the right for high income countries i.e. emissions are typically lower than expected for lower income countries whilst they are higher for higher income countries (Steinberger *et al.*, 2012).

1.2 The United Kingdom

The UK ranks 18th in the list of largest emitters in the world, with *per capita* emissions at 6.5 tonnes CO_2e *p.a.* (Olivier *et al*., 2017). In accordance with the UNFCCC, the UK compiles and maintains a national GHG Inventory (as a requirement of ratification of the Kyoto Protocol). This is maintained on behalf of the government by (consultants) Ricardo-AEA and they are contracted to produce a National Inventory Report. The Climate Change Act (CCA) 2008 enacted an ambitious reduction in emission releases by 2050 (the first of any nation in the world to do so) and established the independent Committee on Climate Change (CCC), responsible for advising the government on strategies to meet an 80% reduction in GHG emissions. The CCC also proposes

[7] The submission of intended determined national contributions (INDCs) was deemed the most likely method of securing a fair emission reduction deal for MEDCs and LEDCs alike. Provision for continued assessment and five-yearly reviews was included as a result of UNFCCC-sponsored research into these INDC pledges shown to not limit GHG emissions enough by 2025 (United Nations Framework Convention on Climate Change, 2016)(United Nations Framework Convention on Climate Change, 2016).

carbon budgets, which are set for five-yearly periods to ensure that sustained progress is made towards the target. Table 1 sets out the carbon budget leading to 2032, featuring the most recent budget published in June 2016:

Table 1: Published UK GHG Carbon budgets until 2032.

Budget (period)	GHG emissions target ($MtCO_2e$)	% below 1990 baseline
1st carbon budget (2008-2012)	3,018	23%
2nd carbon budget (2013-2017)	2,782	29%
3rd carbon budget (2018-2022)	2,544	35%
4th carbon budget (2023-2027)	1,950	50%
5th carbon budget (2028-2032)	1,765	57%

Source: Committee on Climate Change (2017).

The UK has already made inroads towards reaching the 2020 target, having succeeded in meeting the 1st carbon budget, albeit by a narrow margin (having emitted 2,982$MtC0_2e$ in the period 2008-2012 against a target level of 3,018$MtCO_2e$). The dominant sector of the UK's emission profile, as can be seen in Figure 1, is energy production (at 31%), followed by transport (23%), business (17%), residential/domestic (12%), agriculture (9%) and the waste management (4%) sectors.

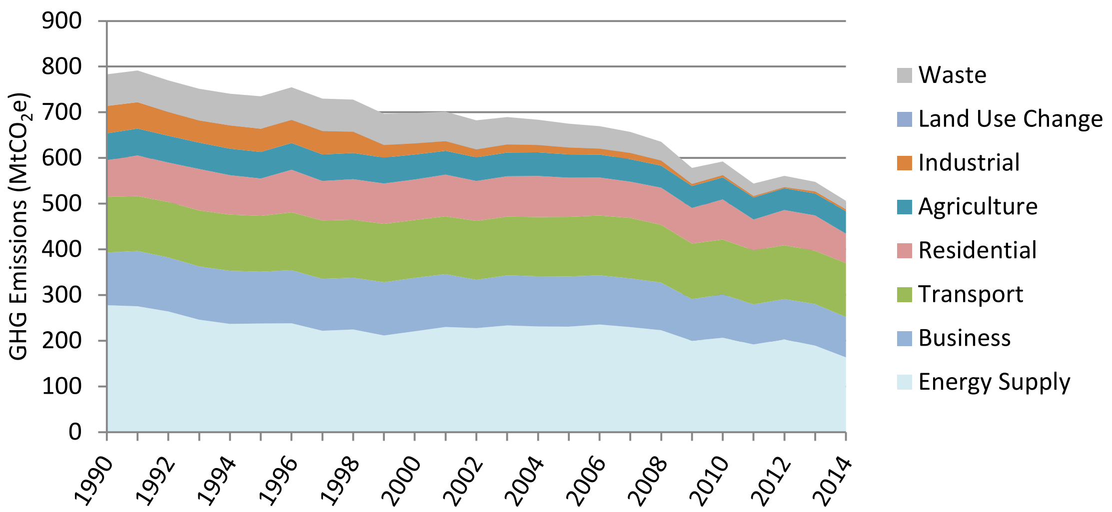

Figure 1: United Kingdom GHG emissions per economic sector, based on final figures for 1990-2014.

Source: Adapted from DECC (2016a).

1.3 Organisations and the environment

Decarbonisation, taken as the permanent reduction of GHG emissions from economic activities and the development of an equitable and sustainable means of production, has become a central strategy adopted by the international community, aimed at limiting the worst impacts of climate change. Preserving resources and affording future generations the ability to meet their needs is the focus of the concept of sustainable development set out in the report of the United Nations World Commission on Environment and Development (World Commission on Environment and Development, 1987). The discourse on these subjects has become more impassioned as the decades have elapsed, whilst progress has been and remains slow. Public sentiment is increasingly challenging the *status quo* and organisations, especially large multi-national corporations, are being challenged on their environmental credentials, often viewed unfavourably in this debate. Numerous examples exist where environmental degradation has occurred as a direct result of the actions of business operations that has caused an upsurge in public discontent. For instance, most notably, is Deepwater Horizon, which due to its scale (where a total of 4.9 million ±10*%* barrels of oil were released into the Gulf of Mexico in 2011 (National Response Team, 2011)) led to a record fine for BP Plc ($18.7 billion) and a global redesign of systems regulating oil well pressure (Rushe, 2015).

Organisations are significant sources of GHG emissions and are seen as instrumental in global decarbonisation efforts. By the very nature of the current economic structure, all natural resources are commodified, extracted and processed into useful products for profit by an organisation. Thus, there is an intrinsic link with organisations and environmentally sensitive activities, and possess the power to dramatically shift the *status quo* whilst remaining profitable. The 500 largest companies in the world (by revenue) contributed 7.3%, or 3.6 Gigatonnes CO_2e to total anthropogenic releases in 2013, demonstrating the significant contribution industrial processes make (The Carbon Disclosure Project, 2014).

Although there are many high-profile examples of environmental degradation caused by business, organisations in the 21st Century are increasingly measuring their success on, and owing their profits to, a triple-bottom line. This term, first coined by John Elkington, in 1994, advocates that companies should not only be measuring success in the traditional sense (profit made on sales), but that they should also include a social account to describe the value added to people, and an environment account to describe the value added to natural capital (Matten, 2015). It is no longer deemed acceptable to focus on maximising profits over the degradation of natural capital (Norman & MacDonald, 2004).

Many business leaders view sustainability as advantageous[8] and are already capitalising on the market opportunities in order to return a profit. There is now an innumerable range of products, goods and services being advertised based on their status as low-carbon targeted at the environmentally-conscious consumer. Nowhere is this more clearly demonstrated than by the ultra-low emission vehicles (ULEV) market; globally there are now more than 2 million ULEVs on the road and market share is as high as 29% in some countries (International Energy Agency, 2017a).

1.4 The role of higher education institutions

Higher Education Institutions (HEIs) are organisations devoted to advanced learning and scholarship (Collini, 2012). Steadily rising emissions from the HE sector also presents a need for fervent emissions reduction. Globally, the sector exceeds 178 million people, (United Nations Educational Scientific and Cultural Organisation (UNESCO), 2014a) (around 34% of the global university-age[9] demographic [UNESCO 2014b]) (having grown 200 fold over the course of the 20th Century (Schofer & Meyer, 2005). The number of institutions that exist to accommodate this number of students now equals some 17,000 around the world and it has been estimated that by 2025 the number of students enrolled in HE will equal 262 million (Pike, 2012). Although traditionally seen as only reserved for the social elite, universities have evolved out of the necessity to be more open and inclusive of people from all social backgrounds (Anderson, 2009). Universities benefit the global economy via the education of highly qualified professionals across myriad disciplines, in addition to the development of new academic ideas (Collini, 2012). Williams & Kemp (2013) highlighted the importance of HE to carbon management, flagging that the sector is a crucial incubator for future leaders and performs a vital role in terms of inculcating and disseminating the value and practices of sustainability in young adults.

In the United Kingdom (UK), the HE sector contributes £40 billion to the economy (3% of GDP) (Universities UK, 2015) and has weathered the recent economic downturn that has befallen other sectors. Increasing emissions and the adoption of a target in 2010 by the Higher Education Funding Council for England (HEFCE)[10] of a 34% reduction below a 1990 baseline by 2020 in scope

[8] i.e. through 'Plan A', Marks & Spencer set itself the goal of becoming the 'World's most sustainable retailer' (Jones *et al*., 2008). In the 10 years of Plan A, numerous environmental, social and governance (ESG) goals have been achieved, including carbon neutrality, zero waste to landfill and savings of more than £750 million in operating costs (Marks and Spencer Plc, 2017) .

[9] The university-age is defined at the point in which undergraduate students enrol on full-time study, typically between the ages of 18-21. Students exceeding the age of 21 are defined as mature students in most higher education systems.

[10] The HEFCE was disbanded at the end of March 2018. It its place, the Office for Students will take over the administration of carbon reduction targets.

1 and 2 emissions (to maintain progress towards the CCA 2008 target) means that carbon management is a high priority for vice chancellors (Williams & Kemp, 2013).

With greater than 1.7 million students and 318,000 staff in 160 universities (Universities UK, 2013), it is easily understandable how HE accounts for 11% of UK public sector emissions (Ward *et al.*, 2008). The total economic value of HE *p.a.* equals £39.9 billion (Universities UK, 2015) and as a result, is one of the largest occupiers of building space in the UK, occupying 27 million m^2; 0.2% of the UK built environment (6% of the UK's total land area). HE is also responsible for some 10,600 hectares of land (Higher Education Statistics Agency (HESA), 2014). It is well documented that HEIs are influential players in both local and national policymaking, both informing society through research and educating graduates (Etzkowitz, 1998). In addition, they are also successful incubators for innovation.

UK HEIs have been reporting on environmental metrics for some time through the Estate Management Record (EMR). The majority of emission releases reported to the EMR are predominantly from Scope 1 and 2 sources, but institutions are able to report some indirect Scope 3 emissions, though no formal target has been set. Scope 1 emissions are directly emitted within the organisational boundary from sources the organisation owns or controls (*i.e.* combustion of fuels), while scope 2 emissions are emissions from purchased electricity which occur as a result of the organisation's activities, but are not directly owned or controlled (Ranganathan *et al.*, 2004). Scope 3 emissions are the remaining indirect proportion of the carbon footprint (Ranganathan *et al.*, 2004). This data, collected by the HESA, has shown a steady increase in carbon emissions since collection began. Currently, It is estimated that this emission scope can account for up to 80% of the footprint (Ranganathan *et al.*, 2004) and, thus, the vast majority of emissions remain unaccounted and unreported. The multifaceted nature of assessing carbon emissions, known as 'carbon footprinting', means that such a process is extremely data-heavy and HEIs must implement extensive data collection programmes. Although the HEFCE has published guidance to assist HEIs to produce a carbon management plan (CMP) and to calculate the emissions arising from their activities (Higher Education Funding Council for England, 2010a), so far the focus has centred on energy, transport and waste emissions. At a time of stretched budgets and more selective students, in-part owing to substantial fee increases, saving money and simplifying the reporting of carbon metrics is universally advantageous.

1.5 **The problem at hand**

Owing to their large number, extensive populations and sizeable estates, HEIs in the UK are significant contributors to public sector emissions. An initial sector target for reducing directly controlled emissions has been set, but indirect emissions are yet to be controlled by any multilateral sectoral agreement. This is leading to a growing need for research to identify accessible methods of measuring and managing indirect emission sources arising from activities of HEIs; typically centred on research and teaching. The literature highlights a growing body of research into quantifying emissions along the organisational value chain and numerous international environmental standards have been published to allow organisations of all types to assess indirect emissions. Designed for a wide audience of numerous organisational types, the applicability of these standards to the activities and operations of HEIs has been little explored.

In addition, there is an increasingly urgent need for institutions to undertake activities and initiatives that deliver emissions reductions as atmospheric greenhouse gas concentrations reach a shifted equilibrium and surpass climatic thresholds. The position of HEIs to influence the carbon management agenda locally, nationally and, evermore internationally, will be pivotal in enabling the move to a future that is low carbon, and research is ongoing that sets out future scenarios and emissions trajectories i.e. the pathway to decarbonisation. Research is needed in this area to ensure that the HE sector can maintain its reputation as an innovator and develop a strong position on measuring and managing emissions over the forthcoming decades. The early decades of the 21st Century are pivotal for the success of the commitment adopted by the Paris Agreement.

1.6 Aims and objectives

This research was partly funded by the Engineering and Physical Sciences Research Council and the University of Southampton's (UoS) Estates and Facilities Department (the latter was the industrial sponsor of the project). The institution chose to fund this work as a result of the recognition of the urgency to quantify GHG emissions and the desire to manage and reduce emissions arising as indirect consequence of business activities. Due to mounting pressure in the HE sector to report and reduce emissions, the university identified, in collaboration with academic staff in the Centre for Environmental Sciences, the need for further research to be conducted appraising and improving current efforts at the institution. The university has invested £1 million a year towards carbon management as part of its CMP, adopted in 2011, and takes carbon reduction seriously.

The goals of the Estates and Facilities team were to improve the quality of data collected generally, and to allow the UoS to enhance its reputation as a centre for innovative environmental management. In 2014, the Estates and Facilities department produced its first carbon report, but the decision was taken not to release this publicly or report externally on the new scope 3 emission categories. This was primarily due to the low confidence in these metrics, which highlighted the need for improved procedures in the collection of activity data.

The aims and objectives were to:

1. Investigate the extent to which existing methodologies for assessing greenhouse gas emissions at the organisation level are applicable to higher education institutions:

   Objective 1.1 Critically review and compare grey literature on organisational carbon footprinting with standards specific to HE, supported by key theories in the academic literature

   Objective 1.2 Discuss the rationale for prioritising research on higher education institutions by exploring the similarities and differences in emission-producing activities with other organisational types

2. Develop a practical and realistically applicable method to calculate the carbon footprint of a higher education institution:

   Objective 2.1 Identify the essential requirements for a universal standard methodology of HE organisational carbon footprinting

   Objective 2.2 Understand the data collection systems that exist in HEIs and propose a standard data collection system

   Objective 2.3 Assess the most (and least) significant sources of GHG emission and their reliability for serving as streamlined environmental performance indicators

3. Assess the future of carbon management in HE, under the scenario of a sector-wide adoption of a universal standardised GHG assessment methodology:

   Objective 3.1 Assess the HE sector's climate vulnerability and understand how this could be improved by adopting a universal methodology

   Objective 3.2 Investigate the potential for the decarbonisation of the HE sector using best available technologies

These aims and objectives are presented as a conceptual framework in Figure 2.

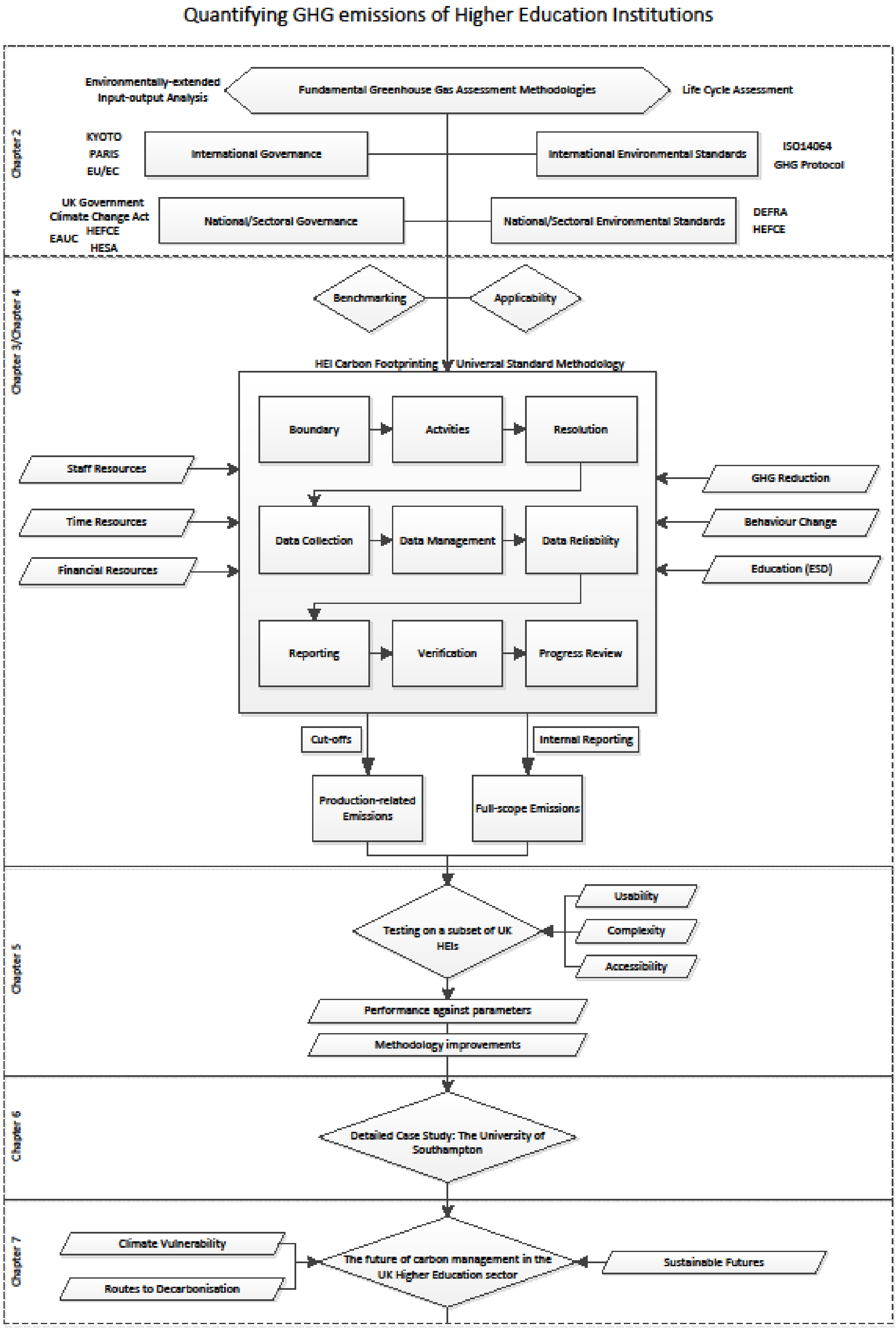

Figure 2: Project conceptual framework and corresponding chapter layout of this thesis

1.7 Scope of the research

This research focused primarily on the quantification of GHG emissions of organisations through hybrid carbon footprinting methods. HEIs were selected as case study organisations and all observations were considered in respect to their operating procedures. Although the research is applicable to, and indeed contextualised in, an international setting, particular attention is paid to HEIs situated in the UK (England, Scotland, Wales and Northern Ireland) because of their proximity and relative accessibility. Additionally, aspects of this work focus on the UoS in Hampshire, England.

1.8 Thesis outline

Figure 3 shows the structure of this thesis, which is subsequently divided into eight chapters. Chapter 1 provides a brief introduction to the study and sets out the aims and objectives which were intended to be addressed. Chapter 2 examines the state-of-the-art knowledge on organisational GHG assessment, critically assessing the published literature and identifying the common themes. Recent advances in HEI emission reporting are given particular weight and the gaps in knowledge are interrogated.

Chapter 3 takes an in-depth view of the existing guidance notes in the grey literature and seeks to analyse their credentials and relationships with one another. Moreover, the chapter focuses on evaluating whether such standards, which are found to be written for a wide variety of organisation types, are suitable for application within HE. A systematic review assesses the degree to which methodological steps are supported by the academic literature. Preliminary work is highlighted for a move towards a universal, comprehensive standard methodology. In addition, environment managers were questioned in order to identify essential requirements and to understand the difficulties commonly experienced by practitioners when compiling carbon reports. Finally, the chapter aims to 'scope' the activities undertaken at universities, detailing which emission sources outlined in the grey literature were in-scope and which were out-of-scope for (typical) HEIs.

Chapter 4 benchmarks the carbon management pledges of the energy intensive English Russell Group of institutions against the case study institution. Baselines for scope 1 and 2 emissions are created for the 20 institutions by which their performance against their self-set targets is analysed. These emission trends are then forecasted to 2020 under a series of future likely scenarios and provides the background knowledge required for the latter chapters is which the processes for procuring emissions-related data at HEIs are investigated in more detail. This chapter also postulates significant increases in unabated and unmeasured scope 3 emissions, establishing the basis for testing later on in the thesis.

Chapter 5 tests the feasibility of a universal, comprehensive carbon footprint methodology for HEIs. The data collection systems at a self-selected sample of 'real-world' universities are evaluated and once again compared against the case study institution. This chapter also introduces a tool devised to: i) promote standardisation of data collection amongst the sample institutions, and ii) aid consistent data collection amongst participants throughout this research project. Quantitative methods are used to assess the practicality of the theoretical methodological proposals outlined in Chapter 3; a logical approach is taken which combines knowledge garnered in the previous chapters.

Chapter 6 introduces the primary case study organisation, the UoS and provides an in-depth look at the experiences of obtaining data to inform the GHG assessment in-line with the universal standard methodology (USM) proposals outlined in Chapter 5. Further to this, a number of standalone studies, which were conducted to understand more about the institution's influence on Scope 3 activities, are also explored and assessed in this chapter. This chapter presents real-world studies (i.e. based upon a real institutional setting) undertaken to explore emission sources both included and excluded from the proposed universal methodology.

Chapter 7 synthesises the results of the preceding chapters holistically and relates them back to the literature and the original research aims and objectives. The implications of a universal methodology and its industrial relevance are outlined, and, more specifically, a series of marginal abatement cost curves are presented to provide some measure of the future options available to tackle scope 3 emissions reduction as a result of the proposed, and empirically tested, carbon footprint methodology. Finally, the chapter outlines the main conclusions drawn from the research and closes with an outline of potential future work. Conclusions are presented in Chapter 8.

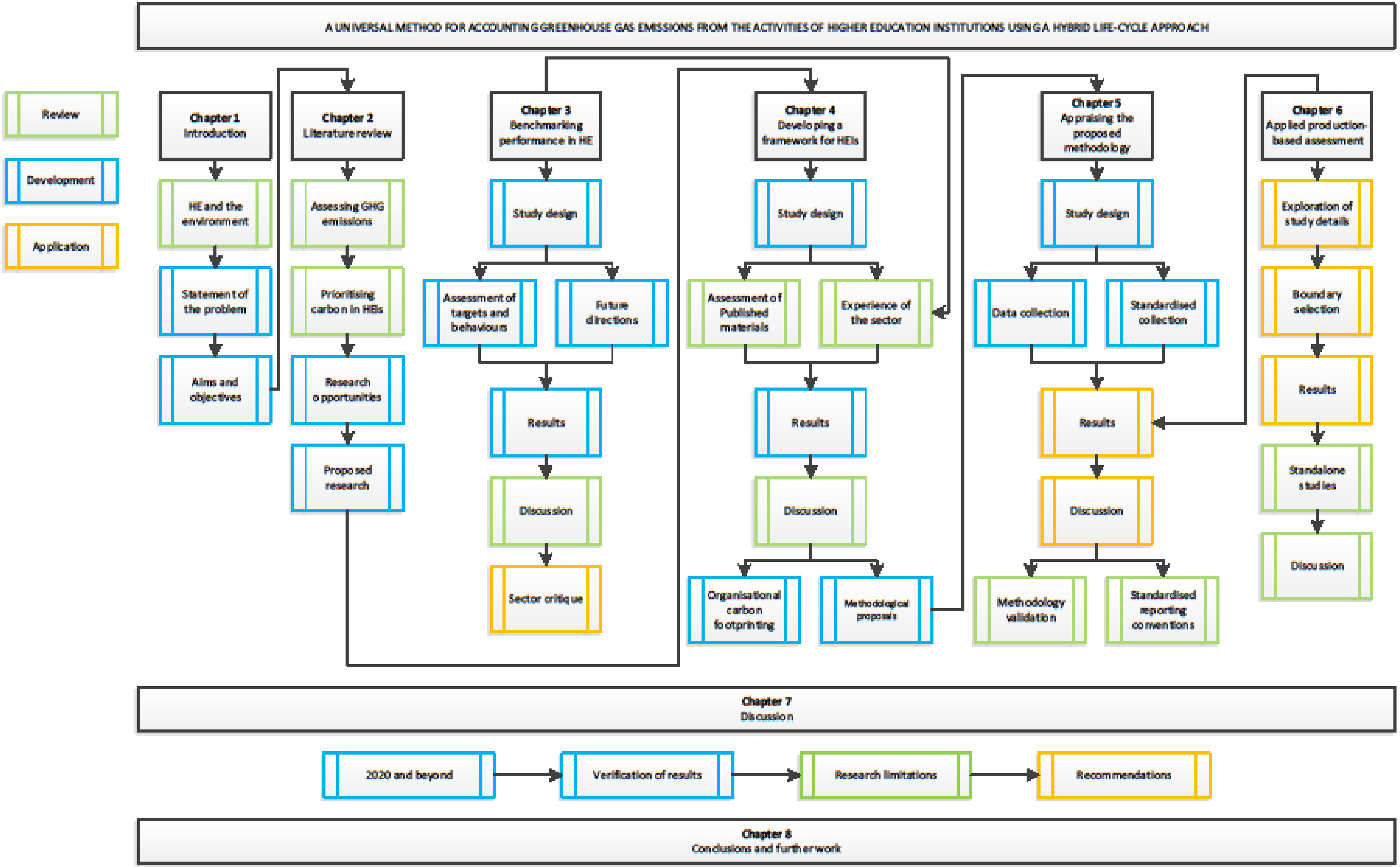

Figure 1: Organisational structure of this thesis and associated chapter linkages

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Chapter 2: Literature review

2.1 Introduction

This chapter outlines the nascent academic literature concerned with the assessment of GHG emissions resulting from the activities and operations of organisations. The chapter commences by documenting the diversity of organisations and the means by which their activities generate GHG emissions. The strategies taken by organisations to align themselves favourably in a difficult global market, under the threat of climate change, are also explored and critically assessed. Additionally, a number of archetypal studies are listed and critically reviewed for the organisation type which is being studied in detail in this research (namely, higher education institutions (HEIs)). Their value as a pertinent case study organisation is also established.

Although there are many differences in the governance of universities in countries around the world, the legal context outlined here is based upon the United Kingdom and is used as a barometer for global HE. In addition to this, the systems in place for governing and operating HEIs are outlined and explored. The literature presented here is limited to concepts that are directly applicable to assessing the GHG emissions from the activities of organisations and the management of carbon emissions in HEIs. It is noted that due to the interdisciplinary nature of the thesis topic, many theories may not be dwelt upon in great detail, despite being key research streams in their own right. Consequently, the review remains close to only describing the theoretical aspects associated with assessing the greenhouse gas emissions of activities and organisations.

The varying methodologies available to practitioners for assisting in conducting, reporting and verifying GHG assessments are explored and prominence is given to integrated environmentally-extended input-output life-cycle assessment (EEIOA-LCA). EEIOA-LCA methods are commonly used to assess emissions occurring on the meso-scale (*i.e.* organisations). These models combine the attributes of both top-down and bottom-up approaches and are thus perfectly suited to assessing GHG emissions of the case study organisations; these models therefore form the basis of the research presented in this thesis.

2.2 Defining organisations

The structures and characteristics of organisations are extremely diverse and, as such, this means that they can be classified in a number of different ways. Equally, this diversity gives rise to palpable disparities in the operating styles of organisations, their business goals and, the activities they undertake. Formally, they are classified by industry (primary, secondary or tertiary industry), size (micro, small, medium and, large), sector (public, private, voluntary) and, legal status (sole trader, partnership *etc.*) and it is these classifications applying simultaneously to organisations, which leads to occupancy in different organisational 'niches'. Even within sectors, countless characteristic combinations mean that organisations can seemingly be virtually unrelated. The following sections explore the characteristics associate with industrial, sectoral and, legal organisational classifications.

2.2.1 **By industry**

Primary industries, such as mining, petroleum extraction and, agriculture, are concerned with the extraction of raw materials. Jobs in this sector require physical work but may not require a highly skilled workforce. Secondary industries process these raw materials and comprise manufacturing companies that shape the raw materials into usable products and components for use. For example, oil refining is an example of an activity carried out by the secondary industry to fraction out useful constituents from crude oil. Tertiary industries are concerned with the commercial services that support the production, and subsequent distribution, of products (such as transport services, insurance services, warehousing, marketing *etc.*).

Typically, as *per capita* income increases (as a result of economic growth), more of the population are employed in jobs in the secondary industry (as a result of 'industrialisation'), as agricultural processes become mechanised and fewer people rely on subsistence farming to survive (Soubbotina & Sheram, 2000). Post-industrialisation occurs as the economy grows further and the population requires fewer material goods for survival, so demand for 'services', such as health provision, education and, wellbeing, is greater. Post-industrialisation is characterised by a high GDP and a high proportion of the population employed in the tertiary industry, whilst countries with a lower GDP are still industrialising. Figure 4 sums up this relationship.

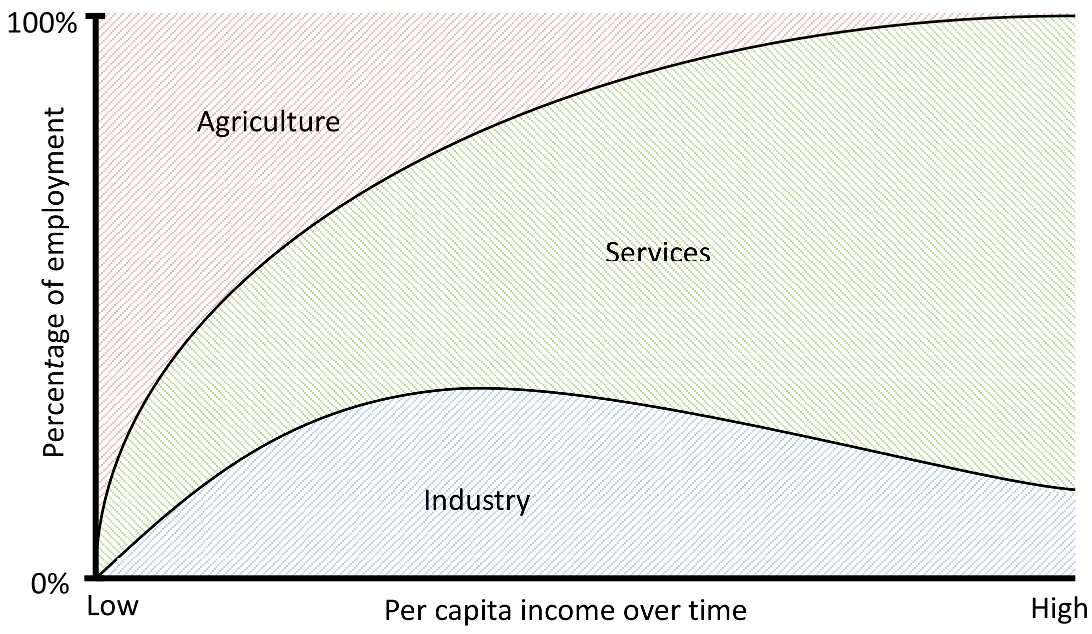

Figure 4: Employment structure against level of economic development
Source: Adapted from Soubbotina & Sheram (2000).

A system of classifying economic activities was developed in the USA in the 1930s in order to allow for economic data to be easily analysed by sub-category. This standardised system, known as the Standard Industry Classification (SIC), is now used internationally to collect and analyse economic performance (as well as to promote the uniform collection of said data) and constitutes 22 separate industrial sectors (from Section A, agriculture, forestry and, fishing to Section U, extraterritorial organisations and activities). Although theoretically simple, the complexity arises when considering that many organisations do not simply focus on one product area or undertake a primary function. As a result, the SIC can only be used for *broadly* grouping together businesses and is only used for comparative purposes between industrial groupings (Dahlstedt *et al*., 1994).

2.2.2 **By size**

A number of methods are used to determine the 'size' of an organisation. Whilst in the main, either output, turnover and, employment levels are commonly employed to provide these measures; the number of employees is the most oft-used due to its simplicity. Used in conjunction, these metrics provide a comprehensive macro view of the organisational boundary; although caution must always be taken since results are dependent on the chosen method. Table 2 ranks the UK's biggest companies by revenue and employment to demonstrate the discrepancy. In determining size, all entities of the organisation must be considered. To aid in this, a distinction is made in which individually defined 'establishments', referring to the discrete business units, comprise an 'enterprise' (the organisation as a whole). Due to the complex nature of some organisational structures, determining which entities belong to the parent organisation is determined by its legal status as outlined in the following section.

Table 2: UK organisations ranked by 2016 revenue and employment statistics

Company	Revenue (million $ USD)	Company	Employment ('000)
Royal Dutch Shell	484,489	National Health Service	1,400
BP	386,463	Tesco	335
Glencore Xstrata	220,030	NHS Scotland	160
HSBC	110,141	Royal Mail	160
Tesco	103,839	Swire	129
Vodafone	74,051	British Army	125
Barclays	68,949	Department for Work & Pensions	111
Lloyds Banking Group	67,048	John Lewis	98

The majority of organisations are small-to-medium-sized enterprises (SMEs) (Wilson, 2011). In the UK, in fact, 99.7% of businesses are classed in this way, determined by the relationship between the number of employees and turnover. The European Commission defines an SME as an organisation that employs fewer than 250 people (as can be seen in Table 3) and has a turnover of less than €50 million, or assets valued at less than €43 million (European Commission, 2015).

Table 3: Categorisation of organisations based on employee size.

Number of employees	Type of firm
<10	Micro enterprise
10-49	Small enterprise
50-249	Medium-sized enterprise
250+	Large

2.2.3 By legal status

Private sector organisations are by far the most numerous of the organisations comprising the three economic sectors by ownership i.e. the public, private and voluntary sectors (estimated to be around 80% of organisations). At the start of 2015, there were 5.4 million private sector businesses, of which 3.3 million were sole proprietorships (62%), 460,000 partnerships (8%), and 1.6 million companies (30%) (Office for National Statistics, 2018). Sole proprietorships are businesses owned by individuals, normally funded by those individuals, who possess sole responsibility for its management (including the hiring of staff, submission of accounts, and setting targets). Limited Companies, meanwhile, have a legal identity separate to that of the owner, meaning that all assets and liabilities are the responsibility of the company itself (Worthington & Britton, 2006)[11]. A business partnership is simply a business whereby the owners (this time, two or more partners are involved) are responsible for the assets of the organisation (Campbell, 1997).

Co-operatives (or co-operative societies) are organisations that are owned by consumers and are operated democratically (Novkovic, 2008). As a result, a number of democratic functions must be assumed, which enables the running of the organisation to maintain transparency and benefit for all members. These functions include the election of a board of directors by members at annual general meetings (AGM), petitioning on issues affecting the future and current performance of the co-operative, and votes. The board of directors remain responsible for setting the aims of the organisation and maximising profit returns (Worthington & Britton, 2006). Co-operatives arose as a response to anti-capitalist sentiment, focussing on service and mutual benefit, rather than profits (Greenberg, 1980).

The public sector is so defined because the state owns the assets of the organisation, used to provide a range of goods and services deemed beneficial to society (Wettenhall, 2001). Many types of organisation comprise the public sector, including government departments, non-departmental public bodies, local authorities and health authorities. There are a number of reasons why governments choose to invest in public sector organisations, such as its importance to society or a necessity for heavy government regulation (Worthington & Britton, 2006).

Most of these organisations offer a distinct service, operated directly by government departments or through delegated authorities Although the onus is not to make profits (or the opportunity to do so does not exist), there are a number of examples where public sector organisations are operated comparatively similarly to for-profit organisations, e.g. municipal businesses and public corporations. Municipal enterprises are not necessarily provided out of necessity, but voluntarily by local authorities; these can often compete with private sector organisations (Rubin, 1988). The premise for local authorities and central government to invest in municipal enterprises is to foster economic development and to create revenue streams which augment local and national treasury funds.

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[11] If limited companies meet a number of certain, they can become Public Limited Companies (PLCs). Criteria include: a minimum of two shareholders and two directors, £50,000 share capital, the right to offer shares, certification by a registrar of companies and has a memorandum stating it to be a public limited company. If these conditions are not met, then a company in law becomes a *private* limited company, often referred to as 'limited' (ltd).

Public corporations are not directly operated by the government, but are, instead, governed by state-owned subsidiaries. In the last 30 years, the number of public corporations has declined as a result of privatisation and the sell-off of much of the state-owned industry in the UK (such as the steel industry in the late 1980s (Bishop & Kay, 1989). As statutory bodies, these corporations are created through the passing of an Act of Parliament (created by statute); the British Broadcasting Corporation and Royal Mail (prior to the 2015 sale) are pertinent examples. Typically, because public corporations are publicly funded, they are highly accountable to government (Ball *et al*., 2014). A sponsoring government department oversees their operation, whilst the relevant Secretary of State assigns the board of directors; the board has a wide degree of freedom in the management of the organisation (free from political interference), but any matters of financing, performance and internal structure are closely tracked and must be approved and audited by the governmental department (Wettenhall, 2001).

The 'third sector' is the final sector in which organisations can be legally distinguished. Organisations within this distinction are less homologous than those already described. This sector comprises voluntary and not-for-profit organisations, charities, social enterprises and non-governmental organisations (NGOs) (Mertens, 1999). They operate across every industrial sector, campaign for social justice for the public, and provide research and support for all types of issues affecting health and wellbeing (Gui, 1991). Third sector organisations are neither publicly or privately funded and rely predominantly on philanthropic donations. Some may operate as commercial businesses (in the case of social enterprises, which can be both for-profit or not-for-profit) or apply commercial strategies in order raise funds; the key common features are the humanitarian and/or environmental values by which they are governed, aimed at delivering social goals and campaigning for justice for the public (Mertens, 1999).

2.3 Sustainable organisations

2.3.1 Environmental, social and corporate governance

It is increasingly being recognised that healthy profits can be garnered by embracing sustainability as an ongoing priority (Lozano, 2007). Consequently, the United Nations Global Compact (UNGC) and its >12,000 signatories from around the world, demonstrates the commitment that organisations give to sustainability issues (Hale & Held, 2011). Intrinsic initiatives (such as corporate sustainability and business ethics) or extrinsic initiatives (such as corporate social responsibility (CSR) initiatives and triple-bottom line accounting) are examples of the types of strategies that organisations can take to act on environmental issues at the top level (Montiel, 2008).

Environmental, Social and Governance (ESG) criteria are a set of standards for a company's operations that investors use to screen investments. These are fast becoming a key metric not only for identifying conscious investment opportunities, but also for the evaluation of future risk in portfolios.

There are a number of established programmes and initiatives for organisations to disclose sustainability information in order for it to be readily available for investors. The initiatives specific to universities will be explored in more detail in later sections, however it is evident that the uptake of institutions reporting to these frameworks is fewer than as is the case for organisations. Many of these frameworks target large organisations where the shareholder has greater influence on the organisation's operations and possesses a vested interest in its success. Many of the global stock listings have indices which demonstrate the performance of organisations, such as the Dow Jones and Financial Times Stock Exchanges which have made knowledge of organisational sustainability activities more widely available to the market.

The Dow Jones Sustainability Indices (DJSI) for instance are a family of best-in-class benchmarks for investors who have recognized that sustainable business practices are critical to generating long-term shareholder value and who wish to reflect their sustainability convictions in their investment portfolios. Launched in 1999 as a joint venture by Standard and Poor, Dow Jones, and RobecoSAM, it was the first global sustainability benchmark, which tracks the stock performance of the world's leading companies in regards to their ESG criteria. The DJSI combine the experience of an established index provider with the expertise of a specialist in Sustainability Investing to select the most sustainable companies from across 60 industries. Similarly, the FTSE4Good Index measures the performance of companies demonstrating strong Environmental, Social, and Governance (ESG) practices used by a wide variety of UK market participants when creating or assessing sustainable investment products.

A well-known framework for self-reporting sustainability activities is the Global Reporting Initiative (GRI) (Lozano, 2013b; GRI, 2013). The GRI is an international independent standards organisation that helps businesses, governments, and other organisations understand and communicate their impacts on issues such as climate change, human rights, and corruption. As of 2015, 7,500 organisations used GRI Guidelines for their sustainability reports which apply to a swathe of organisational types, including multinational organisations, public agencies, SMEs, NGOs and industry groups *etc.* The recently published GRI standard[12] focuses on assisting businesses, governments, and organisations in understanding their impacts on self-determined critical sustainability issues. This places 'materiality[13]' at the heart of the disclosure process *i.e.* organisations must themselves consider the potential impacts of their activities and the significance of these impacts on the environment (Huang *et al.*, 2009). Depending on the experience of the organisation, there are two pathways that can be followed to ensure 'accordance': the core pathway (which requires a small number of disclosures as well as those which are mandatory), or the comprehensive pathway (which requires disclosing information on all identified material aspects). GRI also develop standards for individual sectors in addition to the all-encompassing general standards, for industries such as airport operators, financial services, and the oil and gas industries (Galbreath, 2010).

From 2016, the reporting of ESG information was made mandatory for large undertakings employing on average of more than 500 employees during the financial year. The deadline for transposing the EU Non-Financial Reporting Directive 2014/95/EU was December 2016 and requires organisations to disclose information on policies, risks, and outcomes regarding: environmental matters; social and employee aspects; respect for human rights; anti-corruption and bribery issues; and the diversity levels of their board of directors.

Organisations are increasingly including emissions-related information in their sustainability reports, annual reports, and published accounts. The reporting of specific carbon-related information is the focus for the Carbon Disclosure Project (CDP) whose climate change questionnaire is comprised of three modules; management, risk, and emissions. CDP is an organisation which works with shareholders and corporations to disclose GHG emissions of nearly 2000 major corporations. Four scoring methodologies act as performance levels which are attainable through better performance; these represent levels that indicate the steps that a company moves through as they progress towards greater environmental stewardship, including 'disclosure', 'awareness', 'management', and 'leadership'.

In 2015, the Financial Stability Board (FSB) established the Task Force on Climate-related Financial Disclosures (TCFD) to develop a series of disclosure metrics for more efficient and effective

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[12] The G4 standard was superseded in 2018 by the 'GRI Standards'.

[13] Materiality refers to the concept that individual errors or the aggregation of errors, omissions and misrepresentations could affect the carbon footprint and influence decisions made from this information. Therefore, materiality is used to identify information that, if omitted or misstated, would significantly misrepresent the footprint as a whole and ensure that such material discrepancies are omitted/minimised. Acceptable materiality is determined by the verifier based on the agreed level of assurance. As a rule of thumb, an error is considered to be materially misleading if its value exceeds 5% of the total inventory for the part of the organisation being verified.

climate disclosures originating from financial institutions. Therefore, this initiative takes many of the carbon-related disclosures used in non-financial reporting, applies them and develops more specifically for financial institutions. It is anticipated that these disclosures will have a key influence on understanding climate risk associated with financial investments, as well as allocating funds for climate adaptation and mitigation (Task Force on Climate-related Financial Disclosures, 2017).

2.4 Universities as organisations

HEIs are examples of public corporations. In the UK, they are also defined as charities, but are exempt under the Charities Act 2011. This means that they do not have to register with, or be overseen by, the Charity Commission (for England and Wales). Universities are also limited by guarantee (this term is usually given to non-profit organisations to give them legal 'personality'). Therefore, they straddle a gap between a private company, a not-for-profit organisation, and a charity. As publicly funded entities, funding is garnered externally through an endowment from the government and research grants from research councils and private industries. This university-industry-government relationship is complex and implements checks and balances, which results in HE being highly externally accountable (Etzkowitz *et al*., 2000).

2.4.1 The political context

Prior to the 1960s, only 25 HEIs existed in the UK and there were three dominant model types: the Oxbridge model (which focused on residential, tutorial and character-forming values); the Scottish/London model (which was more metropolitan, professional and meritocratic than Oxbridge) and the civic model (which prioritised local education that was practical and aspirational) (Collini, 2012). The success of the British Empire in the 20th Century led to the establishment of universities around the world modelled on these institutions and dominated the global education system in this period (a position shared with the much larger North American universities).

Many changes in policy, funding, and ethos have occurred in the interim to take the once state-funded HE system from stability and elitism to a highly competitive, constantly evolving, and ubiquitous public resource. In 1960, 5% of university-age people (18-30 years of age) were enrolled on degree courses. Although the number of institutions almost doubled during the decade (to 45), access to higher education was deemed a privilege only reserved for the social 'elite' (Robinson *et al*., 2015). A number of policy changes were implemented, due to the concerns that the UK HE sector was relatively small compared to the rest of the developed world, and that a lack of skills in the workforce would impact on economic growth.

The Robbins report was published in 1963, which recommended immediate expansion of universities and introduced the 'Robbins Principle', which made all university places available for those who 'qualified for them by ability and attainment' (Wyness, 2010). As a result, all colleges of advanced technology (including Loughborough, Surrey and Bath Universities amongst others) were given university status and a plan for further expansion was adopted; these were the only institutions to be established until the 1990s. A gradual decline in central funding, following the implementation of the 1988 Education Reform Act, called for major alterations to the HE funding streams. To this end, financial support was introduced as a 50% loan and 50% grant to assist students with the cost of living and the Student Loans Company (SLC) (in alliance with Her Majesty's Revenue and Customs (HMRC)) was founded to oversee the administration of means-testing applicants and the collection of repayments (Wyness, 2010). During this time, annual university contracts were created and the quinquennial Research Assessment Exercise (RAE) subsequently, the Research Excellence Framework (REF), was introduced to help foster measurable 'impact' and 'value' of HE outputs, as well as to create an effective and highly qualified workforce needed for the growing tertiary sector.

In 1992, 48 polytechnics were granted university status effectively doubling the number of institutions to 85. Now defunct, polytechnics were tertiary education institutions which offered higher diplomas and degrees awarded by the Council for National Academic Awards. Simultaneously the funding bodies, the Higher Education Funding Council for England (HEFCE) in England, the Higher Education Funding Council for Wales (HEFCW) in Wales and the Scottish Funding Council (SFC) in Scotland, were created to pave the way for a more sustainable system of funding HE. These bodies and the publication of the Dearing Report subsequently led to the implementation of tuition fees (of £1,000 *p.a.*) for the first time in 1998 (Altbach *et al*., 2009). Some argue that the origin of the present-day funding issues of universities can be traced back to the policy decisions set in motion by the administrations of Thatcher and Major; more university places were made available than ever before, but institutions were forced to deliver HE at a lower per-unit cost (Wyness, 2010). Universities were no longer on a path that allowed their existence for sole scholarly purposes but, rather, they became businesses that were increasingly motivated by financial success.

In 2004, fees were increased to £3,000 *p.a.* and a further 47 universities were created in a second wave continuation of the 1992 enlargement (which has continued to the present day, see Fig. 5). In 2009, further calls for more funding to be available for universities and the financial uncertainty caused by the 2008 financial crash led the government to commission the Browne Review. This report contained proposals to remove the cap on tuition fees (which by that time had risen to £3,290) and to allow HEIs to charge a maximum of £9,000 *p.a.* in fees (Browne *et al.*, 2010). In addition, HEIs have seen an almost complete withdrawal of the Annual Block Grant (which in *ca.*2009 was £3.9 billion (Collini, 2012). This allowed universities a degree of flexibility and stability in financial planning. Individual universities were able to make educational decisions about the range of subjects they offered, whilst government had direct financial interest in regulating total student numbers and fees were not determined by the actual cost of the student's education. The removal of the tuition fee cap did little to dent the continuing upward trend in recruitment rate (Wyness, 2010)[14]. The year 2015 saw a record number of students recruited at 532,000 and a 3% increase on the previous year (Universities and Colleges Admissions Service, 2015).

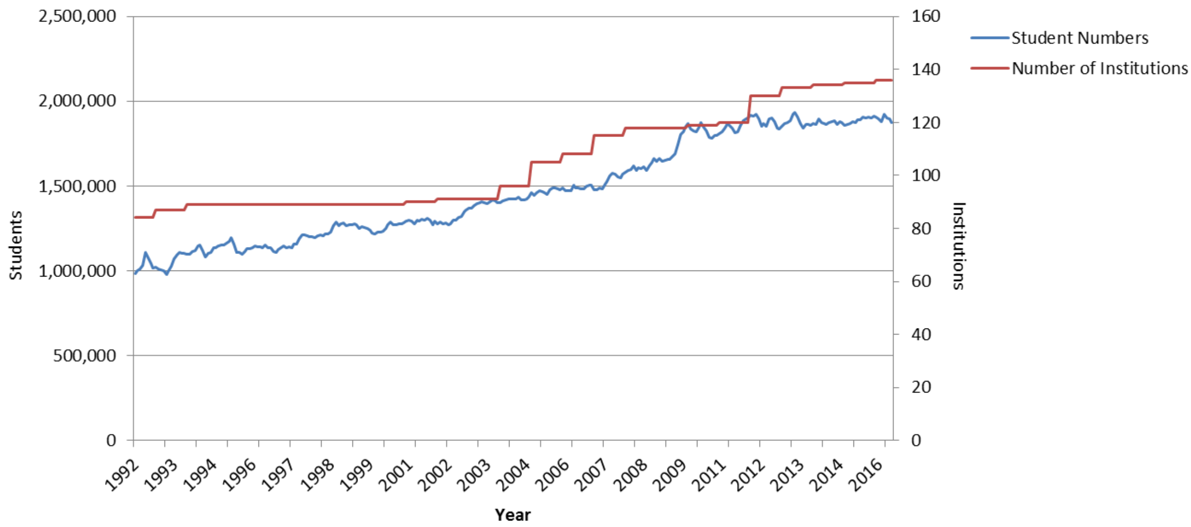

Figure 5: The trends in total number of students (undergraduate and postgraduate) in UK higher education and the number of institutions, since 1992.

2.4.1 Stakeholders

All organisations are somewhat directly and indirectly motivated by stakeholders, and universities are certainly no exception. Stakeholders are the individuals or groups who are affected by the performance of the organisation (and *vice versa*) (Reed, 2008). They have a vested interest for a variety of reasons, as can be seen outlined in Table 4. This compares the interests of for-profit organisations with those of university stakeholders. The role and composition of stakeholders is influenced by both the legal structure and the operations of the organisation.

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[14] Recruitment in the academic year 2012/13 was 637,500; a much reduced amount compared to the peak in 2011 at 670,000, however there has still been an increase over 2011/12 levels of 618,250 (Universities and Colleges Admissions Service, 2013).

Table 4: Examples of organisational stakeholders and their areas of concern for a private sector organisation

Stakeholder group	Concern/interest – for-profit organisation	Concern/interest – universities
Government	Profitability, taxation, jobs, truthful accounting	Widening participation, STEM
Employees	Wages, working conditions, job security, personal development	Working conditions, job security & opportunity, outreach
Managers	Job security, profitability	Research income, quality
Customers	Quality of product, customer service,	Quality of education,
Community/society	Environmental sensitivity, jobs, equal opportunities	Environmental sensitivity, jobs, equal opportunities
Investors/shareholders	Return-on-investment, dividends, security, risk	Generation of quality academic ideas

Source: Adapted from Worthington & Britton (2006); Chapleo & Simms (2010).

Although an organisation's primary objective is to ensure survival through the generation of financial profits, there is often a balance that must be struck. This is between the satisfaction of the board of directors and the organisation's stakeholders, often a fine balancing act. Despite the seemingly different types of interest associated with HEIs evident in the table above, broadly the stakeholder motivations are equivalent. As can be seen, stakeholders can be both internal and external to the organisation and are categorised by their level of influence and reliance upon the organisation, namely, in terms of primary (directly reliant) and secondary (indirectly reliant) stakeholders (Lozano, 2012a). Within universities, primary stakeholders are considered to comprise three groups: i) academic directors; ii) academic staff; and iii) students (Lozano, 2006).

2.4.2 Higher education and sustainability

There have been a number of notable declarations ratified throughout the last 20 year by more than 1000 universities, with pledges to champion environmental issues within their institutions (Lozano *et al.*, 2013). The Talloires Declaration was signed in 1990 and was the first official agreement by universities to commit to environmental sustainability and comprised a broad ten-point action plan of policy goals (ULSF, 1990). The Association of University Leaders for a Sustainable Future (ULSF) champions the commitment to sustainability in higher education and also serves as the declaration's secretariat. A number of other declarations followed, including the COPERNICUS Charter (1993) (Co-Operation Programme in Europe for Research on Nature and Industry through Coordinated University Studies), the formation of the Global Higher Education for Sustainability Partnership (GHESP) as a result of Agenda 21 of the Rio Earth Summit in 1992, and the Lüneburg declaration (2001) among others. More recently, the American College and University President's Climate Commitment (ACUPCC) was pledged by more than 690 American Institutions with the aim of being a 'high visibility effort to address climate change' by creating a network of universities and colleges reducing emissions and researching solutions.

A number of NGOs have formed to help promote the activities of the ULSF and ACUPCC, including the International Institute for Sustainable Development and the Association for the Advancement of Sustainability in Higher Education (AASHE). Table 5 shows a timeline of the evolution of the governance of sustainability in higher education between 1971-1999, while from 2000-present is shown in Table 6 (adapted from (Lozano, Lukman, *et al*., 2013).

Table 5: Initiatives implemented in higher education (or society) to further sustainable development in HE 1972-1999.

Year	Declaration	Focus
1972	The Club of Rome, Limits to Growth	Society
1972	Stockholm Declaration on the Human Environment	Society
1975	The Belgrade Charter	Education
1977	Tbilisi Declaration	Education
1987	"Our Common Future" The Brundtland Report	Society
1990	Talloires Declaration	HE
1991	Halifax Declaration	HE
1992	Agenda 21	Society
1992	Association of University Leaders for a Sustainable Future Founded	HE
1993	Kyoto Declaration	HE
1993	Swansea Declaration	HE
1993	COPERNICUS university charter	HE
1996	Ball State University Greening of the Campus conferences were in 1997, 1999, 2001, 2003, 2005, 2007, 2009	HE
1997	Thessaloniki Declaration	Education
1999	Environmental Management for Sustainable Universities (EMSU) conference held in Sweden, in 2002 (South Africa), 2004 (Mexico), 2006 (USA), 2008 (Spain), 2010 (Netherlands) and 2013 (Turkey) followed.	HE

Table 6: Initiatives implemented in higher education (or society) to further sustainable development in HE 2000-present.

Year	Declaration	Focus
2000	Millennium Development Goals	Society
2000	The Earth Charter	Society
2000	Global Higher Education for Sustainability Partnership (GHESP)	HE
2001	Lüneburg Declaration on Higher Education for Sustainable Development	HE
2002	World Summit on Sustainable Development in Johannesburg	Society
2004	Declaration of Barcelona	HE
2005	Start of the UN decade of Education for Sustainable Development	Education
2005	Graz Declaration on Committing Universities to Sustainable Development	HE
2009	Abuja Declaration on Sustainable Development in Africa	HE
2009	Torino (Turin) Declaration	HE
2015	Sustainable Development Goals	Society

Many institutions tackle carbon reduction through varied and all-encompassing sustainability initiatives (Atherton & Giurco, 2011). Incorporating sustainability into the operating procedures of universities promises to yield a number of significant benefits, which are being identified by Vice Chancellors and an increasing number of HEIs, who are signing on to the 'sustainable development' lobby.

A number of knowledge-sharing initiatives and networks have arisen in the UK in recent years to promote the adoption of sustainability projects by HEIs. There are numerous examples of initiatives receiving a critical reception from members of the sector for a variety of reasons, which often outweigh any intended benefits. In order for an initiative to be successful garnering widespread support ensures universal buy-in, A pertinent example is that of the People and Planet University Green League, which rates the performance of institutions on sustainability, using a number of different metrics. Institutions at the top of the league are awarded a 'first class' rating and proceeding rankings are classified using UK degree boundaries (upper second, lower second, and third class ratings).

Whilst research propounds the use of league tables for speaking a language that stakeholders can understand (in this case university environment managers) (Dobson *et al.*, 2010), People and Planet have been criticised for using an arbitrary and non-transparent methodological approach to their rating system (Environmental Association of Universities and Colleges (EAUC) & AUDE 2014). Although this is designed for HEIs to benchmark themselves and formalise a framework for continual improvement on sustainability, in reality it has been argued that it represents a box-ticking exercise that neglects the human and contextual considerations of the HEI (Jones, 2012).

The Green Scorecard, developed by ARUP for the AUDE, is emerging as the successor to the People and Planet ranking scheme (EAUC, 2016). This is an assessment tool that comprises six specific areas designed to overcome the issues of consistency and the onerous nature of ranking methodologies that rely on separate reporting systems that environment managers themselves are responsible for completing. The aims of the green scorecard are: i) to provide a framework for progress; ii) to drive innovation; iii) to motivate the community; iv) to improve the sector's image; v) to influence policy; and vi) to influence future students. The aim is for this reporting and ranking system to be fed by data from the EMR and a new sustainability planning tool, the Learning in Future Environments (LiFE) index. This is a planning and self-assessment tool developed by the EAUC to guide institutions in designing, planning and delivering their sustainability activities ((EAUC, 2017). It will enable the different frameworks and initiatives that institutions are engaged with (such as ISO1400[15]/Eco Campus[16] environmental management systems and The Flexible Framework) to be brought together in one package.

Learning to engage students is deemed critical to the long-term success of carbon management (Atherton & Giurco, 2011). Many institutions are appointing sustainability champions to drive cultural change from the inside. Initiatives such as 'Blackout', 'Student Switch Off' and *ad hoc* energy audits will be explored in more detail in further chapters. Waste audits are also being used to teach students and staff about the implications of sending waste to landfill and not using recycling facilities.

Universities are seen as breeding grounds for responsible research into the technologies and ideas that will shape the future sustainability paradigm (Waas *et al*., 2010). Additionally, the student body are altogether very powerful and represent a community microcosm (Lozano, 2008). Institutions, therefore, can be a model for sustainable practices ready to be expanded into wider society, and teach the problem-solving skills required to tackle such issues to the next generation of professionals and provide the research knowledge needed (Stephens *et al*., 2008).

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[15] ISO14001 is the standard for implementing environmental management systems in organisations, developed and maintained by the ISO. The most recent revision in 2015 made changes to ensure the EMS was more embedded in the organisation's core strategy.

[16] EcoCampus transposes the ISO14001 Environmental Management System Standard into HEIs gain different awards that represent recognition of improved performance (for bronze, silver, gold and platinum); the platinum EcoCampus award is the HE equivalent of receiving ISO14001 certification.

2.4.3 **Parallels with business**

Universities must consider the interplay between economic, environmental and social factors that affect their performance in the short, medium and long-term in all aspects of the business (Lozano, 2012b). The initiatives outlined above have helped transpose key ideas from profit-driven business into universities. For instance, corporate sustainability is undertaken by addressing, in turn, the credentials of each stage of the value chain[17] (including manufacture, procurement, marketing, management/strategy, financing *etc.*). In universities, corporate sustainability is embedded through Education for Sustainable Development (ESD) and sustainability-based curricula (Lozano, Lozano, *et al*., 2013) [18] to alter the behaviours of staff and students, through student-led campaigns and institution-led sustainability projects.

A number of specific ways have been investigated in the literature seeking to fully embed corporate sustainability which are characteristic of the type of strategy the organisation wishes to pursue, such as: i) an introverted approach (focussing on internal risk management); ii) an extroverted approach (focussing on external relationships); iii) a conservative approach (favouring efficiency savings and cleaner production [Hart, 2000]); and iv) a visionary approach (promoting a holistic strategy across all operations) (Baumgartner & Ebner, 2010).

Corporate social responsibility (CSR), defined by the European Commission as 'the responsibility of enterprises for their impacts on society', is used as a form of self-regulation in which economic, social, and environmental benefits are delivered to their stakeholders. Universities conduct this in much the same way, by ensuring that they: i) comply with the law; and ii) integrate social, environmental, ethical, consumer rights, and human rights concerns into their business operations and development strategy (Stubbs & Schapper, 2011).

Only by using a triple-bottom line can an organisation know the true value it is creating (or costing, in cases where the organisation is responsible for environmental or social damage/decline). The 'green economy', developed in an attempt to create profits from emissions decoupling, has already proven that economic success can be achieved through truly sustainable products and services (Pretty, 2013). Significant weight is given to the power of a green economy to lead the paradigm shift to a low carbon economy, so much so, that the United Nations (UN) launched the

[17] The value chain describes the combination of organisational processes concerned with creating a finished product, whether physical or digital.

[18] According to the United Nations Educational, Scientific and Cultural Organisation (UNESCO), Education for Sustainable Development is defined as "the education of every human being in the knowledge, skills, attitudes and values necessary to shape a sustainable future."

Green Economy Initiative in 2008 to promote investment around the world in environmental projects which promote sustainable development (Jackson & Knight, 2011).

2.5 GHG management policy framework

Carbon management is one particular strand of an intricate sustainability web which drives HEIs towards lower carbon-intensive operations. Due to the nature of higher education, institutions are places of work for staff all year round, places of study for students for part of the year, and are entities that undertake a broad range of activities to fulfil research and teaching commitments. HEIs are governed by a number of conflicting and equal influences and, hence, carbon management can often be neglected. External influence is typically stronger than internal drive, which goes some way to understanding HE governance on a political context (Walker *et al*., 2008).

A number of drivers are at play, which combines to encourage low carbon behaviours and operations. Often, these are unnoticed by the majority of end users, although environment managers typically work extremely hard to ensure that such measures are enacted. There are two types of external stimuli responsible: 'hard' and 'soft' policy influences. 'Hard' instrumental measures include marketization (financial/market instruments), as well as regulatory and legislative approaches (Jerneck *et al*., 2011), whilst 'soft' democratic measures primarily focus on education. This section outlines the legislation applicable to HEIs related to the management of GHG emissions. Relevant legislation is grouped by origin (either European or Domestic) and also by its area of influence (energy, waste, transport); institutions undertake a wide range of activities and are thus covered by a wide range of policy instruments.

Despite the role of national and international legislation in promoting carbon management at universities, a significant challenge lies in transposing these policies into achievable and appealing schemes at the organisational level (Epstein & Roy, 2003), faculty-level (Baboulet & Lenzen, 2010), and at an individual-level (Bone & Agombar, 2011; Milne & Grubnic, 2011). In addition, the vote to leave the European Union (EU) in June 2016 will undoubtedly change the policy landscape in the UK, causing a period of uncertainty for all HEIs. This period is likely to be 2-3 years, whilst the exit strategy is negotiated (at the invocation of Article 50 of the Treaty of Lisbon) and the development of legislation is undertaken in order to replace that lost by leaving the jurisdiction of European legislative institutions. Some authors have warned that without being part of the EU knowledge economy, the UK may not have the international clout it once had as a member.

2.5.1 European legislation

Due to the nature of being a member of the EU, a significant number of policies linked to the management of GHGs are originated by the European Commission in Brussels. Legislation is either directly enacted (in the case of regulation instruments) or transposed into the statute books by Parliament (in the case of directives). In 2009, European leaders and the G8 countries (Canada, France, Germany, Italy, Japan, Russia, UK and the United States) pledged to reduce GHG emissions by [*at least*] 80% below a 1990 baseline by 2050. In order to make progress on this target, the low carbon roadmap was developed, which outlined the policy framework up to 2050 (European Climate Foundation, 2010).

2.5.1.1 Energy

Policies directed at regulating energy-derived GHG emissions can take aim at the supply of energy or the factors responsible for the consumption of energy. For instance, the Renewable Energy Directive 2009/28/EC establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 (to be achieved through the attainment of individual national targets). Additionally, member states must also procure at least 10% of transport fuels from renewable sources by 2020 (Whittaker *et al*., 2011). Individual member states are allocated a share of the overall target and must produce a plan of how they intend to succeed (the UK, for instance, has a 15% share). Applicable to HEIs, increasing numbers of institutions are investing in renewable energy, whilst the UK government is incentivising such organisations to install their own renewable energy systems.

European policy has typically supported regulation energy consumption and behaviours that lead to energy wastage (Environment Agency, 2015). More efficient use of energy is a key policy initiative enacted through numerous directives. The Energy Efficiency Directive 2012/27/EU sets binding measures for EU member states to collectively improve energy efficiency by 20% (individual member states set national contributions to the target, which can be based on primary/final energy consumption, primary/final energy saving, or energy intensity). Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from its production to its final consumption. Although not directly applicable to the HE sector, energy efficiency savings like this are often passed on to energy-intensive industries and significant electricity consumers, such as HEIs.

The European Energy Performance in Buildings Directive (EPBD) 2002/91/EC preceded the Energy Efficiency Directive and was intended to improve the overall energy efficiency of standing assets.

This was introduced through making energy efficiency of buildings transparent by mandating the displaying of energy performance certificates (Display Energy Certificates (DECs) in public buildings), and for landlords to develop strategies for improving the efficiency of their assets. All new buildings are also required to be zero-energy by 31 December 2020 (and public buildings by 31 December 2018). These aims were strengthened in a recast of the EPBD in 2010 (2010/31/EU).

At the organisational level, policies such as the EU Emissions Trading System (ETS) place a cost on carbon from the upstream generation of energy and promotes reduction through the trading of ever-decreasing carbon credits (an allocated amount of GHG that may be emitted over a time period) (Ellerman & Joskow, 2008; Pfeifer & Sullivan, 2008). A market-based instrument launched in 2005, the EU ETS is a 'cap-and-trade' system, which covers more than 11,000 heavy industrial units (power stations and industrial plants) in 31 countries and aims to reduce emissions by 43% by 2030 (European Commission, 2016). Several universities are directly impacted by the EU ETS, typically operating sufficiently large district energy plants that qualify them for inclusion (*i.e.* Oxford, Birmingham, Loughborough, Liverpool, Manchester, Warwick, East Anglia and Glasgow) (Higher Education Statistics Agency, 2015).

2.5.1.2 Waste

The EU Waste Framework Directive 2008/98/EC outlined the basic framework for waste collection, transport, recovery, and disposal of waste. The directive implements an amended waste hierarchy, with an emphasis on preventing waste arisings and the re-use of waste. The polluter pays principle was introduced as a means of holding those accountable for environmental damage (through poor waste management practices) (Hoffmann & Busch, 2008). This law held organisations to account over the destination of their waste and encouraged more rigorous record-keeping through the use of transfer notes. In addition to the EU Waste Framework Directive, organisations implement waste strategies that promote stages higher up the waste hierarchy.

The treatment of waste is regulated predominantly at the treatment facility. Landfilling of waste is discouraged by the use of a tax ('The Landfill Tax') on a per-tonne basis; in 2016, this was set at £84.40 per tonne. The Landfill Directive controls the operations of landfills in order to mitigate adverse impacts from leachate and emissions, as well as the segregation of hazardous, non-hazardous, and inert wastes. The Incineration of Waste Directive imposes strict regulations on the operating conditions and technical specification of incineration plants, especially limits on the allowable release of GHG emissions and air quality pollutants. Producer responsibility is assigned through the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU, which fosters collection, recycling and recovery of electrical goods and related waste (producers were indeed obligated to provide collection schemes free of charge). Similarly, the End-of-life Vehicles Directive 2000/53/EC aimed to ensure the proper disposal of transport vehicles and the reduction in the use of hazardous substances during manufacture. The Battery Directive 2006/66/EC set controls on the production and disposal of batteries.

2.5.1.3 Transport

Due to the far-reaching impacts of transport of the environment and the wide variety of emission sources, the EU's strategy for reducing the environmental impact of transport is inherently broad brush. Generally, the aim is to increase the efficiency of the transport system, promote low-carbon technologies, generate the energy required by the sector from renewable sources and facilitate the universal adoption of low-emission vehicles (European Climate Foundation, 2010).

Road transport contributes *ca.* one-fifth to the EU's overall carbon footprint (European Environment Agency, 2016) and 72% of all transport-related emissions. As the only EU sector where emissions are still rising (20.5% since 1990), the EU has adopted a swathe of legislation to control atmospheric emissions from road vehicles. Much of this legislation is focused on the design of efficient vehicle powertrains which imposes limits on emissions over older counterparts. To this end, vehicles manufactured in the EU and imported into the EU alike are subject to stringent standards. In 2016 the EU achieved its 2020 target for average emissions per kilometre of 130g CO_2/km (with the average being 118g CO_2/km). This has now been superseded by a 2021 target where all new cars must not exceed 95g CO_2/km. In 2013, the target for vans was exceeded, which aimed to limit emissions from vans to 175g CO_2/km by 2017 (the average in 2016 was 163g CO_2/km). Additionally, manufacturers are required under the car labelling Directive 1999/94/EC to provide fuel efficiency and CO_2 emission information.

The maritime and aviation industries are two industries touched least by regulatory controls on emissions (United Nations Framework Convention on Climate Change, 2016). Where efforts are made to adopt low-carbon practices, these mostly originate from voluntary initiatives or are governed by industry bodies and treaties. These industries have for a time, suffered from a significant lack of momentum on adopting more sustainable practices; though recently, some progress has been made which has seen the beginnings of developing change. The international maritime organisation (IMO) will, by 2020 introduce limits on the sulphur content of maritime fuels (IMO, 2015) , whilst the International Civil Aviation Organisation (ICAO) plans to develop a global mechanism for market-based regulation (using cap-and-trade) of global aviation emissions. In October 2016, the first UN accord of its kind introduced a *voluntary* scheme to *offset* passenger and cargo flights (through the purchase of forest) that generate >10,000 tCO_2e per annum (the scheme is to be introduced in 2020). In 2008, aviation activities became included in the ETS for all flights inside the European Economic Area (EEA).

2.5.2 Domestic legislation

In 2009, the UK government outlined a national strategy for climate change and energy policy through the Low Carbon Transition Plan, which outlined the move towards a low carbon economy by 2020 (HM Government, 2009). Five pledges were made: i) to protect the public; ii) to prepare for the future; iii) to limit the severity of anthropogenic climate change; iv) to build a low-carbon UK; and v) to support individuals, communities, and businesses. A number of aims were formulated that would help the UK society deliver on this promise, with specific measures of success, such as procuring 40% of electricity from low carbon sources and producing 15% of electricity from renewables (Department of Energy and Climate Change, 2011), facilitating the development of new nuclear power stations and improving domestic efficiencies. Effective policy efforts have typically focussed on reducing peak energy to reduce the need for additional fast-response fossil-fuel based energy generation; so-called 'demand-side management' (Khasreen, 2013). Through the roll-out of 'smart meters', time-of-use monitoring is allowing domestic consumers to be more aware of their energy consuming behaviours and benefits them through financial savings.

More recently, a move towards centralised monitoring of GHG emissions from organisations led the government to require all quoted companies (those listed on the London Stock Exchange) to report emissions through company director annual reports (HM Government, 2013). Organisations are required to report primarily on Scope 1 and 2 emissions, whilst being encouraged to add extra value through identification of Scope 3 emission sources. The Scope 1 and 2 emission sources encompassed include the combustion of fuel in stationary and mobile sources and electricity consumption.

2.5.2.1 Energy

The UK has become a world leader in climate-related legislation and has enacted into law the world's first instrument designed to reduce nationwide carbon emissions (Department for Environment, Food and Rural Affairs (Defra), 2009a). The CCA 2008 enacted the UK towards an 80% reduction in Scope 1 and 2 emissions below a 1990 baseline by 2050 and simultaneously established the Parliamentary Committee on Climate Change (CCC) to measure performance (Climate Change Act, 2008).

The Carbon Reduction Commitment (CRC) was introduced as a mandatory energy efficiency scheme through enabling powers enacted under the CCA2008. As a mandatory carbon emissions reporting and pricing scheme which covers large public and private sector organisations in the UK that consume more than 6,000MWh *p.a.* of half-hourly metered electricity (DEFRA, 2009b), the scheme has been estimated to save 1 $MtCO_2e$ per annum by 2020. Electricity and gas supplies are submitted to the government, and participants buy ever-diminishing allowances for every tonne of carbon they emit. Significantly more HEIs will fall under the CRC than the aforementioned ETS and it is designed by government to capture emissions not already covered under the ETS and climate change agreements (CCAs) (outlined later in this section). Allowances (each representing a single tonne of CO_2) are either purchased by the reporting organisation in advance of the compliance year (at a discounted forecast sale price) or at the end of the compliance year (where prices are more expensive, see Table 7). Additional or surplus allowances are traded on a dedicated market, should organisations under/over perform against their forecast.

Table 7: Phase 2 prices of allowances in the Carbon Reduction Commitment Energy Efficiency Scheme

Year	Forecast sale price	Compliance sale price
2014/15	£15.60	£16.40
2015/16	£15.60	£16.90
2016/17	£16.10	£17.20
2017/18	£16.60	£17.70
2018/19	£17.20	£18.30

Source: Environment Agency & Department for Business Energy and Industrial Strategy (BEIS) (2017)

The Climate Change Levy (CCL) is a tax that applies to all non-household use of coal, gas, electricity, and non-transport liquefied petroleum gas (LPG). The rates currently set are: electricity: 0.6p/kWh, gas: 0.2p/kWh and LPG:1.7p/kg, and are applied at the time of supply (in effect, a single-stage sales tax (Pearce, 2006; HM Revenue and Customs, 2016)). The transport sector's use of fuels is exempt, as well as fuels used for electricity generation, non-energy uses, and waste-derived fuels. Renewable energy and district energy generation became subject to the tax in 2013 for the first time (HM Revenue and Customs, 2015)). HEIs find themselves subject to the CCL as a result of the stipulated rules, but additionally there were industries with significantly intense usage of energy that were considered when the Climate Change Levy was introduced. More specifically, metallurgical, mineralogical and some agricultural sectors were made eligible for CCAs, which gave them up to a 65% discount from the CCL. The reasons for this were attributed to international competition/investment and of the Integrated Pollution Prevention and Control (IPPC) regime. In return, organisations agree targets for improving energy efficiency or reducing carbon emissions; the discount on electricity increased to 90% in 2013 (Department of Energy and Climate Change & Environment Agency, 2013).

The Energy Savings Opportunity Scheme (ESOS) implements the EU Energy Efficiency Directive. As a mandatory energy assessment scheme, it requires qualifying organisations to carry out energy audits (building, industrial processes and transport energy consumption) every four years (Environment Agency, 2015). ESOS applies to large UK undertakings, specifically: i) any UK company that either employs 250 or more people, or has an annual turnover in excess of 50 million euro (£38,937,777), and an annual balance sheet total in excess of 43 million euro (£33,486,489); and ii) an overseas company with a UK registered establishment which has 250 or more UK employees (paying income tax in the UK) (Environment Agency, 2015). The Environment Agency is the UK scheme administrator. Newly established policies such as ESOS, are often expected to supersede existing legislation (such as CRC), since many of the reporting overlap significantly.

The Renewables Obligation (RO) and the Feed-in-tariff (FIT) scheme are both ways in which HEIs can receive income for renewable electricity generation (the former being for larger-scale projects over the latter). FITs were established under the Feed-in Tariffs Order 2012, and are fixed tariffs awarded to eligible renewable and CHP installations for generated and exported electricity (Energy Saving Trust, 2015a). Up to 17p/kWh[19] can be garnered from obtaining power from anaerobic digestion, solar photovoltaic, hydroelectric and wind generation systems (Energy Saving Trust, 2015a). However, a decision on lowering rates is being made by the UK Government (mooted to be up to 90%). RO was established under the Renewables Obligation Order 2009 and is administered through the issuance of Renewable Obligation Certificates (ROCs) by Ofgem. This scheme features at its heart an ‘obligation’ to generate renewable energy, with producers being mandated to present a sufficient number of ROCs to meet their obligation, or they are able to buy-out their obligation (set at £47.22 per ROC in 2017-18). The obligation in 2017/18 is 0.4 ROCs per MWh in England, Wales and Scotland (0.2 ROCs per MWh in Northern Ireland) and a cumulative obligation of 44.8 million ROCs for the entirety of UK power generation (Defra, 2016). Ofgem ceased accepting new generating capacity to the scheme in 2017.

The Renewable Heat Incentive (RHI) is another payment system, this time for the production of heat from renewable energy sources; all these schemes are designed to encourage uptake of low-carbon electricity generation technologies. The renewable heat incentive is so far unscathed from

[19] This price is based on the highest available feed-in tariff rate for a 15kW hydroelectric generation plant.

these changes and institutions can earn up to 10.44 p/kWh[20] on energy from air and ground source heat pumps, biomass, and solar thermal generation (Energy Saving Trust, 2015b).

Enhanced Capital Allowances (ECAs) allow organisations to invest in energy-saving plant or machinery. Organisations purchase technologies specified on the Energy Technology List and are encouraged to do this because the whole capital cost of the equipment is written off against taxable profit in the year of purchase. Only a handful of UK HEIs will be eligible to exploit the benefits of ECAs because of the tax-exempt status of many/most HEIs. The private institutions that pay corporation tax will be eligible under the scheme. The catalogue of technologies is managed on behalf of the Government by the Carbon Trust.

2.5.2.2 Waste

A devolved matter, the waste strategy for England was laid out in the Waste Management Plan for England, published in 2013 (Department for Environment Food and Rural Affairs, 2013b). Despite the publication of this plan and the government's acknowledgement of better waste management being key to a move towards a 'zero waste' and 'low carbon' economy, no new waste management policies were introduced. The predominant source of waste legislation is derived from Europe, and so many of the policy instruments have been described in 2.5.1.2.

2.5.2.3 Transport

Transport policy centres on the increased efficiency of vehicles to reduce emissions. The most recent framework for transport policy was outlined in 2010. The three main policy areas focused on were: ultra-low emission vehicles (ULEV), shipping and biofuels. Grants for domestic and workplace electrical charging points are available from the Office for Low Emission Vehicles (OLEV), as well as tax incentives to purchase low emission vehicles. A ULEV is considered to be a new vehicle that emits less than 75gCO_2e/km, based on the current European approval test (OLEV, 2013). The Renewable Transport Fuel Obligation (Amendment) Order 2015 encourages the production of Sustainable Biofuels. Under this, suppliers of transport (and non-road machinery) fuel in the UK must be able to show that a percentage of the fuel they supply comes from renewable and sustainable sources. This encompasses suppliers of fuel that supply at least 450,000 litres of fuel per annum.

[20] This price is based on the RHI tariff for commercial solar thermal systems installed up to 1st April 2017.

2.6 The cost of carbon

The social cost of carbon (SCC) demonstrates the amount society is willing to pay to continue emitting behaviours, which avoids future deterioration of the climate, and is typically used by government policymakers for introducing low-carbon legislation. This cost is the economic value of damage associated with emitting one tonne of CO_2 at a given point in time and considers the full residence time of CO_2 in the atmosphere (Pearce 2003). Whilst similar, the shadow price (SPC) is a price based on the cost of GHG emissions, with an added consideration for the optimal level set by the policymaker (this, in turn, accounts for the political and technological setting) (Nordhaus, 1975).

A report by the Organisation for Economic Co-operation and Development (OECD) concluded that globally the price of carbon is too low to deliver significant emission reductions. Only 10% of emissions are priced at an effective carbon rate equal to the social cost of carbon (set at $30 per tonne of CO_2. The value of $30 per tonne of CO_2 was calculated by the Stern Report in 2006, and represents the cost of the damage to society associated with climate change arising from that tonne of CO_2. Therefore, 90% of carbon emitted is not priced at a level that would reflect the societal cost as a result of climate change (OECD, 2016).

2.7 GHG emission assessment options

2.7.1 Different approaches based on scale of activity

Three approaches have typically been taken to GHG assessment (Recker *et al*. 2011; Berners-Lee *et al*. 2011; Stubbs & Downie 2011; Wiedmann 2009). The top-down (Jensen, 2012), input-output analysis (IOA) is ‘environmentally extended’ by assigning GHGs emission factors (EF) of financial transactions normally modelled in economic input-output analysis. Life-cycle assessment forms the basis of bottom-up, process analysis (PA). Models that fit into neither category are commonly referred to as ‘hybrid’ models. Only certain attributes of both models are incorporated into hybrid models, and even then, the procedure is much changed and so a more appropriate name for these models would be ‘integrated’. These techniques are both commonly used in applications ranging from the macro to micro scales, see Figure 6.

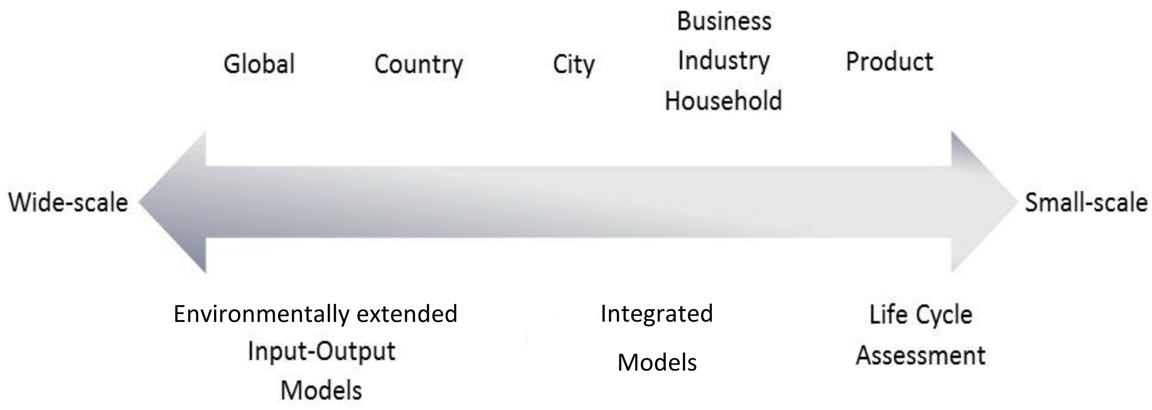

Figure 6: Carbon footprinting at multiple scales
Source: Adapted from Peters (2010).

2.7.2 **Environmentally extended input-output analysis**

For larger complex systems, aggregation of GHG emissions must be undertaken, because of the sheer volume of data and cumbersome analysis that otherwise develops. Environmentally-extended IOA (EEIOA) is used to glean environmental information on economic activities at the macro-level from pre-existing Blue Book[21] financial data (Munksgaard *et al*. 2008; Minx *et al*. 2009). IOA was first introduced by Wassily Leontief in the 1930's and depicts inter-industry relationships (as a customer of outputs from other sectors and as a supplier of inputs). The environmental burden of all supply chain, production, and consumption processes can be determined within an entire economy through inter-industry matrices, where column entries typically represent inputs, while row entries represent outputs to and from an industrial sector (Minx *et al.*, 2009).

The input-output model depicts inter-industry relationships within an economy, showing how output from one industrial sector may become an input to another industrial sector. This format demonstrates the dependency each sector has on every other sector, both as a customer of outputs from other sectors and suppliers of inputs to others. In the model there are *n* industries producing *n* different products such that the input equals the output or, in other words, consumption equals production. Considering a very simple economy that runs on just 3 different types of output: raw materials, services, and manufacturing, the model can be used to predict

[21] The official records of the national accounts of the United Kingdom are published annually by the Office for National Statistics (ONS), known as the 'Blue Book' (nowadays blue book statistics are predominantly published online).

how much output from each industry a given industry requires in order to produce on unit of its own output. In order to do this, Eq. 1 must be solved:

$$x = Ax + d \tag{1}$$

where, x is the vector of total output, Ax is the intermediate demand and d is the vector of final demand.

The requirements of each industrial sector to produce the single unit of output are summarised in Table 8.

Table 8: Industrial sector requirements table for undertaking input-output analysis.

Industry	Raw Materials	Services	Manufacturing
Raw Materials	0.02	0.04	0.04
Services	0.05	0.03	0.01
Manufacturing	0.2	0.01	0.1

The data contained in the industrial sector requirements table forms the input-output matrix by dropping the headings:

$$A = \begin{bmatrix} 0.02 & 0.04 & 0.04 \\ 0.05 & 0.03 & 0.01 \\ 0.2 & 0.01 & 0.1 \end{bmatrix}$$

Next, the demand matrix is defined, which describes the quantity of each type of output that is demanded by consumers or those outside of the economy i.e. exported, for example:

$$d = \begin{bmatrix} 400 \\ 200 \\ 600 \end{bmatrix}$$

X denotes the production matrix, which needs to be solved by rearranging Eq. 1, see Eq. 2:

$$x = (1 - A)^{-1} * d \tag{2}$$

The inverse of the identity matrix produces the production matrix:

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} - A = \begin{bmatrix} 0.08 & -0.04 & -0{,}04 \\ -0.05 & 0.07 & -0.01 \\ -0.2 & -0.02 & 0.9 \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 400 \\ 200 \\ 600 \end{bmatrix}$$

$$\begin{bmatrix} 0.08 & -0.04 & -0.04 \\ -0.05 & 0.07 & -0.01 \\ -0.2 & -0.02 & 0.9 \end{bmatrix} * \begin{bmatrix} 400 \\ 200 \\ 600 \end{bmatrix} = \begin{bmatrix} 449.24 \\ 237.27 \\ 769.13 \end{bmatrix}$$

Thus, in this example the service sector should produce $237.27 billion worth of services etc. in order for the economy to balance.

EEIOA has significant advantages over LCA with regards to time and financial considerations, because it relies on readily available economic transaction data and industry EFs. Although still fairly technical in nature, the process of assessing emissions using such a technique is less onerous than LCA and eradicates the potential for double counting. EEIOA gives a comprehensive view of an entire economic system, which makes it suitable for global GHG assessment and reporting, but what is more important is the consistent view that this also provides policymakers. It can clearly highlight the interdependencies between parts of the economy and allow for carbon management policies to be implemented on specific sectors. The potential for truncation error is fairly low, since the use of cut-offs and boundaries are generally avoided. Truncation errors are defined by Ward *et al*. (2017) as the 'proportion of a system or activity's impact not covered by the system boundaries of the LCA'. These errors tend to occur when part of the system is knowingly ignored, that is, when their contributions are assumed not to significantly or materially affect the overall impact (often mistakenly so by the author).

The drawback of such a large-scale model is that all the data are aggregated due to the volume involved and so there is a lack of resolution down to the individual activity/process. The limitations of EEIOA are associated with the high level aggregation that must be used and the lack of resolution that this provides. Aggregation error occurs when the data is interrogated further and an aggregate is treated as a less-aggregated unit or individual unit. These errors are exacerbated when the economic categories and information that is used are aggregated in a different way to environmental data (Lenzen 2010). The approach assumes that all product groups are homogeneous, and so using a monetary value to represent inter-industrial transactions can be misleading (Wiedmann, 2009). Even when highly disaggregated, the assumption based upon homogenous pricing levels is also a potential introduction of bias. National inventories generally measure emissions associated with the consumption of goods and energy, and the imports and exports of goods and services on a country-wide scale (Gao *et al*., 2013).

IOA is based on the premise that the input coefficients are fixed i.e. it is assumed that there are constant returns to scale in production. In addition, it assumes that the techniques of production remain unchanged, whilst ignoring price changes and inflation (there is no provision made to include it). Final demand is taken as given and treated as independent of the production sector, which in reality can be argued to not be as clearly defined, since the availability of goods often influences demand (albeit indirectly). Finally, IOA takes a very technical concept, the relationships of industries in an entire economic system, comprised of many hundreds of sectors and subsector and simplifies this. This ultimately results in a severely restricted view of reality, which introduces truncation errors (Ward *et al.*, 2017).

The approach taken by EEIOA is valuable to 'hotspot' the entire supply chain for a bundle of goods and services purchased by a company through 'structural path analysis[22]', allowing reductions to be targeted at the highest emitting supplier along the chain (Larsen & Hertwich, 2009; Baboulet & Lenzen, 2010). Recent developments are numerous, and various studies have been produced applying it to multi-regional footprints (Hertwich & Peters, 2009), hybridisation (Suh *et al*., 2004), and at sub-national levels (Larsen & Hertwich, 2009; Thomas Wiedmann, 2009).

2.7.3 **Life-cycle assessment**

Until the 1990s, life-cycle assessment and input-output analysis were the predominant methods of estimating carbon emissions. Whilst there is some diffusion across boundaries, PA is primarily suited to understanding the cradle-to-grave emissions of singular products (using inputs such as materials and energy use) where analysing each single step in producing a product is appropriate (Recker *et al*., 2011). This allows practitioners to understand the environmental impacts of the various life stages of individual products, enabling management efforts to be targeted at the parts of the supply chain with the greatest climate impact (Pattara *et al.*, 2012).

Two approaches can be taken when undertaking PA: via the process flow diagram approach or via matrix notation. The former involves compiling process-specific data for each process in the system and assuming upstream processes have negligible impact. The drawback of this method is that the number and order of upstream processes is limited and disconnected; in reality, all processes are interlinked in some way, so an underestimation of emissions is likely. In matrix notation, each column of the technology matrix is populated by input and output vectors per operation of time. The life-cycle inventory is calculated by inverting the technology matrix and multiplying by its environmental matrix. The obvious improvement that this method provides over the process flow approach is that an infinite number of upstream process combinations can be considered, allowing a more accurate view of the system or product to be analysed. Attention must be paid to the consideration that the number of processes included and the extent of the footprint are typically only as wide as the predetermined system boundary.

Once the goal or purpose for preparing a life-cycle inventory has been determined and the intended use is known, the system should be defined. The "system" is a collection of operations

[22] Structural path analysis is a technique for measuring flows through ecological and linked ecological-economic networks (Lenzen, 2007).

that together perform some clearly defined function beginning with raw material inputs and ending with recycling/disposal (Vigon *et al.*, 1993). It is the accumulation of the GHG emissions associated with these constituent parts which constitutes the life-cycle assessment (Song & Lee, 2010).

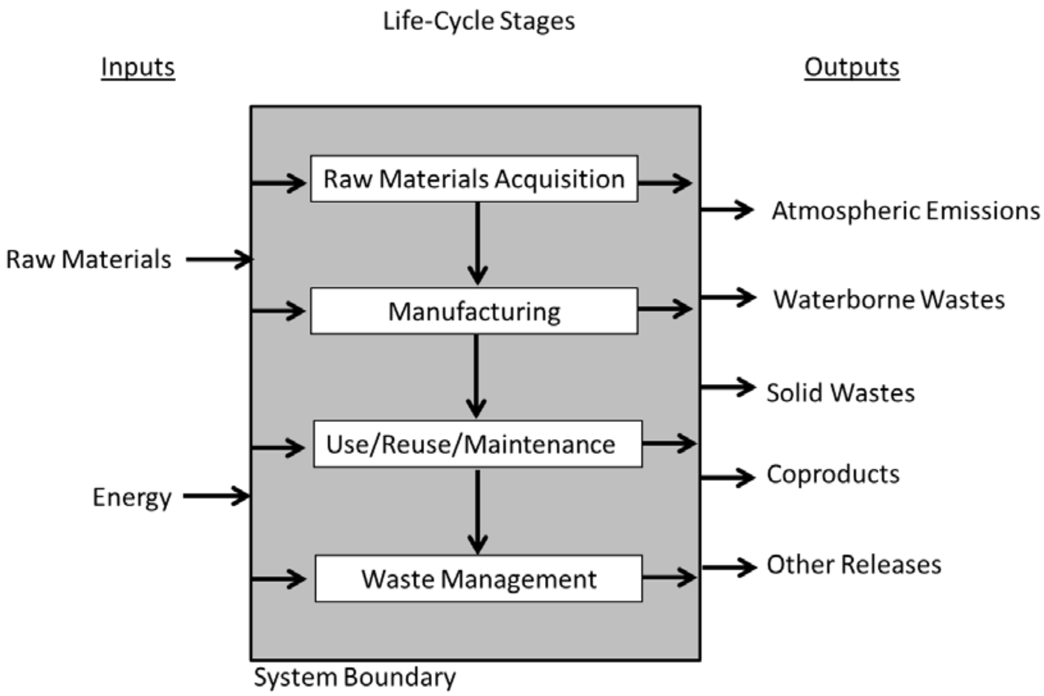

Figure 7: Defining the system boundary of the life-cycle assessment
Source: Adapted from Vigon *et al*. (1993)

A number of LCA types exist which focus on different components of the life-cycle. These include cradle-to-gate (Finnveden et al., 2009), cradle-to-cradle (Sharrard et al., 2008), gate-to-gate or well-to-wheel LCA (Rizet et al., 2012) and variations thereof; together these constitute 'partial LCA'. Cradle-to-gate LCA assesses the part of the product life-cycle from the extraction of resources to the factory gate, after resources have been manufactured into useful components (i.e. before transportation to the consumer). This assessment is particularly useful because it allows for the development of life-cycle inventories (LCI) (Suh & Huppes, 2005). The LCI holds information on the embedded carbon in the upstream manufacture of products (although not often limited to products), which can be used by those further downstream i.e. for eco-labelling purposes etc. Cradle-to-cradle assessment refers to the assessment of products where the end-of-life disposal is a recycling/reconditioning process, while gate-to-gate assessment considers a single value-added process in the production chain in detail, and well-to-wheel (or well-to-tank depending on if the combustion process is included) considers the life-cycle emissions of the extraction, production (i.e. fractional distillation of crude oil, refining of natural gas etc.) and transport of fuels, used in the transportation sector (Heijungs & Kleijn, 2001).

LCA assesses the environmental impact of activities across a broad range of impact categories through the process of normalisation. These impact categories are decided by the practitioner, based on the scope of the LCA and the value they want to take from the assessment. Impact categories can include, but are not limited to: ozone depletion; acidification; smog production; and eutrophication and are compared by the metric, impact potential per person per year, also known as person equivalent (PE).

The advantages of LCA are numerous. The methodology provides a very detailed quantitative assessment of individual products (or product system) along the full life-cycle (Baumann & Tillman, 2004). This has allowed for the development of life-cycle emission inventories for a swathe of products and materials assessed by peer-review. The most notable example of these is the EcoInvent database, which is not limited to storing information on just these two activities, but also contains assessments of energy systems, transport, and chemical manufacture (Wernet *et al*., 2016). It is for this reason, that LCA fosters comparisons between different products and systems; the figures of the EcoInvent database have been used in countless research papers for this exact use. As is increasingly the case in environmental management and assessment, the process of LCA is the subject of ISO14040:2006, a standard issued by the ISO; guidance on applying this methodology is widely available.

There are numerous articles in the literature that describe the drawbacks and limitations associated with LCA techniques. Whilst it is a standard technique and currently accepted by the academic community, it is presently the only tool available for assessing environmental credentials of products. This means that its attributes are little tested against alternative techniques. In practical terms, the observations and description of the real world in LCA studies are often subjective and open to uncertainty. Uncertainty is also introduced in the data used and the associated methodology (a factor that inspired the development of the EcoInvent database of assured data). Finally, whilst the environmental impacts that are considered offer greater visibility for environmental management practices than other assessment options outlined in this literature review, not all impacts are considered (or can be considered) e.g. ozone depletion, eutrophication, other pollutants and GHGs (Finnveden, 2000).

The data-intensive nature of LCA contributes toward a high degree of uncertainty associated with a number of impact categories. In addition, high quality data is often difficult to acquire, especially for activities far-removed from the individual undertaking the analysis. This also adds to the amount of time required to complete a full LCA, as well as to the expense. Ultimately, LCA can be difficult to interpret for the non-expert audience (such as the public, policymakers, and politicians) and is therefore often accompanied by a non-technical summary to be used in policy decisions.

Often, the life-cycle of the product or system being assessed is overly simplified and so the output, therefore, is likely to be significantly underestimated (Ekvall *et al.*, 2007).

2.7.4 **Integrated methods**

Integrated models are commonly used for meso-level applications to improve upon the lack of resolution in EEIOA and the granular detail of PA (Larsen *et al.*, 2013). The scale to which they can be implemented varies considerably, being used for cities, local authorities, and individual organisations. The word 'integrated' is used to describe two situations: the use of physical, measured data alongside monetary values, and the integration of sector-level and industry-level information. An early example of hybrid analysis was conducted by Moriguchi *et al*. (1993) to analyse the life-cycle emissions of a motor vehicle. It was not until the late 1990s that integrated models became the mainstay of published research. Here, the allocation of emissions needs to be more targeted to avoid double counting. These models allow process-level user input to be coupled with large system boundary characteristics from the EEIOA (Suh *et al*., 2004; Sharrard *et al*., 2008). Additionally, integrated models are less time-consuming than PA models, since data are connected with data from an input-output model and only augmented by primary data; the level of detail is also less than that of PA, in the main due to the large amount of data that must be obtained.

The integrated model can be separated into three different categorical types: tiered hybrid analysis (Moriguchi *et al*., 1993); input-output based hybrid analysis; and integrated hybrid analysis (Suh *et al*., 2004). In a tiered hybrid analysis, the direct and downstream emission sources are examined in detail, whilst the remaining upstream emissions sources are covered by input-output analysis. In input-output-based hybrid analysis, the more important input-output sectors are disaggregated where more detailed data is available, while integrated hybrid analysis exhibits characteristics of both by incorporating detailed process-level information (physical quantities) into the model (Finnveden *et al*., 2009).

2.7.5 **Carbon footprinting**

A plethora of methods and models have been developed in recent years that aim to assess the emissions of activities for a wide variety of settings and scales. The 'carbon footprint' is often used as an all-encompassing term to describe these methods of assessments. The term is typically criticised as a misnomer, by conjuring up the idea of referring to a unit of area, and is more specifically referring to a 'carbon weight' (Hammond, 2007; Williams *et al*., 2012). Often used as a buzz word by the media, business, and government (Wiedmann & Minx, 2008), the lack of consensus on a suitable definition has been a prevailing issue since its origin around 2000.

Carbon footprinting is based on life-cycle assessment (LCA) (it is referred to as a partial LCA) and can be used to inform full LCA studies (Wiedmann & Minx, 2008). Carbon footprinting has been applied to myriad subjects, despite its relative recent emergence from ecological footprinting. From households to entire industries, a swathe of guidance has been published to assist practitioners in interpreting and applying the methodology. The carbon footprint is so-called as it focusses solely on a single impact category i.e. Climate Change (unlike LCA as mentioned in 2.7.3).

The 'carbon footprint' is a hybridised version of the previously described micro-level and macro-level techniques. The carbon footprint is noted to its significant advantages over other forms of GHG assessment. Firstly, the carbon footprint is easily upgraded to a full-LCA if the practitioner so desires, but is essentially less time intensive and less data intensive than a full LCA would be (Williams, Kemp, et al., 2012). The carbon footprint is also the subject of international and national standards (particularly for organisations, but also for projects and product-labelling). Most significantly, the carbon footprint has made GHG assessment accessible to the public, business leaders, and policymakers alike, due to results that are easy to understand, interpret, and compare (Ahmad & Hossain, 2015).

Whilst there are many positive attributes of carbon footprinting, significant limitations must be noted. Primarily, the carbon footprint methodology is open to wide interpretation and there is, therefore, considerable scope for variation in results. This is a function of: i) the methodology used; ii) the definition used; and iii) the boundary. These must be stipulated alongside the data in order to make their interpretation reliable. Similar to LCA, carbon footprinting involves an inherent oversimplification of complex real-life systems primarily associated with the boundary cut-offs and the (often) generalised EFs that are used.

It is universally held that carbon footprint reports should consist of: i) organisational goals and inventory objectives; ii) the organisational and operational boundaries; iii) the quantified inventory of emissions (and removals); and iv) targets and actions for performance tracking (British Standards Institute, 2013).

2.7.5.1 Definition

Disagreement over what a carbon footprint actually is, what should be included in its calculation, and how it should be quantified without double counting, is often a cause for controversy (Wiedmann & Minx, 2008; Finkbeiner, 2009; Weidema *et al*., 2008; Peters, 2010; Wright *et al*., 2011).

For this reason, a number of studies have tried to determine the parameters of a carbon footprint and, thus, two competing definitions are currently available. Wiedmann & Minx (2008) proposed that "*The carbon footprint is a measure of the exclusive amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product*". In contrast, Wright *et al*. (2011) developed another definition based on a number of criticisms to be discussed in more detail: "*The carbon footprinting is a measure of the total amount of* CO_2 *and* CH_4 *emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as* CO_2 *equivalent (*CO_2e*) using the relevant 100-year global warming potential (GWP100)*".

2.7.6 Emission calculation

Two pieces of information are required to quantify the GHG emissions of an activity or entity. Parameters regarding the activity that is being evaluated (activity data) are applied to a known quantity of emission per unit of activity (an EF). Eq. (3) shows the emission calculation that applies to all sources of carbon emissions and demonstrates the reason behind the data-heavy nature of carbon footprinting:

$$E = AD * EF \tag{3}$$

Where, *E* are the GHG emissions of the organisation or activity under study, *AD* is data on the magnitude of human activity resulting in emissions or removals originating from the organisation or activity under study, and EF is the emission factor, the average emission rate of a CO_2 for a given source.

If additional GHGs are to be included in the footprint, the aforementioned 'CO_2e' measure provides a single unit that allows the contributions of individual GHGs to be represented proportionately to the same unit of CO_2, Eq. (4):

$$E_{equiv} = \Sigma_{[gas]}(E_{[gas]} * GWP_{[gas]}) \tag{4}$$

where, E_{equiv} is the total GHG emission to atmosphere of the group of selected GHGs, $E_{[gas]}$ is the emissions for each individual GHG, $E_{[gas]}$, and *GWP* is the global warming potential for the given GHG.

2.7.7 Greenhouse gas global warming potentials

The global warming potential (GWP) was developed to compare the global warming impact of different long-lived GHGs (in reference to CO_2). These metrics allow practitioners to understand the effects anthropogenic emissions have on the radiative forcing over a time period against an equal measure of CO_2, and, thus, the metric is known as CO_2 equivalent. The first GWPs were developed and published by the Intergovernmental Panel on Climate Change (IPCC) in the second assessment report and were used in the Kyoto Protocol for national emissions inventories (Boitier, 2012). There have been a number of articles in the literature that have critiqued the limitations of the GWP metric, especially for use for short-lived GHGs (Talbot & Boiral, 2013). Whilst GWPs for long-lived GHGs are independent of time and location, the GWP of short-lived GHGs may have regional and temporal differences which are not accounted for.

GWPs are usually measured on a 20-year or 100-year time horizon (Bhatia *et al.*, 2011; Williams *et al*., 2012) and are regularly updated as analytical scientific techniques improve. Table 9 shows the up-to-date figures, as published in the IPCC fifth assessment report (IPCC, 2013). In the IPCC's fifth assessment report (AR5), the climate-carbon feedback has been incorporated with the publication of two separate figures with and without this consideration. The climate-carbon feedback refers to the climate implications of the release of anthropogenic emissions, creating a positive feedback loop. Since increasing GHG concentrations cause climatic change, climatic change in similar respects can affect increasing GHG concentrations (mostly as a result of negatively affected land-based carbon storage) (Friedlingstein *et al*., 2006).

Table 9: Global warming potentials of methane and nitrous oxide

GHG	Atmospheric Lifetime (years)		GWP 20*	GWP100*
CH_4	12.4	With cc fb	84	28
		No cc fb	86	34
N_2O	121.0	With cc fb	264	265
		No cc fb	268	298

Source: Solomon, *et al.* (2007); IPCC, (2013)

* The GWP is referenced against the radiative forcing of CO_2, which is given the value of 1 and not shown in the table.

A significant point to consider here is the differing views on the inclusion of GHGs in the footprint. Questions have been raised about whether the carbon footprint is limited solely to CO_2, or the Kyoto Basket gases (six GHGs including N_2O, SF_6, HFCs and PFCs; extended in 2013 to include NF_3), which includes some GHGs where carbon is not a constituent element. Wright *et al*. (2011)

suggest including only two GHGs; CO_2 and CH_4 and Wiedmann & Minx (2008) only CO_2. By including two GHGs, 87% of the radiative forcing contributed by anthropogenic emissions can be captured, whilst maintaining ease of data collection (Wright *et al.*, 2011). According to the definition outlined by Wright *et al.* (2011), the inclusion of the Kyoto GHGs is given the term 'climate footprint' and is used in instances where it is necessary to evaluate climate risk more accurately, for example, in national environmental input-output tables. A 'GHG inventory' describes the inclusion of all the anthropogenic GHGs that are released, including (amongst others) aerosols, black carbon, contrails, water vapour, ozone, and particulate matter (see Figure 8).

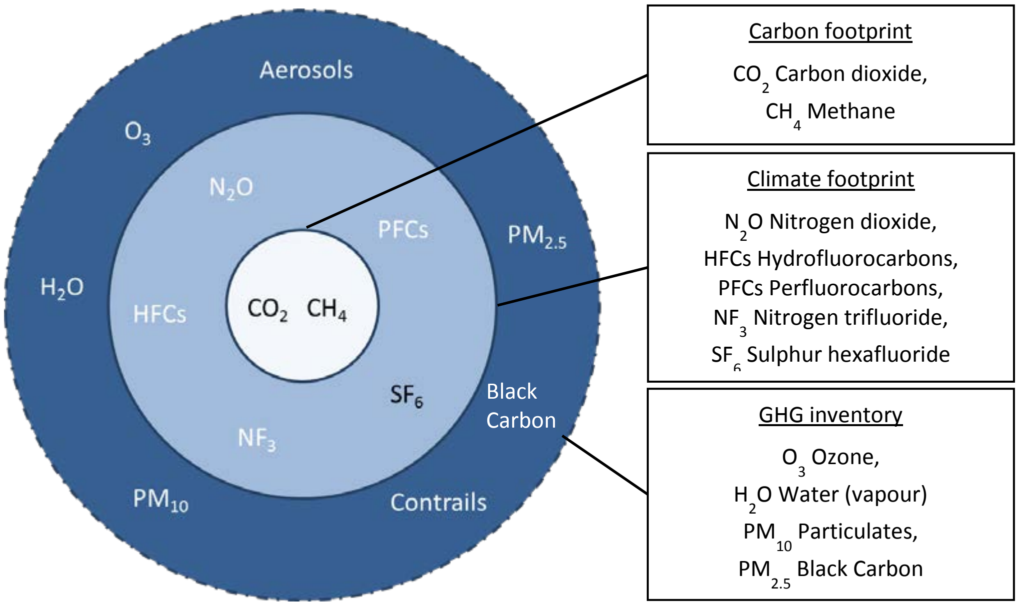

Figure 8: The relationship between the GHGs included in the carbon footprint, climate footprint and GHG inventory.

Source: Adapted from Williams *et al.* (2012).

2.7.8 Emission factors

Where the direct measurement of GHG emissions arising from an activity is unobtainable, organisations may elect to apply a generic pre-determined EF. Industry-derived EFs act as a standard measure of the GHG emissions associated with a particular activity (e.g. the mass of GHG emissions through activities such as the combustion of one cubic metre of natural gas in a boiler) and are often averages of large datasets of detailed activity studies. An example of this is the National Rail EF. This refers to an average emission per passenger kilometre for diesel and electric trains. This has been calculated based on total electricity and diesel consumed by the railways for the year, and the total number of passenger kilometres (Cummis *et al.,* 2013). The international rail factor is based on a passenger-km weighted average of the emission factors for the following Eurostar routes: London-Brussels; London-Paris; London-Marne Le Vallee (Disney); London-Avignon; and the ski train from London-Bourg St Maurice (BEIS, 2017).

EFs which are based on empirical data, such as the aforementioned natural gas EF or those derived for other fuels such as petrol or diesel feature high levels of uncertainty and experimental error (Rypdal & Winiwarter, 2001). This is mainly due to the reason that the EFs are derived from experimental procedures which account little for their real-world application.

Other EFs introduce assumptions in order to quantify the unquantifiable. Following Defra's guidelines (Defra, 2009b), emissions related to aviation includes a 9% uplift factor to account for non-direct routes, delays, and circling of aircraft which can occur during routine journeys. In addition, a radiative forcing (*rf*) coefficient of 1.9 is also considered to account for the climate change effects of other direct and indirect non-CO_2 GHGs (including water vapour, contrails, and nitrogen oxides, *etc.*) of aviation (BEIS, 2017). Separate EFs that include and exclude this *rf* coefficient are published and available for selection by the practitioner.

In the UK, EFs are published annually by Defra. For entities that need to apply EFs for operations occurring internationally, the International Energy Authority (IEA) publish the emission factors for national grids for most countries. There is often a lag time between real time emissions and the production of EFs, owing to the extensive sense checking and validation that must be conducted; this is often around two years.

2.7.9 Approaches to data

Selection of appropriate activity data improves the confidence and resolution of the footprint (Ranganathan *et al*., 2004; Cummis *et al*., 2013). Quantification can be completed by theoretical calculation, measurement, or a combination of both if data is unavailable (Defra, 2009; British Standards Institute, 2013; Gao *et al*., 2013), whilst direct measurement is by far the most accurate. Outside of the organisational boundary is where direct measurement is found to be less achievable and, commonly, organisations rely on secondary data sources or proxies in order to provide best estimates; the options for collecting data can be seen in Figure 9.

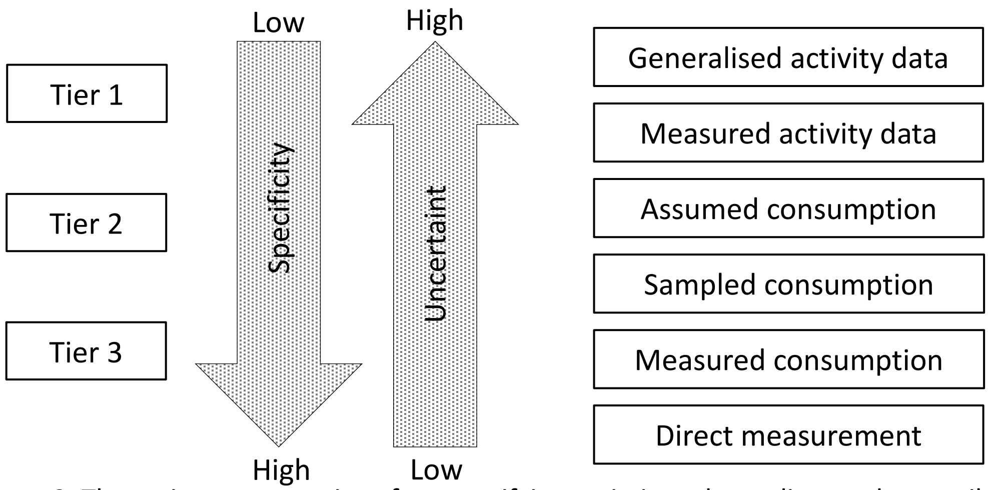

Figure 9: The various connotations for quantifying emissions depending on data availability. Source: Adapted from Williams *et al*. (2012).

The use of data tiers formally defines the relationship between data availability, resource availability (temporal and financial), and the ultimate expectation of the footprint by the reporting organisation. Selection of data tiers helps in order to provide some clarity and uniformity to inform decisions associated with the data collection phase IPCC, 2006. Practitioners are able to select a tier based on a number of considerations that help to alleviate the issues associated with time and financial resource availability. The lower the data tier, the more generalised, less specific and more uncertain data becomes. Tier one, the 'default method' uses non-specific data to *estimate* emissions, whilst tier three is the 'most detailed method' and uses technology-specific data to *calculate* emissions. Tier two methods use country-specific figures in the calculation (Williams *et al*., 2012). These are labelled against the connotations presented in the Figure. This tiered system is similar in-part to the data scenarios implemented in guidelines such as the International Standardisation Organisation (ISO) 14064-1 standard, where a 'best scenario' and a 'minimum scenario' are defined (British Standards Institute, 2013).

By far the greatest factor in drawing reliable conclusions from the carbon footprint is based on the quality of the activity data (Von Bahr *et al*., 2003; Rypdal & Winiwarter, 2001). The detail that is needed by the practitioner is a function of the data tier selected, the aim of the footprint, and the time and financial resource of the reporting organisation (hence, the rationale behind the hot spotter developed by the Carbon Trust to simply and cheaply identify areas of emission intensity).

2.7.10 **Production and consumption perspectives**

In today's interconnected world, where goods and services move from exporting countries to importing countries, determining who is responsible for particular GHG emissions is a cause for considerable debate amongst policymakers. In deciding this, two different perspectives arise, where emissions can either be accounted for on a consumer-only basis or a producer-only basis. The current policy of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol is to assign responsibility to the emission producer (Peters & Hertwich, 2008).

The main motive for consumption-based footprints is to avoid the carbon leakage associated with international trade (a geographical shift in GHG emissions made in the supply chain which impedes real net emission reduction). Territorial emission inventories such as these allow for gross-importing nations to consider the environmental consequences in gross-exporting nations. Production-based assessments restrict the consideration of these far removed emissions by only accounting for emissions arising in the immediate area. Production-based assessments are deemed unfair by some commentators, who view absolving the consumer of goods and services of all responsibility inherently undemocratic. Final consumption and affluence, especially in the industrialised world, are the main drivers for the level and growth of environmental pressure and significantly influence the carbon footprint. Additionally, the distribution of manufacturing industries across the globe is uneven, with many organisational supply chains originating in LEDCs in the East (often due to stringent wage and environmental standards in the West).

Avoiding double counting in the organisational supply chain is critical. Allocating responsibility for emissions is politically sensitive (especially in national inventories) and, for organisations, the inextricability of supply chains makes reporting indirect emissions without some element of double counting a constant issue (Wiedmann *et al.*, 2009; Caro *et al.*, 2013). Most corporate sustainability reports only include impacts arising from operations controlled by the reporting company, and not these supply-chain impacts. As a result, the sphere of influence that consumers have is underrepresented (Heiskanen *et al.,* 2010).

The upstream activities of one organisation are the downstream activities of another and geographic boundaries are harder to define (than a national border for instance). Even with the implementation of emission scopes, double counting cannot be completely eradicated. If all organisations calculated and reported the entire extent of their emissions then all would be committing double counting to a degree external to their own boundaries. This is especially evident when accounting scope 3 emission sources involving products and services provided by external organisations. Peters (2010) argues that these instances can be ignored if the footprints are not combined and if 'internal' double counting has not been performed by the organisation themselves.

The ultimate decision on which approach to take rests on the intended use of the footprint, but consideration that this may become a greater problem in future, as more organisations report carbon data, is outlined by Matthews *et al*. (2008). Demand-side measures to environmental problems are rarely exploited, whilst producer-focused environmental policy (with some consideration for consumption-related aspects) have been the dominant focus in recent years (Bastianoni *et al*., 2004; Wiedmann & Minx, 2008; Davis & Caldeira, 2010). As with many other allocation problems, a politically viable consensus lays somewhere between shared producer and consumer responsibility (Lenzen *et al*., 2007).

It is intuitively clear that the responsibility for impacts associated with transactions in a productive system has to be somehow divided between the supplier and the recipient of the respective delivered commodity. This concept recognises that there are always two entities playing a role in causing impacts: the supplier and the recipient. In order to assign responsibility to agents participating in these transactions, one has to be able to track supply chains or inter-industry relations in detail. The shared responsibility problem is addressed by Gallego and Lenzen (2005), who describe a consistent framework for distributing GHG impacts along economic branches. To this end, suppliers and demanders of any commodity take on a 50% share of the responsibility that the production of the commodity entailed.

2.7.11 **Tools**

The UK's Carbon Trust has developed three pieces of software for quantifying and managing the carbon footprint of various aspects of organisational operations. 'Footprint Manager' is a cloud-based reporting tool that facilitates carbon footprint development. This tool allows organisations to comply with carbon-related legislation (see section 2.4.2) and focuses on Scope 1, Scope 2 and business scope 3 travel emissions. The 'Value Chain Hotspotter' focusses primarily on managing the Scope 3 emissions associated with purchased goods and services and their transportation, employee commuting and business travel. A number of software suites are available for practitioners to undertake LCA, including SimaPro, GaBi, Quantis, and Enviance.

2.8 Organisational carbon footprinting

2.8.1 **System boundary selection**

The setting of the organisational boundary outlines the extent to which organisations acknowledge their own activities, whilst providing the user with detail in understanding the nature of the sites/buildings and entities included in the footprint. This is the first thing an organisation must do before assessment of GHG releases can be conducted. Conducted using a number of approaches (Dragomir, 2012; Gao *et al*., 2013), the formal setting of the boundary can take either an 'equity share' or 'control' approach. This strategy is primarily designed for cases where the structure of the organisation may present a challenge for practitioners by featuring multiple subsidiaries and operating entities for which a decision to be included or excluded must be made (such as in the case presented by Dragomir (2012) for the multinational petroleum-producing organisations BP, Royal Dutch Shell, and BG Group Plc).

The equity share approach allows the organisation to account for emissions of an entity according to the percentage ownership of the operation; consequently, the percentage ownership of the activity determines the percentage responsibility the reporting organisation has over its emissions (Ranganathan *et al*., 2004). The control approach (subsequently divided into a financial or operational control) assigns emissions according to the form of control that the reporting organisation has over the operation. Organisations using a financial control approach include emissions from activities to which the organisation has the ability to direct financial and operating policies, with a view to gaining economic benefits (where 100% of the emissions are accounted for). Finally, an organisation has operational control over an entity if the organisation has the full authority to introduce and implement policies governing its operations (Bhatia *et al*., 2011).

Organisations hire equipment and products and own products that are hired out to other organisations. The term ‘upstream leased assets’ refers to assets owned by one organisation (‘the lessor’), leased to other organisations (‘the lessee’). The emissions of the use of the equipment should be recorded by this organisation. Additionally, the receiving organisation enters into a contract to use another organisation’s equipment and is also expected to record the footprint of the use of the equipment as downstream leased assets (British Standards Institute, 2013). A lease can take a number of different forms which are important to consider for carbon footprinting purposes. The form that the contract takes depends on the type of object being leased and the contractual arrangements, which are recorded differently on the company’s balance sheet (which, in turn, affects the type of control the organisation has over the activity) (Bhatia *et al*., 2011):

- Financial lease - a long-term lease over the expected life of the equipment (usually three years or more and quite commonly used for building leases). The lessee can expect to recover the full cost of the equipment and additional charges over the lease period, whilst remaining fully responsible for its maintenance. Financial leases are shown on the balance sheet as a capital item and are thus reported under the ‘capital equipment’ scope 3 category by lessees;
- Operating lease - the term of an operating lease is short in comparison to the operational lifetime of the equipment and, therefore, the lessee can still make use of it after the terms of the lease have expired. This is not shown on the balance sheet of the lessee; and
- Contract hire - the shortest-term lease, which is most commonly used for vehicle rentals. These are also not shown on the balance sheet of the lessee, but this organisation does take some responsibility for its maintenance and road-worthiness.

The initial organisational boundary setting gives the organisation a clear idea of which establishments should be included in the footprint. During this process, the legal status of these establishments is also determined and, therefore, the reporting organisation can identify the various investments and franchises that they fund and operate. These two entities are treated separately in carbon footprinting terms and pose a risk for misappropriating or double counting. A franchise is a business that operates under a licence to sell and distribute goods and services, using the branding and mode of operation of the parent organisation. The calculation of franchises, therefore, is fairly straightforward and follows the methodology for organisational carbon footprinting (just considered in the reporting organisation’s footprint rather than being reported as a separate entity’s footprint).

The setting of the organisational boundary using a financial or equity share approach can mean that the separate accounting of emissions from investments is irrelevant. The reporting organisation is therefore required to be diligent in this respect, because the risk of double counting is high.

2.8.2 The operational boundary as a means to avoid double counting

In order for organisations to avoid double counting, emission scopes were developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) in the 2004 'GHG Protocol'. Assigning emissions has long been a contentious issue and is made harder at lower scales. Primarily, the emissions arising from within the boundary of the organisation are the easiest to assign and calculate (Bastianoni *et al.*, 2004). As can be seen in Figure 10, emissions can arise upstream (indirect emissions from purchased/acquired goods and services) and downstream (indirect emissions from sold/distributed goods and services) of the reporting organisation, highlighting the different aforementioned perspectives that can be taken to reporting.

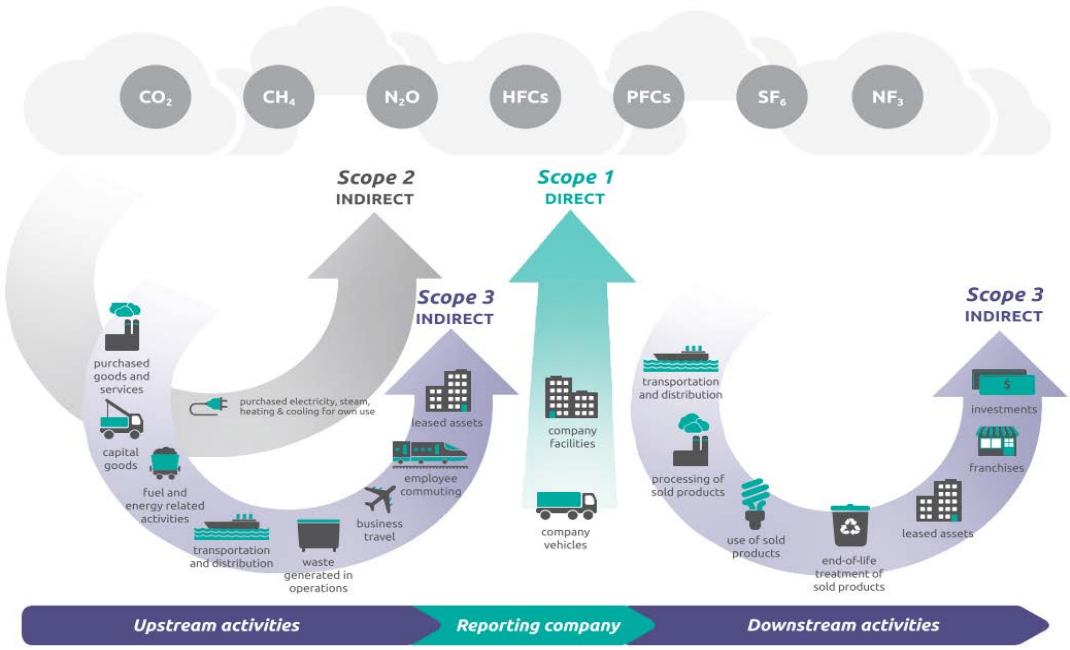

Figure 10: The emission scopes included in a corporate footprint

Source: Reproduced with permission from Bhatia *et al*. (2011).

2.9 Identifying and calculating emission sources

2.9.1 Direct greenhouse gas emission releases

Emissions that occur within the organisational boundary (referred to as Scope 1) are divided among: stationary combustion; mobile combustion; process emissions; land-use; land-use change;

and forestry (LULUCF). Emissions attributed to the combustion of fossil fuels in immobile equipment are referred to as 'stationary combustion emissions', whilst combustion of fuels in movable equipment are referred to as 'mobile combustion emissions'. Stationary combustion is typically limited to onsite boilers and furnaces, and mobile combustion is performed in moving vehicles owned and operated by the organisation *i.e.* fleet vehicles and forklift trucks *etc. etc*. The allocation of mobile emissions to the correct emission category is important and explored in 2.9.2.3.

The combustion of fuels in onsite boilers and furnaces are controlled by their thermal efficiency and the number of 'degree days' in which the equipment is operational. The degree day is a unit which signifies the thermal demand of buildings, by measuring the different between a baseline building temperature and the outside air temperature. The base temperature used in these calculations is 15.5^{o}C in the UK since at this temperature no additional heating inputs are required (DECC, 2016b). The degree day is an average figure and does therefore not account for localised conditions or diurnal variations.

2.9.1.1 Uncontrolled sources of GHG emissions

The release of emissions may be from either controlled or uncontrolled sources. GHG emissions that are uncontrolled are called fugitive emissions, and occur as a result of a leak from equipment, transport systems, and reservoirs (British Standards Institute, 2013). The quantification of fugitive emissions is inherently difficult, and in many settings, impractical to directly measure ((Chambers *et al*., 2008). Although originating from other sources, fugitive emissions are most commonly associated with the handling and use of refrigerants (Chambers *et al.*, 2008; British Standards Institute, 2013). Organisations that control these substances have a duty of care to minimise their release due to their potency (with GWPs often in the order of hundreds or thousands on a 100-year time horizon). Two estimation methods are commonly used to quantify their releases; the screening method and the simplified material balance method (SMBM).

The screening method is a proxy method often used to understand the significance of refrigerant uses on the overall carbon footprint of the organisation. This is also often used if clear records are not maintained by the organisation, the organisation outsources the maintenance of the equipment and uses the total capacity and average leak rate of analogous equipment (US Environmental Protection Agency, 2014). If emissions from this equipment are determined to be significant when compared with an organisation's other emission sources (e.g., stationary combustion, mobile sources), then the SMBM should be applied to calculate emissions with improved accuracy. A considerable issue with using the screening method is the use of average leak rates that can differ in reality, in direct relation to the state of repair of the equipment. For organisations that maintain their own equipment and keep appropriate records, the SMBM method uses a comparison of the quantity of gases bought to charge the equipment at the start and the quantity needed to refill the equipment, again somewhat of a proxy for direct records of atmospheric losses (Department for Environment Food and Rural Affairs, 2009b).

2.9.1.2 Land-use, land-use change and forestry

Process-related emissions are the GHG releases associated with activities that do emit GHGs from combustion or fugitive sources. These occur from within the organisational boundary, making their scope fairly narrow and can be difficult to capture in practise. These cover a wide range of sources however, and the variety across different organisational sectors is especially complex. Examples include (British Standards Institute, 2013):

- Industrial processes *i.e.* cement production, oil and gas refining;
- Agricultural processes *i.e.* fermentation, livestock husbandry, use of nitrogen fertilisers *etc.*);
- Waste and wastewater treatment; and
- Carbon capture and storage (CCS) processes.

LULUCF emissions are most often omitted in individual organisational footprints, simply due to the undeveloped nature of research aimed at applying it at the meso-level. A whole research stream dedicated to quantifying the complex nature of emissions and removals from the biosphere has emerged, and although somewhat computationally complex, LULUCF accounts are annually reported nationally to the UNFCCC (Hallsworth & Thomson, 2010).

There are two accepted methods for assessing LULUCF/AFOLU emissions: i) net carbon stock change over time, or after a special event has occurred; and ii) direct carbon flux rate. The aim of the former in this instance, as outlined in the ISO14064-1, is to quantify the amount of above/below ground biomass, dead wood, litter and soil organic carbon (SOC) per unit area removed/created by the activities of the organisation through direct land-use change (dLUC) or indirect land-use change (iLUC). As an example, Eq. (5) shows the calculation required for the change in soil proportion, as outlined in British Standards Institute (2013):

$$\begin{aligned} SOC_i &= SOC_n * LUF_1 * LMF_1 * IL_1 \\ SOC_f &= SOC_n * LUF_2 * LMF_2 * IL_2 \end{aligned} \tag{5}$$

where, SOC_i = initial soil organic carbon stock of initial land use “1” expressed in t/ha, SOC_i = final soil organic carbon stock of land use “2” (after change) expressed in t/ha, SOC_n = primary soil organic carbon stock, *LUF* = land use factor (dimensionless), *LMF* = land management factor (dimensionless), and *IL* = input level factor (dimensionless).

2.9.1.3 Electricity generation and energy

The GHG emissions from the consumption of electricity can be accurately measured because usage is typically metered or estimated on national average figures. The EF is determined by the energy mix of the host nation (Dragomir, 2012). As this is constantly fluctuating, EFs for electricity generation are constantly updated (BEIS, 2017) and calculated as an average over a given year (which replaced a five-year rolling average in 2013) (Defra, 2013). Traditionally, the UK electricity generation mix is published through the Digest of UK Energy Statistics (DUKES). In 2016, the energy mix was procured from Gas (37.8%), Renewables *i.e.* hydro, wind, and solar PV (25%), Nuclear (19%), Coal (16%), and Oil/other (3%) (Department of Energy and Climate Change, 2016) and, thus, the grid-based emission factor was 0.5 kgCO_2e/kWh.

The distribution and associated losses of electricity (as well as heat and steam purchased through a physical network) are accounted as scope 3 emissions and occur upstream of the reporting organisation. This includes the transmission and distribution losses (59.4% of energy in the UK national grid is lost *p.a.* (Department of Energy and Climate Change, 2015) which occur due to the conversion of energy in turbines, electricity transmission (*i.e.* the increase in voltage for travelling in high voltage power lines), and electricity distribution through the grid, in addition to fugitive emissions associated with transportation. Inherently, error in this figure is introduced through the use of averaging out daily demand fluctuations as registered by automatic meters in industrial and business units.

Organisations which import energy through a physical network, either as hot water for heating or cool air for cooling services report the associated emissions separately. The fossil fuels have been combusted by another organisation, and are thus considered as indirect scope 2 emissions.

In an update to the GHG Protocol in 2015, organisations are now required to report two figures for Scope 2 emissions, according to a 'location-based' method and a 'market-based' method. The former encompasses the conventional reporting technique which applies an emission factor to the grid-based consumption at the location where consumption occurs (with consideration for local grid composition). The market-based method is applicable to organisations that receive product or supplier-specific data for energy that is purposely chosen. Emission factors are derived most commonly from contractual instruments; either through energy attribute certificates such as renewable energy certificates (REC) or guarantees of origin (GOs) or direct contracts.

2.9.2 **Indirect greenhouse gas emission releases**

2.9.2.1 Embodied carbon

Reporting organisations must also make attempts to quantify the embedded emissions of their purchased products. Organisations would need to go to considerable lengths in order to obtain the data required to fulfil each element of Eq. 5. For this reason, many simply apply an emission factor to financial spend data (Arup *et al.*, 2012). Applying a single blanket factor assumes that product categories are homogeneous (Büchs & Schnepf, 2013) and that the relationship between expenditure and consumption is linear. This is rarely ever the case in reality because product categories vary and their costs tend to fluctuate over time in line with the retail price index.

The necessity to avoid double counting once again becomes clear when considering the inclusion of including products in integrated organisational carbon footprints. Were organisations to conduct a full life-cycle assessment of the product itself and report this, those that find themselves in the middle of the value chain would commit double counting. Because all organisations are part of the production system (Wiedmann *et al*., 2009), emissions would be allocated more than once to multiple organisations in the supply chain. There are examples of shared producer-consumer responsibility, as outlined by Lenzen *et al*. (2007), which seek to overcome such controversies. Lenzen *et al*. (2007) also argue that extended producer responsibility (EPR) gives producers significant responsibility for the supply chain emissions (as well as the use and disposal phases of their products).

Organisations are often expected to publish information on the destination of the products they sell, as well as paying particular attention to the carbon implications of the use-phase, and disposal. For these stages of the product life-cycle, organisations have the least control, so manufacturers are advised to produce a number of scenarios which allow for these considerations to be made (Choi *et al*., 2006). Additional to quantifying aggregated purchased goods and services information, capital goods must also be included. Capital goods are defined as '*goods that have an extended life and are used by the company to manufacture a product, provide a service, or sell/store/deliver merchandise*' (Bhatia *et al*., 2011). Only the embedded emissions are attributed to 'capital equipment emissions', since emissions associated with operating the equipment are accounted for in scope 1 and 2.

2.9.2.2 Waste

Varying disposal routes for waste arisings have different burdens on climate, typically attributed to the method of decomposition the waste undergoes at disposal (Chen and Lin, 2008). The waste management sector contributes <5% of global annual anthropogenic, and whilst not the most significant, is noted for its material role in the release of atmospheric methane (IPCC, 2014). Typically, the complexity and efficacy of waste management systems is considerably better in developed economies than developing economies, where disposal routes often favour methods at the top of the waste hierarchy; prevent, reduce, reuse, recycle, and eventual disposal. This can be attributed to higher rates of investment (Wilson *et al*., 2009) as well as better education and improved sorting of wastes resulting in fewer incidents of cross-contamination.

Organisations can play a role in ensuring waste is collected and sorted effectively to improve the recycling rate. This can be achieved primarily through the education of their employees and in providing segregation bins. Recycling waste material results in a net saving of emissions (Manfredi *et al*., 2011) because the re-processing of secondary materials displaces the requirement for virgin materials, often requiring greater energy inputs to produce (Björklund & Finnveden, 2005). Recycling can either be open-loop (where the waste material is reprocessed into a different type of object after recycling) or closed loop (where the waste material is reprocessed into the same type of object after recycling) (Lozano, 2012c).

To capture information on waste arisings at organisations, an EF, disaggregated by treatment type (depending on the waste type it can either be composted, landfilled, incinerated, or recycled) is applied to a waste type quantity (usually the weight) sent for disposal. The central criticism of waste-related EFs is their limited range of the materials they cover and the reliability of the methodology used to derive them. A breadth of research has set about developing reliable factors (Turner *et al.,* 2015).

Organisations possess a number of choices to identify total mass of waste arisings. Either the mass is measured on waste transfer/consignment notes during the transfer to the waste carrier, or it is estimated through waste audits. Identifying the type of disposal is a little more complex, since the organisation has to rely on information from the waste contractor. Transportation of materials to the materials recovery facility (MRF) is also included in emissions from waste arisings, so obtaining distance through garnering the origin of the waste carrier and mapping the pre-determined route using GIS is the simplest employable strategy.

2.9.2.3 Travel

The operations of universities rely on a network of infrastructure to support people and goods moving into and out of the estate boundary. Whilst the development of these infrastructure networks is not the prerogative of the institution itself, many institutions are situated where transport links are favourable and historically reliable. Typically, these transport networks are powered by petroleum and diesel, whilst LPG, biodiesels and electrically-powered vehicles are becoming more popular due to their lower financial cost and improved environmental credentials.

A number of perspectives can be taken when calculating emissions from vehicle transportation, namely either an activity-based approach or an economic-based approach (Raus, 1981). The alternative combines economic fuel data as an indicator of fuel consumption, but can be a less effective measure which is prone to underestimation (Van Mierlo *et al*., 2005).

Business travel occurs when an employee leaves the defined organisational boundary, primarily for reasons intrinsic to the operations of the organisation. Emissions associated with these journeys are undertaken in vehicles not owned by the organisation or in personally-owned vehicles; the term 'grey fleet' is the term often used for vehicles that are owned by the individuals themselves and used for business purposes. Figure 11 shows how organisations decide upon how journeys are assigned under emissions scopes, or excluded altogether from the carbon footprint boundary.

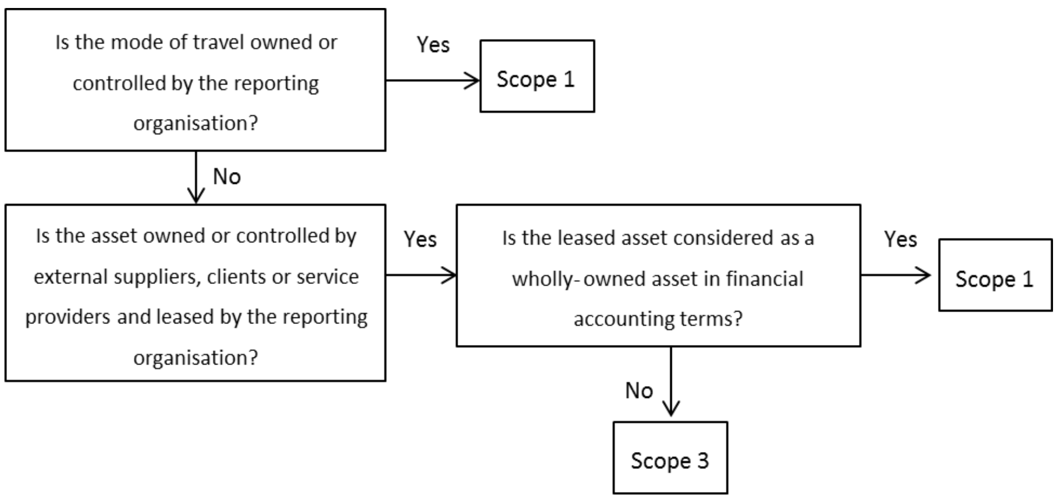

Figure 11: Decision tree used for allocating transport emissions to emission scope.
Source: Adapted from HEFCE (2012b).

The quantification of transport emissions either requires the processing of numerous datasets in order to produce a picture of detailed information for individual trips, or otherwise appropriate sample selection and surveying. Analysis of emissions from fuels can be inclusive of well-to-tank (WTT) emissions or well-to-wheel (WTW) emissions. WTT figures include only the emissions associated with refining and delivering fuel to the customer, whilst WTW figures include the emission associated with burning the fuel in an internal combustion engine (ICE).

Emissions of air quality pollutants (CO, NOx, unburnt hydrocarbons and particulate matter) from vehicles are dependent on a number of factors, including driving style, conditions, and ambient temperature (Van Mierlo *et al*., 2005). Emissions of CO_2 are governed less by these influences and, therefore, cannot be regulated through engine design and specification changes (Stone, 2012)). Fuel efficiency is the relationship between stoichiometric relationship in the air-fuel mix in the ICE and fuel energy density. Therefore, a reduction in fuel consumption leads directly to a reduction in emissions. The EU sets emission limits for cars, vans, trucks and buses; Euro V and VI standards limit the release of air quality pollutants to 80mg/km (Office for Low Emission Vehicles, 2013).

2.9.2.4 Water

The water footprint includes three components: the green; blue; and gray water footprints. The blue water footprint refers to consumption of blue water resources (such as surface- and groundwater) along the supply chain of a product. 'Consumption' refers to loss of water from the available ground-surface water body in a catchment area, which happens when water evaporates, is incorporated into a product, or returns to another catchment area or the sea. The green water footprint refers to consumption of water from rainwater stored in the soil as soil moisture and the grey water footprint refers to pollution and is defined as the volume of freshwater that is required to dilute the loading of pollutants based on existing ambient water quality standards (Kuo *et al*., 2015).

In the UK, water is distributed in a different way to other utilities such as electricity or natural gas, which benefit from national distribution networks. Water is instead distributed through a regional grid-style system with centralised processing, treatment, and supply facilities serviced by a small number of water supply and sewerage companies. Emissions associated with water are calculated on an end-user basis, and includes the extraction and processing of water for the supply to organisations. The metering of water supplies is becoming more widespread in the UK after a government initiative to reduce consumption and identify wasted water through leaks.

Emissions associated with wastewater treatment are accounted for in the waste-related emissions category (Bhatia *et al*., 2011; British Standards Institute, 2013) .

2.9.3 Biogenic emissions

Biogenic emissions are anthropogenic emissions closely related to the natural processes of the carbon cycle. In the context of organisations, these emissions can originate from the combustion of biological material (*i.e.* from forest-derived and agriculture-derived biomass and the solid fraction of municipal solid waste treatment), the combustion of biogas from decomposition (of waste) in landfills, wastewater treatment, and anaerobic digestion.

It is commonly held that biogenic emissions should be treated separately in GHG inventories in respect to emissions originating from the combustion of fossil-fuel based energy sources (Intergovernmental Panel on Climate Change, 2006). Convention holds that biogenic emissions should be assigned a GWP of zero, because an assumption is made that the amount of carbon released through combustion is equal to the amount sequestered by the vegetation when living (Guest *et al*., 2013). Therefore, it is deemed that no net gain in CO_2 in the atmosphere is demonstrated. There has been some debate in the literature about the scientific merit of these assumptions and whether the release of biogenic carbon into the atmosphere still has the same climate impact as GHG emissions from fossil-fuel derived sources (Bhatia *et al.*, 2011; Manfredi *et al.,* 2011; Guest *et al.,* 2013). Some authors suggest that there is no distinction and that biogenic carbon still contributes equally to the enhanced greenhouse effect and should not be accounted for differently (Haberl *et al*., 2012).

2.9.4 Footprint verification

Verification is an important part of the carbon footprint process and is typically the final step (though not mandatory) that the organisation will undertake prior to public release. The process to verify an organisation's report is simple and involves an assessment against industry standard principles, normally conducted by an external and independent person or entity (Ranganathan *et al*., 2004).

Any business may seek verification of the accuracy and completeness of their reported carbon footprint as an assurance to their stakeholders and shareholders, showing that their environmental credentials are credible. This allows organisations to show that their reported data is to an accepted level of accuracy and conforms with industry standards (Ranganathan *et al*., 2004). Typically, HEIs emission reports are internally verified and endorsed by the upper echelons of the management structure (*i.e.* the vice chancellor), whilst some institutions will have external verification from standard-setting bodies, such as the Carbon Trust (though only the former of these is deemed mandatory by the sector).

The process set out by the ISO14064-3 standard requires the production of GHG assessment reports to include eight elements in order to be verified at a reasonable assurance level. These are: i) the use of baseline scenarios, including legal, financial, operational and geographic boundaries; ii) the outlining of physical infrastructure, activities and processes included within the assessment; iii) the GHG sources, sinks or reservoirs determined to be assessed; iv) the types of GHGs in the assessment; v) the time period(s) covered by the assessment; vi) the frequency of subsequent verifications; vii) the intended user of the validation report; and viii) the relative size of the inventory in CO_2e.

The integrity of GHG assessments are evaluated on the basis of:

i) Policies that affect GHG information management;
ii) Management's direction and guidance concerning GHG information and reporting;
iii) Management's approach to identifying, monitoring and accepting GHG risks; iv) management's awareness of GHG reporting;
iv) Documentation and monitoring procedures for boundaries;
v) Documentation of GHG sources, sinks or reservoirs;
vi) Processes for collecting, processing and reporting GHG information;
vii) Methods to ensure that the equipment associated with the monitoring and measurement of GHG data is adequately calibrated and maintained;
viii) Methods for identifying and reporting deficiencies in the performance of the reporting information and management system;
ix) Methods to ensure the implementation of appropriate corrective actions to identified deficiencies;
x) Procedures for access to important records;
xi) Methods to ensure access and updating of current information; and
xii) Methods to ensure that the equipment associated with the information management system is adequately maintained.

In addition, the procedure followed to collect data is appraised in respect to its transparency, based on inclusion of 12 key elements:

i) The process used to determine the organisational boundary;
ii) The methods used to identify and monitor GHG programme;
iii) The methods used to identify reporting;
iv) The methods used for determining the base year;
v) The methods used for determining the baseline scenario;
vi) The methods used to select GHG sources, sinks and reservoirs;
vii) The methods of selecting GHGs;
viii) The methods associated with identifying measurement technologies and data sources;
ix) The selection, justification and application of selected GHG quantification methodologies;

x) The selection and application of the processes and tools used for collecting, processing and reporting GHG information;

xi) The methods used for assessing the effect of changes to other related systems; and

xii) The procedures for authorizing, approving and documenting changes to information systems.

It should be noted, that this is part of the verification process set out by many established standard-setting organisations prior to organisations submitting carbon-related information (see Table 10 for verification standards and organisations accepted as appropriate by the CDP).

Table 10: Verification standards and providers accepted by the CDP for verifying CDP disclosures.

Verification standard	Certified verification provider
AA1000	Bureau Veritas
California Mandatory GHG Reporting Regulations	Lloyds Register LRQA
Carbon Trust Standard	Enviro-Mark Solutions
Earthcheck Certified	Lucideon
ISO14064-3	NSF
Swiss Climate CO_2 label	

Source: CDP (2016).

2.10 **Managing GHG emissions**

2.10.1 **Disclosing GHG emissions assessment information**

Communicating a carbon footprint is central to ensuring the continued performance and accountability of carbon management-related efforts (Sullivan & Gouldson, 2012). Reporting allows organisations to be internally accountable to their governors, directors, and externally to their stakeholders; reasons commonly cited why many organisations release information voluntarily about their environmental performance (Lozano, 2012c). Best practice was outlined by the Climate Disclosure Standards Board (CDSB) (CDSB, 2012) and included a number of factors that organisations should be aware of, including being: i) relevant and capable of informing decisions; ii) honest and unbiased; iii) comparable; and iv) understandable and verifiable. Ensuring these conditions are successfully achieved is assisted by the collection of quality data; therefore, the emergence of guideline methodologies is symptomatic (Sullivan & Gouldson 2012). Disclosure is useful when it:

- Connects the information that management uses internally for decision-making purposes about the company's strategy, goals and objectives with information that is provided externally to investors for their decision-making;
- Explains the priorities for action of top management, as well as the timescales involved, the trends, threats and opportunities that might affect those priorities and the resources that are required to deliver results;
- Explains how managing climate change-related issues affects sales, costs and costs of complying with regulation, cash flow and brand value;
- Outlines opportunities for improvement;
- Explains management's view on not only what has happened, but also why management believes it has happened and what management believes the implications are to the organisation; and
- Shows the linkages between corporate climate change strategies, financial performance and greenhouse gas emissions.

There is a plethora of organisations collecting and disseminating GHG information.. The largest is the Carbon Disclosure Project climate change questionnaire, to which 5,600 organisations around the world subscribe (others also disclose to the forestry, water, and supply chain questionnaires (in 2017)). In fact, 232 of the FTSE 350 organisations report in the UK alone (The Carbon Disclosure Project & PriceWaterhouseCoopers, 2015).

Despite the number of companies that now report climate change-related information, investors have consistently criticised companies for not providing information that can be readily used in investment decision-making (Sullivan & Gouldson, 2012). Reporting frameworks allow customers and investors to answer questions regarding their environmental credentials, whilst demonstrating strength in the company's governance and risk management frameworks (Climate Disclosure Standards Board, 2012). Typical requests that investors make in relation to the reporting and presenting of GHG emissions include total greenhouse gas emissions, details of how the emissions were calculated, the emission factors used, the scope of reporting (*i.e.* how much of the business is covered, by reference to the business' activities and to geography), and whether the reported data has been verified or assured (Okereke, 2007; Sullivan & Gouldson, 2012).

A number of studies have investigated whether carbon reporting meets investor's needs. Sullivan & Gouldson (2012) highlighted two factors that have resulted in the quality of reports not meeting the standard to effectively drive decision-making. Firstly, they show that whilst investors themselves have encouraged companies to report, they pay much too little attention to what is actually reported, making very little of its full potential. Secondly, the quality of organisational reporting falls far short of what is required to make decisions meaningful. Therefore, coupled with comparability issues, reports are broadly unusable by investors anyway.

Once an emission disclosure has been made in the public domain, the task of managing GHG emissions becomes all the more relevant for a variety of reasons (such as reducing the risk of reputational damage if emissions increase). The most visible act that an organisation can make to pledge their commitment to reducing their climate impacts is through setting an organisational emissions reduction target. Targets can be set either on absolute values or through intensity ratios (Wing *et al*., 2006), where an absolute reduction target leads to overall emission contraction and an intensity reduction target seeks to reduce emissions measured against a defined ratio or metric. Whether targets are set as absolute or using intensity ratios, it is imperative that they are set upon a reliable baseline that allows for internal and external performance tracking to be conducted.

From a climate perspective, there is significant advantages in choosing absolute targets over intensity targets. Firstly, the importance of actions that lead to emissions contractions should not be underestimated. It is well documented that significant emissions reductions are needed in order to avoid the worst impacts of climate change and absolute emissions reductions targets allows this more readily (the actions required by the HE sector are explored further in Chapter 7). The disadvantages are that they do not account for significant boundary or structural changes during the commitment period (which can make achieving targets unattainable) and they do not allow comparisons of efficiency or changes to GHG intensity.

Intensity ratio targets reflect performance irrespective of economic growth. These tend to foster comparability between organisations more, because of the way in which they account for individual organisational setting. These are often more suited by organisations because they can be tailored to fit with their activities, but in climate terms, do not always lead to an absolute contraction of emissions. In fact, absolute emissions can increase even if emission intensity decreases which can slow the progress of decarbonisation; the attributes of intensity and absolute targets are explored in further detail in Chapter 3.

There is a growing trend amongst organisations to target becoming ‘carbon neutral’. Carbon neutrality refers to the state of emissions and removals being equal; therefore, the organisation contributes no net emissions to annual anthropogenic GHG emissions. PAS2060 is the only standard available to UK organisations for accreditation and relies heavily on having good knowledge of scope 3 activities (Laurent *et al.*, 2012). Many organisations may, however, declare themselves carbon neutral on a number of stated areas of the footprint, or make assumptions as to the full extent of the footprint. To comply with PAS2060, the carbon credits need to originate from approved sources and should result in a change that would not have happened anyway. The difficulty with these schemes is ensuring that offsetting is making a net reduction in emissions and the importance is that they do not lead to burden shifting (Pattara *et al*., 2012).

2.10.2 The role of carbon management standards, guidelines and reporting frameworks in organisational GHG assessments

A wide range of guidance methodologies have emerged in recent years, attempting to standardise the assessment and reporting of GHG assessments and climate-related disclosures. These, among others, include:

- The GRI G4 sustainability reporting guidelines (2013);
- The CDP guidance for companies reporting on climate change (2014);
- The Defra guidance on how to measure and report on corporate greenhouse gas emissions (2009);
- The Greenhouse Gas (GHG) Protocol corporate accounting and reporting standard (2004) & corporate value chain (Scope 3) accounting and reporting standard (2011); and
- The ISO 14064 series (part I, part II and part III) quantification and reporting of greenhouse gas emissions for organisations (2013).

Authors such as Plambeck (2012) outline the potential issues with the use of environmental standard guidelines. Although many are designed to be flexible, it is noted that when flexibility in built in, significant variations in results occur. Conversely, Stubbs & Downie (2011) extol the virtues of guidelines in assisting organisations to develop more cost-effective reduction strategies through a better understanding of emission profiles. They also highlight that industry-specific guidance would be of huge benefit to organisations, because of their ability at providing unambiguous information of how activities are accounted for in GHG assessments. Their study evaluated the GHG assessments of organisations in Australia. They investigated the extent to which organisations followed published methodologies and found that low uptake of EEIOA was attributable to a definite absence of the acceptance of the methodologies proposed. In addition, there was little awareness amongst organisations. Pandey *et al*. (2011) advocate the use of standards to further the value of carbon footprinting as a widespread tool that guides international negotiations and policymaking.

2.10.3 Barriers to carbon management

Reducing the barriers to carbon management is a priority for environment managers and has been a focus for research in recent years (Townsend & Barrett, 2015). Inertia in large organisations, such as universities, is a key component of why changes are often slow-moving. Changing the culture of the HEI is important for developing low-carbon policies (Barth *et al*., 2013). The transient nature of staff and students, and the challenges that arise from this, create a unique dynamic that must be overcome in order for carbon management to be successfully implemented.

The common focus for carbon management efforts within institutions is in identifying opportunities for cost reduction through energy efficiency measures. Often, an assessment of the return benefits and pay back times against capital expenditure costs is made, with estate managers and budget holders prioritising tasks and allocating appropriate funding. Therefore, high capital costs are sure to hinder the adoption of expensive technologies; technologies that are considerably more advanced and effective at reducing emissions. For high cost programmes, external funding is available from public sector financial bodies such as Salix Finance, which distributes interest-free capital funding from the Department for Business, Energy and Industrial Strategy[23]. There is a perception (and some truth) that low-carbon products are more expensive. As a result, the longer return-on-investment (ROI) timescale make the business case significantly less appealing in the current system (which favours quick-wins (Townsend & Barrett, 2015). Insufficient financial resources will undermine the success of any project and in this regard, getting the buy-in of both the financial manager(s) and vice chancellor is vital (Correia *et al*., 2013).

Even when low-carbon technologies are deployed, operator error can lower the efficiency and reduce any potential savings. In buildings, this is known as the 'performance gap',. Real world operating efficiencies of buildings can be very different to those intended for a number of reasons, particularly due to habitual practice, not knowing the proper use, or perception (Sunikka-Blank & Galvin, 2012). Such is the scale of the performance gap that studies have shown that there are contemporary buildings designed to low-energy standards, which use no less energy than buildings constructed against normal building codes thirty or more years ago (Parkin *et al*., 2015).

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[23] To date, Salix has funded over 16,500 projects with 2,300 public sector bodies, valued at £692 million. This is estimated to have save the public sector over £158 million and 766,376 tonnes annually of carbon, There are two types of Salix funding programmes:

- The first is the Salix Energy Efficient Loans Scheme, where recipients borrow capital to install energy efficiency equipment. The cost savings in the first five years of operations are used to pay back the loan. Once this is repaid, the continued savings enable the recipient to use the capital for other means.
- The second programme available is the Recycling Fund, which is a ring-fenced fund managed by the recipient with money provided by the organisation and match-funded by Salix. The project loan is repaid into the fund from the financial savings delivered by the projects, which allows the fund to be continually used for energy efficiency projects.

It is well established that if a person holds a strong perception that behaviours which contribute towards carbon-reduction will take more time or effort, then the probability of them engaging in such behaviours is minimal (Peters *et al*., 2010). Studies have demonstrated the causal link which exists between education on environmental issues and a positive environmental attitude which extends into altered behaviours (Lozano *et al*., 2013; Zsóka *et al*., 2013). A case study by Meath *et al*. (2015) highlighted that a key barrier to successfully implementing reduction strategies (in this case, in SMEs) was a result of a lack of staff engagement. This is not just limited to SMEs, in fact, the difficulty and subsequent importance of engaging with staff in larger organisations plays a significant role (Gray, 2006).

Little research has been conducted to measure the impact that the changes to HE governance and funding have had on carbon management by universities. However, HEIs have needed to become more accountable to their students (in both financial terms as well as environmentally) and, therefore, some authors predict a paradigm where good environmental credentials make a difference to student recruitment (Nicolaides, 2006; Russell Group, 2010). This has the potential to further the carbon management agenda, although clearly the significant changes that universities are facing make other factors a higher priority. There has also been a recent trend to improve the accountability, accessibility, and performance of research programmes, with the potential to allow for carbon management to take a more central role than previously.

2.10.4 Assessing investment returns

For leaders of organisations, such as universities, societal costs of the release of GHG emissions and subsequent climate change impacts are likely to affect operating costs. It is increasingly recognised that individual institutions should implement carbon reduction policies, planned out in advance with an understanding of the ROI, payback time and carbon savings. Carbon management in HEIs mostly focusses on the retrofitting of low-carbon technologies on a rolling basis (as old technology reaches its end-of-life it is replaced with a low-carbon version), building refurbishment, and behaviour change to encourage carbon reductions (Disterheft *et al.*, 2012). A criticism of this is that many potential options and available technologies are not considered in a holistic and strategic way (Lozano, 2013a).

Marginal abatement costs curves (MACC), although mostly applied at country-wide and city-wide scales (Ibrahim & Kennedy, 2016), have emerged for use by organisations as a way to strategically plan future carbon projects that promise to deliver predetermined emission reductions (Jackson, 1991). Developed as either top-down models, which show cost-effectiveness relative to abatement potential, or bottom-up models, which consider mitigation measures in a series of chronological steps, MACC reflect the cost of reducing emissions per unit (*i.e.* £ per tonne CO_2e)

and are unique for every setting (Pearce 2003). Technologies may be prioritised differently, but are commonly set against the total carbon saved over an intervention's entire life.

2.11 Emission removals

The scientific consensus established on limiting temperature rise above a pre-industrial baseline to +2^{o}C requires significant progress on GHG emission reduction in the near term, and, from 2030, some form of carbon removal (IPCC, 2017). Emission removal is the active removal of GHGs from the atmosphere (leading to negative emissions) and many authors advocate for the global deployment of technologies and initiatives that will, in the second half of the 21st Century act to reduce current concentrations of GHGs in the atmosphere by locking away significant quantities in Earth's carbon sinks.

There are numerous existing technologies that could achieve negative emissions in 2030, which get split into two types in the literature: schemes that enhance natural land sinks or schemes that transfer CO_2 to geological storage. Particular initiatives include: widespread afforestation; soil enrichment using biochar; and carbon sequestration, as well as direct air capture (Kriegler *et al*., 2013; Hawken, 2017) and bio-energy with carbon capture and storage (BECCS). Currently, emission removal receives criticism because of a significant risk of relying on meeting future carbon targets with as yet unproven techniques. There are numerous uncertainties, which have thus far hindered their widespread adoption, including their scalability, effects on land use, financial viability, and social acceptability (Kampman et al., 2016). The immediate challenge lies in developing these technologies to become commercially viable prior to wide-scale rollout and build the required political momentum.

2.11.1 Avoided emissions

Avoided emissions are emission reductions that occur outside of the organisational boundary of the reporting organisation as a direct consequence of a change in the organisation's activity (British Standards Institute, 2013). Businesses can play a key role in developing technologies which avoid emissions through their use (*i.e.* energy saving lightbulbs, fuel efficient tyres, energy-star rated electronics *etc.*). However, currently there is no internationally agreed method of accounting for, or defining, avoided emissions. Organisations such as HEIs are not actively considering avoided emissions; however, it could be said that by creating a generation of environmentally-aware and climate conscious graduates, the adoption of low-carbon behaviours could, in fact, represent avoided emissions attributed to universities in the future (Ranganathan *et* *al.*, 2004; Sullivan & Gouldson, 2012). If avoided emissions are calculated, all methodologies should be reported as part of the emissions inventory in order to maintain transparency in the light of a lack of standardised approach.

2.12 Previous studies

As an active research area, the literature on GHG assessment is growing and has a wide reach due to its interdisciplinary nature. GHG assessments of organisations can take any of the forms outlined in section 2.7; studies can either be in-line with a wider LCA investigations (Baumann & Tillman, 2004; Finnveden *et al.*, 2009; Martínez-Blanco *et al.*, 2015) or stand-alone through IOA (Minx *et al.*, 2009; Peters, 2010) and finally, integrated (Peters, 2010). This section starts by outlining a number of the most influential articles published on each of these applications. There are numerous examples in the literature of authors applying these theories to universities.

Table 11 shows the results of published examples for a number of HE case study institutions. The percentage contribution to the footprint of scope 1, 2, and 3 emissions are calculated and highlights plainly that published GHG assessments differ significantly from study to study. Two studies exclude scope 2 emissions, but all have some provision for calculating scope 3 emissions, which contradicts authors which state that very few studies have tackled the measurement, monitoring and reporting of HE scope 3 emissions. The proportion of the footprint that is comprised of scope 3 varies widely between the five studies and supports the finding of Stubbs & Downie (2011) that the emission sources included in the scope 3 assessment influences the overall carbon footprint. Generally, this variance means that care must be taken when drawing conclusions.

Table 11: Results from published examples of HEI carbon footprint studies, grouped by method

Case Study Institution	Method	Carbon footprint					
		Scope 1 (tCO_2e)		Scope 2 (tCO_2e)	%	Scope 3 (tCO_2e)	%
De Montfort University	Integrated EEIOA-LCA	3065	6%	7662	15	40 353	79
Yale University		166 060	19%	43 700	5	66 4240	76
Norwegian University of Technology and Science	EEIOA	17 499	19%	0	0	74 601	81
The University of Illinois	LCA	176 000	64%	46 750	17	52 250	19
The University of Cape Town		68 790	81%	0	0	16 136	19

Source: Adapted from Townsend & Barrett (2013).

Despite numerous examples of applying existing methodologies to HEIs and obtaining resulting GHG emissions for case study institutional settings, little evidence can be found that investigates the practicality of these studies. It is clear, that the reliability of these studies varies from case to case as a result of the variation in methodology used. For HEIs, dubious carbon footprints limited by accuracy and scope will possibly hinder campus greening efforts (Atherton & Giurco, 2011) and sustainability initiatives (Velazquez *et al*., 2006).

2.12.1 **Examples of life-cycle assessment studies**

Whilst LCA was originally conceived to be applicable for the detailed assessment of products, studies are emerging that extend it for the organisation, although this is only a recent phenomenon. To put this into context, carbon footprinting grew out of LCA-style assessments as it was included as one of the impact category indicators (GWP).

The aim of O-LCA studies is to gather information on the multiple life-cycles of product flows through the organisational value chain. Most organisations are engaged in many product life-cycles and a large part of environmental impact can reside outside the organisation’s gate, upstream and downstream of the value chain, making these studies highly complex (Martínez-Blanco *et al*. 2015). As such, the value chain of an organisation is unique and involves not only one chain of suppliers and other partners, but also a network of them, which may be largely complex in big organisations. Technical Specification 14072:2014 extends the application of both ISO 14040 and ISO 14044 (Blanco *et al*., 2015). Encompassing all the activities of the organisation means that the reporting unit of the system allows coverage of different products and unit processes of any organisation within the same LCA study. Very few practical examples of a life-cycle approach to organisations can be found in the literature.

Pelletier *et al*. (2013) proposed a new methodology for organisational carbon footprinting, outlining four key criteria: ‘cover the entire life-cycle’ along the supply chain, provide for ‘multi-criteria environmental assessments’ (incorporate all relevant environmental performance criteria, not just GHG emissions), ‘increase reproducibility and comparability by emphasising prescriptiveness over flexibility’ and to ‘maximise the physical representativeness of the study outcomes.’ They identify the control approach as preferable to the “equity share” approach. The equity share approach it is better suited to financial risk management, whereas the control approach is better suited to environmental performance measurement because there is greater potential to make management changes in response to insights derived from environmental footprint studies where the organisation has direct influence.

Other notable approaches include assessing emissions using the Compound Method based on financial accounts as outlined by Alvarez *et al*. (2014). The method used ensures the ability to work with easy-to-obtain data (financial). The scope is the assessment of all upstream emissions, including land-use emissions, and all the waste generated from downstream emissions. Process mapping is used in order to allocate the correct weight of each product and service released.

2.12.2 **Examples of input-output analysis**

Carbon footprint analysis has been predominantly based on non-input–output methods and applied on a large scale. Wiedmann (2009) shows that input–output analysis can contribute to the practice of carbon footprinting at all levels. Many authors show an advantage to using IOA as a means of getting environmental metrics into organisations for decision-making, to a greater extent than LCA has not been able to (Finkbeiner, 2009).

Baboulet & Lenzen (2010) applied IOA and a structural path analysis, to an investigation of the University of Sydney's supply chain. They deem the advantages of this method to be the ability of practitioners to replace economy-wide average input-output path with any information whatsoever (not only with commercial process databases). Further, practitioners are guided towards important aspects of their applications, and need not spend resources on following up minor contributions to their applications' supply chains. In theory, IOA studies remove system boundaries and provide assessment of the entire supply chain. Whilst this study did not feature cut-offs, analysis at the product level was not investigated to demonstrate the reliability of the 1033 financial spend codes used. The potential for unreliability was introduced.

Larsen *et al*. (2013) explored the case of the Norwegian University of Technology and Science. By undertaking an EEIO solely relying on institutional spend data they were able to assign emissions to some 200 different spend categories. This was hybridised with Scope 1 and 2 data that currently existed. The authors were able to demonstrate that the carbon footprint was fairly evenly distributed across the categories (although there was a clear weighting on energy), with buildings and equipment making up a significant proportion of the footprint in front of travel, consumables and services.

2.12.3 **Integrated EEIOA-LCA studies**

The integrated studies in the literature primarily couple a simplified IOA that informs one of the key steps in a broader LCA study. These methods are most favoured by the environmental standards outlined in section 2.10 because the combination of the two methods ensures full system coverage unencumbered by aggregation errors or system boundaries. Authors such as Huang *et al*. (2009a) make a number of observations about the means of assessing emissions through integrated methods, concluding that direct emissions are almost always going to be more significant than indirect (supply chain) emissions, scope-3 emissions that are 'close' to the organisation in the supply chain will be more significant than those further up the chain and that it is unrealistic to expect companies to develop a full list of scope 3 emissions.

In reality though, the collection of data focuses primarily on direct emissions (Riddell *et al*., 2009). However, certain examples of carbon footprints do exist that tackle scope 3 calculations. Schmidt (2009) expresses doubts over the scope 2 methodology, stating that the national average generating conditions for the energy mix portfolio of coal, gas, nuclear power, and hydro-power cannot be clearly assessed. Lee (2011) states, that without considering Scope 3 and the supply chain, it is not realistic to identify and calculate carbon emission and carbon footprint at the corporate and industrial levels.

Many versions of integrated EEIOA-LCA dominate the literature as adapted case studies. For instance, Lee (2011) assesses the supply chain of Hyundai Motor Company using 10 participating 1st-tier supplier's scope 1 and 2 emissions. They adopt a direct measurement-based methodology to identify and measure actual GHG emissions for one component (the bumper of a passenger car), resulting in a final figure of 2.53 kgCO_2e/unit. The National Health Service Sustainable Development Unit undertakes an annual assessment of the health service's carbon footprint, which accounts for energy use, travel and procurement (NHS Sustainable Development Unit, 2016). Procurement emissions are calculated based on IOA, building energy emissions are calculated from NHS energy consumption data collated by the Estates Return Information Collection data system and travel emissions are calculated from National Travel Survey data.

There are numerous examples in the literature of authors applying integrated EEIOA-LCA to GHG emission assessments of HEIs. Riddell *et al*. (2009) assessed the energy usage of Rowan University. Of the nearly 38,000 tCO_2e emitted during the study year (2007 fiscal year), 40% of which was due to purchased grid electricity. The remaining 60*%* were due to on-campus generation of steam and direct combustion of natural gas to completely meet the heat and hot water demands as well as on-campus generation of electricity to meet the remaining electricity needs. Per capita, the emissions were approximately 4 tCO_2e per full-time equivalent (FTE) student per annum.

A study of De Montfort University (DMU) by Ozawa-Meida *et al*. (2011) in Leicester, UK, was an early study into investigating the full carbon footprint of university operations. The scope 3 emissions (found to account for 79*%* of total emissions) that are included comprise staff and student commuter travel, business travel and procurement. The supply chain emission factors derived from a top-down environmentally extended input-output analysis refer to economic sectors (in this case, 75 Defra sectors) and not to specific product or processes. Therefore, the use of national 'sector-average' emission factors does not reflect 'local' differences in consumption, such as the purchase of recycled or virgin paper. They acknowledge that it does not reflect differences in institutional practices related to waste management and recycling either. For changing practices in the long term towards the consumption of less carbon intensive products and more resource efficient waste management, more specific methodologies considering the product carbon footprints of goods and services and life-cycle analysis of waste streams would be required.

Thurston & Eckelman (2011) undertook a study of Yale University to investigate the influence of purchases on the footprint using an integrated approach. The study showed that HEIs can use publicly available EIO-LCA software to efficiently estimate indirect emissions resulting from the procurement of goods and services (used to relate institutional purchase codes with five economic sectors to GHG emissions). They found that the majority of indirect emissions resulted from a small component of the university's expenditure categories, most notably purchased electricity, construction activities, and natural gas. This inventory demonstrates that indirect emissions, often an irregular component of campus GHG assessments can be systematically measured.

Gómez *et al*. (2016) undertook an assessment through a hybrid environmentally extended input output model in a multiregional framework. The hybrid model addresses some problems of EEIOA, in our case by including some regional data that avoids the use of national averages and by making first-step calculations with a higher sectorial disaggregation, restricting the high heterogeneity of sectors in EEIOA. The multiregional model increases the accuracy of the results by avoiding the assumption that domestic technology or technology from another country is applied to imports, as previous research did.

2.12.4 **Use of assumptions**

Assumptions are used throughout the literature to extend the scope of carbon footprints where data is scarce. Whilst this can afford practitioners greater control over activities directly and indirectly influenced, the use of assumptions can be misleading unless expressed clearly and unambiguously. The use of assumptions can have significant effect on the reliability of calculations due to inherent contraventions built in to existing models. This is no more blatant that in environmental input–output analysis, which falls down when required to assess microsystems owing to the assumption of homogeneity at the sector level.

The study by Ozawa-Meida *et al*. (2011) used assumptions for a number of emission sources, for which data is reputably hard to obtain. These included commuting journeys and international journeys. For staff and students, it was assumed that full time students attended the university 31 weeks per year, while staff commuted 45 weeks per year, before applying to the results of the travel survey. It was assumed that part-time students made one return journey to the university each week and part time staff travel 50% less than full time staff (that make 10 trips per week). For international journeys (for which only full time students were considered due to an assumption that part-time UK students were local and their travel was included in existing student commuting data 3 returns), it was assumed that EU nationals made two trips home each year, and non-EU nationals made one trip. Air travel was assumed to be from London to the capital city of their country of origin (obtained from internal enrolment records) and coach travel was used to get to London Airports (Heathrow, Gatwick or Luton). UK students were assumed to take three trips home per year (one per term), using a 50/50 mixture of car and train travel. Students from Northern Ireland, Isle of Man and Gibraltar were assumed to travel by air from East Midlands Airport. Students from England, Wales, Scotland and Northern Ireland were assumed to originate from London, Cardiff, Edinburgh and Belfast respectively. Arguably, these may be deemed to be reasonable assumptions for the institution under study since they are based on detailed study of the student body.

2.13 **Research Opportunities**

A review of the literature has identified a number of knowledge gaps in EEIOA-LCA and HE GHG emissions assessments.

A recurring trend is the lack of consistency of reported results. Despite there being numerous methodological techniques available for selection, significant differences in studies of comparable activities using analogous techniques points solely to a central reliability issue. This is also an issue that is not just limited to research related to assessing the GHG emissions of organisations either. Dias & Arroja (2012) outline the differences in estimations for office paper between ISO14040, PAS 2050 and Confederation of European Paper Industries (CEPI) frameworks at 4.6g, 4.7g, and 4.3g CO_2e per A4 sheet respectively, whilst Turner *et al*. (2015) cite the methodological considerations made in the calculation of emission factors of waste materials as the predominant reason for significant discrepancies identified in waste-related studies.

Data uncertainties are compounded by methodological inconsistencies prevalent throughout the literature. As evidenced in section 2.12, a wide variety of techniques are used in organisational GHG assessments. Many authors highlight that whilst methodological consistency is vital to enabling the credible interpretation of GHG studies, in practice this consistency is lacking and often influenced by data availability. Advocating a standard methodology for organisations would foster the greatest progress in this respect (Townsend & Barrett, 2015).

What is also clear from the literature is that an exploration of the virtues of current organisational GHG assessment methodologies, and their applicability to HEIs, has not been conducted in great detail. For the majority of literature reviewed where HE has been the focus of study, broad environmental standards (such as the GHG protocol or ISO14064-1) have been applied without much consideration for the specific situational aspects unique to HEIs. The extent to which this impacts the results is little understood and a potential key research opportunity.

Ultimately, there is an absence of full-scale emission assessments of HEIs undertaken in the literature. Further investigation is required to identify whether the applicability of environmental standards is the driver behind this. The literature often does not explicitly segregate HEIs from profit-driven organisations, and therefore, little has been explored around the operational distinctions of HEIs. Moreover, this has not been contextualised for GHG assessment and means that a large area of research is absent. An in-depth analysis of the existing techniques employed to produce activity data will allow this research to be supported by empirical evidence and a standardised methodology by sound science; the development of new methods or the improvement of existing methods, will allow environmental standards to be more easily applied to HEIs.

Beyond assessing the applicability of existing techniques to the HE sector, there is also little clarity as to the quality and reliability of data currently used in HEI GHG assessments. This is especially surprising, when data quality is a central concern for GHG assessment studies and that there are widely known data quality standards set out. Whilst data for direct emission calculations are generally reliable, the challenge for obtaining necessary data for indirect emissions has long been discussed. The aforementioned examples show that it is common for practitioners to make ‘best estimates’ based on assumptions. Using assumptions which are not supported by observations and experimentation again decreases the robustness and credibility of the outputs. When uncertainty is introduced in this way, the power of the institution’s decision-makers is severely weakened. The critical analysis of assumptions, widely prevalent in the published literature, already conducted earlier in this literature review will help to provide a much-needed sense check.

If emission reporting is to be of any significant use in managing GHG emissions from HEIs in the future, there must also be consideration for the rapidity with which it is changing. An exploration of the changing nature of HE and the prognosis for the ongoing management of GHG emissions at institutions is also a significant research opportunity and centrally important once quantification has been conducted. Carbon Management Plans (CMPs) developed by HEIs since 2010 have thus far provided the basis of strategy-setting for individual institutions. Conducting an evaluation of these is a key initial step in evaluating current efforts on decarbonisation (required by the sector to keep global temperature increase within +2^{o}C above the pre-industrial baseline). By providing a projection of the future along with scenarios of potential situations that could arise, the sector will be as prepared as possible for the future climate challenge. Strategies for Scope 3 emission reduction in particular, not found in the research evaluated in this literature review, can make a valuable and unique contribution to the body of research in this area and by using techniques such as MACC to assess the technologies available to practitioners for the management of activities upstream and downstream of the value chain, an holistic post-2020 strategy can be mooted.

2.13.1 **Future trends**

The research presented in this literature review has focused on the state-of-the-art knowledge regarding the quantification of GHG emissions at organisations (particularly HEIs) and the options available to practitioners for their management, reduction, and removal. A number of research trends have also been identified that will help to focus the trajectory of this research and underpin its relevance to society for the future transition to a low carbon economy. It is clear that organisations, especially HEIs are becoming more accountable to their actions and that their stakeholders (as well as direct consumers) no longer condone blatant environmental degradation.

It is also clear that the management of GHG emissions will focus less on the direct emissions in the future and more on the emissions along the entirety of the value chain. Although not yet tested or set, sector-wide mandatory scope 3 emission, reduction targets have been postulated. The consideration of growing estates on these emissions and the increasing internationalisation of the sector mean that the importance of understanding the indirect proportion of the carbon footprint has already increased in significance.

The rise in the ‘internet of things’ means an increasing number of systems are becoming automated, generating data. For carbon footprint calculations, as data becomes more widely available, the speed it can be disseminated will also continue to improve. As people lead increasingly connected lives (to online media and the internet) (Perera *et al.*, 2015), the way in which the communication of, and engagement with the low-carbon agenda, will continue to be transformed for the better. The need for this is certainly an urgent one.

2.14 **Literature Review Summary**

Broadly, the methods required to understand the carbon emissions of organisations are well established, having been developed over the last 20-30 years as the need for reduction and pragmatic management of carbon has prevailed. However, less focus has been given to whether these standards are always applicable, especially in the higher education sector. A number of standards are available for practitioners in HEIs to choose as a basis in which to work from and some detailed guidance has arisen from within the sector itself (in the form of guides to good practice from the HEFCE, mostly developed with the intention of ensuring institutions could develop a carbon management reduction plan) focused on scope 1 and 2 emissions and a handful of scope 3 emission sources.

Despite the development of practitioner guidance methodologies aimed at improving the situation for organisations in undertaking GHG assessments, little evidence can be found that investigates the virtues of their practical application. This chapter has reviewed the regulatory framework that universities as organisations find themselves governed by and get steered towards a low carbon *modus operandi.* Despite the emergence of research focussed on developing methods for assessing climate impacts at different scales (as life-cycle assessment at the micro-scale and input-output analysis at the macro-scale), a comprehensive approach for organisations at the meso-scale is little explored. The applicability of methods to HEIs is not explored in detail in the literature.

Studies that have focused on HEIs tend to employ a number of assumptions due to the data-intensive nature of the task. The indirect portion of the footprint, scope 3 emissions, can account for as much as 80% of the organisation's emissions, representing the trickiest and costliest of emission sources to quantify. Although there are some research themes undertaken in organisations that can be directly applied to HEIs (such as fostering behavioural change by employees to reduce emissions), the complexity and individuality of data collection is such that particular attention to the methods of data collection should be given.

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Chapter 3: Benchmarking performance in the higher education sector

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The research opportunities presented in the previous chapter established a series of research questions. The aims and objectives set out in 1.6 were developed after the literature review to address these in a methodical and scientific way. This chapter now turns to understanding the area of study (higher education) further and seeks to benchmark its performance on carbon management against appropriate comparisons. Intended as a supporting chapter that provides context for the research, this chapter also contributes to objective 1.2 concerned with exploring the similarities and differences in HEIs with other organisational types.

3.1 Introduction

Thus far, institutions have had more than five years to enact estate changes necessary to meet their emission reduction targets. The Higher Education Funding Council (HEFCE) established the sector target in 2010 as a response to the introduction of the Climate Change Act 2008, which placed the collective responsibility of emissions reductions on the different economic sectors of the UK. The Climate Change Act itself set down the legal clarity in the long term direction of travel, and was calculated as the UK's fair contribution to the international mitigation effort. It was based on careful modelling and the latest scientific information presented in the Fourth Assessment Report of the IPCC (IPCC, 2007) derived from an international climate objective of keeping the increase in global mean temperatures below 2°C with a 50% chance.

It was deemed imperative to the future standing of HE that the sector did its part to contribute to by reducing the sector's emissions. The damaging fallout of not contributing was an unnecessary risk for Vice Chancellors, which was mitigated by the appetite amongst institutions for targets to be set. Responses to the consultation on HEFCE's 2008 sustainable development strategy and action plan demonstrated a high level of support (70%) for a higher education carbon reduction strategy. Targets were deemed necessary in order to identify the size of the challenge, coordinate efforts, and demonstrate commitment to meaningful change. This necessitated institutions developing their own targets as a contribution to the overall sectoral target and an action plan on how this would be met through the publication of a carbon management plan (CMP). These targets and associated management plans represented a commitment from institutions to achieve actual improvements through actions that are appropriate for their institution. This was an official statement of intent by the HEFCE that it recognised diversity in the sector.

As a result of the consultation undertaken by the HEFCE, a number of elements were added to ensure continual improvement and incentivise institutions. Provision of an aspiration to achieve reductions beyond the sector targets was added along with the establishment of milestones throughout the course of the commitment period to measure progress and ensures that it was maintained. These were equivalent to a reduction of 12% by 2012 and 29% by 2017 with a target of 43% by 2020 against a 2005 baseline. Finally, a commitment was made by HEFCE to undertake work to assess what is needed to monitor and report scope 3 emissions, which included a commitment to measure a scope 3 baseline needed for establishing a sector-wide target by 2013 (this subsequently did not happen due to opposition by institutions).

The challenges in meeting targets are not going to be equal or proportionate. With some institutions better off and others struggling due to the inherent differences in their commitment and estate setup. As the commitment period advances, few studies have assessed progress and the potential likelihood of overall success or otherwise. This chapter provides an in-depth exploration of the performance of institutions against the sector's targets.

Investigation is carried out by a number of analytical techniques: firstly, a series of emission baselines is created and comparisons made for the case study institution (the University of Southampton [UoS]), a subset of institutions (the English Russell Group[24]) and aggregated for the entire sector. The inequality that exists around institutional setting and potential for successful progress on targets is of particular concern for the Russel Group institutions, who are considered to be the highest consuming, research-intensive institutions. A rolling average forecast, based on observed campus growth and recruitment rates is made to 2020. Secondly, emission-generating behaviours and corresponding attitudes at the case study institution are identified, whilst an appraisal of institutional CMPs is conducted as the third and final analysis. Special focus is given to the self-imposed targets of institutions and the likelihood of their success. Similarly, the overall

[24] The Russell Group represents 24 UK (England, Wales, Scotland and Northern Ireland) institutions dedicated to world-leading research and teaching. Member institutions garner 80% of the HEFCE's research funding (Lipsett, 2009), produce over 80,000 graduates and contribute £22.3 billion to the UK economy *p.a.* (Russell Group, 2011).

direction of carbon management in the sector, implemented through the HEFCE's carbon strategy, is critically reviewed.

When target setting, the perspectives of those dictating the direction of travel can play a big part in the level of ambition that is achieved. There are also a number of perspectives that can be taken, even by those that are supportive of the sustainability ethos. Two such perspectives are defined by Steffen (2011). The 'dark green' ideology stipulates that environmental issues are inherent to industrialised capitalism and the current economically driven political setting that gives rise to consumerism and resource depletion. The 'light green' ideology views environmentalism as a personal lifestyle choice that exhibits cynicism towards politically-driven motives. Recognising the different perspectives, that may mean that institutions themselves may deem to be over performing, when the league tables suggest otherwise. Value can be assigned to understanding reasons behind the level of ambition and environmental perspectives.

3.1.1 University structure, operations and associations

Despite the number of individual HEIs in the UK, there are a number of comparable characteristics with which they can be explored in more detail. Universities are commonly led by Vice Chancellors (as the executive head) who provide strategic leadership, management and act as the principal representative to the wider world. The governing body (known as the University Council or Board of Governors) is responsible for the effective management and future development of the affairs of the institution.

The Education Act 1994 enshrined the rights of Student Unions to democratically represent the interests of their members (Students) in university affairs and wider issues in which students are vested. Generally, they are legally separate entities, but are often inextricably linked to the operations of the institution. Also important to note is that the students who are not members of their union are still entitled to use the Union's social and sports facilities provided as these are often the main or only such facilities available and are constructed for the benefit of all students of the institution.

The varying specialisms in which HEIs operate makes profiling them a complex undertaking. However, they tend to be grouped into associations by similar interests or educational direction. Table 12 shows the three largest associations in England by membership: Million +, the Russell Group and the University Alliance. In addition, most universities are members of Universities UK, an advocacy organisation for the entire sector that lobbies the government and funders on behalf of HEIs.

Table 12: UK University associations

Million +[25]	The Russell Group[26]	University Alliance[27]
Anglia Ruskin University	University of Birmingham	Cardiff Metropolitan University
Bath Spa University	University of Bristol	Coventry University
University of Bedfordshire	University of Cambridge	Kingston University
University of Sunderland	Durham University	Liverpool John Moore's University
University of Bolton	University of Exeter	Manchester Metropolitan University
Canterbury Christchurch University	Imperial College London	Nottingham Trent University
London South Bank University	King's College London	Oxford Brookes University
University of Cumbria	University of Leeds	Plymouth University
University of East London	University of Liverpool	Sheffield Hallam University
Middlesex University	London School of Economics & Political Science	Teesside University
Staffordshire University	University of Manchester	University of Greenwich
London Metropolitan University	Newcastle University	University of Hertfordshire
University of West London	University of Nottingham	University of Huddersfield
Southampton Solent University	University of Oxford	University of Lincoln
	University of Sheffield	University of Portsmouth
	University of Southampton	University of Salford
	University College London	University of the West of England
	University of Warwick	
	University of York	

The Russell Group is of particular interest as it comprises institutions that have the greatest challenge in altering behaviour, being among the UK HE sector's highest-emitting as a result of energy-intensive research programmes. The 20 institutions in the group consume 40% of the energy (fuels and electricity) consumed by the entire HE sector (2,900,000 MWh/6,900,000 MWh). Table 13 shows the targets proposed by the 19 institutions up to 2020. An average reduction of 35.6*%* has been pledged, although 14 institutions have proposed targets that fall considerably short of the overall sector target (34% below a 1990 baseline or 43% below a 2005/06 baseline). A number of notable examples considerably exceed the HEFCE requirement *i.e.* London School of Economics (LSE), Warwick, and York. The remaining three, Durham, Kings College, and Newcastle proposed targets that will match emissions with the sector.

[25] Million + is a group of modern, former polytechnic institutions and a think tank comprising 18 universities aiming to develop and shape public policy in order to enable people from all walks of life to benefit from access to university (Million+, 2015)
[26] The Russell Group represents 24 leading UK institutions (15% of HEIs). Together, they garner 75% of funding from the UK Research Councils (over £1.1 billion), award 60% of doctorates and contribute £32 billion to the economy *p.a.* (The Russell Group, 2014)
[27] The University Alliance combines representatives from the different regions and cities of the UK and acting to enhance the capability of the institutions for innovation (University Alliance, 2015)

Table 13: Targets pledged by the 20 English Russell Group Institutions to be met by 2020.

Higher Education Institution	Carbon Reduction Target 2020/21	Baseline Year	Notes
University of Warwick	60%	2005/06	
London School of Economics	57%	2005/06	
University of York	48%	2005/06	
University of Durham	43%	2005/06	
King's College London	43%	2005/06	
University of Newcastle upon Tyne	43%	2005/06	
University of Manchester	40%	2009	
University of Bristol	35%	2005/06	
University of Leeds	35%	2005/06	
University of Cambridge	34%	2005/06	
University of Nottingham	34%	2005/06	
Queen Mary, University of London	34%	2005/06	
University College London	34%	2005/06	
University of Oxford	33%	2005/06	
University of Liverpool	30%	2006/07	
University of Exeter	28%	2005/06	
University of Birmingham	20%	2005/06	
Imperial College London	20%	2008/09	30.0% incl. growth
University of Sheffield	20%	2005/06	by 2016/17
University of Southampton	**20%**	**2005/06**	
Mean ± Standard Deviation	35.55% ± 11.4%		

3.2 Methodology

3.2.1 Russell Group Benchmarking

A benchmarking exercise was carried out, comparing the carbon performance (scope 1 and 2 emissions) of the English Russell Group Institutions (by creating an emission baseline) with the UoS. The estates management Record (EMR) data was collected for the chosen period 2005-2010, i) to show how emissions have changed since 2005 (the baseline year for which targets were set) and ii) to investigate the progress made on 2020 targets.

This chapter also critically reviews the HEFCE's carbon strategy and its likely effectiveness as a way to initiate carbon reduction in the HE sector and appraises institutional CMPs with a special focus on their self-imposed targets and the likelihood of success. Three key performance indicators (KPIs): gross internal area, full-time equivalent staff and student numbers, and institutional income, were utilised to compare normalised emissions, as per the Department for Environment, Food and Rural Affairs (Defra) guidance (Defra, 2009b).

In terms of testing the success of the individual CMPs, a set of 10 questions was developed to analyse the CMPs for their environmental credentials (see Table 14). In order to identify appropriate target-setting, the analysis needed to assign scores to: the institutional target, whether normalised or absolute data has been used, whether interim targets and monitoring has been proposed, agreement with sector targets and if commitment is shown by high-level management.

Table 14: Questions used to appraise the institutional carbon management plans

Number	Question
1	Percentage reduction?
2	Year of emissions baseline?
3	Absolute or normalised data used to calculate emissions?
4	Any interim targets proposed?
5	Will strategies outline in CMP result in a net carbon reduction?
6	How does this target compare with the HEFCE's?
7	Pledge to reduce scope 3 emissions?
8	Full responsibility assigned to a relevant and qualified member of staff?
9	Is the CMP agreed by top management (*i.e.* Chancellor, Vice Chancellor) of the institution?
10	Is continual monitoring of emissions proposed?

A rank of carbon targets was produced by defining outcomes to the questions above and assigning scores using definitions of 'light' and 'dark' green environmentalism[28] defined by Steffen (2011) and explored at the start of this Chapter; see Table 15. Scores were intended to represent the closest fit to the light/dark green definitions as possible and explains the subtle differences in the assigned score. This method assumed that all Russell Group institutions would be able to meet their intended target by 2020 (a view that is shared by the institutions themselves) and for this reason a 'reality check' was applied to identify how realistic the targets were. A more realistic target of 10% reduction in absolute emissions by 2020 was proposed, with the expression x-10 being applied to check alignment.

[28] Dark green ideology stipulates that environmental issues are inherent to industrialised capitalism and the current economically driven political setting that gives rise to consumerism and resource depletion. Consequently, targets claiming a greater overall emissions reduction were assigned higher scores, despite the uncertainty in using 1990 data (Ellerman & Joskow, 2008) and growth omitted in absolute targets. Light green ideology views environmentalism as a personal lifestyle choice that exhibits cynicism towards politically-driven motives. Higher scores were thus assigned to targets that aligned with the HEFCE and those beyond were lower as the ideology stipulates that personal carbon management should drive emissions down (Steffen, 2011).

Table 15: Answers and assigned scores for CMP appraisal for dark and light green viewpoints.

Question	Dark Green Environmentalism		Light Green Environmentalism	
	Answer/Outcome	Assigned Score	Answer/Outcome	Assigned Score
1	71.0-100.0%	10.0	31.0-50.0%	10.0
	51.0-70.0%	8.0	71.0-100%	8.0
	31.0-50.0%	6.0	51-70%	6.0
	16.0-30.0%	4.0	16-30%	4.0
	1.0-15.0%	2.0	1-15%	2.0
	0.0%	0.0	0.0%	0.0
2	1990	10.0	2011	10.0
	1991-2000	7.0	2001-2010	7.0
	2001-2010	4.0	1991-2000	4.0
	2011	1.0	1990	1.0
3	Absolute	10.0	Use of both absolute and KPIs	10.0
	Use of both absolute and KPIs	7.0	Normalised (KPIs)	7.0
	Normalised (KPIs)	4.0	Absolute	4.0
4	4 or more interim targets	10.0	4 or more interim targets	10.0
	3 interim targets	8.0	3 interim targets	8.0
	2 interim targets	6.0	2 interim targets	6.0
	1 interim target	4.0	1 interim target	4.0
	No Interim targets	0.0	No Interim targets	0.0
5	Net Carbon Reduction	10.0	Net Carbon Reduction	10.0
	No change	5.0	No change	5.0
	Net Carbon Gain	0.0	Net Carbon Gain	0.0
6	Surpasses the HEFCE Target	10.0	Meets the HEFCE target	10.0
	Meets the HEFCE target	5.0	Surpasses the HEFCE Target	5.0
	Fails to meet the HEFCE target	0.0	Fails to meet the HEFCE target	0.0
7	Yes	10.	Yes	10.0
	No	0.0	No	0.0
8	Yes	10.0	Yes	10.0
	No	0.0	No	0.0
9	Yes	10.0	Yes	10.0
	No	0.0	No	0.0
10	Yes	10.0	Yes	10.0
	No	0.0	No	0.0
	Maximum Total	100.0	Maximum Total	100.0

3.2.2 **Emission-related behaviours and attitudes**

An online snapshot questionnaire was also administered to FT staff and students at the UoS (via www.isurvey.soton.ac.uk, the university's online surveying tool developed by the School of Psychology) and accessed through the Southampton University Staff/student Social & Educational Directory [SUSSED]) in order to gain a picture of self-reported behaviour that generated emissions. A copy of the questionnaire can be found in Appendix A. This commenced for two weeks in term-time in February to maximise the response rate and vary the demographic of the respondents. A preliminary trial was undertaken with a group of 10 staff and students in October/ November 2011 with questions altered to reduce the risk of bias and misinterpretation; an important consideration when surveying (Oppenheim, 1992).

3.3 **Results**

3.3.1 **Carbon emissions and targets**

The rank order of institutions for both methods outlined in 2.1 is shown in Table 16. Newcastle and York were consistently high for both tests in the light/dark green analysis, with Nottingham and Bristol scoring consistently low. The difference between the two tests is apparent; institutions that scored highly in the light green and dark green appraisal ranked lowly when the "realistic" scenario was applied. In the latter case, the UoS is ranked joint first, along with a number of institutions that ranked in the mid-ranges for the light/dark green tests *i.e.* Birmingham, Imperial College and Sheffield. LSE and the University of Warwick were ranked 19th and 20th respectively.

The overall emissions of each institution were compared in order to review performance against their 2020 targets. In Figure 12 (a) it is clear that Imperial College had by far the highest overall emissions at 84,437 tonnes CO_2 *p.a.* in the baseline year and was one of only two institutions where emissions decreased over the study period (-0.7% to a level of 83,836 tonnes CO_2 *p.a.* by 2009/10); the University of Birmingham being the other.

Large increases in emissions to 2009/10 were experienced by a number of institutions *i.e.* Manchester, Nottingham, LSE, and UCL posted rises of 17.7%, 40%, 143% and 91% respectively. Manchester increased sufficiently to overtake Imperial College as the Russell Group's largest emitter of absolute emissions. The emissions baseline for the UoS in 2005/06 was 31,983 tonnes CO_2 *p.a.* and like a number of institutions rose significantly by 2010; up 13.3% to 36,228 tonnes CO_2 *p.a.* A consequential reduction of 29% would be needed to meet their 2020 target, which amounts to 25,586 tonnes CO_2 *p.a*.

Table 16: Outcomes of the carbon management plan appraisal and application of a 'reality check'.

Higher Education Institution	Carbon Management Plan Appraisal Method					
	Light Green	Rank	Dark Green	Rank	x-10	Rank
University of Birmingham	58	16	58	15	10	=1
University of Bristol	41	20	40	20	25	=12
University of Cambridge	65	=9	74	=2	24	=8
University of Durham	75	=4	69	7	33	=15
University of Exeter	61	=14	55	18	18	5
Imperial College London	65	=9	64	=9	10	=1
King's College London	71	=6	65	8	33	15
University of Leeds	65	=9	64	=9	25	=12
University of Liverpool	65	=9	59	14	20	6
London School of Economics	77	3	71	6	47	19
University of Manchester	61	=14	60	13	30	14
University of Newcastle upon Tyne	81	1	75	1	33	=15
University of Nottingham	51	19	41	19	24	=8
University of Oxford	71	=6	61	=11	23	7
Queen Mary, University of London	71	=6	61	=11	24	=8
University of Sheffield	55	=17	58	=15	10	=1
University of Southampton	**55**	**=17**	**58**	**=15**	**10**	**=1**
University College London	75	=4	74	=2	24	=8
University of Warwick	64	13	72	5	50	20
University of York	78	2	73	4	38	18

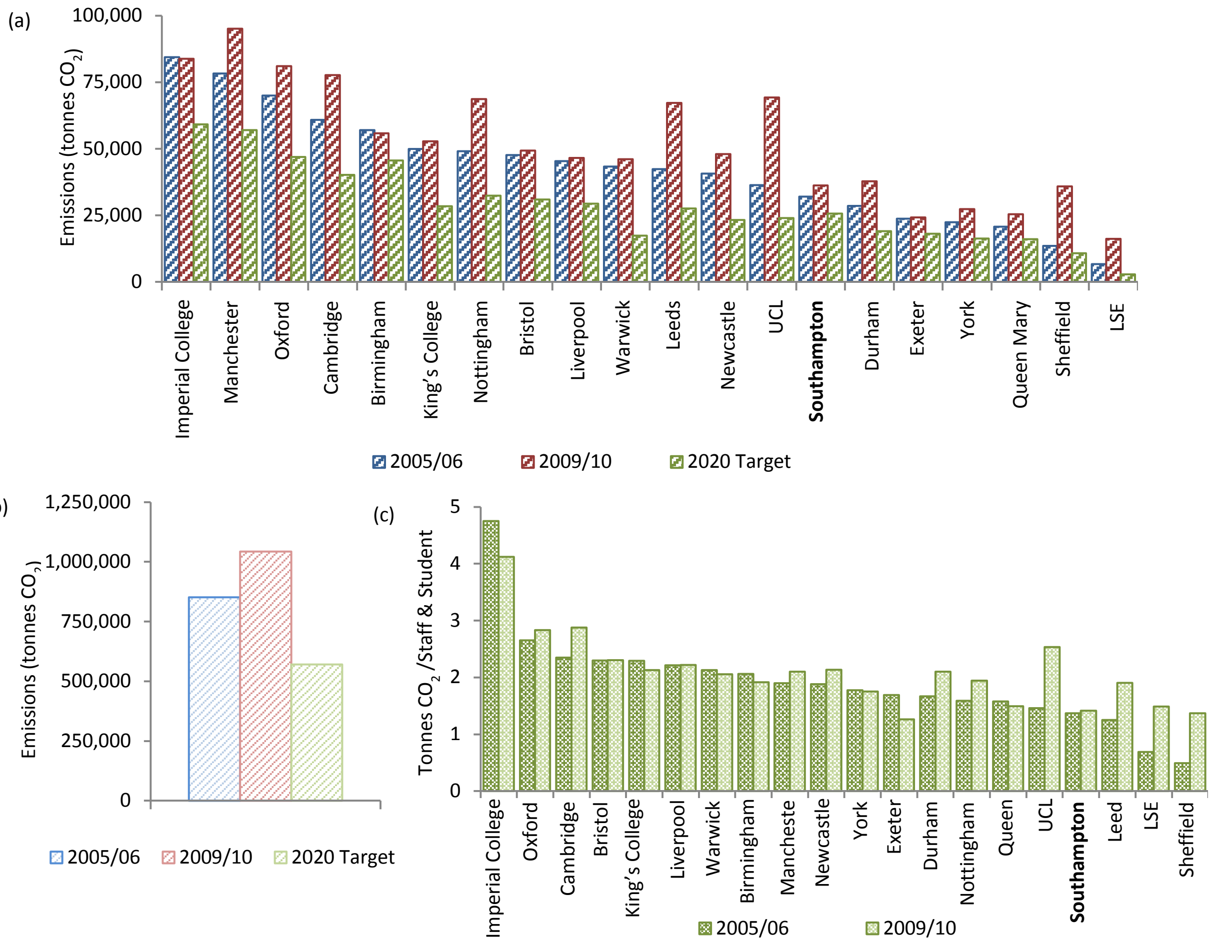

Figure 12: Comparison of English Russell Group emissions in 2005/06-2009/10 (a) absolute emissions against 2020 targets (b) total group emissions against 2020 target (c) normalised emissions against full-time equivalent staff and student numbers.

The implication of these increases in the group's total emissions is shown in Figure 12(b), compared against the 2020 target level. Emissions increased from 856,560 tonnes CO_2 *p.a.* in 2005/06 to 1,043,824 tonnes CO_2 *p.a.* in 2009/10; the 2020 target would bring emissions to 484,959 tonnes CO_2 *p.a.* (based on 43 % reduction below 2005/06 levels for the group's total emissions). The pledged reductions, based on the institution's own self-imposed targets would bring the Russell Group's emissions to 570,484 tonnes CO_2 *p.a.*, meaning that the reductions pledged by the individual institutions will significantly fail to meet the collective target. To put this into perspective, the overall sector aim is to reach emissions of 690,000 tonnes CO_2 by 2020, thus the Russell Group contributes a significant proportion of the HE sector's emissions. The 20 institutions comprising the English Russell Group alone exceeded the 2020 sector target considerably in 2010.

Projecting the sector's emissions on the trajectory seen since 2005 reveals this finding to be part of a systemic issue. All weighted average projections suggest that emissions may stagnate between the present and 2020, but will be remain elevated above the baseline and target level (Figure 13).

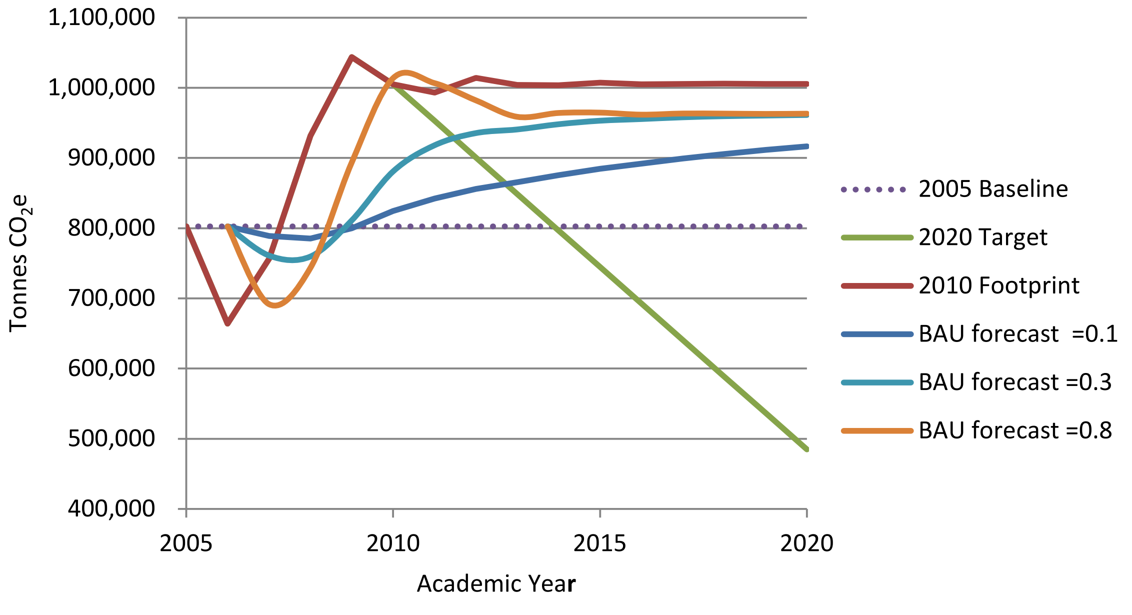

Figure 13: Weighted average moving forecast of sectoral emissions to 2020. An exponential weighting smoothing constant of α =0.1, α=0.3 and α=0.8 are applied.

Figure 12 (c) shows the normalised emissions of each institution by staff and student numbers. Imperial College emitted by far the most per staff and student of any institution in the group. Some institutions reduced their normalised emissions, whilst increasing absolute levels over the time period e.g. Exeter and Queen Mary, University of London. Only two institutions had fewer emissions per staff and student than the UoS in 2009/10 (accounted for 1.37 tonnes per person in

2005/06, rising slightly to 1.4 tonnes in 2009/10), which was Exeter and Sheffield at 1.3 and 1.4 tonnes CO_2 emitted *p.a.* per staff and student respectively.

Linear regression analysis was carried out to identify the relationship between income and emissions at the UoS. In 2005/06, the UoS emitted 0.103 tonnes CO_2 per million pounds of income, which declined to 0.1 tonnes CO_2 per million pound of income by 2009/10 (09/10 value corrected for the retail prices index) (RPI); found to be highly significant at $p < 0.001$. The independent variable, income was perhaps unsurprisingly significant in determining CO_2 emissions. Nottingham featured top with an emission of 0.134 tonnes CO_2 per million pounds of income in 2009/10, having reduced from 0.142 tonnes CO_2 per million pounds of income in 2005/06. In fact, most institutions reduced their normalised emissions by income, with only a few exceptions (Leeds, LSE, and UCL).

At the UoS, emissions per gross internal area were among the lowest of the Russell Group at 0.07 tonnes per m^2 in 2005/06, but rose to 0.09 tonnes per m^2 in 2009/10. Over the study period, the UoS's income increased, whilst internal area decreased and staff and student numbers were roughly equal (as demonstrated in Table 17). This meant that emissions per income decreased and emissions per internal area and staff and student increased.

Table 17: 2009/10 HE sector characteristics compared to the University of Southampton

	English HE sector	UoS	UoS/English HE sector
Students [FTE]	1 416 620	20 897	1.5%
Staff [FTE]	253 905	4710	1.9%
Gross internal area (GIA) [m^2]	21 007 593	388 976	1.9%
Energy consumption – oil [MWh]	61 922	0	0%
Energy consumption – coal [MWh]	13	0	0%
Energy consumption – gas [MWh]	3 165 689	97 676	3.1%
Energy consumption – steam/hot water [MWh]	45 270	0	0%
Energy consumption – other fuels [MWh]	19 892	0	0%
Energy consumption – electricity [MWh]	2 664 085	37 704	1.4%
Energy consumption – total [MWh]	6 361 478	135 379	2.1%
Energy consumption – vehicles total [Litres]	5 107 982	72 157	1.4%
Water consumption [m^3]	20 420 148	569 540	2.8%
Waste – total [Tonnes]	1 394 322	33 300	2.4%

Whilst many reporting disclosures are optional reporting items (the entire record totals some 620 entries), there are 94 mandatory categories, which cover all manner of activities from consumption of energy and subsequent emission of GHGs to waste mass per treatment and water consumption. Table 18 details the mandatory items which institutions are expected to obtain information and return to the Higher Education Statistics Agency (HESA).

Table 18: Mandatory data items for the Estates Management Statistics reporting system delivered by the higher education statistics agency

Non-residential assessment definition condition A (BNRADCA)	Energy consumption onsite photovoltaic (EECONPHO)	Scope 1 and 2 carbon emissions gas oil (E12CEGOI)	Non-residential scope 3 carbon emissions from water supply (E3NRCEWS)
Non-residential assessment definition condition B (BNRADCB)	Energy consumption onsite wind (EECONWIN)	Scope 1 and 2 carbon emissions liquefied natural gas (E12CELNG)	Residential scope 3 carbon emissions from water supply (E3RCEWS)
Non-residential assessment definition condition C (BNRADCC)	Energy consumption steam and hot water (EECSHWAT)	Scope 1 and 2 carbon emissions liquefied petroleum gas (E12CELPG)	Total scope 3 carbon emissions from water supply (E3CEWST)
Non-residential assessment definition condition D (BNRADCD)	Energy consumption other onsite renewables (EECOTONR)	Scope 1 and 2 carbon emissions lubricants (E12CELUB)	Total scope 3 carbon emissions from wastewater treatment (E3CEWWTT)
Non-residential assessment upgrade cost definition C to B (BNRAUCB)	Non-residential energy consumption total (ENRECT)	Scope 1 and 2 carbon emissions natural gas (E12CENGAS)	Total waste mass recycled (EWMRECT)
Non-residential assessment upgrade cost definition D to B (BNRAUDB)	Residential energy consumption total (ERECTOT)	Scope 1 and 2 carbon emissions other petroleum gas (E12CEOPG)	Total waste mass incineration (EWMINCT)
Non-residential insurance replacement value (BNRIRV)	Total energy consumption (EECTOT)	Scope 1 and 2 carbon emissions petroleum coke (E12CEPCO)	Total waste mass composting (EWMCOMT)
Energy consumption grid electricity (EEGELEC)	Total generation of electricity exported to grid (EEEXPGDT)	Scope 1 and 2 carbon emissions biomass (E12CEBM)	Total waste mass anaerobic digestion (EWMADIT)
Energy consumption biofuels (EECBIOFU)	Fuel used in HEP owned vehicles aviation spirit (EFUVAVSP)	Scope 1 and 2 carbon emissions onsite photovoltaic (E12CEOPH)	Total waste mass landfill (EWMLANT)
Energy consumption burning oil (EECBUOIL)	Fuel used in HEP owned vehicles aviation turbine fuel (EFUVAVTF)	Scope 1 and 2 carbon emissions onsite wind (E12CEOW)	Total waste mass energy (EWMENET)
Energy consumption compressed natural gas (EECCNGAS)	Fuel used in HEP owned vehicles biofuels (EFUVBIOF)	Scope 1 and 2 carbon emissions steam and hot water (E12CESHW)	Total waste mass other (EWMOTHT)
Energy consumption coal (industrial) (EECCOALI)	Fuel used in HEP owned vehicles diesel (EFUVDIES)	Scope 1 and 2 carbon emissions other onsite renewables (E12CEORO)	Total waste mass (EWMT)
Energy consumption fuel oil (EECFUOIL)	Fuel used in HEP owned vehicles liquefied petroleum gas (EFUVLPGA)	Scope 1 and 2 carbon emissions vehicles aviation spirit (E12CEVAS)	Non-residential GIA (SMGIANR)
Energy consumption gas oil (EECGAOIL)	Fuel used in HEP owned vehicles petrol (EFUVPETR)	Scope 1 and 2 carbon emissions vehicles aviation turbine fuel (E12CEVAT)	Residential GIA (SMGIAR)
Energy consumption liquefied natural gas (EECLNGAS)	Total fuel used in HEP owned vehicles (EFUVTOT)	Scope 1 and 2 carbon emissions vehicles biofuels (E12CEVB)	Total GIA (SMGIAT)
Energy consumption liquefied petroleum gas (EECLPGAS)	Non-residential water consumption (ENRWCON)	Scope 1 and 2 carbon emissions vehicles diesel (E12CEVD)	Non-residential NIA total (SMNIANRT)
Energy consumption lubricants (EECLUBRI)	Residential water consumption (ERWCON)	Scope 1 and 2 carbon emissions vehicles liquefied petroleum gas (E12CEVLG)	Residential space total (SRESPT)
Energy consumption natural gas excluding that used as input for a CHP unit (EECNGSEX)	Total water consumption (EWCONTOT)	Scope 1 and 2 carbon emissions vehicles petrol (E12CEVPE)	Non-residential functional suitability grade 1 (BNRFSG1)
Energy consumption natural gas used as input for a CHP unit (EECNGCHP)	Scope 1 and 2 carbon emissions grid electricity (E12CEGE)	Non-residential scope 1 and 2 carbon emissions total (E12CENRT)	Non-residential functional suitability grade 2 (BNRFSG2)
Energy consumption heat consumed from onsite CHP (EECHECHP)	Scope 1 and 2 carbon emissions biofuels (E12CEBF)	Residential scope 1 and 2 carbon emissions total (E12CERT)	Non-residential functional suitability grade 3 (BNRFSG3)
Energy consumption electricity consumed from onsite CHP (EECELCHP)	Scope 1 and 2 carbon emissions burning oil (E12CEBO)	Total scope 1 and 2 carbon emissions (E12CET)	Non-residential functional suitability grade 4 (BNRFSG4)
Energy consumption other petroleum gas (EECOPGAS)	Scope 1 and 2 carbon emissions compressed natural gas (E12CECNG)	Non-residential volume of wastewater (ENRVWW)	Total carbon reduction target (ECARRTT)
Energy consumption petroleum coke (EECPCOKE)	Scope 1 and 2 carbon emissions coal (industrial) (E12CECIN)	Residential volume of wastewater (ERVWW)	Total scope 1 and scope 2 emission baseline for 2005 (E12E2005)
Energy consumption biomass (EECBIOMA)	Scope 1 and 2 carbon emissions fuel oil (E12CEFOI)	Total volume of wastewater (EVWWT)	

3.3.2 Staff and student behavior

A total of 155 responses were recorded for both staff and student individuals (students: 85% 18-24 years old, 66% female; staff: 75% 25-54 years old, 58% female). This represented 0.67% of the total student body. Staff reported spending more time at university than students, 60% spending 31-40 h there. The responses were more evenly spread for students, with the majority (30%) spending 11-20 h at university per week. Staff also reported using computers for a longer duration each week than students; 81% using them for longer than 20 h per week as opposed to 38% of students using computers for the same period. Mobile phone and laptop charging accounted for the majority of personal energy consumption (Figure 14).

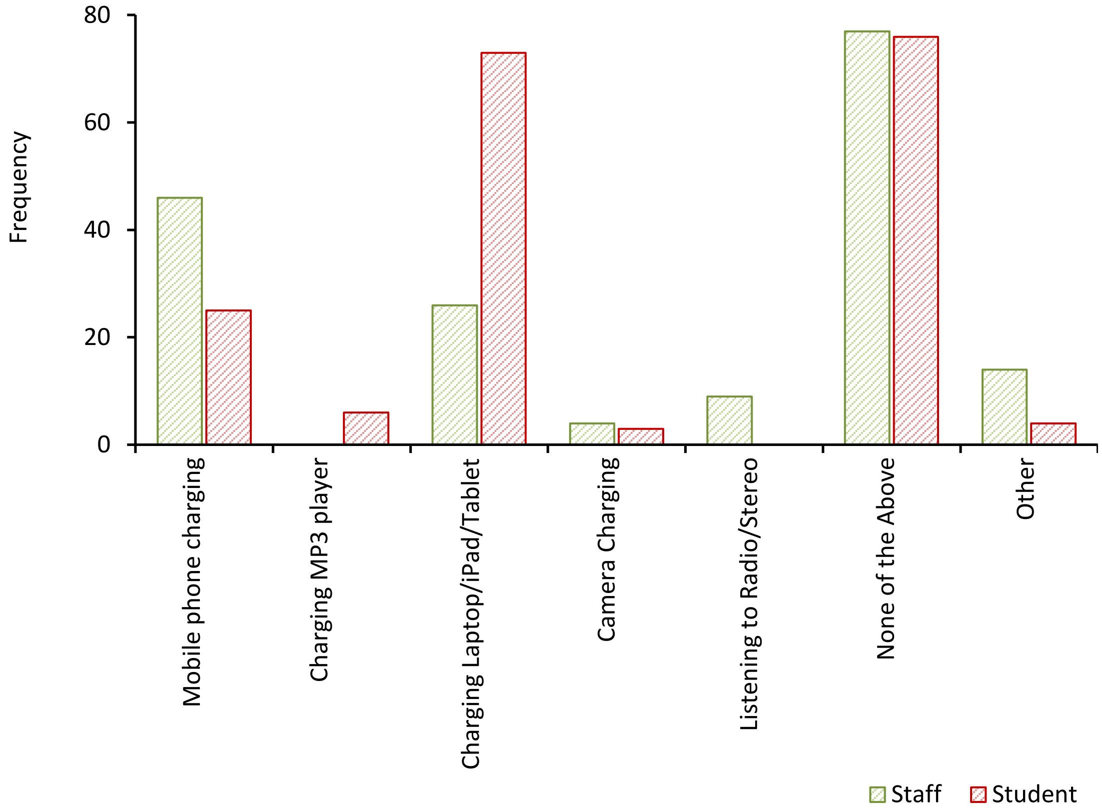

Figure 14: Equipment used by staff and students at the University of Southampton; results from the snapshot questionnaire.

Simple strategies, such as turning lights off when leaving rooms and taking the stairs instead of the elevator were reported by respondents to reduce their energy consumption. For student respondents in halls of residence, 35% reported spending >41 h at their halls. 100% of respondents used a computer or laptop for longer than five hours per week, with two respondents in particular exceeding 41 h per week of computer use.

When asked about the UoS's carbon emission target, 40% of staff and 47% of students knew the correct target for 2020. On whether this target would actually be met (*i.e.* yes/no/maybe) there was no significant difference found between the difference in staff and student opinions (35% of staff and 40% of students agreed). A Wilcoxon Rank Sum Test was performed to identify significant differences between staff and students' views of carbon emissions and climate change which was found to be not significant; a large proportion of respondents in both categories held the opinion that climate change was undeniable and occurring. Environmental issues did not rate very highly for either staff or students when individuals were asked to rate the greatest issues faced by HE institutions with institutional funding ranked number one by respondents the most frequently (42% of staff and 33.5% of students). “Tuition fees”, “student experience”, and “standard of scientific research and teaching” were also among the top rated.

3.4 **Discussion**

3.4.1 **Target-setting culture**

In recent years, a target-setting culture has become prevalent in the UK. Whilst this has become a common-place mechanism to direct change and bring about improvements in organisations during a specific time period (O’Neill & Drillings, 1994) and is often seen as a positive first step towards addressing environmental issues, target-setting is not always appropriate. Targets should not be set in circumstances when e.g. an organisation has limited ability to affect an outcome, when achieving the target is not a real priority, when the cost of measurement outweighs the benefit, or when there are no resources for delivering it. Simply setting a target does not guarantee that a positive change will occur (Harris & Crane 2002); rhetoric is no substitute for real action. It could be argued from the results in this paper that target-setting in the UK HE sector is incentivised (through high league table results) and praised, sometimes to the detriment of realistic activities by individual HEIs and to the benefit of those who have placed words before actions. This is evidenced by the results of the analysis of CMPs.

The publication of CMPs has galvanised the sector to take the carbon issue seriously; HEIs are considered important facilitators of change (Sedlacek, 2013), however a danger is that having unachievable targets, senior decision makers will lose interest and support for their hard-pressed energy and environment managers. In terms of environmental management, high targets often have a low likelihood of success. A paradox for HEIs that set realistic but relatively low targets is that they can be penalised in league tables and lambasted by critics for an apparent lack of ambition when in fact they may be more likely to succeed in delivering regular, incremental environmental improvements than those who set wildly unrealistic targets (Lozano, 2006; Velazquez *et al*., 2006). Setting high targets for emissions reduction and then not making a realistic attempt to achieve them should be dismissed as "greenwash[29]". It could be embarrassing for individual HEIs if their approach to target-setting turns out to be either i) a cynical, short-term strategy devised to improve upon league table positions in order to e.g. improve recruitment or ii) simply ill-considered and poorly thought out.

The results suggest that many of the targets set by Russell Group institutions are extremely ambitious and almost certainly unachievable; compare the University of Warwick's target of 60% reduction with the UoS's 20% target for example. It is anticipated that this will take a significant, sustained and concerted effort to achieve a 20% reduction at the UoS and regard the target as optimistic at current rates of energy consumption and estate growth. Arguably, to retain credibility, the HEFCE must ensure that institutions, which set realistic and proactive targets, are rewarded with greenwash being actively discouraged.

The HEFCE have proactively taken a lead on carbon management in the UK HE sector, raising the profile of carbon reduction and placing it, and ESD in general, firmly on the agendas of HEIs across the country (Karatzoglou, 2013). Many institutions have responded well to instructions so far, as demonstrated by the publication of CMPs, even if this is as a result of the threat of penalties. It should be noted that the HEFCE's remit, following the 2010 general election and subsequent changes to tuition fees has changed since the adoption of carbon targets. From being a HE regulator and funder, the focus is now on becoming a 'champion of the student'. As a result, the future of directly linked funding and emission reduction is in doubt, with wider connotations for the sector as a result of limited impetus to meet targets in 2020. Now there is no 'stick' that will drive HEIs towards reduction and so the 'carrot' (financial savings *etc.*) must be prioritised. Once aware of this, the delivery of targets will most certainly become a lower priority business activity for senior personnel.

Even though the drivers for carbon management in the HE sector seem clear, the details in the delivery of this plan are becoming lost; unrealistic target-setting and environmental rhetoric is being rewarded in practice to the detriment of real action and leadership. This problem could be addressed through the use of more appropriate KPIs. Further, interim targets should be included as a requirement of the HEFCE guidelines, which will allow institutions to identify future difficulties in reaching their target, allowing early action to be taken.

[29] Greenwash occurs when an organisation promotes pro-environmental initiatives but actually operates in a fashion that may be damaging to the environment or in an opposite way to the goal of stated initiatives (Banerjee, 2004). It can also include misleading people about environmental benefits and unsubstantiated claims.

3.4.2 Key performance indicators and institutional growth

Targets should be based on appropriate KPIs in order to ensure fairness across different institutional settings (Weber, 2008) and to allow comparisons between institutions for the sector to collaborate on future reductions. Significantly, many institutions are expanding in terms of student and estate size and this is seldom taken into account. A number of HEIs lacked consideration of their emissions at the time their targets were set and HEIs that have posted an emissions increase of more than 1% between 2005 and 2012 are at risk of missing the 2020 target altogether unless drastic action is taken (Higher Education Funding Council for England, 2010b); this is a reality check for 90% of Russel Group institutions in this study.

Reducing normalised emissions so far has worked to the benefit of institutions, with a recent example being financial incentives from the HEFCE Capital Investment Framework (CIF),[30] which supports one-off expenditures in institutions. This is the same fund from which institutions would have been penalised if not having prepared a CMP by 2011 (CIF round one). CIF round two has imposed penalties on four institutions for failing to reduce normalised emissions (Leeds, LSE, Sheffield, and UCL) during this round’s commitment period.

Internationally, organisations set targets through corporate social responsibility (CSR) policies using both KPIs and specific, measurable, attainable, relevant, and time-sensitive (SMART) targets (Doran, 1981). These are meant to be manageable, comparable, and attainable, allowing continuing progress and further targets to be set. The HEFCE may have created an unintentional barrier to carbon management as a result of stipulating that targets should be set on absolute reductions, rather than reductions based on KPIs. Normalised emissions are useful in order to find out the intensity of emissions per KPI (Department for Environment Food and Rural Affairs, 2009b), which is a more practical method of target-setting due to institutional inertia which masks progress (Samarasekera, 2009).

3.4.3 Electricity usage

Electricity usage has the greatest effect on direct emissions at university institutions and is likely to increase in future as the demand for power increases, which supports findings by Ang (1999) and Soytas *et al*. (2007). ICT consumption has rapidly increased (Levy & Arce, 2003; Sadorsky,

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[30] The Capital Investment Framework was introduced by the HEFCE in 2008 to foster academic excellence in universities through good quality infrastructure, equipment and information communication technology (ICT) and has so far allocated £598 Million in funding for 2011/12-2014/15 ((Higher Education Funding Council for England, 2012a).

2012) with personal 'gadgets' now being ubiquitously used daily. Changes to the way HE is delivered, with a shift away from the traditional forms of education and research and turning to online and remote forms of teaching (Roy *et al*., 2007) has a direct impact on the emissions arising from operations; moving towards reassigned, or even better, avoided emissions. The rise in the number of students enrolled on MOOCs (Massive Open Online Course) is demonstrative of this shifting pattern (Barber *et al*., 2013). The results here have shown that electricity usage is a large part of the emission-generating activities of a university. Although the results of the questionnaire suggests that computer usage is a significant activity as a proportion of time spent by staff and students (with 81% of staff and 38% of students at the UoS using a computer for longer than 20 h per week), when considered against total energy consumption the impact is less significant; only 3% of the energy consumption of the institution can be attributed to computer usage:

$$\mathrm{Wh} = 25{,}000 * \left(\frac{40}{52}\right) * 365 * 50\mathrm{W} * \left(\frac{20}{168}\right)$$

$$\mathrm{kWh} = 25 * \left(\frac{40}{52}\right) * 365 * 50\mathrm{W} * \left(\frac{20}{168}\right)$$

$$\mathrm{MWh} = 1300$$

$$\left(\frac{1300}{38{,}000}\right) * 100$$

$$\sim 3\%$$

Where, total consumption of the UoS is estimated at 38,000 MWh, the number of students is estimated at 25,000 and all staff use a computer, 50W power is used per week (to power computer for 20 hours per week), 40 weeks per year are spent at work and there are 168 hours in a week.

Little consideration is made for institutions with differing electricity base loads, which is where significant emission reductions can be made whilst being noted that engineering and sciences-based institutions have higher energy than humanities-dominated institutions (Klein-Banai & Theis, 2013; Larsen *et al*., 2013). Inefficient infrastructure is a major cause even though simple actions can be taken to address this. For example, significant savings have been made through the installation of a swimming pool cover to reduce heat loss and a combined heat and power (CHP) system to the base load at the UoS. Studies have shown that in the School of Chemistry, a particularly energy intensive department, the base load (overnight measurements) can be as high as 50% of daytime peak electricity usage. This is predominantly due to the overnight use of laboratory fume cupboards.

To demonstrate the importance of electricity usage on carbon emissions, energy savings potential and generate awareness, the UoS undertook the first annual 'Blackout' in 2012. This engaged staff and students in a mass-switch off of all non-essential electrical equipment in order to raise awareness of the amount of electricity wasted as a result of leaving equipment switched on unnecessarily. The UoS Blackout in 2012 demonstrated the savings that can be made through changing behaviour and regularly switching off non-essential equipment. The switch-off reduced weekend electricity consumption by 6%, saving 16,000 kWh of electricity and seven tonnes of CO_2 as well as £1600 in electricity cost (Figure 15) (University of Southampton, 2012). Subsequent blackouts have engaged greater numbers of staff and students, and even additional universities. At its peak in 2015, 11 institutions across the UK took part and more than 350 students switched off 10,300 pieces of equipment.

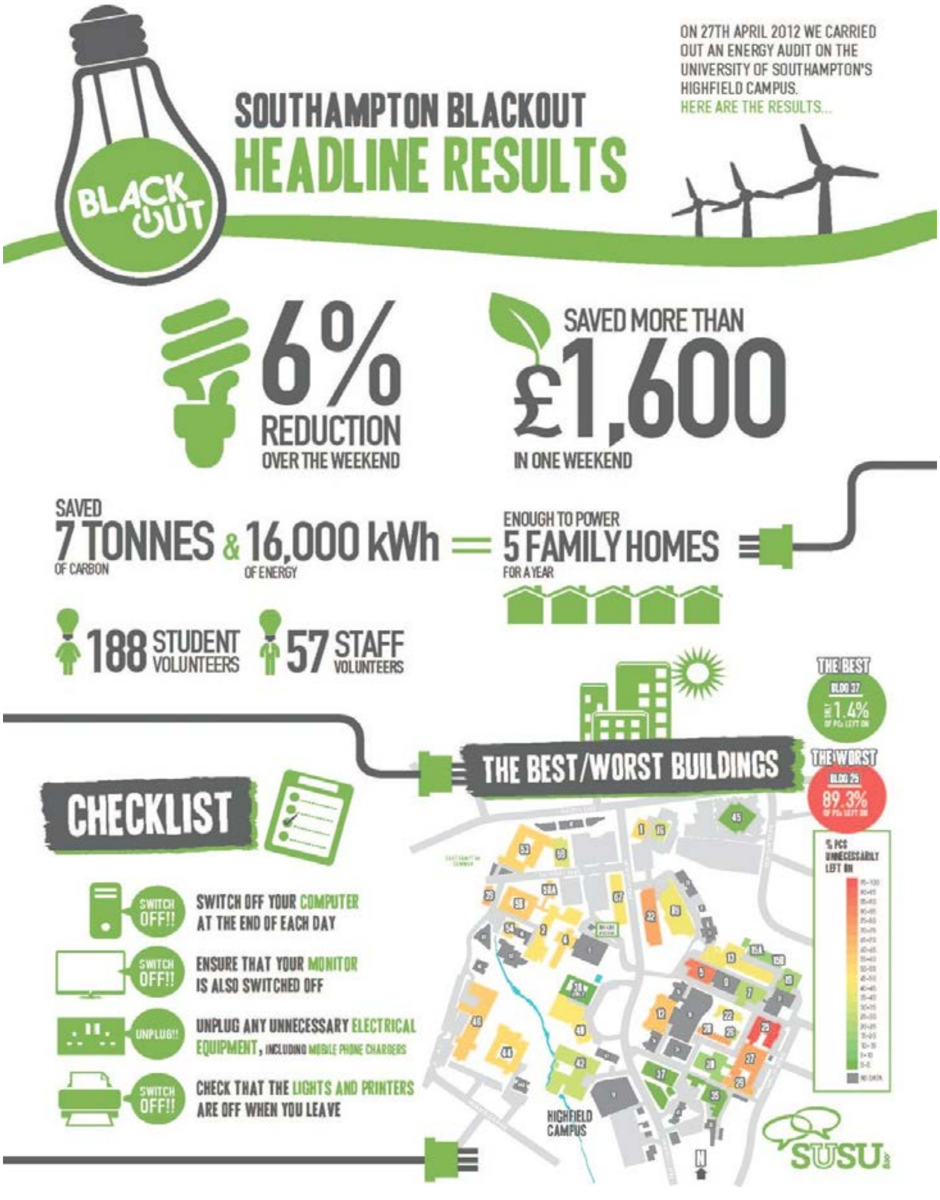

Figure 15: Headline results of the 'Blackout' undertaken at the University of Southampton in 2012. Source: Reproduced with permission from University of Southampton (2012).

3.4.4 Staff and student engagement/awareness

Activities such as the UoS Blackout demonstrate that staff and student engagement is a very important and effective way to permanently change the culture of an institution (Barth *et al*., 2013). Student societies are an important way to increase engagement across the student population, with national groups such as Transition and initiatives like Student Switch Off representing fun and interactive activities that all students can participate in. Student Switch Off in particular focusses on students in their halls of residences; providing incentives for students to reduce their electricity usage, usually extremely problematic due to electricity being essential, free, and unsupervised. Additionally, when on campus, staff and students may over-consume electricity for the same reason; it is "free" and (apparently) inconsequential to do so.

To this end, improving awareness of sustainability issues is needed to address personal carbon management on the university premises. Raising awareness on the impacts of electricity usage should be made more apparent to staff and students alike, in order for the increased participation of energy efficient activities (*i.e.* switching lights off, appliances on standby *etc.*) (Wilk, 2002; Savageau, 2013). This will also highlight the need to reduce the charging of peripheral appliances (smart phones *etc.*). Raising awareness of the carbon reduction targets by means of advertising, to promote community-based involvement is the key to develop a holistic approach to carbon management (Disterheft *et al*., 2012), which are much more likely to be met through a joint bottom-up approach than a disjointed, expensive top-down strategy (Lozano, 2006; Stephens & Graham, 2010). Increased staff engagement is also important since the staff population is less transient than the student population (Saks, 2006), whilst praise and encouragement is needed for those already undertaking strategies to reduce emissions, as well as incentives for those currently not undertaking such activities to alter behaviour.

Increasing awareness and education on the potential impacts of climate change will also assist in boosting the profile of the environment as a major issue affecting HEIs in the 21st Century (Fien, 2002); issues that were not rated very highly in the snapshot questionnaire, although they are generally understood to be matters that students want to learn about (Drayson *et al*., 2013). The removal of individual (increasing individual knowledge) and social barriers (*i.e.* distrust among social groups of politicians and climate change evidence) is seen to improve awareness (Lorenzoni *et al*., 2007). Communication must be clear and understandable; otherwise those targeted will not act on the information and enact a substantial and everlasting change (Polonsky *et al*., 2011). Efforts should be directed to sustained awareness campaigns that force behaviour through choices staff and students make. The agents of change should be focused on in order to produce long-term change. Staff and student behaviours are complex, with more interdependent factors than wider sector policy, it still promises to deliver the biggest gains in terms of actual carbon reductions.

The results here suggest that the majority of staff and students feel that issues other than environmental matters currently take priority at the UoS (42% and 33.5% respectively selected institutional funding). Whilst this is understandable, institutions must ensure that environmental issues do not fall far down the agenda since future impacts are potentially devastating for the sector as a whole, the UK and the World. Climate change awareness however, is particularly positive (100% of respondents had heard of climate change).

3.4.5 Measurable is manageable

The activities and funding methods for HE are changing and so this will inevitably bring greater challenges in the future of carbon management at HEIs (Barber *et al*., 2013; Higher Education Funding Council for England, 2013). What is certain however is that the issue of carbon management is becoming more important, with the HE sector looking to academia for more answers. Although studies have traditionally focused on scope 1 and 2 emissions, methods for assessing Scope 3 emissions urgently need refining and standardizing given they are likely to the most significant portion of a typical university's carbon footprint. The scale of the issues relating to carbon management will only ever be tackled once the true scale is identified: 'what is measurable is manageable'. HEIs must work hard to reduce errors when quantifying their emissions, at which point reduction can take place. For this reason, the methods that are currently carried out to obtain data required for carbon footprinting, as well as the footprinting methods themselves need adapting in order to become truly effective and uniformly implemented (Turner *et al*., 2012).

Further collaboration is needed to ensure that HE carbon management is addressed ubiquitously so that the targets adopted by the HEFCE are attainable for the entire sector. Whilst it seems that time is running out for institutions to meet their targets within a decade, this is still enough time for concerted, collaborative and holistic actions to be taken.

3.5 Conclusions

Some English HEIs have set very high targets for carbon reduction, the result of an ambitious sector target set by the HEFCE, governmental and external pressures. We have demonstrated for the first time that current CMPs are not a good indicator of future carbon management performance and represent a clear underestimate of the challenge of carbon emissions reduction by all institutions, the degree to which has been demonstrated through a 'reality check'. This is supported by the trends in institutional emissions which are fast-growing, not only hindering the institutions in delivering higher education in the future as they confront the inevitable environmental costs, but this also stands to jeopardise the competitiveness of the English HE sector on the global stage if it is not addressed (Ellis, 2013). This issue is likely to become exacerbated since there is little evidence of this slowing at the present.

To this end it certainly remains to be seen if such targets will be accomplished within the set time frame to 2020. Despite this, pledged targets are calculated to significantly fall short of the sector-set targets and represents an issue that must be addressed before the time for action has passed. The HEFCE and HEIs alike have made little provision to account for individual institutional setting in target guidelines and CMPs. By utilizing three KPIs; FTE staff and student numbers, gross internal area, and income, simple comparisons can be made regardless of institutional size and scope which means the HE sector could better monitor progress on emissions reduction in the future. These findings can also benefit the strategies used in carbon management practices at all organisations, which has fallen victim to a target-setting culture that has little regard for the semantics of achieving targets. This Chapter has highlighted the disparate nature of target setting on paper against real-life applications of emission reduction strategies. Understanding that emission reduction must be achieved without hindering the business-critical practices of the university makes it all the more difficult to see how targets will be reached.

Electricity consumption contributes to a significant proportion of emissions. Whilst computer usage occupies a large amount of time for staff and students and is without question the greatest source of individually controlled contributions, the overall impact is low (~3% of the institution's energy consumption. More specific factors, such as lecture hall usage, wind tunnel, and research machinery *i.e.* 'shared activities' have not been investigated and could provide greater understanding of energy use. By reducing overnight power usage and the electricity base load, it has been demonstrated that electricity consumption reduction, coupled with emissions reduction can be achieved in a short timescale. An increased awareness of staff and students to the impacts of electricity usage at university is needed in order to achieve a culture change in HEIs. Furthermore, greater engagement will act to completely change the way HE is delivered in the future.

The implications of these findings can have contributions to institutions across Europe and the world as HE carbon management is a pressing issue for leaders in HEIs globally. It is also vital to maintain dialogue on the strategy of institutional carbon management so that complacency is avoided and continual improvement is fostered. Understanding the role that staff and students have in carbon management is important, but further than this; institutions should take lessons from the carbon-management-through-target-setting culture that is prevalent in the UK.

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Chapter 4: Developing a framework for Higher Education Institutions

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The previous chapter sought to explore the HE sector specific target and the ambition of individual institutions. The results demonstrated the low probability of the sector collectively reaching the target in 2020 without drastic and immediate action being taken. This highlighted a culture of target setting introduced by the HEFCE where an apparent lack of action on making steps towards significant emission reductions has sullied the ambition of the sector. The limitation of the target and its prioritising Scope 1 and 2 emissions, highlights the challenge for institutions, which are only now beginning to measure and manage indirect Scope 3 emissions.

The literature review in Chapter 2 summarised a number of active research areas for further development in this thesis. Having established a view on the collective efforts to prioritise carbon management practices in higher education, this chapter now turns to addressing the second aim outlined in 1.6 in order to explore improving reporting of greenhouse gas emissions data. This is done through building on available tools and environmental standards in order to develop a practical and realistically applicable method to calculate the carbon footprint. More specifically, this chapter also addresses objective 2.1 by identifying the essential requirements for a university standard methodology of organisational carbon footprinting directly applicable to HE.

4.1 Introduction

A global research agenda towards identifying sources and sinks of greenhouse gas (GHG) emissions across a breadth of scales has fostered the development of specialised methodologies. Many examples have emerged that aim to understand emission profiles, for products (*i.e.* Publicly Available Specification (PAS) 2050/GHG protocol product life-cycle standard), individuals, urban areas (e.g. PAS 2070), and entire nations (*i.e.* Intergovernmental Panel on Climate Change (IPCC) national greenhouse gas inventory), which differ by the sources of emissions encompassed in them. Guidance for generating organisational carbon footprints is less developed than that for other forms, as identified by Pelletier *et al*. (2013) due to the complexity of organisational operations and interactions, and the many competing interpretations of theory.

The need for addressing this issue is pressing; organisations of all types are significant contributors to global GHG emissions but assigning and accounting for the entire range of emissions attributable to an organisation's activities is difficult (Bastianoni *et al*., 2004). Guidance has often favoured the emission sources for which data is readily available, despite a compelling case for quantifying Scope 3 emissions and is compounded by the varying scales in which organisations operate (Williams *et al*., 2012). To mitigate the issues experienced by practitioners, environmental standards are developed. These interpret highly theoretical peer-reviewed literature into readily accessible technical notes (Auger, 1994). The number and variety of competing methodologies has the potential to introduce an unacceptable degree of discrepancy; organisations operating under one system are incomparable and may perform better than those favouring a different system.

Ensuring data are collected using analogous methodologies means that footprints are comparable (Rypdal & Winiwarter, 2001), reliable (Dragomir, 2012) (referring as much to the conclusions that can be drawn as the potency of the procedures in place to collect information), and robust (Kasah, 2013). Despite challenges, the business sector is beginning to capitalise on the low carbon economy emerging as carbon management tools and methods improve (Chakraborty & Roy, 2013) (in regards to their access/ubiquity, their value to consumers, and their overall accuracy). These improvements are measured in the value to the consumer, in addition to their improving resolution.

The Higher Education Funding Council for England (HEFCE) published a number of guides in 2012 with the aim of assisting institutions to report and reduce emissions. These focused primarily on direct emissions or on a limited number of Scope 3 sources (*i.e.* water and waste (HEFCE 2012c), transport (HEFCE 2012b) and procurement [Arup *et al*. 2012]). Although no specific international standard for HE carbon footprinting exists, it is common for practitioners to adapt methodologies from those designed predominantly for profit-making enterprises. This is often conducted with limited success alongside the unrestricted use of assumptions and caveats to complicate their interpretation (Almeida *et al*., 2014). The integration of input-output analysis and life-cycle assessment theories (EEIOA-LCA) (Peters, 2010) are favoured here because they generate assessments in greater detail, absent of aggregation errors (Berners-Lee *et al*., 2011; Ozawa-Meida *et al*., 2011). Baboulet and Lenzen, (2010) used input-output analysis (IOA) informed with readily-available financial expenditure information of an Australian university as a means of assessing supply chain emissions of universities without any addition informational inputs. These can measure *total* environmental impacts of institution's activities (Mattila *et al*., 2010), whilst broadly hot-spotting areas for improvement along the supply chain.

Explored in Chapter 2, there is a notable absence of empirically supported full-scale institutional footprints in the literature. Growing sectoral scope 1 and 2 emissions, coupled with a considerable funding challenge to make emission cuts means that institutions are under growing pressure to reduce emissions and are in danger of falling behind on pledged targets for direct emissions; see Chapter 3 (Robinson *et al*., 2015). This preoccupation means that the probability of successfully managing and reducing Scope 3 emissions is somewhat lessened (Jackson & Knight, 2011). The priorities favoured by universities in promoting growth and economic fortune can conflict with the importance they assign to carbon management (Lozano, 2013b); estate growth disproportionately magnifies scope 3 emissions occurring upstream and downstream of the organisational boundary (Sharp, 2009).

Universities serve a number of functions, influencing the activities they undertake and the GHG emission releases for which they are responsible. Specifically, the four major functions which universities serve (and from which, all other activities emanate) are in education, research, governance (Stephens *et al*., 2008; Sedlacek, 2013), and enterprise (Rae, 2010). Teaching perhaps influences the greatest number of activities and as a result, HEIs need not only be providers of physical learning facilities (such as lecture theatres, libraries, ICT equipment *etc.*), but a whole host of other amenities in order for students to thrive (such as health and wellbeing services; sports and social services; and, retail, food, and drink outlets). For this reason, a comparison with small towns is often made (Zhang *et al.*, 2011). The concentration of these amenities is highly disparate, with some universities based on a single location (a campus), multiple sites, or scattered around cities. A rise in internet access means that the traditional means of delivering HE in a classroom has evolved and migrated online (Roy *et al*., 2007) (examples include, Coursera and Kahn Academy); the Open University has been a distance-learning institution since its founding in 1969.

Diverse infrastructure plays a key role in the delivery of degree programmes, which adds to the complexity of HEI carbon footprinting. The nature of research programmes has also been seen to have a direct correlation with the energy-intensity of activities, often being cited as one of the primary reasons for contention when research-intensive institutions are compared to teaching-intensive institutions (Klein-Banai & Theis, 2013) and *vice versa*. The varying specialisms of universities highlight the incongruent nature of the activities that are performed. An increasingly international outlook is seeing many institutions establishing campuses in emerging markets, such as in South East Asia, to cater for the demand in HE around the world (Universities UK, 2012). For instance, in the year 2000, the University of Nottingham established a campus in Malaysia and in the last five years, the universities of Southampton, Reading, and Newcastle have all followed suit (UK Trade & Investment Malaysia, 2013).

The reason for examining university carbon management is to continue the debate of the role of HE on sustainability over the 21st Century, whilst allowing institutions to position themselves favourably in tackling the future challenges associated with a changing climate (Barber *et al.*, 2013). Universities play an increasingly influential role in providing technical solutions to climate-related issues (Sedlacek, 2013). The chapter delves more specifically into *whether* universities are distinct enough to require a specific carbon footprint standard and critically challenges current thinking in this space.

This Chapter aims to make three key contributions to the literature: first, through highlighting the considerable disparities between carbon management standards designed for organisations; second, by identifying the key of industrial practitioners tasked with interpreting these standards and third, by proposing a universal standard methodology (USM) for universities that overcomes data collection issues in HEIs. This research focusses on UK HEIs but can be used as a barometer for present issues in campus sustainability departments in institutions across the world.

A qualitative comparative analysis (QCA) (Gao *et al.*, 2013) is conducted using a selection of frequently used organisational carbon footprinting standards, in-turn evaluated for their relation to the published literature through a systematic review. By combining these results with the results of a practitioner consultation, a framework for conducting organisational carbon footprints for universities is proposed. By considering the needs of university environmental practitioners themselves, a series of recommendations are made which are sympathetic to the role that universities play and the activities they conduct.

4.2 Materials and Methods

4.2.1 Systematic review: inclusion criteria

A systematic review was carried out using Google Scholar and Science Direct, to identify the theoretical underpinning of key ideas. Research papers were selected following a pre-determined set of criteria which amounted to (i) being written in English; (ii) featuring state-of-the-art knowledge, *i.e.* published on or after 1st January 2010 and not superseded by additional research; and (iii) being specific to the carbon footprint of organisations *and/or* HEIs. The year 2010 was deemed to be the appropriate timescale for research to remain state-of-the-art. Often, elements of organisational carbon footprinting are research streams in their own right and are only applied to organisations retrospectively. In these instances, inclusion of papers was based on the importance of all search terms being present.

Search criteria were based on selecting papers that exhibited the terms ‘organis(z)ation’, ‘carbon’, ‘footprint’, and a selected additional ‘search term’. Here, the ‘search term’ refers to any one of the 55 phrases outlined in Table 19 that describe procedural elements categorised by individual actions. The development of these used a methodology founded in Grounded Theory (GT); the individual constituent elements of pre-existing carbon management standards were coded and categorised into these phrases (Corbin & Strauss, 1998). This highlights the interconnectedness of the systematic review with latter sections of this paper, in particular the review of grey literature outlined in the proceeding section (2.2). Papers included in this research study were full research articles; therefore, conference proceedings, reviews, and editorials were discarded.

Table 19: Carbon footprinting 'principles'; key words included in the systematic review.

Emission baseline (benchmark/base year)	Equity share or control boundary-setting (organisational boundary)	Temporal boundary	Emission Scopes: 1, 2 and 3	Up/downstream
Direct emissions from stationary combustion (on-site energy production)	Direct emissions from mobile combustion (vehicle fleet)	Direct process-related emissions	Direct fugitive emissions	Direct emissions/removals from Land-use, Land-use Change and Forestry
Indirect emissions from imported electricity consumed (purchased electricity)	Indirect emissions from consumed energy imported through physical network	Energy-related activities not included in direct & energy indirect emissions	Upstream emissions of purchased fuels Upstream emissions of purchased electricity	Transport/distribution losses Generation of purchased electricity sold to end users
Purchased/procured products (Product cradle-to-gate emissions)	Production-related procurement	Non-production-related procurement	Capital equipment (goods)	Waste generated from organisational activities
Upstream transport/distribution Transport and distribution of purchased products	Business travel (staff travel)	Emissions from business travellers in hotels	Upstream leased assets	Investments
Client and visitor transport	Downstream transport and distribution	Emissions from retail and storage	Use stage of sold product Direct/indirect use-phase emissions	Maintenance of sold products
End-of-life (disposal) of sold product	Downstream franchises	Downstream leased assets	Employee commuting	Land-use
Emission calculation (activity data x emission factor)	Carbon dioxide only	Kyoto Basket GHGs (six: CH_4, N_2O, HFC, PFC, SF_6)	Air pollutants	Published emission factors (*i.e.* not from a national database)
National emission factors [*Defra, Bilan Carbone, IPCC, IEA*)	Organisation-specific factors	Use of data scenarios (best, inter, min)	Centralised [*data collection*] approach	Decentralised [*data collection*] approach
[Reporting] Acknowledgement of significant emissions changes	[Reporting] Assumptions (Standards and methodologies used)	Intensity ratios (normalised)	Disaggregated emissions	[Report] Excluded emission sources
Uncertainty analysis	Base year recalculation policy	Internal performance tracking	Scope 1 and 2 emissions independent of GHG trades, sales, purchases, transfers, banking allowances	Emissions data separate for each Scope and Scope category
Metric tonnes and in tonnes of CO_2 equivalent	Emissions data for direct CO_2 emissions from biologically sequestered carbon (e.g. CO_2 from biomass/biofuels) reported separately	Set targets/guidelines for target-setting (SMART)		

4.2.2 Review of grey literature

To analyse the uniformity of existing standard guidelines, five of the most widely-used methodologies were chosen using the results from the annual Carbon Disclosure Project (CDP) survey on carbon strategies, as outlined in Matisoff *et al*. (2013). These findings show the respective proportion of reporting organisations using carbon footprinting standards (Table 20). The five selected methodologies include the GRI[31] G4 sustainability reporting guidelines (2013), the Carbon Disclosure Project (CDP)[32] guidance for companies reporting on climate change (2014), the Department for Environment, Food and Rural Affairs (Defra)[33] guidance on how to measure and report on corporate greenhouse gas emissions (2009), the Greenhouse Gas (GHG) Protocol[34] corporate accounting and reporting standard (2004) & corporate value chain (Scope 3) accounting and reporting standard and the ISO[35] 14064-1 quantification and reporting of greenhouse gas emissions for organisations (2013). The HEFCE[36] guides to good carbon management practice (2012) were selected as a matter of course.

[31] The non-profit GRI promotes the use of sustainability reporting as a way for organisations to contribute to sustainable development; the GHG emissions working group produces reporting guidelines that are included in the sustainability reporting guidelines. These use the fundamental theories outlined in the GHG protocol corporate accounting standard as their basis.

[32] The CDP is an organisation that works with shareholders and corporations to disclose the GHGs of major corporations.

[33] Defra is a government department responsible for environmental protection, food products and standards, agriculture, fisheries and rural communities in the UK. Largely based on the GHG protocol corporate standard, their guidelines for business set minimum for what companies should report (reporting Scope 3 emissions are discretionary but encouraged); a separate version is available for SMEs.

[34] The GHG protocol was developed by the WRI and WBCSD and The WRI is a global research organisation that works to turn big ideas into action to sustain a healthy environment and the WBCSD is a CEO-led organisation of forward thinking companies that galvanises the business community to create a sustainable future for business, society and environment.

[35] The ISO is an international standard-setting body composed of representatives from various national standards organisations. The ISO international standard is published in three parts, ISO14064-1 deals with the accounting of corporate/organisational carbon footprints whilst ISO14064-2 focusses on the accounting of projects. ISO14064-3 is concerned with the verification of assertions made in accounts compiled using part 1 and 2 methodologies. A verification plan is outlined which shall be formulated to set out objectives, data collection approach, sampling plan, schedule for performance tests and a system maintaining test records.

[36] The HEFCE is a non-departmental public body of the Department for Business, Innovation and Skills (BIS) that distributes public money for higher education to universities and colleges in England and ensures that this money is used to deliver the greatest benefit to students and the wider public.

Table 20: Implementation of standards by firms tested by the Carbon Disclosure Project.

Year	WBCSD/WRI[1]	Defra[2]	ISO[3]	IPCC[4]	GRI[5]	EU ETS[6]	IPIECA[7]	EPA[8]	CCAR[9]
	Implementation by UK organisations								
2007	41%	11%	1%	4%	2%	4%	1%	0%	0%
2008	48%	13%	4%	6%	3%	4%	2%	0%	0.4
2009	55%	20%	10%	10%	7%	6%	2%	0%	1%
2010	67%	24%	8%	9%	6%	5%	2%	1%	0$

[1]WBCSD/WRI – World Business Council for Sustainable Development/World Resources Institute; [2]Defra – Department for Environment, Food and Rural Affairs; [3]ISO – International Standardisation Organisation; [4]IPCC – Intergovernmental Panel on Climate Change; [5]GRI – Global Reporting Initiative; [6]EU ETS – European Union Emissions Trading Scheme; [7]IPIECA – International Petroleum Industry Environmental Conservation Association; [8]EPA – Environmental Protection Agency; [9]CCAR – Californian Climate Action Registry.

Source: Adapted from Matisoff *et al*. (2013).

These methodologies were selected on the basis that they all have origins in the GHG Protocol methodology developed by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) in 2004. This is regarded as the *de facto* standard for carbon accounting for organisations (Ascui & Lovell, 2012). Each has been somewhat successful in fostering action on emission reporting for corporate profit-driven organisations in its own right. For instance, the CDP is now the world's largest repository solely for carbon reporting, annually collating information for more than 2000 companies which contribute 26*%* of global anthropogenic emissions (Tang & Demeritt, 2017).

4.2.3 Consultation: UK university environmental practitioners

A workshop was undertaken at the 19th annual Environmental Association of Universities and Colleges (EAUC) conference at the University of Leeds in March 2015. A focus group was deemed the most direct method for collecting information about practitioner experiences of carbon management. Time pressures and venue limitations were among the push factors in preferring this method (since conference slots were allocated at 45-minute intervals), whilst relative simplicity and the potential for shared-learning (Krueger, 1998) were significant pull factors. The aim of the session was to understand the apparent gap between the theoretical application of carbon standards and the real-world issues faced by staff at universities; participants were conference delegates and therefore, self-selected. The reason that participants were not directly selected or sought after was that the conference enabled a wide variety of institutions already engaged on sustainability-related issues to opt in and involve themselves in the study. It was anticipated that those participating in the focus group were to become the study group in follow-up studies. Therefore, due to the long-term commitment that participating in latter studies required, having participants that were engaged and committed early was imperative to future success.

For many institutions, issues arise as a result of attempting to complete the annual Estates Management Record (EMR) returns to the Higher Education Statistics Agency (HESA). Further investigation of these issues allowed for the identification of key requirements for a universal carbon footprinting standard for HEIs (known as user-sensitive inclusive design; Newell and Gregor, 2000). A 40-minute focus group discussion aimed at highlighting a series of broad-scale issues was followed by the administering of an individual questionnaire to focus group attendants, designed with a series of Likert and semantic differential scale questions for classifying attitudinal attributes. The aim of both questioning methods was to answer four research questions:

- Q1. Which emission sources are the best understood in higher education institutions?
- Q2. Have difficulties been experienced to calculate data needed for the carbon footprint and if so, what can be improved?
- Q3. Do you think sector targets should be introduced which push institutions to calculate and subsequently reduce Scope 3 emissions?
- Q4. Would a universal standard methodology lead the sector closer in reaching carbon management goals?

4.3 Results

4.3.1 Appraisal of standards

Appendix B shows the results of the systematic review and Appendix C shows the results of the comparative analysis. In total, 57 publications were interrogated, highlighting the considerable academic interest in organisational carbon footprinting methods since 2010. Organised by the four main principles of carbon footprinting identified in the peer-reviewed literature (boundary-setting, identification of activities, collecting of data and reporting/verification), these are further categorised into 32 broad groupings (‘variables’) and are in-turn disaggregated into 180 ‘constituents’, defined as a discrete methodological step or action. The grey scale coding represents the degree of coverage exhibited by each constituent across all standards, ranging from 22% for the CDP standard to 60% for the ISO standard (Table 21).

Table 21: Coverage of constituents from the six standard methodologies tested.

	HEFCE Guidelines (2010)	GHG Protocol (2004) Scope 3 (2011)	ISO14064 Standard (2006)	Measuring and Reporting GHG Emissions (2009)	Global Reporting Initiative Sustainable Reporting Guidelines (2013)	Carbon Disclosure Project (2014)
No. of constituents	51	98	107	47	45	39
Total constituents				180		
Coverage	28%	54%	59%	26%	25%	22%

4.3.2 **Results of the consultation**

The questionnaire yielded 35 respondents from 31 individual institutions, representing a response rate of 66% (n=53) of focus group attendees; an example can be found in Appendix D. The sample is deemed sufficiently representative because 19% of the HEIs in the UK were represented (corresponding to a combined student population of 323,000). Typically, respondents were those responsible for the sustainability or energy management brief at their respective institutions. Questioning provided supporting information for the four original research questions:

Q1. Which emission sources are best understood?

The emissions categories reportedly calculated by each respondent can be seen in Figure 16. Respondents were able to rate each emission source (as outlined in the ISO14064 standard) to reflect their institution's ability to fully quantify them with reliable data. This was based on four options: 'reliable data, calculated fully', 'improved reliability but incomplete', 'basic understanding, some data collected but unreliable', and 'not currently calculated'. In the figure, data are arranged in descending order by emission sources rated as '*not* currently calculated' by the respondent. As can be seen, stationary combustion, mobile combustion, imported electricity, imported energy, and waste were the most commonly fully calculated with the most reliable data (supported by more than half of respondents). Of these, stationary combustion and imported electricity (Scope 1 and Scope 2 emission sources) were found to be the best understood with the highest number (77%, n= 27) of responses.

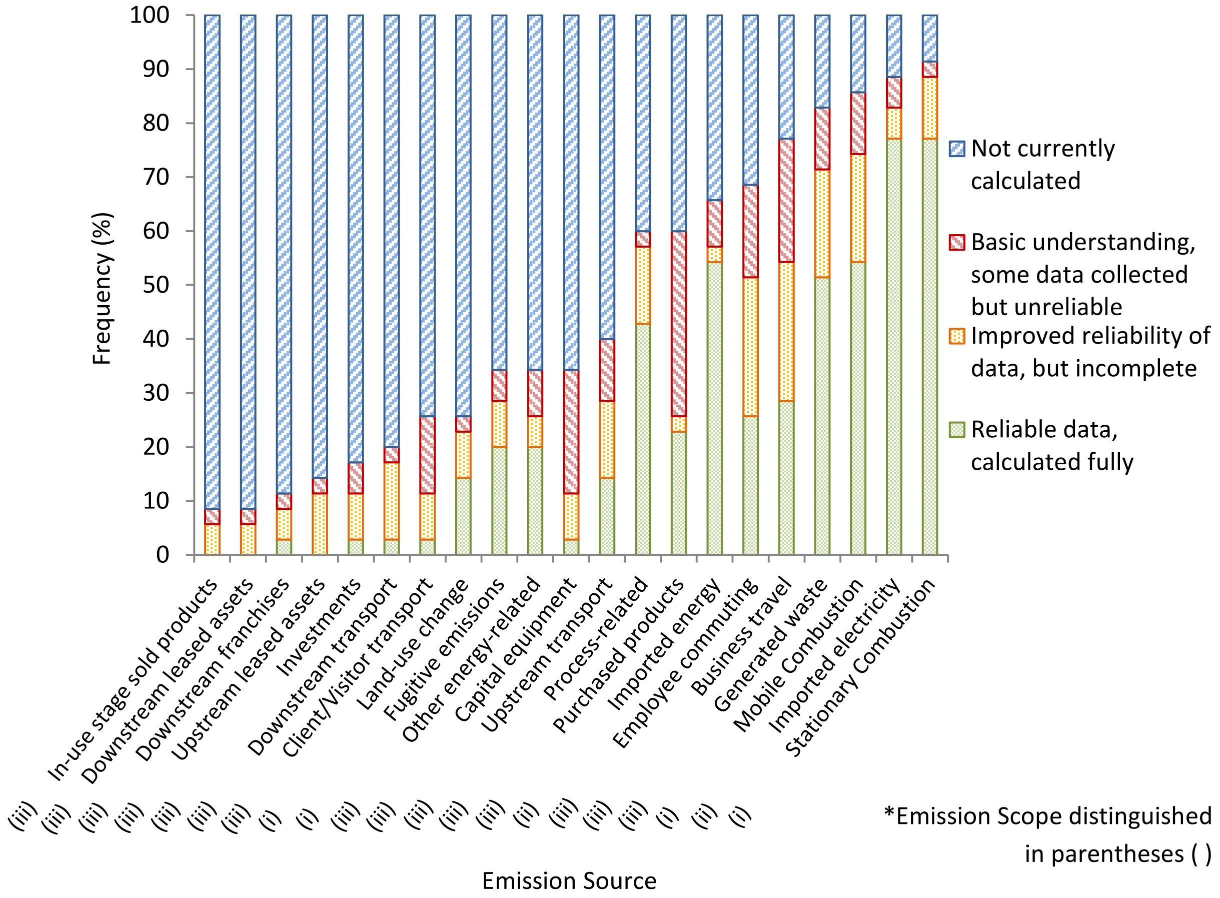

Figure 16: The frequency of emissions sources calculated at the institutions represented by respondents. Emission source categories available for selection were based upon those in the ISO14064-1 standard.

The majority of Scope 3 emission sources were not quantified with any certainty. For many, these sources have yet to be tackled and for reliable data to be obtained. For 91.4% (n=32) of the respondents, both in-use stage of sold products and downstream leased assets were the least understood. In fact, responses for 10 of the Scope 3 categories reflected the inability for practitioners to quantify the impact of activities ranging from in-use emissions (from sold products) to upstream/downstream leased assets by more than 50% of respondents. This was only typical for two Scope 2 sources and for zero Scope 1 sources. The Scope 3 sources found to have been quantified with more reliability were generated waste, business travel, and employee commuting. These received the fewest 'not currently calculated' responses.

Q2. Have difficulties been experienced and if so, what can be improved?

Figure 17 shows the results of a semantic differential question posed about attitudes towards the carbon footprint of the respondent's institution. The mean respondent's score is shown for each of the bipolar adjective pairs: adequate-inadequate; chaotic-ordered; open-secretive; complex-simple; old-fashioned-modern; ineffective-effective; and innovative-non-innovative. From this analysis, respondents exhibited a somewhat optimistic view of their institution's carbon footprint with a slight skew towards 'ordered' and 'effective'. The strongest attitude overall was identified in the open-closed pairing which fell significantly in favour of 'closed'. Although fewer negative connotations were identified, respondents also favoured 'inadequate' over the more positive alternative.

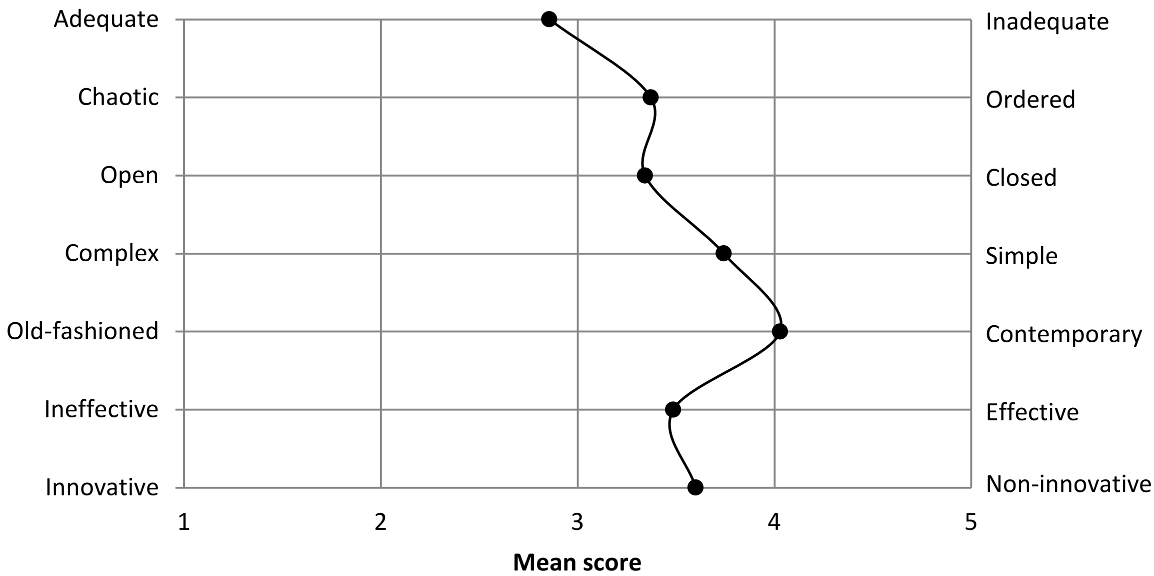

Figure 17: Results of the semantic differential questions; respondents were asked to rate where their attitude placed along a continuum of adjective pairs.

Respondents were asked to rate the factors that most influenced the accuracy of the carbon footprint (see Figure 18). Data reliability, staff resources, and time constraints had the highest rate of high impact responses, with the former two receiving 16 responses apiece. Whilst a mixed spread of responses was recorded, four of the eight factors recorded a response for 'no impact'; namely budget constraints, staff training, top management support, and technical support (albeit from between one and three respondents only). Negative impacts, such as budget constraints and staff training were less influential and received most responses in the 'medium impact' categories.

A number of specific issues were identified during the verbal questioning and written open questions about data collection and reporting. Respondents expressed the view that they were often left to 'fend for themselves' when identifying the correct type of data sources. By following the guidance set by industrial bodies, respondents found the detail for data collection lacking.

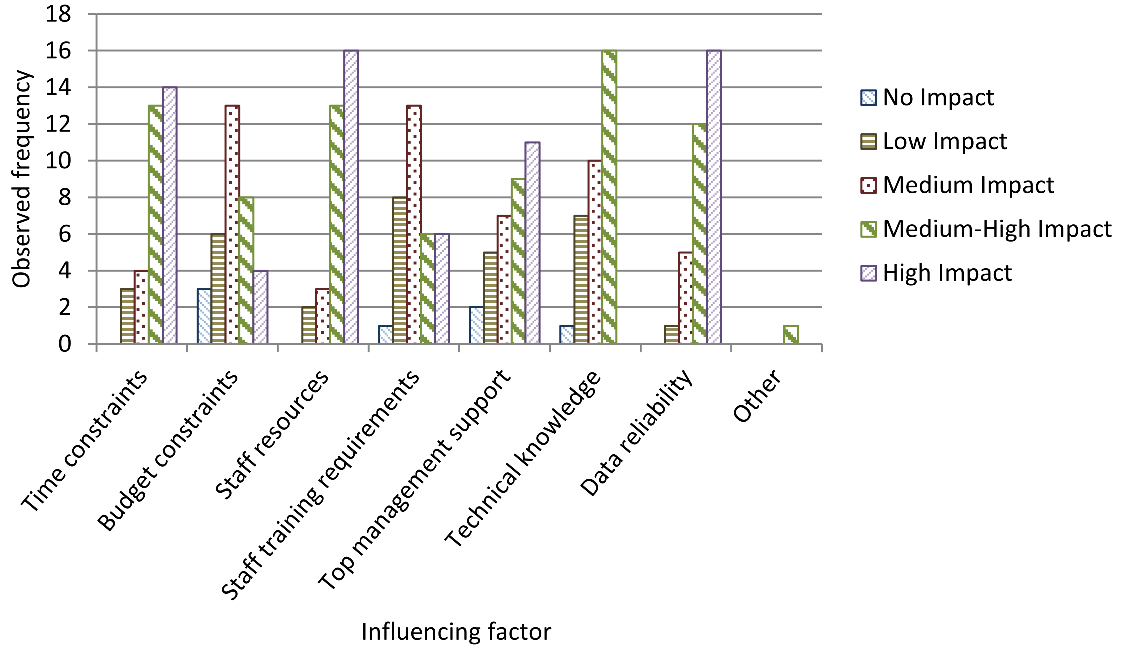

Figure 18: Impact rating of factors influencing the full-scale calculation of the carbon footprint at the institutions represented by respondents.

Where it was sufficient, this was limited to emissions sources where reliable data was already obtained (such as energy data), making the guidance somewhat irrelevant in places and directly attributable to their omission in returns to the HESA.

Often, practical limitations caused data reliability issues. Access to data was restricted because of the complicated and external nature of some calculations. For instance, some institutions attempted to collect environmental information regarding purchased products directly from suppliers (citing the methodology which utilised financial spend data to be insufficient) but struggled to identify them or receive the information:

"…Getting data from suppliers is the most difficult for us..."

"Scope 3 calculation for procurement is very difficult to calculate as we purchase from tier 1, 2 and 3 suppliers. We don't always know where products are manufactured."

Doubt was expressed about the ability to quantify emission sources accurately. Individuals sometimes have to physically measure and/or obtain data from other employees across the estate and supply this to environment managers who are typically the focal point for data and responsible for compiling reports. Respondents felt they had to scrutinise information from these sources particularly closely, citing the absence of a vested interest in ensuring the data supplied was authoritative and consistent.

"…The sources of information need to be managed better."

Often miscommunication between these employees was experienced due to the number of people involved. In addition, respondents found that besides the lack of reliability in data discouraging the ability of HEIs to compare between peers, gaps in data exacerbated this problem:

"Simplify data collection to minimise gaps so that everyone has comparable data."

As a result, practitioners exhibited desire for a simplified process, in which obtaining a full data set was more likely. The practical-focus of responses meant that no respondents provided contrary answers regarding *extending* the current scope of mandatory reporting metrics.

Q3. Do you think sector Scope 3 reduction targets should be introduced?

It was clear that the level of preparedness required for pragmatic reduction targets was not yet in place. Respondents saw the current lack of scope 3 emissions reporting to be a barrier to implementing targets in the short-term. Without good baseline years to inform targets, the strength of future reduction efforts was perceived to weaken. Time would be needed for institutions to produce reliable datasets, whilst further consultation and research would result in a more carefully designed set of objectives supportive of the needs of all institutions.

"If targets are based on years of high-volume construction or 'acts of god' then targets become irrelevant and lose the support of institutions."

Respondents were concerned with the probability of being portrayed unfairly as a result of differential reporting. The heterogeneity of the data reported by institutions was deemed significant enough to deter them from wanting performance-based targets associated with scope 3 emissions. Whilst an institution might have taken responsibility for, and reported all indirect emission sources, respondents foresaw the potential for their institution to receive negative publicity. This forms a paradox when comparing institutions with those reporting lower emissions (as a result of understanding fewer emission sources across the estate); on the surface, the latter institution 'performs' better in the eyes of the media, funders, and peers. As a result, these actions were predicted to lead to potential reputational damage:

"Institutions would only report on Scope 3 emissions if everyone else was doing it!"

Respondents also suggested the lack of control over emission sources was a factor in not supporting Scope 3 targets. Ultimately, if such targets were necessary, then being disaggregated by activity type was favoured. An all-encompassing target was criticised because it would be impractical for the majority of institutions; even the most experienced institutions would struggle to manage the full breadth of activities in the short term. Indirect targets, based on behavioural change, were deemed highly favourable to influence emission reduction. Institutions already manage their waste, had a travel plan, and a procurement policy, and so focussing on areas where institutions already directed efforts through sustainability measures was regarded as more sensible.

"In reality, if this was to be introduced, it would have to be a target broken down for each of the emission sources in order to be meaningful and attainable."

Despite a general feeling against the introduction of Scope 3 targets, it was clear that all respondents shared a desire to manage emissions arising from indirect activities. In addition, all respondents supported the notion that the reporting of these sources should be mandatory and coupled with a published management plan:

"Reporting and having a plan to manage Scope 3 should be mandatory, but not carbon targets!"

"It is important that *reporting* *is mandatory."*

This is somewhat contradictory of answers gleaned from Q2 and evidently, a fine balance between oversimplifying the GHG assessment process and dismissing ethical and altruistic responsibilities and the abilities of overstretched environmental practitioners was highlighted.

Q4. Would a universal methodology improve the *status quo*?

Practitioners reported a desire to prioritise carbon management as it was *"seen as the right thing to do for responsible organisations"*. The respondents demonstrated a general positive reaction to the idea for a USM, believing that this would lead to an increased number of institutions fully reporting emissions for the full breadth of activities. Forty *%* (n=14) agreed that a universal, comprehensive standard would be beneficial to their home institution. Thirty-one *%* (n=11) strongly agreed that the number of institutions undertaking full-scale carbon footprints would increase, as there was a perception that if all institutions followed the same method, better comparability would instil the confidence to report emissions.

A number of points were outlined that advocated a USM for reducing the influence of a number of perceived issues. For instance, many practitioners found that prescriptive and standardised guidance could reduce the loss of knowledge that can occur when individual staff members depart the institution:

"A universal standard for HEIs would go a long way to solving issues around members of staff leaving and taking certain methodologies that have taken years to produce with them..."

For institutions with very small environment and sustainability teams, this was found to be an even more significant consideration. However, the key to switching current approaches and adopting any of the proposals outlined was university leaders seeing the financial benefits, suggesting that the decision was not theirs to take:

"The number of institutions using a universal carbon footprint would depend on the financial situation of the HEI."

When asked about the likelihood of their institution using a USM, a skew towards 'very likely' was evident (34% (n=12), the highest proportion of respondents made that selection), whilst the remaining 66% were split between the other options (likely to very unlikely, or were undecided). In addition, there were calls for this methodology to be used in urging the HEFCE to change its stance on carbon management in favour of something designed *'by the sector, for the sector'.*

4.4 Discussion

4.4.1 The organisational carbon footprinting process

Organisational carbon footprinting is typically a four-step process (Gao *et al*., 2013), characterised by: (i) setting the organisational boundary (identifying the facilities that should be accounted for); (ii) establishing the operational boundary (the activities for which the organisation deems itself to be responsible for); (iii) quantifying the carbon footprint (through collection of appropriate activity data); and (iv) reporting and verifying the result (Dragomir, 2012; Pelletier *et al*., 2013; Gao *et al*., 2013). The methodologies involve the practitioner identifying the activities they are responsible for in separate emission Scope categories upstream and downstream of their organisation's operations. This is based upon the integration of methods used in [*environmentally-extended*] input-output analysis and life-cycle assessment (EEIOA-LCA) (Peters, 2010); two well-established fields of carbon assessment at opposite scales.

A number of key pieces of literature identified in the systematic review have highlighted recent augmentations to the organisational carbon footprinting process, fully explored in Chapter 2. For example, Pelletier *et al.* (2013) attempted to develop a new methodology for the European Commission (EC) based on a number of criteria, aiming for a new method which was: inclusive of the life-cycle emissions across the supply chain; reproducible; comparable (as opposed to flexible); and physically realistic. Others, have vocalised the need for Scope 3 methodologies (Stubbs & Downie, 2011) and established preliminary research that can be taken forward in making this a reality. A few examples of full-scale Scope 3 carbon footprints have arisen, but these changes have not yet proved radical enough to increase the number of organisations reporting Scope 1, 2 & 3 carbon footprints; our search criteria identified only three examples (see: Larsen & Hertwich 2009; Letete & Marquard 2011; Ozawa-Meida *et al*. 2011). Often, the choices that make such methodologies applicable to a wide audience are removed in the hope of achieving simplicity

(Pandey *et al*., 2011). However, in the process, truncation errors are introduced and the Scope is narrowed without sufficient explanation.

Some would argue that little progress has been made since the publication of the first GHG protocol in 2001, which had been hailed as a major breakthrough in environmental advocacy and widely adopted and accepted since (Green, 2010). There has been little in the way of developing this methodology to account for the changing need of carbon reporting in the intervening 15 years; a time of rapid adoption of environmental legislation (Tews *et al*., 2003; Jordan *et al*., 2013). As a consequence, the scope for change is equally and simultaneously, significant in its potential, but encumbered by well-established methodologies.

By clearly delineating the steps required in conducting an organisational carbon footprint, the process can be understood in its entirety and evaluated for its functionality. The commonalities identified as a result of our analysis means that we can build upon this relationship to propose

Figure 19 as a more complete description of the organisational carbon footprinting process. These four steps are supported by the themes ‘scoping’, ‘conceptualising’, and ‘communicating’, which help to distinguish the individual actions required of the environmental practitioner. ‘Scoping’ incorporates two steps: the setting of the organisational boundary and the identification of the organisation’s activities (conducted using a control approach or equity share approach). ‘Conceptualising’ refers to the collection of activity data (itself categorised into operational[37] and non-operational[38] data) and the application of the carbon equation. ‘Communicating’ describes the reporting of carbon information to key stakeholders in an understandable format, which is externally verified, to ensure reliability and maintain rigour. Additionally, an initial theoretical reconciliation is made to the constituents by accepting those with coverage greater than 66.6*%* (as can be seen in the column in Appendix C marked ‘Reconciled’); this captures 24 of the 180 constituents (13.3*%*) *i.e.* ‘setting an emission baseline’ and ‘defining the organisational boundary’.

[37] Operational data is defined by the author as data that is directly transposable into the organisation’s carbon footprint without much required processing
[38] Non-operational data is defined by the author as data that requires manipulation in order to obtain an emissions profile

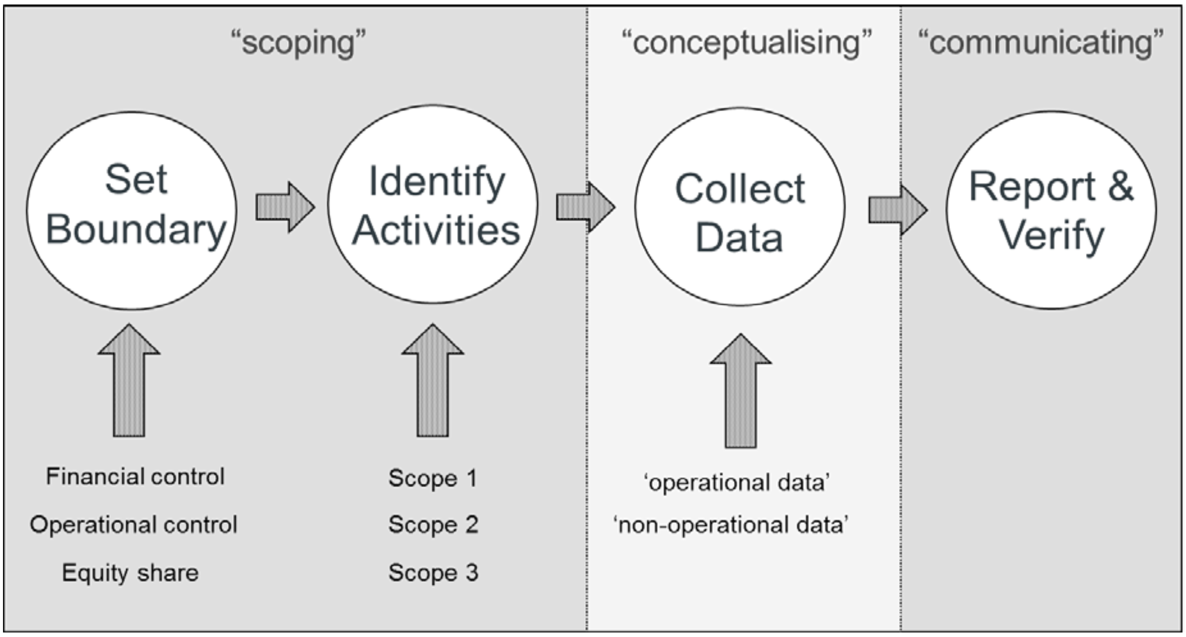

Figure 19: The relationship between the seven principles of organisational carbon footprinting.

Combining these initial changes with the results of the analysis, a number of interrelated issues are identified. These are listed below alongside simple corresponding improvement solutions:

i a There is no guidance on clearly deciding whether activities are to be included or excluded, leading ultimately to a high level of double counting. When EEIOA-LCA footprints are reported, double counting is unavoidable since these activities overlap with many other organisations;

i b. Potential solution: The implementation of simple cut-off criteria would allow the user to make a definitive in-out decision of activities along the supply chain.

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ii a There are deficiencies in time, cost, and staff resources in organisations, which means that the process cannot be conducted to the 'end' (defined by the published standards or the reporting organisation);

ii b. Potential solution: Minimise the number of actions required by environmental practitioners.

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iii a The description of data collection methods is not clear nor prescriptive, making reliable or useful inferences from data impossible;

iii b. Potential solution: Introduce guidance outlining methods for the robust activity data collection, which is appropriate for the resolution and aim of the footprint.

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iv a The GHGs included are inconsistent, potentially leading to false reporting and high margins of error.

iv b. Potential solution: Standardise the GHGs included in the footprint.

A second column is added to the Table in Appendix C labelled 'Robinson *et al*. proposed'. This incorporates reconciled constituents with additional ones that are deemed imperative to the functioning of the methodology (n=77). Sixteen constituents are made 'dependent', where their inclusion is subject to certain considerations, and dismissing them outright would be inappropriate. For example, constituents referring to the manufacture or use of products for sale or the operations of franchises may not be applicable to all universities but the scope for their inclusion cannot be disputed, when considering that the activities of universities are highly variable.

A number of constituents have been omitted, following decisions to ensure parity with the suggested improvements (supported by the systematic review); three instances can be highlighted. Previously, practitioners had been given the option to choose which approach they took to setting the organisational boundary. Now, only the entities through which the organisation can enact meaningful carbon reduction measures are considered (through the allocation approach based on financial or operational control) (Pelletier *et al*., 2013). Secondly, through the use of data scenarios, an illustration of the best, minimum, and intermediate quality data is provided (British Standards Institute, 2013). Ensuring all footprints conform to an acceptable degree of accuracy has become a central idea, controlled much more closely through the verification process. Finally, the GHGs included are aligned with those outlined in Wright *et al*. (2011), who formed a definition inclusive of only two GHGs (CO_2 and CH_4) based on their contribution to global anthropogenic emissions. This standardisation is important owing to the variability found in all standards and the literature; with authors favouring solely the accounting of CO_2 (such as Recker *et al*., 2011; Chakraborty & Roy, 2013 and Rietbergen *et al*., 2014), or the seven Kyoto basket GHGs (referred to as a 'climate footprint') (Dragomir, 2012; Matisoff *et al*., 2013).

4.4.2 **Cut-off criteria**

The difficulty in assigning responsibility for emissions has been well documented and still remains a highly divisive topic in the literature (Stubbs & Downie, 2011; Bastianoni *et al*., 2004). For internal use, carbon footprints that detail the emissions arising from all activities under the influence of the reporting organisation are a highly useful decision making tool (Lenzen, 2008) that allow organisations to exert a greater degree of control over their activities which impact on the environment (Dragomir, 2012). Upon aggregation of multiple organisations comprising a sector, the resulting figure is artificially inflated and the accuracy undermined (Dragomir, 2012), therefore proving to be less effective for carbon management on a sector-wide scale (Andrew & Cortese, 2011). Cut-off criteria establish a set of rules that assist the environmental practitioner in deciding which activities should be included and which should be excluded in their footprint (after organisational and operational boundaries are set; Dias & Arroja, 2012). Thus, they offer a potential way of improving the accuracy and usability of reported figures and assist in addressing [i a] and [ii a] in the list of issues outlined above.

Simple criteria comprise: i) the exclusion of paid-for Scope 3 products and services (as these are the Scope 1 or 2 emissions of another organisation); ii) the exclusion of activities with any potential to be counted elsewhere and iii) include the business-critical and geographically significant activities (*i.e.* Scope 1 and 2)[39]. The potential for double counting is eradicated because only emission-releases arising from production-related[40] activities would be reported by organisations and aggregated by sector. Activities along the supply chain are assigned to the producer, meaning that time and financial savings can also be realised for the reporting organisation. The consequences of introducing cut-offs can be seen in the final column in the Table in Appendix C; the number of constituents now equals 90. Yet, fully removing the ability for organisations to understand GHG emissions at this scale would be counter-productive due to their usefulness in aiding policymaking decisions. Therefore, it is proposed that two figures should be produced by organisations: i) a 'catch-all' figure that is used for internal strategic carbon management planning; and ii) a 'minimum standard' that details emissions through the employment of simple cut-off criteria.

Certainly, the use of cut-off criteria isn't without controversy and have been dismissed in the past for their tendency of being arbitrary and for producing inconsistencies (Huang *et al*. 2009a; Pelletier *et al*. 2013). Whilst this isn't the only proposed solution to double counting of aggregated organisation emissions (shared responsibility, has been shown to be an effective compromise; Gallego and Lenzen, 2005 & Lenzen *et al*., 2007), the proposal for three well-defined instructions (see previous paragraph) addresses assumptions and streamlines the process from beginning to end. This is advantageous because often, the greater the time spent collecting and preparing

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[39] These are included as default, due to a robust assigning methodology being already widely accepted by the academic community.

[40] Production-based emissions are allocated to the organisation that generated them, whilst consumption-based emissions are allocated to the organisation whose consumption caused the emission (Hoornweg et al., 2011). The virtues of both of these methods have been greatly studied in detail, and there has generally been a move from reporting a production-based footprint (following the guidelines set by the IPCC) to a more consumption-based approach (Larsen & Hertwich, 2009; Ozawa-Meida et al., 2011) in recent years.

information for organisational carbon footprints, the costlier the process becomes (whilst improvements to accuracy are negligible) and the less accessible it is (Plambeck, 2012). Eventually, a threshold is reached beyond which the cost to the organisation exceeds the exploitable benefits ('the law of diminishing returns' [Shephard and Färe, 1974]). Therefore, this methodology, which prioritises directly influenced and production-based emissions, removes barriers to carbon footprinting by ensuring organisations remain far removed from any threshold.

With the number of environmental carbon standards growing, the introduction of a new methodology could 'muddy the water' of an already complex field. Despite this, the importance of developing new academic ideas should not be underestimated. Beyond the more immediate regulatory measures which organisations are governed by, the better understood environmental impacts are, the more security organisations can assure for their future (Hoornweg *et al*., 2011). After all, the world is growing ever more uncertain as a result of climate change (IPCC, 2014). This allows organisations to be better placed in contributing to society's adaptation in the coming decades (Hulme, 2003; Linnenluecke & Griffiths, 2010), whilst facing up to the increasing significance placed on business resilience through good carbon management (Williams *et al*., 2012). The appetite for honest environmental claims has never been greater, coupled with a growing popularity of conscious consumerism (Sullivan & Gouldson, 2012). Organisations fail to engage on this agenda at their peril, as failing to do so would mean missing out on a vast swathe of potential customers and revenues.

4.4.3 University carbon footprints: practical realities

In the context of a university, the activities considered on a production perspective (the downstream activities in Figure 20) are minimal due to the nature of their operations, whilst the activities considered on a consumption perspective (the upstream activities in Figure 20) are considerable. To allow for strategic emission reduction policies to be implemented, commentators have customarily preferred a consumption-based perspective to be developed (Ozawa-Meida *et al*., 2011). Ultimately, the decision upon which approach is taken rests on the environmental practitioner and the intended use of the footprint, though a consideration should be highlighted: predictions suggest this problem will worsen as more organisations report carbon data (Matthews *et al*., 2008).

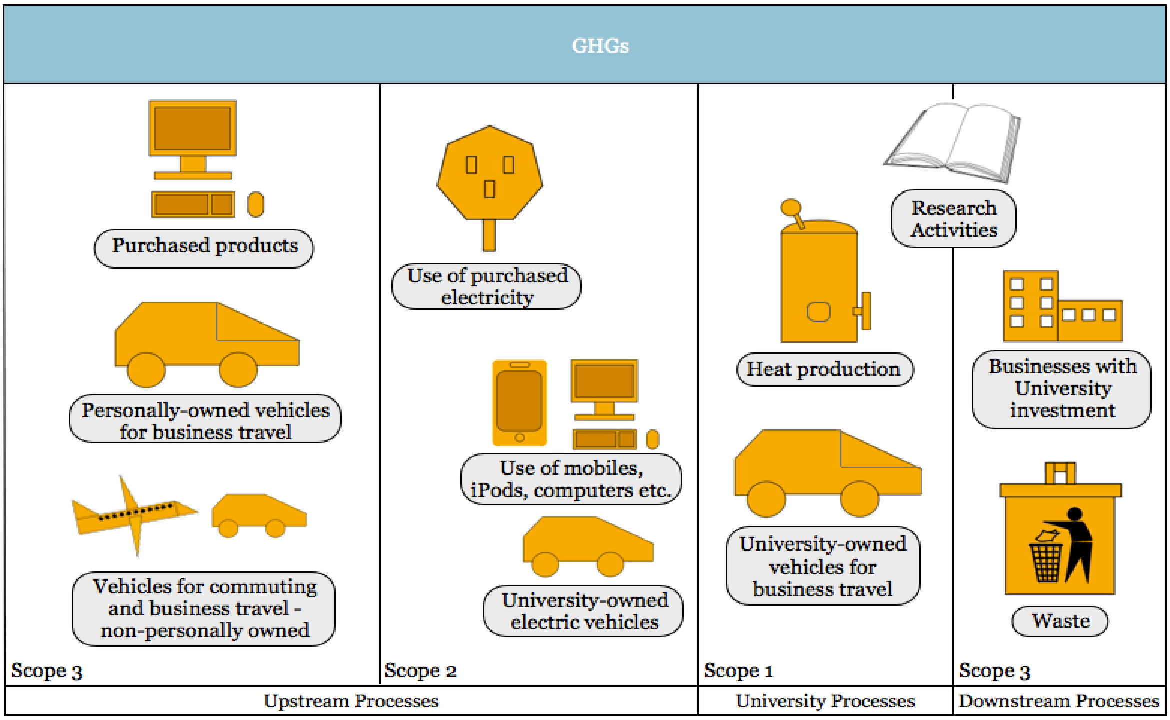

Figure 20: Examples of activities of universities as sources of GHG emissions.

Evidently, a 'one-size-fits-all' approach is common across all of the environmental standards interrogated. However, it remains to be seen how suitable this attitude is in promoting pragmatic carbon management in the real world. Arguably, the lack of GHG reporting of scope 3 activities by organisations is indicative of deficiencies in the methodology. For Universities in particular, funding pressures and time constraints are the reasons most cited for avoiding or underperforming on carbon management, which is exacerbated by the changing influence of policymakers. Currently, the sector is facing a lack of direction on carbon-related policies, especially in regards to the management of Scope 3 emissions. The issues arising from this as a result are only just starting to be realised. For instance, there are early indications that predict a collective failure on targets enacted in 2010 to reduce Scope 1 and 2 emissions by 2020 (where 2015 represented the halfway point) (Robinson *et al.*, 2015). The lack of cohesion and clear direction is having tangible and potentially damaging consequences, whilst the bodies that control both the direction and pace of progress, have seen their influence wax and wane through concurrent government shake-ups over the last decade (Universities UK, 2015).

A streamlined and prescriptive methodology, based on empirical evidence, emerging out of a sector-wide collaboration is a logical first step in addressing these issues. Whilst it cannot be said that scientific expertise is lacking or governments have been inactive in this field (in fact, Defra itself commissioned an input-output assessment of UK emissions (Wiedmann *et al.*, 2009); data which organisations can use to support IOA-based footprints), the knowledge within universities needs nurturing. Similarly, a perception that collecting data (internally and from external suppliers/organisations) is an obstacle to developing reliable GHG assessment has emerged, despite readily accessible financial accounts, with which detailed upstream footprints can be calculated (Wiedmann *et al*., 2009; Townsend and Barrett, 2013). Now more than ever, there is a requirement for clarity in a time of significant change for carbon management in the sector. With the introduction of new funding policies and universities playing an increasingly key role in local and national policymaking, the traditional outputs of universities (the intellectual 'assets'; Collini, 2012) are being tested and developed. HEIs are under increasing demands to demonstrate their direct financial contributions to the economy (Etzkowitz *et al*., 2000) and as a result, growth and expansion have been inevitable. Although wholly welcome by those responsible, the impact on indirectly influenced emissions is unknown and for these reasons, the future for Scope 3 carbon management in particular remains uncertain.

Universities act to transfer knowledge between industry, government, and the public (described by Etzkowitz, (1998) as the triple helix model) and for this reason, can also act as good influencers of carbon management in wider society and other organisations (Lozano *et al*., 2013). Rapidly changing estates, transient populations, and different academic specialisms mean that the variety and intensity of activities are in constant flux (with timings dictated by the structure of the academic year) (Flint, 2001). As a result, the study of universities is extremely insightful due to the considerable challenge carbon management represents. Critically, they find themselves needing to fulfil certain mandatory responsibilities and activities, which are driven by their research, teaching, and innovation-based agendas. Consumption-based activities dominate the emission profile, whilst activities such as travel, procurement or construction are inherently strategic, important and thus, unavoidable (Ozawa-Meida *et al*., 2011). Those that work and study at university will spend a large majority of their lives there and so, investing in sustainability initiatives at the grassroots level through HE, can and will have wide reaching benefits to students and staff for the rest of their lives (Zsóka *et al*., 2013); and not forgetting the societal benefits too.

4.4.4 University carbon footprints: scoped-out activities

Appendix E shows site-specific activities listed under each of the ISO-designated emission categories and the treatment applied under the proposed methodology. Some may argue that the treatment of these activities could provide a case for universities to abstain on carbon management because the majority of Scope 3 sources are excluded. Likewise, the shifting responsibility of emissions from the HEI to their suppliers could enable institutions to continue their current trajectory of growth and increasing consumption without due regard for environmental consequences (Jackson & Knight, 2011). Whilst there may be truth here, the methodology outlined here considers these issues in a number of ways and allows institutions to address them individually. Firstly, universities are still held to account because of the emphasised importance of developing full-scope carbon footprints for *internal* use (to aid carbon management) and secondly, the reporting has been made easier for GHGs *within* their organisational boundary.

A responsibility now falls onto the various agencies that govern the HE sector to foster collaboration on understanding individual institutions' carbon management needs. Ensuring that institutions are able to report data (currently controlled by the HESA using the Higher Education Information Database for Institutions (HEIDI) and are compared fairly (by using carbon intensities to compare similar-sized institutions) removes the many unwanted barriers that can pose a threat. In addition, this research should serve as a wakeup call to policymakers and institutions that more work needs to be done to decouple growth from emissions (Pelletier *et al*., 2013). This is a call that joins a host of academic research and grassroots movements building the momentum (such as the global divestment movement and rootAbility's Green Office initiative). Whilst universities should retain the right to grow nationally and internationally, new ways of delivering HE with a lower environmental impact must be a priority, be it managing the estate more efficiently or challenging the traditional methods of teaching to favouring distance-learning and offsite degree courses (Roy *et al*., 2007; Barber *et al*., 2013).

The use of carbon footprinting can assist in creating better ownership by individuals in organisation like HEIs (Paterson & Stripple, 2010). As individual stakeholders of HEIs, getting staff and students to take a more central role in contributing to carbon management is important in fostering significant reductions. A cost for carbon, in-line with the published figure of the social cost of carbon (the cost to society as a result of environmental damage caused by anthropogenic GHG emissions) should be introduced by manufacturers and purveyors of services. Consequently, the cost of emissions would be borne by the consumer and so a potential win-win scenario is presented. This influences the behaviour of the consumer through selecting products and services with the least environmentally damaging credentials. In-turn, the provider adapts favourably to remain competitive and maintain market-share; Grote *et al*. (2014) considered this in an example of the aviation industry. By increasing ticket prices for flights as a means to reduce aviation emissions, considerable emissions savings could be predicted. However, the low probability that strong policy decisions will be taken like this, offers little certainty about the future trajectory of carbon reduction.

4.5 **Limitations**

Limitations of this work and the other chapters are more fully assessed later in this thesis in section 7.5.

4.6 **Conclusions**

Scope 3 emissions typically represent the largest proportion of the organisational carbon footprint (see Table 11), but are seldom the priority in carbon management policies (Ozawa-Meida *et al*., 2011). The three most influential barriers to assessing and reporting indirect GHG emissions from upstream and downstream of the organisational boundary of HEIs have been identified as time, cost, and data reliability. HEIs transpose key theories from guidance notes, intended to be suitable for all organisation types. Along with inconsistencies in the grey literature, a limited number of institutions have a detailed understanding of GHG emissions associated with all of their directly and indirectly influenced activities.

A USM for assessing the carbon footprint of HEIs in the HE sector is proposed and supported by university environmental practitioners. It has been shown that whilst the virtues of understanding all emissions for which an organisation is responsible are clear for implementing appropriate sustainability initiatives, when reported, inherent double counting undermines conclusions that can be made about entire economic sectors. Therefore, the use of full-scale footprints for internal purposes and the external reporting of production-based emissions are proposed. With the latter, cut-offs that exclude paid for services are outlined to reduce the financial and temporal cost associated with reporting and data collection.

The year 2015 represented the halfway point between the setting of institutional targets in 2010 to reduce Scope 1 and 2 emissions by 2020 (HEFCE, 2010). The interest and desire to manage indirect GHG emissions exists in the HE sector today, but the tools in order to do this are yet to be put in place. Carbon management will be a cornerstone for institutions aspiring to grow internationally at a time when advocating sustainability and low-carbon production is high on the list of priorities (Lozano *et al.,* 2013). Clearly, the time to act is now.

This Chapter forms the basis of efforts to improve Scope 3 GHG emission reporting rates for HEIs. Future work aims to investigate the current practices that HEIs undertake to assess their GHG emissions using these techniques in order to build upon the findings presented here. Identifying exactly which of the barriers recognised by practitioners can be addressed through employing a streamlined carbon footprint methodology will extend the scope of this research. In particular, the degree to which this method fosters more efficient use of the time and financial resources available to non-technical personnel (such as the university environment managers that formed the basis of this research) will be the subject of further study.

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Chapter 5: Appraising the proposed universal standard methodology on a subset of institutions

The proposal of a universal standard methodology (USM) in the previous chapter established the idea that challenges the current status quo on calculating and reporting campus greenhouse gas (GHG) emissions data in the higher education (HE) sector. A status quo, which means that 70% of UK institutions fail to report emissions data from indirect (scope 3) activities to the Higher Education Statistics Agency (HESA) on an annual basis. Chapter 4 has shown that a streamlined methodology is not only practical, but desirable (as attested by HEI environmental practitioners through consultation). With the knowledge of a possible new methodology, the scope of the research now narrows to build on applying this theoretical idea practically on real world institutions.

This chapter appraises both the positive, and negative attributes of the methodology and its role in influencing and simplifying GHG reporting. The most and least significant emission sources in a HEI GHG assessment are used to identify a suite of reliable environmental performance indicators. The results of the initial test on a subset of HEIs are presented and its suitability explored in depth. In particular, exploration of whether the methodology is open to all institution types is undertaken, as well as its propensity to align with pre-existing audit and verification practices already in widespread use in the industry.

This research continues the work of the previous chapter in addressing the second research aim outlined in 1.6. Objective 2.3 is also addressed.

5.1 Key implications from the previous chapter

Highlighting the disparities between the published environmental standards and methodologies most frequently used by practitioners in the assessment of organisational GHG emissions, a number of proposals were outlined in Chapter 4. These sought to overcome four key issues, including:

i) The lack of guidance on clearly deciding whether activities should be included or excluded from assessment and the inherent double counting this leads to upon aggregation at a sector level;

ii) Time, cost and staff resources are limiting factors in whether GHG assessments are prioritised and conducted fully;

iii) The description of data collection methods is not clear nor prescriptive, making reliable and useful inferences from data impossible; and

iv) The inconsistent use of GHGs, potentially leading to inconsistent and misleading reporting and high margins of error.

The proposals represent a streamlined methodology that possesses four key features designed to directly address these issues, including:

i) The implementation of cut-off criteria to allow the user to make definitive in-out decisions of activities along the supply chain to reduce the time spent collating data and eradicate double counting when aggregated at a sector level;

ii) An approach which requires the smallest number of actions to secure a consistent, robust and accurate outcome, to make the activity more cost and resource-effective;

iii) Guidance on the robust and uniform collection of activity data rated by preference in order to assure the accuracy of data inputs; and

iv) Standardised GHGs (CO_2 and CH_4) to improve comparability and capture the majority of climate impacts without need for further detailed study of individual activities.

By also considering the experiences of practitioners in conducting GHG assessments, the proposed methodology was carefully tailored for practical use. Three overarching factors that were identified through consultation with university environmental practitioners were found to hinder progress most of all (Table 22). The discovery of these three factors is central to enabling the proposed USM to be designed as a pragmatic and realistic approach that it is sympathetic to the needs of the industrial practitioners who will use it. The identified factors were time, financial cost, and reliability [*of data inputs*].

Table 22: The highest-rated factors selected by practitioners as hindrances of conducting HEI GHG assessments.

Factor	Description of issue
Time	Time constraints due to multiple priorities experienced by environment managers in their daily roles.
Financial cost	Closely related to the temporal factor, an environment manager’s time is economically valuable. Decreasing the time spent compiling GHG assessments has a direct influence on the cost required.
Data reliability	Data reliability is the propensity for an experiment or study to repeated and yield identical results. This relies on good experimental design.

5.1.1 The development of environmental performance indicators for corporate reporting by Higher Education Institutions

The use of environmental performance indicators has enabled organisations to generate and disseminate environmental information in a scientifically robust and transparent manner to non-scientists. The increasing importance of these disclosures is due in part, to stakeholders demanding greater environmental stewardship (Sullivan & Gouldson, 2012). Additionally, organisations are under statutory requirements to report environmental metrics (*i.e.* as a result of the Companies Act 2006 (Strategic and Directors' Reports) Regulations 2013, which made carbon reporting mandatory in the England and Wales). Indicators can be used for environment reporting, measurement of environmental performance and reporting on progress towards sustainable development. They can further be used in planning, clarifying policy objectives and setting priorities. The need for an integrated framework for environmental performance indicators has been well researched (Azzone & Noci, 1996).

In order to guide the development of the USM, it is the intention that the results of the qualitative comparative analysis (QCA) and use of simple cut off criteria in the previous chapter will develop into a series of environmental performance indicators to be carried forward by the sector. For environmental performance indicators to be widely accepted, they must follow a number of principles. These principles are outlined in the ISO14031:2013 standard on Environmental Performance Evaluation, which includes:

- Comparability: the indicators must be comparable and reflect changes in environmental performance;
- Target-orientated: the selected indicators must be chosen so they can act towards goals which are able to be influenced by the firm;
- Balanced: the indicators must reflect environmental performance in a concise manner, and display problem areas as well as benefits in a balanced manner;
- Continuity: for sake of comparison, the indicators must be derived by the same criteria and relate to each other through corresponding time series and units;
- Frequency: indicators must be derived frequently enough (monthly, quarterly, yearly) so that action can be taken in due time; and
- Comprehensibility: the indicators must be understandable for the user and correspond to informational needs. The system has to be lucid and concentrate on the most important figures.

5.2 Materials and Methods

5.2.1 Environment manager semi-structured interviews

The semi-structured interview was chosen to capture information about an institution's data collection procedures because it affords a great deal of freedom to ask in-depth and the use of spontaneous questions (Whiting, 2008). Open questioning, coupled with detailed transcribed recording, allowed more information to be revealed than could be gleaned from interrogating written publications or other interviewing techniques. Publicly available documents regarding carbon management at these institutions were interrogated to gain further insight into chosen methods. These included documents such as Carbon Management Plans (CMPs), published methodologies, travel plans, and funding documents.

The interviews were conducted with HEI environment managers, as these were deemed most appropriate due to their expertise in this domain, often responsible for collating and reporting on an estate's environmental credentials. Participants were briefed via email and decided to take part in the study via a follow-up telephone conversation. Questions and the basis of question structuring are outlined in Table 23.

Table 23: Data methodology interview questions posed to university environment managers.

Main question	Additional questions	Clarifying questions
How many staff members comprise your environment/sustainability team?	Does the environment team collect all the data, or are there other members of staff in the institution working on it?	Can you expand a little on this? Can you tell me anything else?
Can you give a succinct explanation about the methods used to obtain activity data?	What guidelines have you used? Are there activities for which you knowingly do not have confident data available for? What organisational boundary is used? Which sites are included and excluded from the footprint? For emission sources you do not already have data for, are there those that you do see benefit in understanding and are there those you do not see benefit in understanding?	Can you give me some examples?
How are the Estates Management Reports compiled?	Have you made any changes to the way the reports are produced? Do you have any criticisms of the process? How do you think should be done to make the process more efficient? Are all the categories relevant? Do you report on an annual basis?	
How ready are you for scope 3 reduction targets?	Has the institution set any targets to reduce Scope 3 emissions already? If so, is this an aggregate target, or categorised by activity?	
Barriers to carbon footprinting which environmental practitioners commonly rate as most influential are cost and staff resources. Would you agree with this?	How vital is the EAUC network to fostering change in HEIs and supporting their actions? What commitment to carbon management has been pledged by the management team of the University to address these issues? Which team is responsible for setting this agenda? Are there any other issues that you have experienced you could share?	

The interviews were carried out at the initial phase of the project at a location convenient to the participant (in total, 10 interviews were conducted and only one of these was not at the home institution of the interviewee). On average, each interview lasted one hour and featured a number of phases (adapted from Whiting, 2008):

- Building rapport - The importance of building a rapport with the participant has been emphasised and that it occurs in stages throughout the interview;
- Exploration - The initial stage of the interview displays elements of strangeness and uncertainty. In view of the potential discomfort that the participant can feel, the wording of the opening question is important. As the interview progresses, the participant should begin to engage in more in-depth descriptions;

- Co-operation - At this stage a comfort level is reached and there is the potential for more free discussion. For example, the interviewer and participant show signs of enjoying the process and are less worried about offending each other;
- Participation - It is during the participation phase that the greatest rapport is developed, success is indicated by the interviewee 'guiding and teaching the interviewer'; and
- Conclusion.

Observations and thoughts were noted prior, during, and after the interviews, whilst a number of probing techniques were performed during, including 'verbal agreement', 'silence', 'baiting', and 'echoing' as defined in Table 24. The semi-structured interview was chosen over other forms of interview due to the degree of flexibility in questioning. Semi-structured interviews are often viewed more as a purposeful conversation around a certain subject, which the interviewer guides. Due to the flexibility, the interviewee is often encouraged to reflect, ask questions and drive the direction of the conversation also.

Table 24: Examples of probing techniques used during semi-structure interviews

Type of probing technique	Description
Silent	Interviewer remains silent and allows the participant to think aloud.
Echo	Interviewer repeats the participant's point, encouraging them to develop ideas further.
Verbal agreement	The interviewer expresses interest in the participant's views with the use of phrases such as 'yes', 'okay' or 'uh-huh'.
'Tell me more'	The interviewer clearly asks the participant to expand on a particular point or issue, without the use of echoing.
Long question	The interviewer asks a lengthier question that suggests a more detailed response is sought.
Leading	The interviewer asks a question that encourages the participant to explain his or her reasoning.
'Baiting'	The interviewer gives the impression of being aware of certain information, which might prompt the participant to explain further.

Source: Adapted from Whiting (2008).

5.2.2 **Methodology testing**

To evaluate the practical attributes of the developed methodology, a data management tool, henceforth referred to as the 'Higher Education Institution Carbon Calculator' (HEICC), was developed using visual basic for applications (VBA). Remaining as close to the conventions used in the Estates Management Record (EMR) record as possible, the tool was developed in-line with the methodological points proposed under the universal standard. The EMR system was chosen because it is well-established, popular amongst environment managers, and easy to use.

A briefing document was provided to participants during initial consultation, which provided a succinct description of the data for each data source. In these instructions were the details for the collection of data at their home institutions to ensure that a dataset was returned using uniform and standardised collection methods. The methods followed an integrated version of those found in a number of guidance documents: the GHG Protocol developed by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI); the International Standardisation Organisation (ISO) 14064-1 standard; and the UK Government Department for Environment, Food and Rural Affairs (Defra) guidance on measuring organisation emissions and the Global Reporting Initiative (GRI) sustainability guidelines. Participants were expected to report data quarterly (January 2016, April 2016, July 2016, and October 2016) in order to mitigate any developing issues. In reality this was not always practicable for respondents, so annual reporting was conducted where data streams did not lend themselves to shorter reporting intervals.

Accompanying the final return, participants were asked to complete a system usability score (SUS)[41] questionnaire (following the procedure set out in Brooke, 1996) and a detailed record of their time spent compiling data to input into the HEICC. This type of questioning, which consists of 10 Likert-scale questions, was used to evaluate the psychometric factors of the respondents and allows the system developer to effectively understand user thoughts to distinguish between unusable and usable systems. Some additional information was also obtained which helped identify areas of the system that could be improved.

5.2.2.1 Data sources

The overall carbon footprint was calculated for the academic year 2015-2016 for each of the case study institutions. Data was collected for each of the 13 USM emission categories, across the following Scope 1, 2, and 3 emission categories:

Scope 1:

- Direct emissions from stationary combustion;
- Direct emissions from mobile combustion;
- Direct process-related emissions;
- Direct fugitive emissions; and
- Direct emissions and removals from Land use/land-use change and forestry (excluding combustion).

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[41] Bevan (1995) states that the objective of usability is to achieve 'quality of use'.

Scope 2:

- Indirect emissions from imported electricity consumed; and
- Indirect emissions from consumed energy through a physical network.

Scope 3:

- Energy-related activities not included in direct emissions and energy indirect emissions;
- Waste generated from organisational activities;
- Grey fleet emissions;
- Investments;
- Downstream leased assets; and
- Commuter car emissions.

Both primary and secondary data was collected. Primary data was obtained through the act of direct monitoring, collected through in-situ physical monitoring equipment; in the case of energy usage data, this took the form of energy meters used to measure natural gas consumption and electricity usage. Secondary data was obtained from a number of different sources where best estimates based on rigorous calculation methodologies were used in lieu of reliable primary data. The carbon footprint definition chosen for this study was adapted by Wright *et al*. (2011) as defined in chapter 2. This definition expressed all GHG calculations using the equivalency metric 'CO_2e', which included two GHGs, CO_2, and CH_4 and the Global Warming Potential (GWP) of CH_4 based upon a 100-year period.

Data for refrigerant F-gas fugitive emissions were excluded. Table 25 highlights the emission sources included in this study and the following sections provide a summary of the underlying theory used in the accompanying methodology document given to study participants at the start of this particular research project.

Table 25: Emission sources associated with activities undertaken by higher education institutions participating in this study.

	Emission source	Scope
Direct energy emissions	Stationary combustion: natural gas consumption in boilers in university-owned buildings	Scope 1
	Stationary combustion: natural gas consumption in combined heat and power (CHP)	Scope 1
	Stationary combustion: burning oil consumption	Scope 1
	Stationary combustion: fuel and gas oil consumption	Scope 1
	Stationary combustion: LPG, LNG	Scope 1
	Mobile combustion: fleet vehicles fuel consumption (petrol, diesel, LPG, CNG)	Scope 1
	Consumption of biofuels	Scope 1
	Consumption of biomass	Scope 1
Land-use changes	Landscaping activities	Scope 1
	Agricultural activities	Scope 1
Indirect energy emissions	Electricity consumption	Scope 2
	Consumption of heat/steam through a physical network	Scope 2
Energy-related activities	Well-to-gate emissions from natural gas supply	Scope 3
	Well-to-wheel emissions from fuel supply	Scope 3
	Well-to-gate emission from electricity generation	Scope 3
	Well-to-gate emissions from heat/steam generation	Scope 3
	Well-to-gate emissions from biofuels	Scope 3
	Well-to-gate emissions from biomass	Scope 3
Travel	Business travel grey fleet	Scope 3
	Commuter journeys by car	Scope 3
Waste	Waste fraction emissions by treatment type	Scope 3
	Wastewater	Scope 3
Downstream leased assets	Stationary combustion: natural gas consumption in boilers in university-owned buildings	Scope 3
	Stationary combustion: natural gas consumption in combined heat and power (CHP)	Scope 3
	Electricity consumption	Scope 3
	Consumption of heat/steam through a physical network	Scope 3

5.2.2.2 Energy emissions

Total energy demand was quantified from a number of sources; from the consumption of electricity, natural gas, and other fuels (e.g. coal, wood, biomass, steam). Due to the differences in grid energy mix and energy intensity, where applicable, country-specific grid emission factors were taken from the dataset compiled by the IEA (International Energy Agency, 2017b). In most instances, operations were UK-based and therefore country-specific factors were not needed, however a small proportion of institutions included their overseas operations in their organisational boundary. Data from AMS systems was used as the primary information source for electricity (in kWh) and natural gas usages (typically in cubic metres or converted using the standard government natural gas conversion methodology) since institutions were typically supplied by half-hourly meter readings. Indirect fuel and energy-related emissions associated with upstream production were quantified using published emission factors, as were emissions from purchased heat and steam where quantities could be obtained through energy bill consumption data.

Emissions related to the combustion of fuel in mobile sources (such as fleet vehicles) were quantified using fuel card information. Data entry of fuel usage information captured the total spend and the volume of fuel consumed, allowing very accurate figures to be obtained. Institutions kept a list of all university-owned vehicles.

For ease, electricity produced from the incineration of waste materials was accounted for in the waste-related emissions category. Emissions from local generation and renewable 'offsets' was assumed to be based on inputs to the national grid, and was therefore calculated using an identical national grid emissions factor used for electricity-based calculations.

Indirect energy-related activities, namely, well-to-grid emissions (associated with electricity) and well-to-tank emissions (associated with fuels) were calculated using readily available emission factors published annually by Defra. These factors account for the upstream emissions from the extraction and production of fuels, as well as the losses throughout the national grid associated with the transmission and distribution of electricity.

5.2.2.3 Land use, land-use change and forestry

Changes to land use *i.e.* from a vegetated state to an urbanised state, can significantly alter natural ecosystem processes that influence GHG fluxes in the carbon cycle (e.g. decomposition, photosynthesis etc.) and on a global scale is of utmost importance to climate change management. In some respects, the significance of carbon fluxes associated with LULUCF or agriculture, forestry, and other land-use (AFOLU) may be deemed too low for inclusion in the organisational carbon footprint. However, in regards to the study sector used in this research project, the suggestion that land use changes are insignificant would be inappropriate for a number of reasons outlined below.

Many institutions are owners and managers of considerable mixed-use land estates, which act as both a source and sink of carbon. For instance, forestry biomass absorbs atmospheric carbon, whilst agricultural land can be classed as either a net emitter of carbon or net sink for carbon depending on the time of year, the agricultural practices taking place, and their intensity. There are particular examples of institutions dealing heavily in large scale forestry or agricultural practices (and also deforesting or afforesting practices), and for those that don't, campus-level activities can also be significant, *i.e.* biomass burning, landscaping, grass cutting, and composting. These can all influence the emission releases and removals associated with LULUCF and AFOLU categories. Perhaps most importantly, many institutions are known to have large estates comprised of investments in land, as reported by Shrubsole (2018). Institutions will invest in rural or forested areas, and a beneficial consequence is the offsetting and sequestering of emission releases (most commonly for Scope 1 and 2 emissions). More frequently, private companies are investing in emission offsets as the demand for environmentally-conscious business practices becomes standard as explored in chapter 2 and chapter 7.

Due to its simplicity and high-level resolution, the direct carbon flux approach was selected for calculating LULUCF and AFOLU emissions and removals. This approach was found to suit the majority of institutions. The aim for this research project, was for a baseline to be created, from which future emissions and/or removals could be quantified. For this reason, the net carbon stock change method was not possible (and is not possible until a dataset is established containing two or more years of data).

Calculated for each institution in-turn, the Rothampstead Roth-C carbon flux model was chosen. Having been published in *ca.* 90 published land-use and soil carbon studies in the last five years, the model was deemed the most reliable and readily available method for this study. Firstly, meteorological data was inputted into the model for each institutional site, which included details of the average monthly temperature (^{o}C), rainfall (mm), monthly open pan evaporation rate (mm), and soil clay content (%) for each study site (Coleman & Jenkinson, 2014). GIS software and aerial photographs were utilised to create a land use profile for extrapolation of the model's results. The model was run over a year and represents the baseline from which future comparisons can be made with additional land-use change data inputs. Using Eq. (5) in 2.9. SOC was calculated for each land cover category (Table 26).

Table 26: Land cover categories used to model soil organic carbon and examples.

Land cover category	Activities/examples
Forestry	Coniferous trees, non-coniferous trees
Agricultural land	Arable land, ploughed soil, fallow open soil
Grassland	Improved or unimproved grasslands, meadows, rough grass, perennials
Marsh/Wetland	Saltmarsh, peat bogs, inland water, tidal water
Impervious surfaces	Roads, buildings, car parks, tracks,

Source: Adapted from IPCC (2006).

5.2.2.4 Grey fleet

Emissions from the use of the Grey fleet (vehicles privately owned by employees used for business purposes), required information on the total distance travelled by vehicles attributed to the study organisation, combined with fuel efficiency, fleet composition, and journey characteristics. This concept focusses on the relationship of the mass of fuel consumed in the distance travelled (when aggregated data is unavailable).

Approved Mileage Allowance Payments rates are used to reimburse drivers and also assist in GHG calculations by providing distance (if not recorded appropriately). These rates include estimates for all vehicle purchase and running costs, such as fuel, maintenance, insurance, and depreciation and are currently set by the government at 45 pence per mile for the first 10,000 miles, and 25 pence per mile thereafter (HM Revenue and Customs, 2017). Grey fleet mileage re-imbursement rates are normally considerably higher than alternative modes of travel and a focus on grey fleet vehicles helps employees make conscious decisions about the journeys they make. The Grey fleet is typically older than the company-owned fleet and is known to contribute to the bulk of the road transport GHG emissions in some organisations (Department for Transport & Department for Environment Food and Rural Affairs, 2011). .

5.2.2.5 Commuter car emissions

Quantifying commuter car journeys could be undertaken by a number of different means. Due to the existence of these numerous methodologies and variable data streams available amongst institutions, the HEICC was able to accept a number of different inputs. Data were converted into a standardised unit for undertaking the carbon calculation (passenger.km) These inputs included: i) the number of daily commuter trips; ii) the number of days completing the trip per year; iii) trip distance; iv) the percentage who car shared; and v) the percentage who drove alone. The average vehicle occupancy rate of 1.4 was used and an average emission factor was used when vehicle details were not given by the user. It was intended that data from annual travel surveys would be used to calculate travel frequency from the transportation survey responses regarding the number of days per week and weeks per year that an individual commuted to the respective university campus. Although the instructions stated this as the intended data source, theoretically, participants could input data from a number of sources or assumptions. The participant was encouraged to record all assumptions that were made in the course of the data collection.

5.2.2.6 Waste arisings

The treatment of waste represents a significant transboundary emissions source, where transport and treatment facilities lay outside of the organisational boundary. Often, the influence of waste arising from within the organisational boundary means that significant emission savings can be made through engagement and behavioural change. Once waste is destined for disposal, direct control is lost by the producer and waste becomes harder to track since it is mostly undertaken by third party organisations at a remote location (either domestically or internationally). Often, organisations specify the means of disposal in the waste contract, which ensures there is full transparency over disposal methods; improving visibility for reporting purposes. Emissions from waste can overlap with other emission sources through electricity generation (*i.e.* incineration to produce energy-from-waste) or AFOLU-related emissions (*i.e.* changes to carbon stocks on land due to landfilling).

A clear understanding of the composition of waste streams is required in the first instance in order to succeed in modelling emissions arising from waste disposal by treatment type. Alterations to the composition or treatment method selected will alter the mass balance and carbon flux. Data on waste arisings was supplied by waste carriers as the mass disposed of by each waste type; the composition of each waste stream was assumed to be homogenous *i.e.* there was no contamination of wastes, or inadvertent crossover of waste streams. Less information was collected regarding the disposal treatment of the waste, although despite this five accepted treatment methods were considered namely: i) landfill disposal; ii) incineration; iii) recovery and recycling; iv) composting; and v) anaerobic digestion.

Landfilling is the most popular method of waste disposal globally and represents one of the largest source of anthropogenic emissions of methane (Powell *et al.*, 2015). In this study, it is assumed that when biogenic materials in landfills degrade, CO_2 and CH_4 are generated in anaerobic conditions; CH_4 is the predominant GHG generated. Nowadays, technology can assist in ensuring that releases of CH_4 are minimised and used for energy production (known as landfill gas) via gas capture systems. The climate benefits of converting CH_4 from landfill to CO_2 are well understood. Constants for methane generation rates were taken from IPCC (2006) (these are not changed since they were first published) and landfill emission rates were calculated using the WRATE tool (Environment Agency, 2010).

Despite its popularity, many organisations now choose to divert waste from landfills and implement waste disposal methods higher up the waste hierarchy (reduce, reuse and recovery, recycle, and disposal). Carbon contained in organic materials that do not degrade during the 100 year time period considered is assumed stored within the landfill indefinitely, effectively removing it from the global carbon cycle. As this process would not occur naturally, landfills constitute as an anthropogenic carbon ‘sink’.

Incineration is an increasingly popular method for disposing of vast quantities of waste as it can involve recovery of energy. This can also be carried out for a wide range of materials, depending on their combustibility. Energy is released as heat during thermal treatment, which can be used to generate electricity and heat (known as energy-from-waste). Energy is typically recovered by means of a boiler and a fully-condensing turbine and transformed to electrical energy by an electrical generator. Electrical energy generation efficiencies at incinerators vary widely between technologies have been reported to range from between 1-34% (Astrup *et al*., 2015).

Recovery and recycling are both common methods used in waste management and are important for reducing the reliance upon virgin materials and new products. A significant proportion of the dry component of the municipal solid waste (MSW) stream can potentially be recycled, with the most commonly recovered materials being paper, cardboard, metals (ferrous and non-ferrous), plastics, textiles, and glass. These materials can be segregated at their source by the waste producers or they can be collected commingled and sent to a material recovery facility (MRF) where materials are sorted, either manually or mechanically, to reclaim the recyclable fractions. There are two main types of MRF that have been designed to deal with different waste streams: residual waste MRFs accept a mixed, residual waste stream; whilst commingled MRFs (either single-stream or two-stream) sort a commingled dry recyclate waste stream containing more than one recyclable fraction.

The main source of emissions from waste processing, recovery, and recycling are a result of energy use (e.g. diesel and electricity for the operation of MRF plant equipment). Reprocessing facilities remanufacture waste materials in one of two forms of recycling: 'closed-loop recycling', in which recovered waste materials are reprocessed to produce a functionally-equivalent product (e.g., waste paper recycled to produce a recycled paper product); or 'open-loop recycling', in which the recycled materials are reprocessed and used to manufacture a product that is inherently different in nature to that of the original waste material.

Composting is an aerobic process whereby organic waste with high carbon content is degraded in the presence of oxygen. Material is predominantly converted to CO_2, whilst some CH_4 is formed in anaerobic sections of the compost matrix but is oxidised in well-aerated parts of the pile. Composting produces an organic solid residue, known as compost that can be used (non-exclusively) in agricultural land-spreading, gardening, and horticulture, or for the preparation of growth media.

Anaerobic digestion (AD) refers to the natural process in which organic waste is degraded in anaerobic conditions to produce a CH_4-rich biogas and a liquid and/or solid effluent (digestate). Whilst the use of AD to treat wastewater and agricultural slurries is widely established in the UK, its use to treat biodegradable municipal waste (BMW), such as food and garden waste is being strongly promoted by the UK government and the number of operational AD facilities in the UK that treat BMW has rapidly increased in recent years. AD is widely recognised as often being the best treatment option for food waste in terms of its potential climate impact, principally due to the utilisation of biogas to generate electricity.

5.2.2.7 Downstream Leased Assets

Emissions from downstream leased assets originate from the operation of assets that are owned by the reporting company (acting as lessor) and leased to other entities in the reporting year that are not already included in scope 1 or scope 2 (Sotos *et al.*, 2015). Using the equity share or financial control approach, the lessee only accounts for emissions from leased assets that are treated as wholly owned assets in financial accounting and are recorded as such on the balance sheet (*i.e.*, finance or capital leases) (Bhatia *et al*., 2011). Using the operational control approach, the lessee only accounts for emissions from leased assets that it operates. Because institutions were encouraged to use the operational control approach when setting their organisational boundary in this study, scope 1 and 2 data for operating leases was expected. When requesting scope 1 and scope 2 data from lessees using the asset-specific method in category 8 (Upstream leased assets), additional information may be required from the lessee in order to properly allocate emissions to the reporting company's leased assets. If data were not available, emissions could be allocated using average emissions per floor area.

Guidance on which leased assets are operating and which are finance leases should be obtained from an organisation's accountant. In general, in a finance lease, an organisation assumes all rewards and risks from the leased asset, and the asset is treated as wholly owned and is recorded as such on the balance sheet. All leased assets that do not meet those criteria are operating leases.

5.2.3 Participant selection and sample

In a similar approach to that described in Chapter 4, member institutions of the Environmental Association of Universities and Colleges (EAUC) network were again approached to participate in this study. Institutions that had been involved with the focus group presented in the foregoing chapter were targeted first. No formal selection criteria were applied beyond being public institutions with an energy consumption of greater than 2000MWh, which was established to entice larger institutions with stable supply chains. This was due to the desire to obtain a broad and representative sample of UK HEIs, however should there have been a larger number of institutions wishing to take part, then a more selective approach would have been taken. A representative sample of institutions from all regions of the United Kingdom and educational specialisms was obtained, comprising nine institutions (Table 27); the tenth institution was the primary case study, the University of Southampton (UoS).

Participant institutions volunteered themselves. Although the benefits of participating in this study were not directly financial, numerous benefits were acknowledged by participants, such as securing greater insight of scope 3-related carbon footprints and identifying previously unrecognised data streams. Institutions just starting out on managing Scope 3 emissions could expect to exploit these benefits in particular.

5.2.3.1 HEI institutional profiles

Table 27 shows key information about the institutions included in this study *i.e.* region, campus information, and their baseline emissions on which their 2020 targets are based. In total, the group represent more than 30,000 staff (7% of total HE staff in the UK n=410,130), 129,000 students (6% n=2,280,830), and garner more than £3 billion annually in research income and fees (Higher Education Statistics Agency (HESA), 2015). There are clear differences in the location, size (in terms of occupied area and personnel), and wealth of the institutions sampled. For example, the University of Oxford is by far the largest HEI on income, area, and staffing, whilst on the same metrics, the University of Winchester is the smallest.

Table 28 shows the environmental advocacy and procurement consortia groupings for each of the institutions. The power of purchasing consortia, to pool the resources of institutions, obtain deals for large-scale materials and tender contracts means that these organisations can have a key role in the emissions along the university supply chain. In fact, sustainable procurement is a key driver for consortia, who operate sustainable advisory groups and provide scope 3 carbon assessments to the Higher Education Funding Council for England (HEFCE) on an annual basis.

Table 27: Basic information about the institutions included in the standardised data collection study: staff/student and income in 2014/15.

Name of Institution	Region	FTE Staff/FTE students	Total Income (£)	Gross Internal Area (m^2)	2005 Scope 1 and 2 emission baseline (t)	2020 target emission level (t)
Aston University	W. Midlands	1460 / 8360	124 874 000	106 847	16453	8720
Birmingham City University	W. Midlands	2075 / 18 445	187 461 000	175 003	17480*	9090
Canterbury Christchurch	South East	1635 / 11 440	126 386 000	115 087	9407	4045
De Montfort University	E. Midlands	1895 / 15 305	168 025 000	156 368	13 217	7533
Glasgow Caledonian University	Scotland	1445 / 13 275	122 423 000	102 328	10 952	9857
University of Keele	W. Midlands	1680 / 7800	134 343 000	159 365	13 803	8558
University of Oxford	South East	11 935 / 19 180	1 429 389 000	650 412	65 980	44207
University of Salford	North West	1830 / 15 510	187 864 000	166 251	20 000	11400
University of Winchester	South East	700 / 6165	64 876 000	69 834	4207	2398
University of Southampton	South East	5635 / 21 260	526 901 000	425 311	51 878	41502
Total		30308 / 129720	3 072 542 000	2 126 806	223 377	147 310

*Includes emissions from energy and water consumption in buildings, business travel in fleet vehicles, waste management and paper consumption.

Source: HESA (2015)

Table 28: The environmental advocacy group memberships of the study sample

Institution ID	SUPC[a]	NWUPC[b]	NEUPC[c]	HEPCW[d]	LUPC[e]	APUC[f]	ACU[g]	EAUC[h]
Aston University	✓							✓
Birmingham City University	✓							✓
Canterbury Christchurch	✓						✓	✓
De Montfort University	✓							✓
Glasgow Caledonian						✓	✓	✓
University of Keele		✓						✓
University of Oxford	✓						✓	✓
University of Salford							✓	✓
University of Winchester	✓							✓
University of Southampton	✓							✓

[a] Southern Universities Purchasing Consortium. [b] North Western Universities Purchasing Consortium. [c] North Eastern Universities Purchasing Consortium. [d] Higher Education Purchasing Consortium, Wales. [e] London Universities Purchasing Consortium. [f] Advanced Procurement for Universities and Colleges. [g] Association of Commonwealth Universities. [h] Environmental Association of Universities and Colleges.

(1) Aston University occupies a 60-acre campus in the centre of Birmingham (Gosta Green) composed of 33 mixed-use buildings. Sandwiched by the A38 expressway (a major trunk road approaching the M6 motorway at Gravelly Hill - 'Spaghetti Junction') and the Digbeth Branch Canal, the campus comprises accommodation blocks, leisure facilities, lecture theatres and laboratories. A series of upgrades across the estate were completed in 2016 and the construction of a medical school was completed in 2015.

(2) Birmingham City University (BCU) is serviced by three campuses spread across Birmingham: Perry Bar (North), Eastside (Central), and Edgbaston (South). The central campus, less than a mile from Birmingham's geographic centre is part of the £6-8 billion Eastside Development which opened in 2015; it is bordered to the East by the Digbeth Branch Canal. The estate encompasses other locations including International College (Bourneville) and the Birmingham Conservatoire (Central). BCU was awarded EcoCampus™ platinum in 2013.

(3) Canterbury Christchurch University (CCCU) comprises three campuses and a number of other locations across Canterbury and Kent. The North Holmes Campus encompasses only a small part of the university's presence in Canterbury, which has expanded across the city with a newly built library, student accommodation and student services building in the Southern quarter. The institution also delivers services from sites located in Broadstairs (on the East Kent coast) and Medway, as a part of the 'Universities at Medway' collaboration with the Universities of Greenwich and Kent (situated at the mouth of the River Medway).

(4) De Montfort University (DMU) has consolidated its estate in recent years following a period of expansion across the South East of Leicester. As a result many outlying properties have been sold and operations are now focused on a campus in Leicester City Centre. A number of significant construction projects have been completed in recent years, including a performing arts building at the centre of a £136 million campus development plan (completed in 2015). The campus is bounded in the West by the River Sour and Leicester City centre in the East.

(5) Glasgow Caledonian University's (GCU) main campus is situated in the centre of the city of Glasgow, Scotland's second largest city. The hub of the campus is the Saltire Centre, completed in 2006, adjacent to the institution's main halls of residence, Caledonian Court. The institution has recently established itself in a number of additional locations, in East London (as the British School of Fashion) and the SoHo district of Manhattan, New York.

(6) The University of Keele is situated on a single campus set in 600 acres of the North Staffordshire countryside. It is the largest main university campus in the UK, with 35 academic buildings, six halls of residence, a science park and a conference centre. A programme of redevelopment and expansion of halls of residence was completed in 2017 and it has had an energy management system certified to ISO50001 standards since 2013.

(7) The University of Oxford, the oldest university in the English-speaking world (ca. 1096) is a collegiate university comprised of 38 self-governing colleges governed by a federal system. The functional estate comprises 235 buildings and 140 commercially managed properties across the city of Oxford (including the Bodleian Library, Radcliffe Camera, Sheldonian Theatre, and Ashmolean Museum). Some 25% of the buildings on the estate are listed, with the oldest dating to 1424. The current estate development strategy proceeds to 2018.

(8) The University of Salford has facilities spread over a number of sites in Salford, a borough of Greater Manchester. The main campus, Peel Park is located on the banks of the River Irwell two miles west of Manchester city centre. The institution occupies building space across Manchester, most notably since 2011 at MediaCityUK™ (Salford Quays). The institution constructed and opened a new £55 million theatre and media centre in 2016. In 2012 Salford was awarded EcoCampus™ Silver.

(9) The University of Winchester is located near the centre of the city of Winchester, Hampshire. King Alfred Campus, the university's main site has undergone significant development in recent years including construction of a new university hub (featuring a Student's union, reception, bookshop and café) and more recently in 2013, a new art and teaching facility. Facilities are also situated at the West Downs campus (300 metres from King Alfred Campus); the predominant location for self-catered accommodation. Just over a mile away are the sports facilities at Bar End, South East of the main campus.

(10) The University of Southampton is located in the north of the City of Southampton. As a multi-campus institution, there are clusters of university buildings and operations spread out around the city of Southampton and the wider area of South Hampshire. The hub of activities and main administrative centre is Highfield Campus, located to the north of the suburb of Portswood. The surrounding satellite campuses of the Avenue Campus, Boldrewood, National Oceanography Centre and Southampton General Hospital are serviced by a number of halls of residence ranging in size, from those housing only a handful of students (Shaftesbury Avenue) to over 1,900 (Glen Eyre Halls). Further halls complexes are dotted around the city with capacity for over 5000 students.

Table 29 shows the emission sources that are reported in the EMR by the 10 institutions. Records for the consumption of natural gas, fuels, and water are submitted to the HESA for each of the institutions. During reporting, the HESA undertakes sense-checks of the data, which results in a record of significant reliability. This is conducted using a series of techniques, including standard data-cleansing practices and checking for data validity, completeness, and consistency across years in the record. Due to the longstanding record in the EMR, covering many concurrent years, reporting of exceptions is possible and assists in providing validation.

These practices afford practitioners the confidence in the recorded data, which can be used as an important open-source resource for the sector as a whole. For the purposes of this study, due to the stringent data quality requirements, data obtained from this record were assumed to be of such quality that little or no data processing was required to improve it. What is unclear from this analysis is testimony of the data's confidence, or the prevalence of data gaps, impossible for the researcher to identify due to the EMR being a secondary data source; raw data does not accompany the HESA data download. Interestingly, many environmental performance indicators proposed in the USM methodology are missing from the EMR record, including well-to-tank, well-to-grid emissions, and visitor journey emissions.

Table 29: Emissions sources reported to the estates management record in the academic year 2015/16.

Emission source	Institution ID									
	AU	BCU	CCU	DMU	GCU	UoK	UoO	US	UoW	UoS
Natural gas consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fuel and gas oil consumption	✓									
Fleet vehicles fuel consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Consumption of heat/steam							✓			
Consumption of biofuels	✓									
Consumption of biomass		✓		✓		✓				
Business travel by mode	✓	✓	✓	✓						
Commuter travel by mode	✓		✓	✓	✓		✓			
Multimedia Supplies	✓	✓		✓	✓		✓			
Library and written supplies	✓	✓		✓	✓		✓			
Catering supplies	✓	✓		✓	✓		✓			
Medical/surgical supplies	✓	✓		✓	✓		✓			
Agricultural/horticultural supplies	✓	✓		✓	✓		✓			
Furniture and textiles	✓	✓		✓	✓		✓			
Janitorial supplies	✓	✓		✓	✓		✓			
Water consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Computer/ICT equipment	✓	✓		✓	✓		✓			
Laboratory supplies	✓	✓		✓	✓		✓			
Workshop supplies	✓	✓		✓	✓		✓			
Printing	✓	✓		✓	✓		✓			
Telecommunications	✓	✓		✓	✓		✓			
Stationary	✓	✓		✓	✓		✓			
Security equipment	✓	✓		✓	✓		✓			
Vehicles	✓	✓		✓	✓		✓			
Estates – building/construction materials	✓	✓		✓	✓		✓			
Estates – plant purchase	✓	✓		✓	✓		✓			
Estates – grounds maintenance equipment	✓	✓		✓	✓		✓			
Capital equipment	✓	✓		✓	✓		✓			
Waste fraction emissions by treatment type	✓	✓		✓	✓		✓			
Wastewater	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

AU, Aston University; BCU, Birmingham City University; CCU, Canterbury Christchurch University; DMU, De Montfort University; GCU, Glasgow Caledonian University; UoK, University of Keele; UoO, University of Oxford; US, University of Salford; UoW, University of Winchester; UoS, University of Southampton.

5.2.4 Test Parameters

The performance of the developed universal methodology was examined against a series of test parameters. These parameters, taken from published studies, represent baseline scenarios for each of the three key hindrance factors outlined in Table 22. The factors are defined in Table 30.

Table 30: Baseline test parameters used to measure the performance of the universal higher education carbon footprinting methodology.

Factor	Issue descriptor	Performance Measure	Proposed methodological solution
Time constraints (P1)			
	Due to the multiple priorities of HEI environment managers.	A baseline unit of 150 hours (*per annum*) based on a fully costed finance model*.	Limit the methodological steps and avoid the necessity to collect third party data.
Financial limitations (P2)			
	Decreasing the time spent compiling GHG assessments has a direct influence on the cost required and preserves valuable time.	£1210 per day or £160 per hour**. Total cost of £24,200, based on a fully costed finance model.	Limit the methodological steps and avoid the necessity to collect third party data.
Data reliability (P3)			
	The propensity for an experiment or study to be repeated and yield identical results relies on good experimental design.	Satisfy the requirements for external verification to the ISO14064-part 3 standard.	Standardise the data collection approach and provide data collection scenarios.

* Based on a comparative estimate of the time taken to produce GHG reports, reported by the Environment Manager of the UoS and in consultation with industry consultants Carbon Credentials Energy Services Ltd.

** Hourly price is based on the average industry consultant rate, from four industrial consultancies: Carbon Credentials Energy Services Ltd; Carbon Footprint Ltd; Arup Group Ltd; and Ricardo Plc.

The amount of time spent on collecting data and inputting into the HEICC was recorded and compared against P1; a baseline time of 150 hours. This baseline was taken as the average time a dedicated consultancy team (at ‘consultant’ grade) would require to complete a comparable GHG reporting project. A test was set to see which of the respondents could complete their HEICC tools with a full dataset in 150 hours or less. This duration was determined from gathering information on the estimated time taken to produce GHG reports by the environmental manager of the UoS, consultancy partners Carbon Credentials Energy Services Ltd and other industrial contacts in HE. If this could be achieved, the USM was considered to have performed positively against the baseline of existing methodologies.

Temporal performance was deemed to be directly related to financial performance. Thus, P2 was an average hourly consultancy rate of £160 per hour (once again, at ‘consultant’ grade) applied to the baseline temporal parameter (P1). This was the cost of the consultant; though it is acknowledged that the cost to the institution may be higher if completed internally, primarily due to the cost of overheads, including: associated energy consumption and payroll (plus national insurance and pension contributions). A 150 hour project resulted in a total estimated project cost of £24,200 based on this costing model; the fewer hours needed to conduct the work, the fewer costs involved in using the USM to assess GHG emissions.

5.2.4.1 ISO14064-part 3 Verification

Data reliability could not be measured directly, but was instead inferred using a proxy. The act of external verification was the measure chosen to demonstrate good data reliability; whether the requirements of external verification could be satisfied would mean data were of significant quality to use in GHG assessments. Although numerous standards by which GHG assessments can be verified exist, ISO14064-part 3 was chosen for this study, due to its widespread use internationally for assessing the provenance of GHG assertions; as evidenced by its inclusion on the list of verification standards accepted by the Carbon Disclosure Project (CDP). For this reason it was therefore deemed of sufficient scope and robustness for use in this study.

In practice, verification ensures that carbon disclosures meet established standards of quality, confidence and completeness and in addition, is a useful mechanism for establishing the eligibility of data for reporting. A number of approaches can be taken to assess the quality of data that informs an organisational carbon footprint. In many instances, this is a simple numerical sense-check to ensure that values are within expected limits. For readily available data and where data is comprised over multiple years, assessing the quality of data involves straight-forward procedures and conducting an assessment via this method is appropriate.

Often discrepancies within 5% are deemed immaterial (‘*de minimis*’) and such errors are discounted and attributed to scientific uncertainty. In GHG accounting, emissions from *de minimis* sources can be approximated, rather than through careful quantification or excluded from reporting altogether (Busch, 2011). This helps organisations to prioritise their efforts with regard to GHG record-keeping.

In practice, verification is conducted by independent and accredited third-party organisations, which offer two assurance levels; "reasonable assurance engagements" or "limited assurance engagements" (International Organization for Standardization, 2006). These describe the user’s intentions for verification where the former refers to whether the information contained in the

GHG assessment is 'materially correct and is a fair representation of GHG data prepared in accordance with the related International Standard on GHG quantification, monitoring and reporting'. The latter does not conform to these statements.

In this study, data were assessed for: i) completeness, consistency, accuracy, transparency, relevance, and (as appropriate) conservativeness of the GHG information, including origins of the raw data; ii) appropriateness of selected baseline scenarios and GHG baseline quantification methodologies; iii) uniformity in approaches to collate, transfer, process, analyse, aggregate, disaggregate, adjust, and store information across the organisation's facilities; iv) crosschecking of the GHG information through other quantification methodologies; v) uncertainties in the GHG information arising from different data sources or GHG quantification; vi) the accuracy of equipment to meet the required accuracy of reporting; vii) any other factors that are likely to significantly affect the GHG information; and viii) the appropriateness of selected GHG estimation and quantification methodologies.

The verification process is designed to ensure the appropriateness of organisational carbon disclosures and generally takes a qualitative approach to data quality assessment. In other instances, widespread verification of numerical data is conducted using quantitative means e.g. in post-LCA studies. Further quantitative assessment of the data quality was performed using a data quality rating (see below).

5.2.4.2 Data quality rating

In conjunction with methodological verification, the qualities of submitted data were qualitatively assessed using a pedigree matrix. Data were assessed on a five point scale (1, best quality; 5, worst quality) against five data quality indicators (reliability, completeness, temporal correlation, geographical correlation, and further technological correlation) (Weidema & Wesnaes, 1996). Descriptors for each of these indicators can be found in Table 31, used to calculate a data quality rating (DQR) for each data point calculated for each institution. Eq. 6 shows the method used to calculate DQR by summing the pedigree matrix scores:

$$DQR = \frac{R + Co + TeC + GC + TC + Wi * 4}{i + 4} \qquad (6)$$

where, R, Co, TeC, GC and TC are the scores assigned to the data quality criteria.

Table 31: Data quality descriptors in a pedigree matrix for deriving DQR, adapted from Weidema & Wesnaes, 1996.

Indicator Score	1	2	3	4	5
Reliability (R)	Verified data based on measurements	Verified data partly based on assumptions	Non-verified data partly based on assumptions	Qualified estimate (e.g. by industrial experts)	Non-qualified estimate
Completeness (Co)	Representative data from sufficient sample of sites over an adequate period	Representative data from a smaller number of sites but for adequate periods	Representative data from an adequate number of sites but from shorter periods	Representative data but from a smaller number of sites and sorter periods or incomplete from an adequate number of sites	Representative ness unknown or incomplete data from a smaller number of sites
Temporal correlation (TeC)	Less than three years of difference to year of study	Less than six years difference	Less than 10 years difference	Less than 15 years difference	Age of data unknown or more than 15 years of difference
Geographical correlation (GC)	Data from area under study	Average data from larger area than that under study	Data from area with similar production conditions	Data from area with slightly different production conditions	Data from unknown area with different production conditions
Technological correlation (TC)	Data from enterprises, process and materials under study	Data from processes and materials under study but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials but same technology	Data on related processes or materials but different technology

5.2.5 Beta test of the data collection tool

Prior to commencing data collection, the HEICC system was externally beta-tested (also known as user-acceptance testing). As per established rules of beta-testing, a sample of the intended audience (in this case, HEI environment managers) tried out the tool and provided generalised feedback based on a series of pre-prepared questions sent via email. This was conducted after the alpha test, performed on colleagues in the UoS's Centre for Environmental Sciences and the Estates and Facilities Department in autumn 2015. Local independent university environment managers were chosen to conduct the beta-test. Respondents were: i) local, because they were from the Universities of Winchester, Southampton Solent, Bournemouth, and Portsmouth); and ii) independent because they were not expected to take part in the full study to maintain impartiality. Feedback was required on open questioning in three key areas:

"Usability" - defined as the ease by which the tool could be navigated and completed.

- How simple did you find the tool to use?
- Did you know what you needed to do?
- Did you understand what was being asked of you?
- Have you used a tool like this before?
- What could be improved?
- Was the tool presented in a logical structure?
- Would you like some instant analysis of your input data?
- How would this analysis improve your understanding of the tool?
- What form of analysis would you find most useful?

"Complexity" - defined as the ease by which accompanying guidance notes and built-in prompts could be understood.

- Were the instructions prescriptive?
- Did the instructions provide enough relevant information to complete the exercise?
- Was the language easy to understand?
- Were technical terms explained?
- How useful were the built-in prompts?
- Was there any additional information/guidance you required?

"Accessibility" – defined as the ability to access, edit and select sensitive content in the tool.

- Would you have liked the tool to have given you more permission to make amendments?
- Would you have liked the tool to have given you less permission to make amendments?
- Did seeing the formulae detract from what you were being asked to do?
- Did viewing the emission factors used in the calculations help you to use the tool?
- Would you have liked to have been able to access more of the tool?

5.3 **Results**

5.3.1 **Results of the HEICC beta test**

5.3.1.1 Usability

The HEICC tool was deemed by the beta test sample of institutions to be suitable for gathering and analysing GHG data, collected in-line with the UM. However, numerous suggested improvements were identified that were either incorporated into the tool in order to make it more user-friendly. Where suggestions were rejected, they were disregarded with a suitable justification. The usability of the tool and the user interface that respondents were presented with was a particular source of interest and was where many changes to the tool were made for version 2.0.

Firstly, the use of an excel-based tool was not contested by respondents, however changes to the structure of the tool were made, based on the suggestions that real-time data analysis of data inputs was more beneficial to the user. This entailed the addition of emission factor tabs, calculation lookups, and validation lists which overly improved the quality of the interface. Analysis was focused on providing headline results on Scopes 1, 2, and 3, as well as normalised against the three HE-relevant KPIs previously considered in Chapter 3 of this thesis (staff and student full-time equivalent (FTE) numbers, gross internal area, and spend).

5.3.1.2 Complexity

Few changes were made to the instruction sheets provided to study participants, as the majority of respondents in this initial test found the instructions prescriptive and sufficiently containing enough information for the data sources relevant to them. Many of the hints and tips were amended and a summary sheet was added which provided explicit guidance on the expectations of the respondent in using and completing the tool. This helped to explain more of the technical jargon, highlight the means by which the data were being analysed in real time, and consequently, improve overall usability.

5.3.1.3 Accessibility

Due to the addition of an analysis tab, the need arose for complex formulae to be written, which therefore needed locking to prevent the user from inadvertently breaking the tool. Formulae and superfluous pages were hidden and non-editable cells were locked, whilst all effort was made to avoid compromising on the level of access the respondents desired. This was achieved by making it extremely evident where cells could and could not be edited. This did affect the accessibility of the tool, but this was not deemed to be a significant issue by respondents, because the real-time information was of greater value than tool accessibility. The locking of cells hides formulae, which had a number of benefits for improving accessibility, since it would reduce the likelihood of overall confusion and show the editable cells more clearly.

5.3.2 Prevailing methodologies

The results outlined here are taken from the semi-structured interviews conducted at the beginning of the study and are combined with an interrogation of their publicly-available documents, primarily the institutions' sustainable travel plan, sustainable procurement plan, annual report, and corporate governance report (if available). Transcripts for each of the semi-structured interviews accompany this thesis are available from the University of Southampton's research repository. Table 34 is the output from these interviews, and shows a comparison of the attributes of data collection procedures at the 10 institutions.

Generally, confidence in reported data was found to be highest for Scope 1 and 2 emission calculations. As expected, this was in direct support of the findings in Chapter 3. All institutions sampled had automatic metering systems (AMS) which provided high quality electricity and natural gas data for use in carbon footprint calculations (either half hourly or invoices based on (typically) actual reads). More variation in Scope 1 fuel usage data was evident; either calculated using mileage data obtained from fuel card receipts, internal account systems and through the finance department records or mileage on MOT certificates. The UoS rated Scope 1 emission methodology more conservatively than the rest of the sample, rating the source originating from the consumption of natural gas as 'medium-high' confidence. Scope 2 emission sources were consistently rated as 'High'. Only the University of Winchester rated medium confidence in Scope 1 and 2 calculations. This would correspond with the concept of data tiers introduced in 2.7.9, which stated that there is more certainty with directly measured data.

The data confidence for emissions from water consumption was rated 'high' by all 10 institutions, however Scope 3 emission sources were rated consistently low. Sources rated a 'low' confidence level most frequently were i) business travel and ii) procurement; the former being applicable to four institutions and the latter to six institutions. These particular emissions sources did not have well-established data collection processes and the means by which data were identified and collected differed the most out of any other emission source interrogated. This was also to be expected, once again in direct support of previous assertions made in Chapter 3 of this thesis. For Scope 3 targets, the majority of institutions prioritised activity-led targets (for example, reducing the number of single occupancy commuter cars, decreasing waste arisings, or promoting sustainable procurement. This was found to be contrary to the method of setting scope 1 and 2 emissions targets, usually based on absolute emissions reductions (or intensity metrics that led to absolute emissions reductions).

Two predominant environmental standards could be seen as the preferred choice of methodology; the GHG protocol and the HEFCE guidelines. The latter borrowed heavily from the GHG protocol in many of its characteristics. The time boundary was found to be identical and followed an annual reporting period, which began at the start of the academic year (officially September in the United Kingdom) with a small difference from institution to institution distributed across late summer and early autumn.

A disparity in the number of personnel tasked with collecting data and compiling reports was also identified. The ratio of these individuals against the number of FTE staff and students is revealed in Table 32. Institutions with the lowest ratio of personnel include Glasgow Caledonian and the University of Salford at 1:14720 FTE staff/students and 1:17340 FTE staff/students respectively. In compiling assessments, responsibility is broadly held by estates and facilities departments, sustainability teams or dedicated strategic management groups.

Table 32: The ratio between staff & students and personnel compiling GHG emission assessments at the participant institutions.

Institution ID	Personnel	$\sum_{\text{FTE Staff and Student}}$	Ratio
Aston University	4	9820	1 : 2455
Birmingham City University	5	20520	1 : 4104
Canterbury Christchurch	10	13075	1 : 1308
De Montfort University	9	17200	1 : 19111
Glasgow Caledonian University	1	14720	1 : 14720
University of Keele	1	9480	1 : 9480
University of Oxford	9	31115	1 : 3457
University of Surrey	1	17340	1 : 17340
University of Winchester	2	6865	1 : 3433
University of Southampton	5	26895	1 : 5379

Table 1: Comparison of data collection methodologies of the study group universities

	Institution									
	Aston University	Birmingham City University	Canterbury Christchurch	De Montfort University	Glasgow Caledonian	University of Keele	University of Oxford	University of Salford	University of Winchester	University of Southampton
FTE Staff allocation	4	5	10	9	1	1	9	1	2	5
Guidelines followed	GHG Protocol	HEFCE	GHG Protocol	GHG Protocol	GHG Protocol	HEFCE	GHG Protocol	HEFCE	GHG Protocol	HEFCE
Organisational boundary – sites incl./excl.	Main campus, excl. halls	Centre, North, South campuses	Canterbury, Broadstairs, Medway campuses	Main campus and halls incl. private halls	Glasgow campus and halls	Main campus, university hospital	Main buildings, excl. colleges	Main campus excl. halls	King Alfred, West Downs campuses	Highfield, Winchester, Boldrewood, Avenue campuses
Confidence: Scope 1	High[a b]	High[a b]	High[a b]	High[a b]	High[a b]	High[a b]	High[a b]	High[a b]	High[a b]	Medium[b] - High[a]
Confidence: Scope 2	High[c]	High[c]	High[c]	High[c]	High[c]	High[c]	High[c]	High[c]	High[c]	High[c]
Confidence: Scope 3	Low[f] Medium[c] High[g]	Low[f] Medium[e h] High[g]	Low[d f] Medium[h] High[g]	Low[d f] Medium[e h] High[g]	Medium[d e] High[f g h]	Medium[d] High[g h]	Low[d f] Medium[e h] High[g]	Low[e] Medium[h] High[g]	Low[h] Medium[d] High[g]	Low[d f h] Medium[e] High[g]
Origins: Scope 1	AMS Data[a]	AMS Data[a] MOT mileage[b]	AMS Data[a] Invoice Data[b]	AMS Data[a] Internal records[b]	AMS Data[a] Mileage records[b]	AMS Data[a] Mileage records[b]	AMS Data[a] Mileage[b]	AMS Data[a] Fuel Card[b]	Utility Data[a] Spend[b]	AMS Data[a] Fuel Card[b]
Origins: Scope 2	AMS Data[c i]	AMS Data[c i]	AMS Data[c i]	AMS Data[c i]	AMS Data[c i]	AMS Data[c i]	AMS Data[c i]	E: AMS Data[c i]	Utility Data[c]	AMS Data[c i]
Origins: Scope 3	Travel Agent[d] Annual survey[e] Spend[f] AMS Data[g] Waste mass[h]	Survey (one-off)[e] Spend[f] AMS Data[g] Waste mass[h]	Expenses/Travel Agent[d] Spend[f] Bills[g] Contractor mass records[h]	Spend/ Travel Agent[d] Annual Survey[e] Spend[f] AMS Data[g] 95% wastewater[h]	Travel Agent/ Mileage[d] Triennial Survey[e] Paper spend[f] Spend[g] Contractor mass records, 95% wastewater[h] Electricity calculations[j]	Rail, Air,Mileage Spend[d] AMS Data[g] Contractor mass records[h]	Expenses[d] Triennial Survey[e] Spend[f] AMS Data[g] Spend[h]	Biennial survey[e] AMS Data[g] Mass records[h]	Expenses/Travel Agent[d] Utility Data[g] Calculation based on average data, number of bins and use frequency[h]	Spend/Travel Agent[d] Biennial survey[e] Spend[f] AMS Data, 95% wastewater[g] Contractor mass records[h]
Scope 1 and 2 Target	-48% below 05/06 by 2020[a b c]	-48% below 05/06 by 2020[a b c]	-57% below 09/10 by 2020[a b c]	-43% below 05/06 by 2020[a b c]	-20% below 08/09 by 2014[a b c d g h]	-34% below 1990[a b c] & 50% onsite gen by 2020[c].	-33% below 05/06 by 2020[a b c]	-43% below 05/06 by 2020[a b c]	-30% below 06/07 by 2015[a b c]	-20% below 05/06 by 2020[a b c]
Scope 3 Targets	Modal shift[e] Non-specific, rolling upgrades[g] Zero waste to landfill[h]	Modal Shift[e] Non-specific, adoption of sustainable policy[f] Non-specific, rolling upgrades[g] Zero waste to landfill[h]	Total: -35% below 09/10 by 2020[d g h] -20% below 11/12 by 2020[e]	Total: -14% below 05/06 by 2020[d e f g h] <45% single occupancy car[e] $3m^3$ per student by 14/15[g] Recycle 85% non-res waste by 17/18[h]		Non-specific Modal shift[e] Flexible Framework[f] Non-specific, rolling upgrades[g]	18% staff car travel & 5% increase in alternatives by 2012[e] Non-specific, adoption of sustainable policy[f] -11% below 09/10 by 2015[g] Zero waste to landfill[h]	Non-Specific reducing need[d] Non-specific Modal shift[e] Non-specific, adoption of sustainable policy[f] Increase recycling to 50% by 2016, reduce normalised quantity[h]		Non-Specific reducing need[d] Targets by mode[e] Non-specific, adoption of sustainable policy[f] 75% recycling rate by 2016, 85% recycling for refurbishments[h]
Time Boundary	1 Year	1 Year	1 Year	1 Year	1 Year	1 Year	1 Year	1 Year	1 Year	1 Year
Reporting Date	Oct-Oct	Aug-Aug	Sept-Sept	Sept-Sept	July-July	Aug-Aug	Oct-Oct	Sept-Sept	Sept - Sept	Aug-Aug
Responsibility for carbon management	Environment & Sustainability Team	All key personnel in Estates	Sustainability Strategic Management Group	Estates Department	Carbon Management Team – Key Estates Personnel	Carbon Management Group – Key Estates Personnel	Sustainability Team	Key Estates Personnel	Carbon Management Team – Key Estates Personnel	Estates Department

[a] Referring to fuel usage (oil and gas)
[b] Referring to vehicle emissions
[c] Referring to emissions from electricity generation
[d] Referring to business travel
[e] Referring to Commuter travel
[f] Referring to Procurement emissions (excluding water consumption, unless specified)
[g] Referring to emission from water consumption
[h] Referring to emissions from waste
[i] Automatic Measuring System (AMS)
[j] Referring to the embedded emissions of electricity supply (transmission and distribution networks)

5.3.3 GHG contribution analysis

The emission sources for which data was returned by respondents during methodology testing are presented in Table 34. Typically, full data coverage for the reporting period was received for Scope 1 and 2 emissions sources; where activity data was missing, consumption was pro-rated using established pro-rating techniques for missing data (see: Environment Agency, 2014). Only ten emission sources were quantified by all institutions. No data was received on downstream leased assets for any institution. It is important to note that numerous other emission sources were irrelevant for some institutions (such as the consumption of burning oil, LPG, or biofuels) since the activity was not carried out on their estate and thus not included in their operational boundary. In these instances, data from these sources was not considered to be purposefully absent.

Table 34: Data reported through the HEICC tool by emission source by study participants, with associated aggregated DQR score, descriptor (poor, fair, or high quality), and associated data coverage.

Emission source		DQR			Institution ID									
		Score	Descriptor	Coverage	AU	BCU	CCU	DMU	GCU	UoK	OoO	US	UoW	UoS
Direct energy emissions	Natural gas consumption	1	High quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Burning oil consumption		No Data											
	Fuel and gas oil consumption	1	High quality	10	✓									
	LPG and LNG consumption		No Data											
	Fleet vehicles fuel consumption	1	High quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Consumption of biofuels	1	High quality	10	✓									
	Consumption of biomass	1	High quality	10		✓		✓		✓				
Land use changes	Landscaping activities	1	High Quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Agricultural activities		No Data											
Indirect energy emissions	Electricity consumption	1	High quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Consumption of heat/steam	1	High quality	10							✓			
Energy-related activities	Well-to-gate emission - natural gas	3.2	Poor quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Well-to-wheel emissions - fuels	3.2	Poor quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Well-to-gate emission - electricity	3.2	Poor quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Well-to-gate emissions - steam	3.2	Poor quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Well-to-gate emissions - biofuels	3.2	Poor quality	10	✓									
	Well-to-gate emissions - biomass	3.2	Poor quality	10		✓		✓		✓				
Travel	Business travel grey fleet	3	Fair quality	5	✓			✓						✓
	Commuter journeys by car	2.3	Fair quality	4			✓	✓		✓				✓
Waste	Waste fraction emissions	2.7	Fair quality	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Wastewater	2.6	Fair quality	10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Downstream leased assets	Natural gas consumption		No Data											
	Electricity consumption		No Data											
	Consumption of heat/steam		No Data											

DQR, data quality rating; LPG, liquid petroleum gas, LNG, liquid natural gas.
AU, Aston University; BCU, Birmingham City University; CCU, Canterbury Christchurch University; DMU, De Montfort University; GCU, Glasgow Caledonian University; UoK, University of Keele; UoO, University of Oxford; US, University of Salford; UoW, University of Winchester; UoS, University of Southampton.

Each data source was rated using the DQR criteria outlined in the pedigree matrix (Table 31). Data that were consistently rated as high quality included the Scope 1 sources (natural gas consumption, fuel, and gas oil consumption, fleet vehicles fuel consumption) and scope 2 sources (electricity consumption). Travel (business grey fleet travel and commuter car journeys) was regarded as fair quality, whilst well-to-gate emissions data was rated as poor. Since no data was collected for downstream leased assets or LPG consumption, the DQR was not calculated.

Annual GHG emissions from the Scope 1–3 sources in Table 34 for the participant institutions are summarised in Figure 21. The most significant emission sources across institutions were stationary combustion, purchased electricity and commuter car emissions. On average, Scope 1 emissions contributed 40% to the institutional GHG emissions, whilst Scope 2 contributed 49%. On average, the six Scope 3 emission sources included in the USM accounted 11% of the footprint of the institutions on average (ranging from 25.6% to 6.5%). The remaining sources (process emissions, fugitive emissions, and purchased heat/steam) collectively contribute less than 5% of total scope 1–3 emissions and can therefore be classified as *de minimis*. Stationary combustion typically contributed 99% of Scope 1 emissions, purchased electricity 99% of Scope 2 emissions and energy-related emissions 90 % of the Scope 3 sources considered.

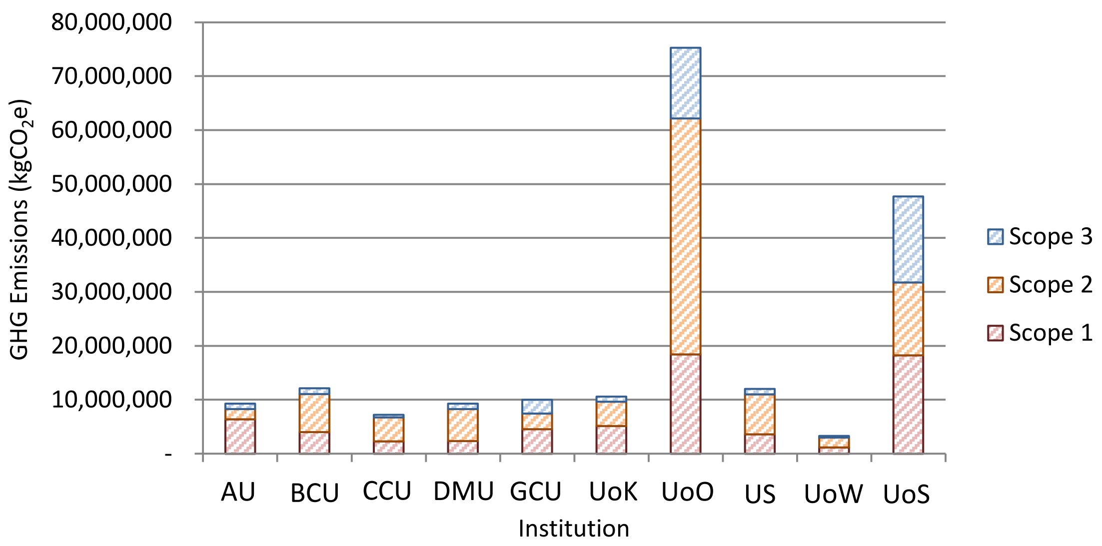

Figure 21: 2015-2016 GHG emissions of the 10 participant institutions quantified in accordance with the proposed USM.

AU, Aston University; BCU, Birmingham City University; CCU, Canterbury Christchurch University; DMU, De Montfort University; GCU, Glasgow Caledonian University; UoK, University of Keele; UoO, University of Oxford; US, University of Salford; UoW, University of Winchester; UoS, University of Southampton.

5.3.4 Participant experience

After the study, participants were asked once again to rate their attitude towards the carbon footprint and the status of their data collection systems. This echoed (and can be compared to) the rating presented in Figure 17 in Chapter 4 where respondents were asked to rate where their attitude placed along a continuum of seven adjective pairs: adequate-inadequate; chaotic-ordered; open-sensitive; complex-simple; old-fashioned-modern; ineffective-effective, and innovative-non-innovative. It was evident that respondents found a number of improvements using this methodology over their previous methodology in a number of categories, including 'adequate', 'open', and 'innovative'. Conversely, the mean score given to a number of other categories was skewed to a more negative outlook; including the 'chaotic', 'old-fashioned', and 'ineffective' categories. Figure 22 shows the pre-study and post-study attitudinal responses recorded.

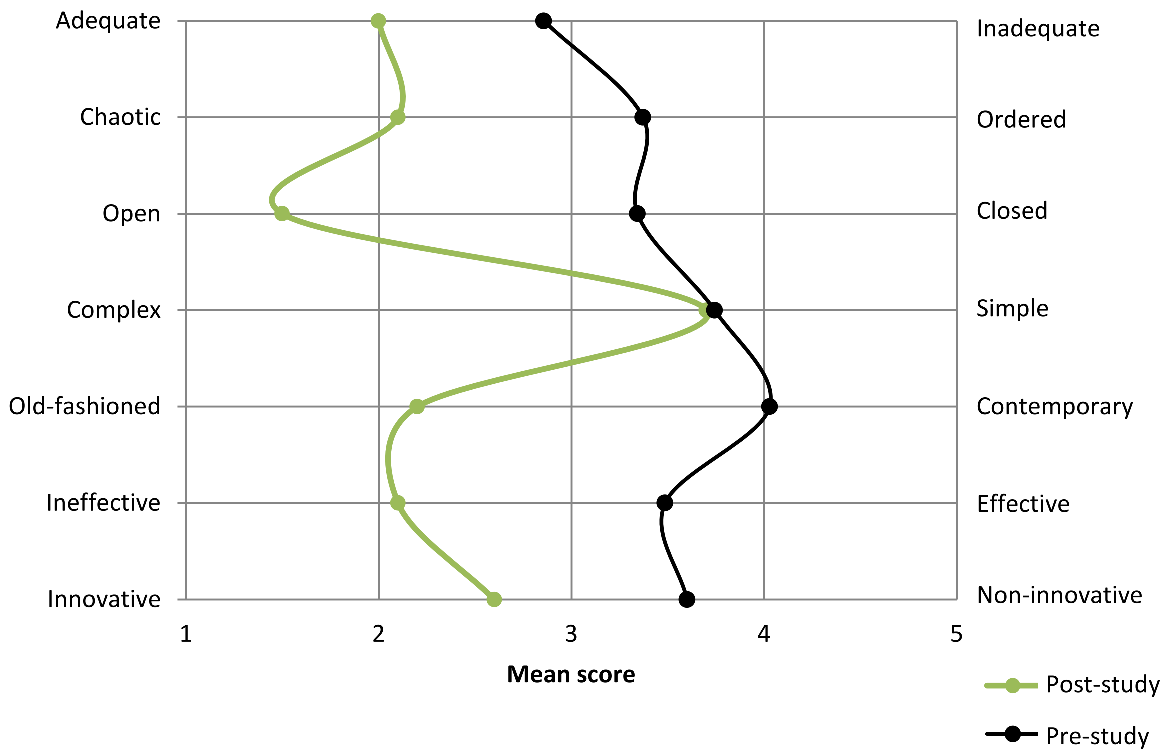

Figure 22: Study participant attitudes pre- and post-study; adjective pairs rated through semantic differential questions.

5.3.4.1 System usability score results

When asked to rate the system based on its usability, respondents were broadly positive. The SUS score was calculated by converting responses (total n =50) to a score out of 100, following the methodology set out in Bangor *et al.,* 2008. The SUS is a 'quick and dirty' survey scale for allowing an easy assessment of the usability of a product or service. The SUS is composed of 10 statements score on a five-point scale based on strength of agreement. The higher the score, the more usable the product or service is deemed to be. The average SUS score across all 10 respondents was 69.3; narrowly above the average published SUS score for usability (based on the *percent*ile grading of scores where 80.3 or higher is rated an A, 68 is a C, and 51 or under is an F rating. Higher scores demonstrate greater usability, ease of learnability, and an increased proclivity for users to recommend the system to others; results can be seen in Table 35.

Additionally, questions about the ease of reporting data for each emission scope revealed a degree of ambivalence; when asked about the amount of time required to complete the work, the responses were predominantly for 'neither strongly agree or strongly disagree' for Scope 1 and 2 emission sources. Of particular interest were the responses that were skewed towards 'disagree' for Scope 3 emission sources; evidently despite the streamlined process, for some, the Scope 3 requirements were still rather time consuming. When asked how satisfied respondents were about the ease of collecting Scope 1, 2, and 3 emission data responses were more frequently 'strongly agree'. The support and guidance received during the study was reported positive and was evidently well received. Six respondents advocated the need for additional assistance in completing the tool with the data requested.

Table 35: System Usability Scores assigned by participating institutions, rating the HEICC tool developed to collect GHG data in-accordance with the USM.

Institution ID	SUS Score
Aston University	63
Birmingham City University	65
Canterbury Christchurch	45
DeMontfort University	75
Glasgow Caledonian	88
University of Keele	63
University of Oxford	48
University of Salford	63
University of Winchester	93
University of Southampton	93
$\underline{x}$	69

5.3.4.2 Test parameter performance

With regards to the performance of the system, it is once again pertinent to consider the test parameters (Table 30) on page 148. Whilst the study participants described the HEICC and USM as usable (as revealed by the SUS), or somewhat usable to a certain degree, the test parameters quantitatively defined a baseline against which the system's performance could be measured to reveal significant advantages (or conversely, disadvantages) over the status-quo of existing methodologies.

For all participants, the USM considerably reduced the time required to identify and collect GHG information, out-performing the defined parameter by a significant margin. This demonstrated that using the UM, on average could save environment managers 81.2 hours, with a standard deviation of 25.6 hours and a range of 75 hours (the shortest duration recorded was 35 hours against the longest duration recorded which was 110 hours). The number of hours saved equates to savings of £12,992 per institution over the proposed test parameter. These results are directly comparable because all study participants were expected to identify, collect, and report identical GHG-related information on their own estates and thus, quantifiably demonstrated the first advantage the USM had over existing methodologies.

Since the linear relationship between cost and time was assumed, the time reductions already identified translated directly into significant financial savings for the participant institutions when recalculated. This demonstrated the second advantage the USM had over existing methodologies; full temporal and financial results can be seen in Table 36.

Table 36: The total time and cost results associated with participants conducting the methodological test.

Institution ID	$\sum_{Time}$	$\sum_{Cost}$
Aston University	75	12,000
Birmingham City University	40	6,400
Canterbury Christchurch	60	9,600
DeMontfort University	95	15,200
Glasgow Caledonian	82	13,120
University of Keele	43	6,880
University of Oxford	110	17,600
University of Salford	35	5,600
University of Winchester	58	9,280
University of Southampton	90	14,400
$\bar{x}$	69	11,008
SD	26	4089

The third and final parameter was data reliability, defined as the potential for the data reported to satisfy the requirements of ISO14064-3 verification. Simply, this was evaluated through conducting an independent verification of the calculations of the HEICC using the raw data supplied by the respondent. The process began with setting out the level of assurance and the verification's objectives; in this instance 'reasonable assurance' was chosen and the primary objective was to ensure that GHG assertions were verifiable to the ISO standard and within defined materiality limits of the verified GHG value. Secondly, the criteria of the verification were agreed against which, the reported data was measured; the ISO14064-3 criteria are presented in Table 37. Subsequently, the scope of the verification was defined, which included the organisational and operational reporting boundaries, sources of emissions, time periods, and GHGs. Materiality was once again set at a threshold of 5%; results of the verification are presented in Table 38.

Table 37: Verification criteria defined in the ISO14064-3 standard, against which the GHG assertions of the participant institutions were tested.

Principle	Definition	Comments
Relevance	Ensure the GHG inventory appropriately reflects the GHG emissions of the company and serves the decision-making needs of users – both internal and external to the company.	Selected GHG sources, data & methodologies are applicable to the organisation. Appropriate boundary is selected (organisational & operational).
Completeness	Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Disclose and justify any specific exclusion.	All relevant sources are accounted for; where actual quantification is not technically, or economically feasible, the organisation may opt to apply estimates.
Consistency	Use consistent methodologies to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series.	To enable meaningful comparisons year on year. Changes shall be documented and justified
Transparency	Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate reference to accounting/calculation methodologies and data sources used.	Sufficient information should be available to enable a third part to recalculate & reproduce the same results if given the same source data. Audit trails are clear, and available upon request
Accuracy	Ensure the quantification of GHG emissions is systematically neither over/under actual emissions, as far as can be judged. Reduce uncertainties to achieve sufficient accuracy, enabling users to make decisions with reasonable assurance as to the integrity of the reported information.	Where reasonable, uncertainty and known misreporting will be reduced as far as possible.

Table 38: Results of the independent verification to the ISO14064-3 standard, showing reported aggregated emissions against independently verified emissions.

Institution ID	Reported cumulative aggregated GHG emissions ($kgCO_2e$)	Independently verified GHG emissions ($kgCO_2e$)	Difference +/- ($kgCO_2e$)	Materiality threshold
1	9 331 354	9 331 355	0.05	5%
2	12 180 913	12 180 920	0.05	5%
3	7 243 223	7 243 500	0.05	5%
4	9 292 510	9 293 000	0.1	5%
5	10 014 362	10 017 500	0.1	5%
6	10 590 269	10 590 010	0.1	5%
7	75 277 059	75 285 100	0.2	5%
8	12 023 282	12 023 282	0	5%
9	3 292 300	3 292 300	0.1	5%
10	47 695 226	47 695 226	0	5%

As can be seen, only minor discrepancies between the reported and verified emissions were found (*n.b*. the primary researcher conducted the GHG assessment for the University of Southampton, and therefore there was no discrepancy with the verified consumption). The data repeatedly holds up strongly against the verification criteria. Appropriate boundaries are selected by each of the institutions. As was evident from the contribution analysis, all relevant sources are accounted for; where actual quantification was not feasible, the use of data scenarios became relevant and institutions were able to apply estimates based on long-established techniques (for instance, business travel-related emissions from grey fleet could be estimated using data based on the number of journeys multiplied by the average distance between the organisation's location and the destination if recorded information wasn't available). Relevant assumptions were disclosed in the tool's open text boxes and data sources were sent alongside the reported information. Finally, the quantification of GHG emissions was ensured to be neither systematically over/under actual emissions through the vouching of GHG assertions presented in Table 38.

5.4 Discussion

5.4.1 Proposed methodological amendments

The experiences of the participant environment managers during the study period are an invaluable record, which demonstrate that common difficulties are still experienced when completing the GHG assessment process using the technique. Whilst the proposed USM improves the current paradigm, the focus must now be on considering the operational realities which hinders its use. The first key improvement identified by the participants during testing was for the inclusion of market-based GHG reporting, in order to align it with current trends established by the GHG Protocol update in 2015 (Sotos *et al.,* 2015) and their own reporting procedures. More than ever, institutions are procuring low-carbon energy (through renewable energy guarantees of origin-backed (REGO) supplies) to mitigate the climate impacts of their need to consume electricity. Even for institutions operating internationally, there is now more choice on sourcing low-carbon energy. Prior to this methodological change however, these purchase agreements were not reflected in their reported Scope 2 figures and accounted mostly for total consumption. The simplest way this can be accommodated is by giving the practitioner the ability to manually input supplier-specific emission factors into the HEICC based on their electricity supply contracts/instruments.

Another issue was that some participants required additional guidance in order to satisfy all requirements of the test, despite the accompanying briefing document being written in simple terms. This included site visits and telephone calls to instruct and advise on the correct course of action regarding data collection and emission calculation. As is commonplace in this research area, there was an expectation of some assumed knowledge. Further guidance notes can be added, however, it does beg the question about the competencies of environment managers and the level to which they are trained in matters of GHG assessment. Whilst the sharing of best practice has been commonplace in the sector through networks like the EAUC, a shortfall in detailed subject knowledge is evident. Sectoral training, whether through workshops or remote webinars, provided by the HEFCE, the EAUC or other industry bodies should be explored. Internally at institutions, environment managers should be encouraged to gain the required knowledge. The urgency in HE to change this situation is somewhat lacking; because this is a common issue, collective inertia preserves the *status quo*. The evident shortfall in skills and knowledge is one possible suggestion for participants diverting from the proposed methodology, the other being that alternative methods were deemed to be more efficient (or were repeated from previous times the GHG assessment was conducted).

The inertia that is often experienced when proposing new methods of working means that for some environment managers, changing the processes they use to conduct GHG assessments will be challenging. Although the proposed USM is at its heart, sympathetic to the current internally engrained processes of institutions, further development of the means in which data is inputted would allow even greater autonomy by the participant. A number of issues were taken over the requirement for data to be formatted in a certain rigid manner; a change to this, through the allowing of data to be inputted in a number of different fashions was made to suit the individual. In particular, due to the use of excel and the functional abilities therein, participants were able if they so desired to link to their own documents with the in-built GHG calculations.

A series of additional useful features were incorporated to increase the usability of the HEICC tool and afforded the ability for participants to update the tool when required. For instance, the construction of the tool, using Microsoft Excel's 'SUMIFS' and 'VLOOKUP' functions to look up and calculate GHG emissions from a dedicated emissions factor tab, allowed the user the freedom to annually update the tool with the most current emission factors (published in the UK by Defra around June/July). This ensured that the outputs from the tool are always current and avoid the need to redesign the tool in any way. This design also assists the auditor, because the calculation methodology is transparent and traceable throughout the tool. This means verifications can be conducted with greater ease and fosters 'standardisation' which has become a key theme throughout the development of the UM. Not only this, but the user is also able to follow the calculations; in the past, calculations tools have been victim to a lack of transparency (primarily in order to protect intellectual property among other reasons), but have alienated the user as a result. The resultant 'black-box syndrome' considerably reduces the confidence the user has in the data outputs and its frequency of use.

5.4.2 A usable and verifiable methodology

The results presented here vindicate the development of a streamlined methodology for assessing the GHG emissions of universities for a number of reasons. The three test parameters, devised by institutional environment managers themselves, to some degree are improved under the conditions of the test as a result of choosing to employ the USM over other methodologies. This chapter has shown that this theoretical proposal, when practically tested on a subset of UK HEIs, overcomes many of the most significant barriers to carbon management in the HE sector identified in this research. Fewer data points means quicker data collection procedures, which rely less on external third parties to provide information, which in-turn saves considerable money for the institution; fewer resources are consumed, yet the sustainability benefits of carbon management are preserved and can even be enhanced.

The inclusion of institutions from varying locations and specialisms shows that the methodology can be amended to suit all institution types. This diversity demonstrates the ubiquitous potential and appeal for a sympathetic GHG assessment methodology which will enable HEIs across the sector to improve their GHG assessments in the future.

Furthermore, the data obtained in-line with the methodology is verifiable to external GHG standards most commonly used by industry auditors (regardless of which emission sources are included or how cut-off criteria are defined). This represents a key consideration for the potential adoption of a new GHG assessment methodology, since independent GHG verification is mandatory for many existing sustainability reporting programmes (such as the CDP). External verification adds an added element of reassurance that the data and the assertions used are legitimate and truly representative.

The ease by which existing methodologies can be transposed into the USM cannot also be underestimated. The reconciliation of the methodological steps conducted initially when developing the methodology means that many commonalities still exist. Therefore, in many cases, switching from one methodology to the other does not involve any lengthy research or learning to be able to do. Often, significantly changing the way procedures are followed, especially if they are deeply entrenched, can be viewed negatively because of beliefs that are held that the traditional way of working is the best way of working. This is often a noteworthy hindrance which stops institutions adopting improved procedures. The advantage of the USM is that significant changes are not required, with the more consequential changes being the exclusion of certain GHG emission sources.

Appendix F presents the HEICC and details of the USM in their final iterations, based on the proposed changes and experiential feedback by study participants.

5.4.3 Study limitations

The GHG emissions presented in this chapter were based on a number of subjective choices and methodological assumptions. This study was fundamentally limited by the availability of data and the associated quality of data due to the reliance on colleagues in external institutions. Although regular contact was maintained with study participants, there was an expectation that study participants would be self-sufficient following the initial project briefing. Due to the differences in experience at conducting GHG assessment of study participants, it should be acknowledged that not all issues or difficulties could be rectified or were indeed highlighted by the participants and therefore there is a degree of uncertainty is associated with data returns.

All efforts to minimise, quantify, or explain limitations have been made as far as practicably possible, however additional work is required to better address these limitations. In doing so, this will enable more informed and less uncertain decision-making pertaining to the outputs of the USM. Further exploration of the limitations in this study and of the research conducted in this thesis can be found in Chapter 7.

5.4.4 Significance of findings

The ability to measure quantifiably the environmental impact of organisations relies on compiling broad datasets from external organisations and sources along the corporate value chain (Tukker *et al*., 2006). Understanding these activities is vital in making the case for adopting cleaner methods of production and using data to monitor changes in near real-time. The generation of environmental data has grown exponentially year-on-year in recent decades due to rapid technological developments (the amount of scientific data is oft quoted as doubling every year (Szalay & Gray, 2006; Hashem *et al*., 2015). Often, a greater onus is placed upon the user to cast a critical eye over data they are selecting and fully disclosing this procedure when it is presented. This is particularly important in instances where information may be garnered from a multitude of secondary sources, and the user has waived control over the method of collection.

GHG information is used by a wide range of individuals from across the social and economic spectrum for a plethora of reasons. Policymakers consider it in the process of creating new legislation (Holmes & Clark, 2008); advocacy groups use it in environmental campaigns, financial analysts are increasingly accounting for it in risk evaluations (Pfeifer & Sullivan, 2008), and the public act upon it when adopting pro-environmental behaviour (Shaw, 2011). For organisations, technology allows for challenges to be modelled in detail and for future-proof solutions to be adopted through the operations of the organisation by its decision making body.

This methodology is developed for universities, by universities. The proposed methodology is designed with the activities of universities at its heart. Key features, which support this statement include: i) the development of a tool that can inform the EMR record; ii) the use of turnover, internal area and staff and student-related KPIs to normalise data; and/or iii) its interrelatedness against commonly used GHG assessment standards from which, transposition can be readily effected. Evidently, GHG assessments are possible with readily available data and a structured data collection methodology and data tool. For internal purposes, assessing emission sources that lay outside the boundary of the cut-off criteria still hold an invaluable place in pragmatic HE carbon management programmes.

The development of a methodology which: i) is sympathetic to its users' experiences and daily workload pressures; ii) standardises and streamlines approaches to the collection of environmental estate data; and iii) enables emissions to be aggregated at the sectoral level without the potential for double counting, has numerous advantages for sector-wide carbon management over the *status quo*. Its utility across an entire sector enables consistency of reporting and enables similar types of institutions to be easily compared. The discovery that despite similarities, diverse differences remain, demonstrates the urgent need for reform in current GHG assessment procedures employed by UK HEIs. This is something that could happen immediately with a holistic, multilaterally agreed and forward-thinking plan. Coordination of this plan could come from the many actors at play in the governing of the HE sector's purely carbon management-related activities or general sustainability-related activities *i.e.* the HEFCE, the EAUC or governing groups such as the Russel Group or the Million+ think-tank.

What is clear is that there is a need for a universal adoption of a *single* methodology. Adopting the proposed USM (or not) is left for debate by the sector. Although, it is difficult to identify any closely competing methodologies which are designed specifically for the HE sector and therefore, adopting this methodology has significant advantages. Even if adoption is not possible, increasing the transparency of tools and methodologies currently available to environment managers will also allow institutions to make significant strides towards better accountability and confidence in data inputs. This directly affects the confidence in data outputs, and therefore fosters more forthright decision-making by institutional leaders.

Whilst there may be a need for a multilateral agreement on the HE sector's 'official' GHG assessment methodology, a more pressing issue is the evident skills gap in undertaking GHG assessments. To this end, a national programme of training and best practice knowledge transfer should be introduced. This should be a continual process, perhaps adopted in-line with continuing professional development programmes administered by most professional environmental bodies to which environment managers are encouraged to join. This will eradicate the apparent skills shortfall, whilst enabling environment managers to feel continually supported, share problems, and have their questions answered.

Reporting of GHG information, based on the cut-off criteria, is made easier with the use of a data collection system that is closely aligned with current data reporting processes. Results here show that integrating data collection with prescriptive instructions and a standardised tool may facilitate the collection of effective and verifiable data. The USM saves time and has the potential for reallocating precious financial resources away from administrative tasks (data collection, data cleansing and processing, and GHG analysis) to more pressing emission reduction initiatives.

Whilst the costs quoted in this chapter may be small against the multi-million pound research budgets of the institutions featured here, the impacts should not be underestimated. Greater capital funding enables and empowers institutions to drive deeper savings against emission reduction pledges. In addition to this, research and teaching standards may also benefit, creating positive multiplier effects through increased student recruitment, staff retention and interminable growth. A streamlined and cost-effective assessment methodology means that the speed with which policies can be planned and deployed is increased exponentially. The role of the environment manager can shift to where greater impact can be made (considering also, the varied and time-pressured role they lead).

As political momentum on sustainability issues increases, universities should be committing more capital funding to ambitious GHG reduction initiatives. However, in a time where budgets are being significantly squeezed, in reality the situation is vastly different. Universities right now have an opportunity to ensure lasting progress is made against the Paris Climate Agreement's ambitions, whilst also having influence on a wider national move to sustainable development. The agenda set by the updated Sustainable Development Goals (SDGs), adopted in 2015, aims to 'end poverty, protect the planet and ensure prosperity for all' by 2030 (United Nations, 2015). The quantification and eventual reduction of GHG emissions (and by extension, emissions of substances that result in poor air quality) contributes directly to a number of the thematic aims of the 17 SDGs. Namely, (4) – quality education, (9) - industry, innovation and infrastructure, (11) – sustainable cities and communities, (12) – responsible consumption and production, (13) – climate action, and (15) – life on land. This alone demonstrates the potential that responsible and pragmatic carbon management has on the wider sustainable development agenda.

Due to their ability in shifting world paradigms, universities have for some time been a driving force on sustainable development, through their actions in conducting leading research and nurturing the minds of graduates. Through their spheres of influence, they are able to drive the agenda, embodying the 'responsible organisation' ideal and encouraging others to follow their example. Though some would argue that institutional fortunes and funding are at the behest of the incumbent government and that as a result, institutional allegiances are malleable, in the main institutions remain independent and non-partisan. Due to this strong position, and in alliance with funding networks and unique governance structures, universities can often be much more ambitious than private organisations in this field, which is disproportionate to their comparably diminutive size. It is clear that institutions do not often exploit this unique and privileged position.

5.5 Conclusions

Presented in this chapter are the results of a year-long data collection study, based on a subset of 10 UK HEIs with varying characteristics (*i.e.* location, education specialism, sources of funding, and staff and student population etc.). These differing characteristics demonstrate the diversity within the HE sector and highlight the vastly different priorities that institutions have. The results show that adoption of a universal GHG assessment methodology that streamlines onerous reporting requirements has numerous advantages, namely, that it is more cost-effective, timely, and eradicates double counting risk (when aggregated at the sector level). The time spent compiling data through a streamlined process, which requires the user to quantify and report on eight emission sources (two Scope 1, two Scope 2, and four Scope 3 sources), can be significantly reduced. This has a direct consequence on reducing the financial burden required by the institution, which can be diverted to core research and teaching activities or in implementing carbon reduction projects. Significantly, this methodology has the potential to create reliable and comparable assessments of institutions against their peers because of the means by which emission sources are included and excluded. The need for decisions to be made by environment managers over whether data sources should be included or excluded from reporting due to data uncertainty (which is currently commonplace) has been reduced and is now supported by formal cut-off criteria. Removing the need to disclose data with spurious origins increases certainty of reported data and reduces the reputational risk to the institution.

The appeal of this methodology is predicated on the basis of its universal adoption, but inherently, this is going to be a challenge. Inertia in the sector is inherently likely, due to its size and the competing priorities of its constituent institutions (Robinson *et al*., 2015). Therefore, there is work to be done on securing consensus on the forward direction of travel. The design of the methodology is such that it allows easy transposition from existing methodologies, whilst permitting external verification (tested in this chapter to the ISO14064-3 standard); it is clear to see that beyond individual issues, the barriers to implementation are minimal. A data tool, considerate of its usability, transparency, and robustness has been developed to accompany the USM and has been shown to benefit environment managers with useful guidance and *aide-memoires*. The design, developed in collaboration with university environment managers, means that the ability to drive continual improvements to the methodology and associated tools are in easy reach.

Institutions are traditionally seen as leaders on sustainability; they are often very effective at rolling out successful staff and student engagement programmes, incubating profitable low-carbon business ideas and conducting innovative research. Historically though, the same cannot be said on their reporting of GHG information. The ability to continue to lead the way on the sustainability agenda is in jeopardy if the HE sector fails to act on the quality of information that it reports; the opportunity now falls with individual institutions to become a catalyst for change and on the sector's leaders to listen and take action.

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Chapter 6: Production-based university GHG assessments: The case of the University of Southampton

The previous chapters have sought to propose and test a universal methodology for HEI carbon footprinting on a subset of UK institutions including the primary institution, the University of Southampton (UoS). When applying this methodology to the UoS, a number of challenges were experienced and decisions made in order to obtain the high level data presented in the previous chapter. In this chapter, further detail is provided on these decisions and what influence (if any) these had on the reported results. The reporting of key methodological considerations alongside the organisational carbon footprint is imperative in aiding the understanding and interpretation of the stakeholder using the information.

This chapter explores a number of detailed elements of the full environmentally-extended input-output analysis and life-cycle assessment (EEIOA-LCA) footprint that, although out-of-scope of the universal methodology, provide additional insights to this research project. This work was conducted to further the existing work undertaken by the UoS and demonstrates the intricacy and complexity of such studies.

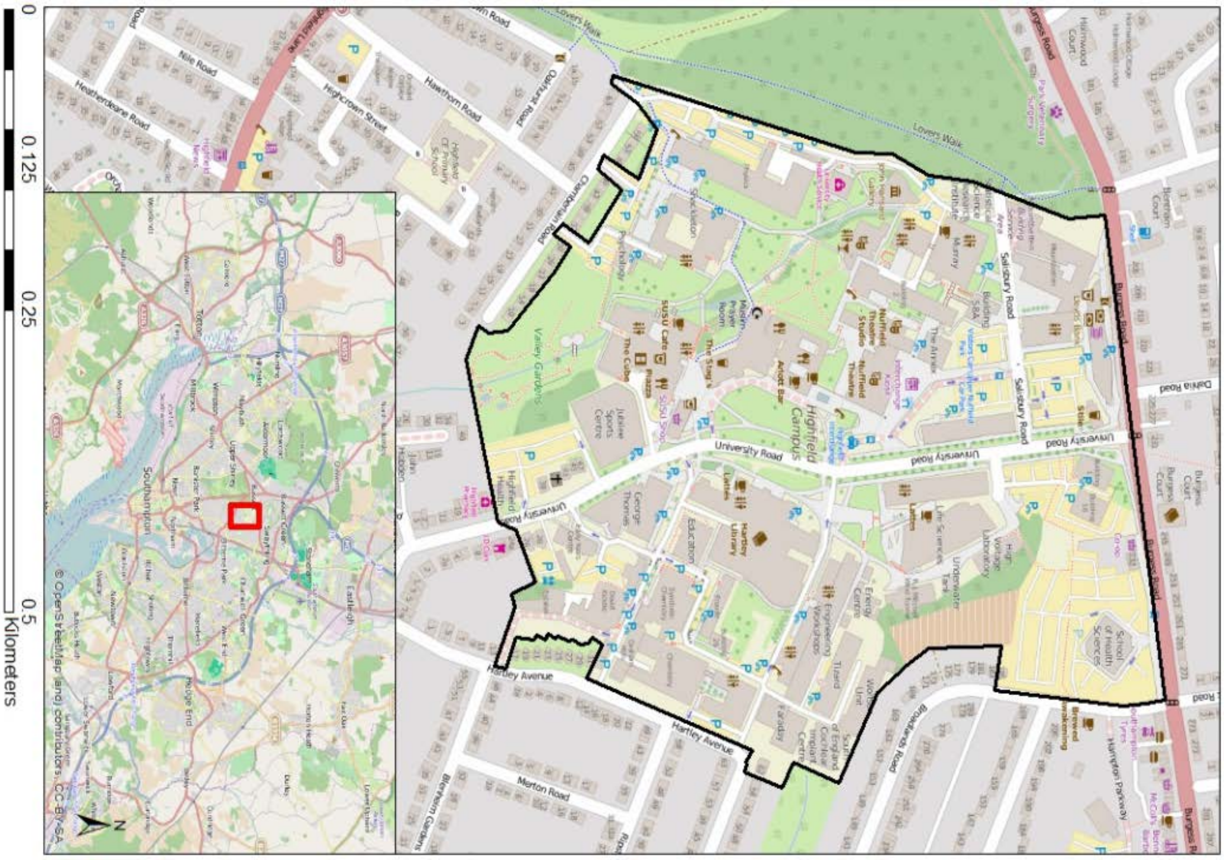
6.1 Introduction to the case study institution

6.1.1 Location

The UoS is located in the north of the City of Southampton. Southampton is predominantly a port city and the largest city in the county of Hampshire, with a population of 250,000 (of which 39,000 (15.6%) belong to the two universities; the UoS and Southampton Solent University). Southampton is part of the wider South Hampshire conurbation, which joins Southampton in the west with Portsmouth in the east. The Solent Local Enterprise Partnership oversees the development of the region which has a total population of over 1.3 million people and 50,000 businesses (Solent Local Enterprise Partnership, 2017). Situated at the confluence of the rivers Test and Itchen, Southampton occupies a unique position; bounded in the north by the South Downs (a range of chalk downlands) and the New Forest in the southwest (one of the largest remaining areas of lowland pasture and heathland in the UK). As a result of its positioning, the growth of the region is geographically limited by wild areas of particular local, national and international importance.

The UoS is one of only 60 institutions in the UK that houses research and teaching operations on a dedicated campus and one of only five multi-campus institutions (the others include Edinburgh Napier University, Heriot-Watt University, Nottingham University, University of Reading, and the University of the West of England). These campuses are spread out around the city of Southampton and the wider area of South Hampshire. The hub of activities and administration is Highfield Campus, located to the north of the suburb of Portswood. The Highfield campus is situated adjacent to Southampton Common; an internationally important Site of Special Scientific Interest (SSSI) occupying 365 hectares of mixed deciduous woodland, grassland, and ponds (Newton, 2010).

The surrounding satellite campuses of the Avenue Campus, Boldrewood, National Oceanography Centre, and Southampton General Hospital are serviced by a number of halls of residence ranging in size, from those housing only a handful of students (Shaftesbury Avenue) to over 1,900 (Glen Eyre Halls). Further halls complexes are dotted around the city and include Archers Road Halls (central Southampton, 510 students), Highfield Halls (north, 160 students), Bencraft Halls (north, 130 students), Wessex Lane halls (north, 1,700 students), Liberty Point (central, 310 students), Mayflower halls (central, 1,000 students), and City Gateway (north, 350 students). Additionally, the UoS has a campus and halls of residence in Winchester (the Winchester School of Art, Erasmus Park halls of residence, 380 students) and a newly-opened campus in Johor, Malaysia.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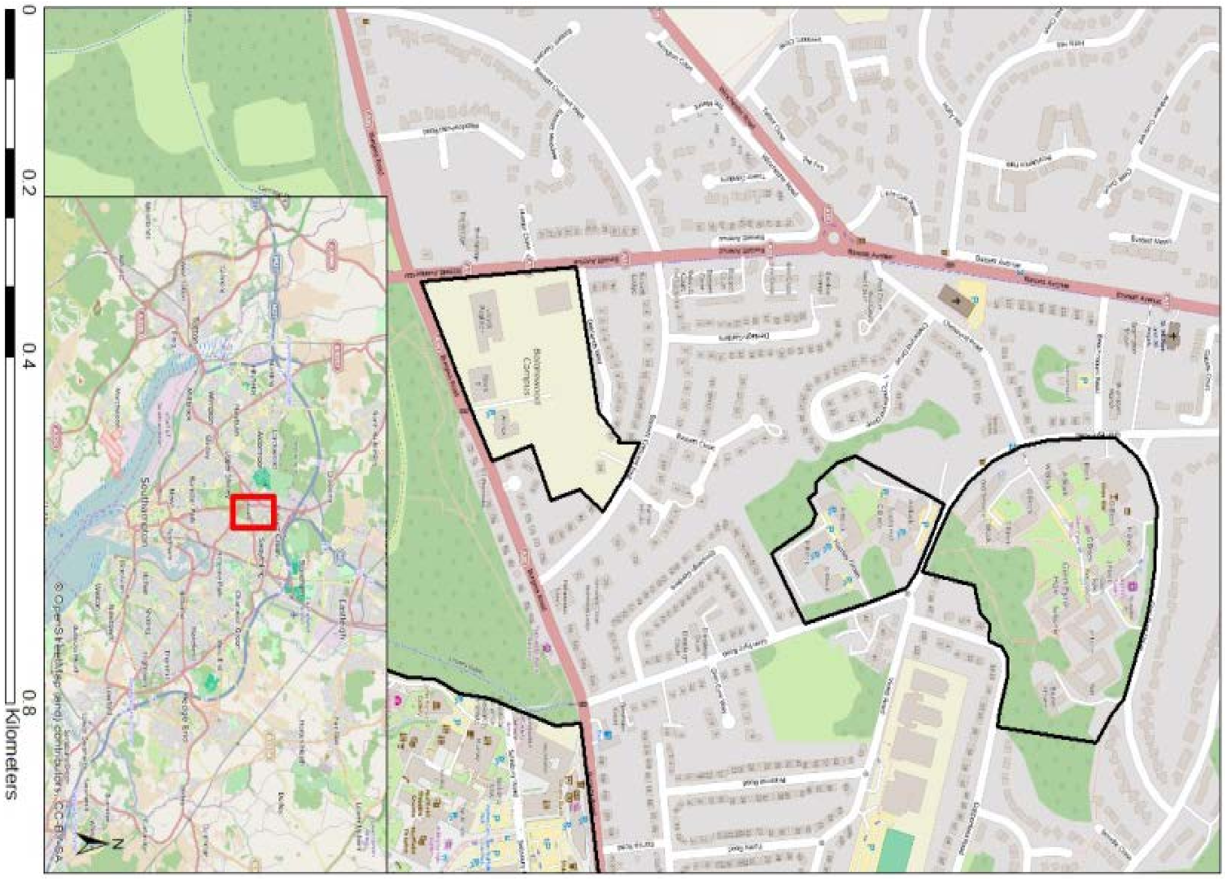
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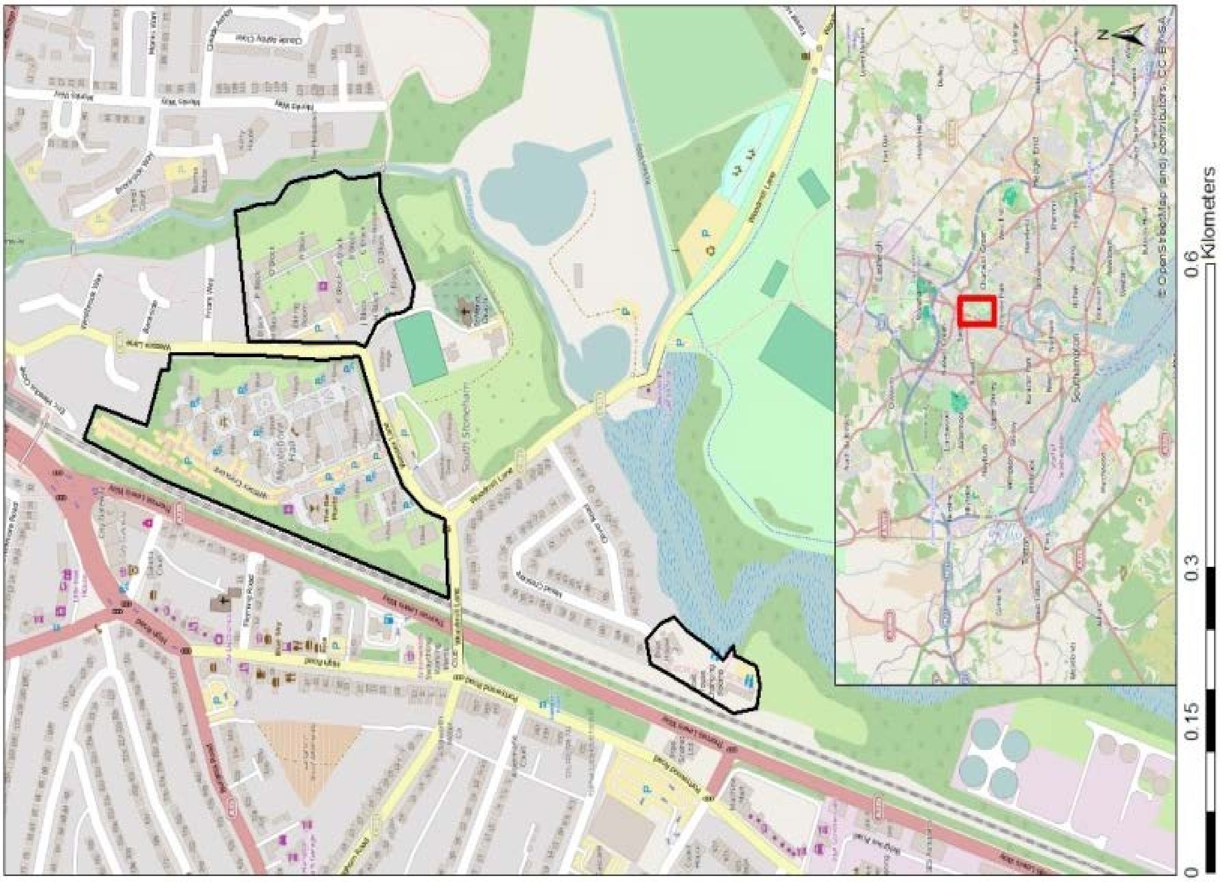

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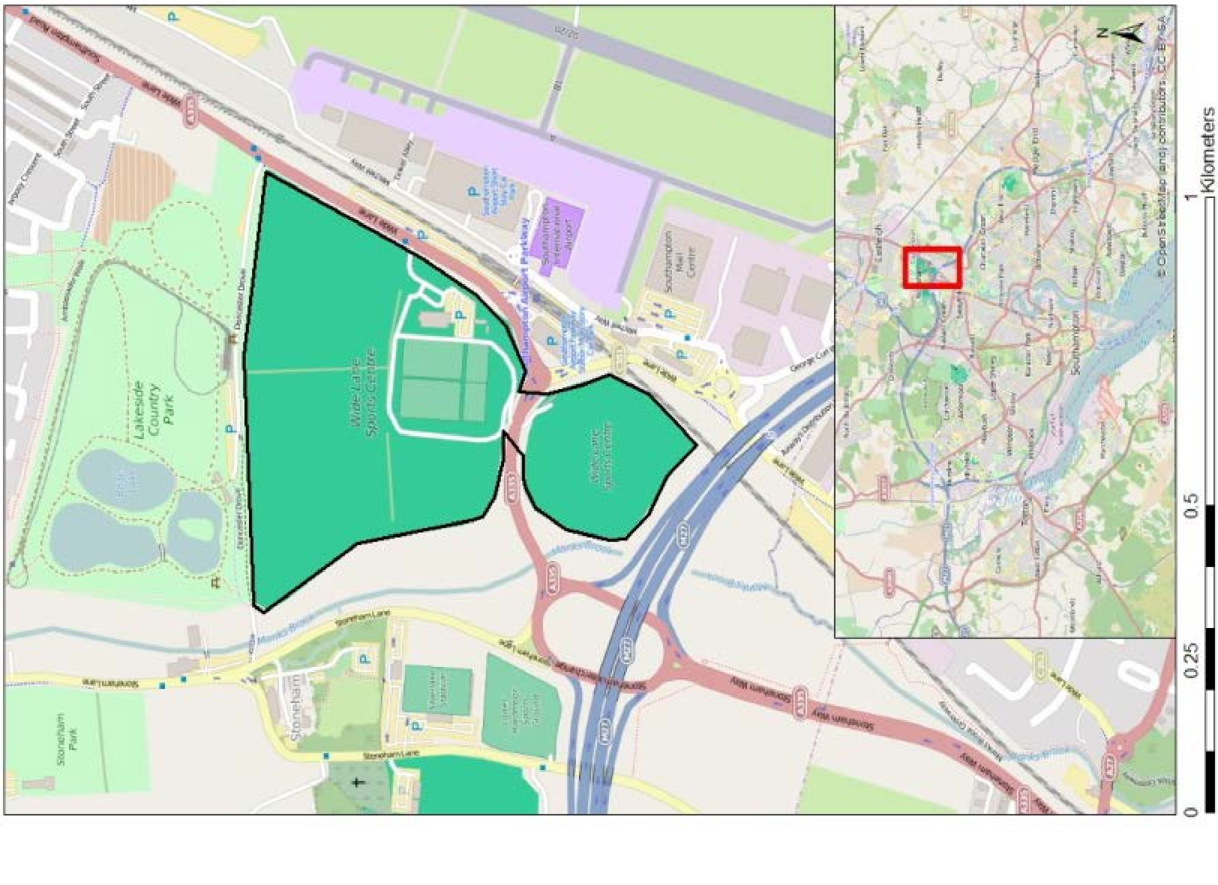

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Wide Lane Sports Centre
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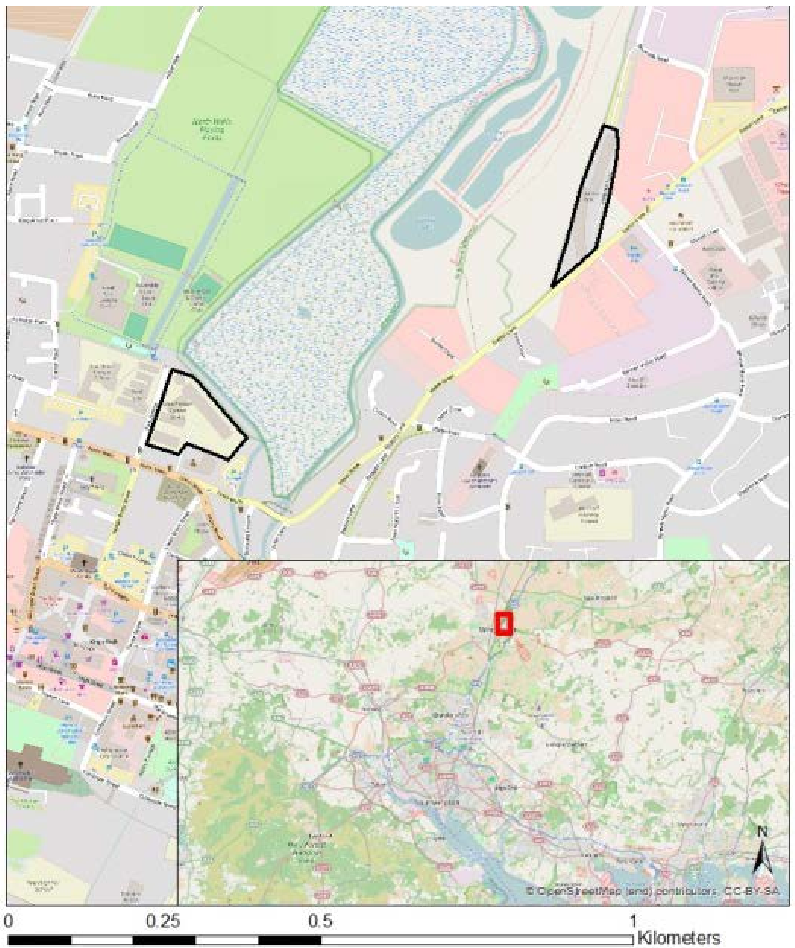

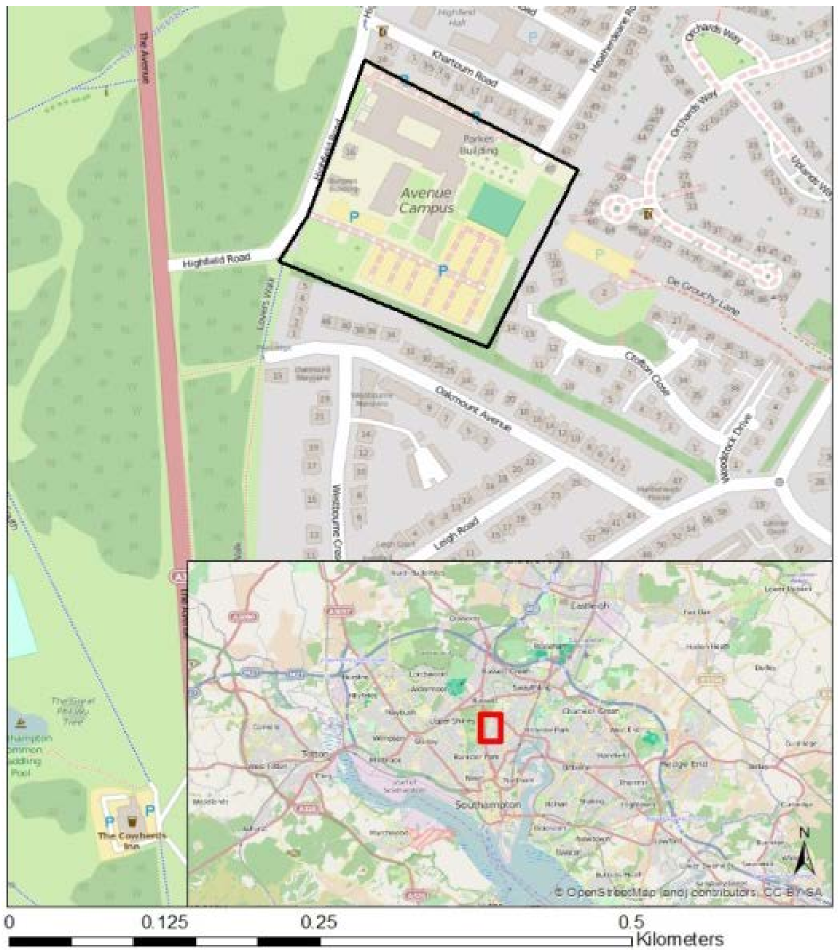

Figure 2: The campuses of the University of Southampton included in the scope of the Eco Campus certification and those considered in this research project. Row 1, left to right: Highfield Campus, Boldrewood Campus and Glen Eyre halls complex. Row 2, left to right: Wide Lane Sports complex, Wessex Lane halls of residence and university boatyard. Row 3, left to right: Winchester School of Art and Erasmus halls of residence, Avenue Campus.

6.1.2 Policy and organisational setting

The governance structure of the UoS is shown in Appendix G. The University is governed by a Council and a Senate that yield power over separately defined institutional operations. The Council governs the general functional operations of the institution and is the executive and principal policy-making body (as stipulated in the University's Royal Charter), whilst the Senate is the primary authority on academic matters and oversees the direction and regulation of education, examinations, as well as the awarding of degrees and the promotion of research. Membership of the Council includes academics, external stakeholders, representatives of the Students' Union, and members of the Executive Team. The Senate, meanwhile, comprises 150 members including: the President and Vice Chancellor; Deans and Associate Deans of Faculty; academic staff representative and research staff representatives, as well as student representatives (including the President of the Students' Union. The Chancellor is the official head and primary spokesperson for the University, whilst the Vice Chancellor is the principal academic and administrative officer; the Executive advises the Vice Chancellor on matters regarding the day-to-day management of the institution and acts as counsel for strategic decision-making.

The strategic direction of the UoS, as agreed by both the Senate and Council and promoted by the Vice Chancellor formalises the institution's ambitions of being a world-class research institution. Already recognised as one of the leading research universities in the UK, this builds upon many years of strong research and education performance. For instance, in the 2014 Research Excellence Framework, the UoS was ranked 8th for research intensity and consistently scores highly on teaching and learning assessments. As an institution with one of the highest proportions of income derived from research activities in the UK (exceeding £100 million) it is annually ranked in the top 100 universities in the world.

Managing an ever-changing estate can be a considerable challenge for campus facilities managers. Setting campus-wide policies is a commonly used method of managing the estate on a wide number of issues. The enforcement of these policies can often be the most time consuming and controversial aspect of campus management and thus, detailed implementation plans are required to ensure the programme's success. The following section outlines a comprehensive list of policies instituted across the estate relevant to carbon management.

6.1.2.1 Sustainable travel plan

The UoS instituted a travel plan which facilitates the transportation activities of staff, student, and visitors to and from its campuses. The second travel plan period 2015-2020 builds upon the first travel plan period 2010-2015 and focusses primarily on connecting Highfield Campus (as the hub of institutional operations) to satellite campuses and halls of residences elsewhere in Southampton. The commitments which the university has made through the adoption of the travel plan are fourfold:

1) Reduce transport-related emissions and wider environmental impacts of transport by raising awareness amongst staff and students;
2) Provide low carbon alternatives to the car and improve the choice of alternatives;
3) Promote the smarter ways of working to reduce the need to travel; and
4) Maximise the use of land.

The travel plan is continuously supported by the inputs of both staff and students via surveys and also includes a plethora of deliverable objectives. In meeting these objectives, the institution can expect to deliver on these four commitments.

A number of these have already been achieved successfully, including improvements to the interchange for bus services, the renegotiation of the contract for the university's bus service ('Uni-Link'), and a reduction in the overall number of parking spaces. There are also a number of outstanding objectives, which the institution aims to achieve before the end of the second period, under a number of broad KPIs: measurement, reduce the need to travel, active travel, public transport, cars, business travel, and the optimisation of supplier deliveries. Objectives include the introduction of a bike rental scheme, recording of business-travel related carbon emissions, a cycle to work scheme, review timetabling to avoid peak-hour journeys, and the promotion of existing showering facilities. The institution aims to implement flexible working arrangements that enable staff and students to reduce their need to travel, providing improved walking and cycling facilities on campuses and halls, work in partnership with other stakeholders to provide improved walking and cycling routes and other transport initiatives and Implementing a car parking policy to encourage car users to seek alternatives or car share.

The institution has invested in research to identify how best to employ a centralised sustainability-focused booking system for staff travel for business purposes. A centralised method offers a number of additional significant benefits as a result of business-to-business booking agreements and bulk ordering, including cost saving and increased flexibility (Guizzardi *et al.*, 2016). There are many examples of institutions already deploying this technology to manage travel booking. For example, the Universities of Exeter and Lancaster employ the services of a third party travel organisation with an online software platform that all budget holders across the institution can access.

6.1.2.2 Sustainable procurement

Institutions engaging in sustainable procurement place themselves in two roles. Whilst participating in the market as a buyer/purchaser they can simultaneously yield power over purchasing decisions to promote social, economic and environmental values extending beyond the estate. The UoS' procurement policy stipulates that a list of approved suppliers is kept, from which resources are ordered. A tendering process is used for individual purchases and works exceeding the EU's threshold for public procurement; >£164,176 for supply and service contracts, >£4,104,394 for works contracts and >£589,148 for social services (OJEC, 2016).

The university's sustainable procurement policy is informed by the priorities and agenda set by Procurement England Ltd (a key alliance vehicle for regional English HE purchasing consortia[42]). This group aims to support member institutions in achieving value for money on a whole life cost basis. This means that wider economic, social, and environmental benefits must be taken into account when purchases are made. As a member of the SUPC, the UoS receives a wide variety of benefits including access to free cost-based Scope 3 procurement assessments.

Typically, institutional approaches to sustainable procurement should act to support counterpart environmental and ethical policies. Whilst the institution is yet to implement its own bespoke sustainable procurement policy, broadly, the institution can follow the aims of Procurement England, whose aims are to:

1) Ensure that environmental, social and whole life cost impacts are appropriately considered in the assessment of 'value for money'. This means committing to undertaking regular assessments of the life-cycle impact of products, services and works procured by universities;
2) Manage the procurement of goods and services to support members in achieving supply chain carbon emission reduction targets. Encourage staff to review their consumption of goods and services;
3) Broaden the awareness of sustainable procurement principles and ensure procurement processes are open, transparent. Ensure that staff, students and suppliers understand the aims and objectives of the policy, continually improve and develop it;
4) Embed good practice in day-to-day procurement activities;

[42] There are six main regional purchasing consortia in the UK: the London Universities Purchasing Consortia, the North Eastern Universities Purchasing Consortia, the North West Universities Purchasing Consortia, the Southern Universities Purchasing Consortia, Advanced Procurement for Universities and Colleges in Scotland and the Higher Education Purchasing Consortium, Wales. These organisations perform a central purchasing role for member institutions in their jurisdictions, existing to foster value-for-money collaborative procurement.

5) Undertake sustainability risk/impact assessments of products & services and supply chains;
6) Engage suppliers to improve supply chain management *i.e.* by working with key vendors, educating them on sustainable procurement and, as appropriate, persuading them to offer more sustainable products, utilise more sustainable working practices, and encouraging them to propose innovations which improve the sustainability of their tender responses;
7) Promote the sustainable purchasing policy, strategy, objectives and activities to members, suppliers and students;
8) Manage tendering strategies that ensure fair access to contracting opportunities for businesses of all sizes and types; and
9) Collaborate with other organisations to improve knowledge and understanding of sustainable procurement and not knowingly deal with companies whose activities include practices which directly pose a risk of serious harm to individuals or groups, or are inconsistent with the mission and values of the institution.

At a more local level, the UoS engages with the SUPC for most of its tendering contracts and procurement activities. The SUPC also have a range of policies for ensuring that procurement is conducted sustainably, by aiming to:

1) Comply with all applicable local and national environmental laws, regulations and directives of the countries working in, manufacturing in or trading with;
2) Actively avoid causing environmental damage and/or negative environmental impact through manufacture and supply of the goods or services and disposal of supply chain waste;
3) Have a business plan in place to minimise environmental impact year-on-year and adopting or working towards internationally recognised environmental standards and/or behaviours; and
4) Encourage the development and use of environmentally-sensitive technologies.

The UoS is also a member of the ‘Warp-It’ scheme; an online network where institutional members can share unwanted resources (such as furniture and office equipment), seeking to reduce spend on new equipment and its wastage. This is used as a means of procurement on an ad-hoc basis when goods become available.

6.1.2.3 Sustainability action and engagement

The UoS’ Sustainability Action initiative is dedicated to providing opportunities to all staff and students across the institution to take part in sustainability events throughout the year. Many of the initiatives have been world firsts for a university and demonstrate an innovative approach to engagement (often the success of sustainability policies relies on the level of engagement that often can be seen as a significant challenge when attempting to enact strategic change). This initiative has enabled the university to host a variety of engagement events, including the 'Blackout', 'Waste Wars', 'Swap Shop', and 'Shift Your Stuff'

Blackout is the centrepiece of this initiative, where a large number of students are trained in energy auditing and measure the change in energy consumption against baseline weekends throughout the year. Twice a year, in partnership with the Student's Union, the swap shop provides the opportunity for staff and students to exchange their unwanted clothes for new items for free, with the aim of decreasing the reliance on newly bought fast fashion items. The third programme led by Sustainability Action is 'BioBlitz', which is an outdoor community event where expert naturalists and the public work undertake a survey to identify of all forms of life in the local vicinity. Finally, Waste Wars allows staff and students to work together to calculate the recycling rate at the university by undertaking an audit of the university's waste streams.

6.1.3 The organisational boundary of the University of Southampton

The organisational composition of the UoS is set out in Table 39, which shows the ownership status of the UoS and related entities outlined in the 2015/16 financial statement. The institution receives financial remuneration from these entities (except those that are currently dormant) as part of its investment portfolio. Although they are distinct legal persons, they are within the jurisdiction of the UoS' university leaders (in particular, the Vice-President for Research and Enterprise) and the Director of Finance. The UoS itself comprises eight faculties and three administrative units; Business and Law, Engineering and the Environment, Health Science, Humanities, Medicine, Natural Sciences, Social, and Human Sciences and Physical Science. These operational units can be found in Appendix G.

The Southampton University Students' Union (SUSU) is of notable importance for understanding the organisational boundary of the institution. Because it is a separate legal person, the financial affairs of SUSU are not listed in the financial statements of the UoS. The SUSU occupies facilities on campus (leased from the UoS) and receives some university funding (in addition to its own fundraising activities). Although the activities of the SUSU are excluded from study here, there is a probability that some activities are included, such as the consumption of electricity. This is because the AMS record flows to the central estates department and is recharged to SUSU.

Table 39: Investments held by the University of Southampton, adapted from the UoS 2015/16 financial statement

	Holding	Nature of Activity
Investments held by the University of Southampton		
ECS Partners Ltd	100%	Consultancy
IT Innovation Ltd	100%	Dormant
IT Innovation Centre Ltd	100%	Dormant
Photonic Innovations Ltd	50%	Investment Company
Southampton Asset Management Ltd	80%	Investment Company
Southampton Innovations Ltd (SI Ltd)	100%	Investment Company
Southampton International Singapore Limited	100%	Research
USMC Sdn Bhd (Malaysia)	100%	Education
University of Southampton Holdings Ltd (USH Ltd)	100%	Holding Company
The University of Southampton Science Park Ltd	100%	Science Park Management
Investments held by USH Limited		
The University of Southampton Consulting Ltd	100%	Consultancy
Investments held by SI Limited		
Photonic Innovations Ltd (PI Ltd)	50%	Optoelectronics

Initial work to set the organisational boundary concluded that an operational control approach was the most appropriate. Although the institution is composed of several entities, the secondary or tertiary entities listed in Table 39 were excluded due to their immateriality:

1) Firstly, these entities are typically holding companies with very few physical assets; therefore they contribute little to the GHG profile of the institution;
2) Secondly, many of these entities use the physical infrastructure of the UoS' estate and would therefore be difficult to apportion out, or would already be included in Scope 1 and 2 emissions; and
3) Thirdly, the importance of maintaining consistency with work previously undertaken meant that the boundary used in the Carbon Reduction Commitment (CRC) and EcoCampus was sufficient for this study as the institution has already set a well-established boundary.

Therefore, only the sites in Table 40 were included in the scope of this study.

Table 40: Sites occupied by the UoS included in the GHG assessment.

Site Description	No. of residential buildings	No. of non-residential buildings	Total Gross Internal Area (m^2)	Post Code
Highfield Campus	45	82	193 989	SO17 1BJ
Avenue Campus	1	4	10 537	SO17 1BF
Boldrewood Campus	1	5	62 168	SO16 7PX
Winchester School of Art	43	6	19 510	SO23 8DL
Wide Lane	0	7	2221	SO50 5PE
Water sports Centre	1	15	889	SO18 2JL
Glen Eyre Halls	41	1	49 051	SO16 3ZE
Wessex Lane Halls	45	3	39 960	SO18 2NS
Bencraft Halls	5	0	4695	SO16 3QB
Archers Road Halls	7	0	11 863	SO15 2WF
Astro House Data Centre	0	1	2622	PO15 5TX

A number of other sites are also excluded including the laboratories at Chilworth, units on the Belgrave industrial estate, College Keep, offices and research space at the hospitals: North Hampshire, Royal Hampshire, Southampton General, and St Mary's.

6.1.4 Campus developments and special events 2005-present

The developments seen at the UoS are highly indicative of the fast pace of growth experienced by the UK HE sector in the last decade. Despite being good for business, the wider implications for carbon management are often under-considered and are not a significant factor for campus planners and developers. In addition, the importance of maintaining steady growth which enables planners to lessen the carbon intensity of operations gradually; it is widely held that the potential for succeeding on emission reduction targets (especially absolute targets) is highly dependent on carefully considered low-carbon growth. The emissions baseline set by the UoS in 2010 was based on the academic year 2005-06. In practical terms, a number of matters (described in paragraph 6.1.4.1) occurred in 2005 which made the baseline year abnormal; this has left a legacy which has created a challenge for carbon management and is worth noting when assessing the GHG emissions of the organisation.

6.1.4.1 Special events during the baseline year

During the baseline year, the UoS estate experienced a catastrophic fire which saw 10,000 sq. m of floor space taken offline and subsequently demolished. The infrastructure in question at the time was home to the UoS' Computer Science and Optoelectronics departments and accounted for a significant proportion of the UoS' energy consumption due to the intensive use of computers, clean rooms and other equipment in the building. This represented an artificial lowering of the baseline and consequently skewed the rate of growth in the intervening time to be much faster than would otherwise have been expected due to the construction of replacement buildings. The construction of the replacement building was completed in 2008, which saw a state-of-the-art £55 million building add 10,000 sq. m back to the university portfolio.

Also in 2005, the Highfield campus library was extended and redesigned to create 3200m^2 of additional study space and the student services building refurbished with a new glass atrium installation which joined two pre-existing buildings together. The latter scheme was lauded as an extremely sustainable construction, making use of natural light, ventilation and grey water and features a photovoltaic (PV) array on the roof. The 25^o west of south-facing array is pitched at 30^o to enable self-cleaning and yields a nominal power of 12 kWp. The academic year 2005 also saw the UoS' CHP plant brought online, providing localised heat and power to the campus for a period of at least 25 years.

6.1.4.2 Timeline of constructions and special events, post-baseline year

The year 2005 was selected as the baseline for Scope 1 and 2 emissions reduction targets in order to comply with the sector-set targets explored in Chapter 3. The Higher Education Funding Council for England (HEFCE) assumed that individual institutions would follow the same emission growth trajectory (1.6% per annum) as the aggregated target between these years, without accelerating or slowing their rate of ascent. The evidence demonstrated by the UoS shows that this trajectory was much steeper and sustained throughout the intervening period.

The occurrence of a number of irregular events during the baseline year possibly suggests that the particular year upon which the UoS now measures emissions reduction performance was atypical. Subsequent to the baseline year, a number of changes have occurred which have affected the UoS' performance and offer an insight into why the growth trajectory since the baseline year has been so considerable. It is pertinent to consider this impact in order to learn the most pragmatic way of striving to set Scope 3 emission reduction targets (to be explored in latter chapters).

Table 41 shows the fluctuation in gross internal area (GIA) over the period since the baseline year. Although total area marginally declined during the period, a considerable reduction in 2007/08 is followed by a period of continual growth and expansion.

Table 41: The gross internal area of the UoS between 2005/06-2015/16.

Academic Year	Non-residential (m^2)	Residential (m^2)	Total (m^2)
2005/06	279 862	147 567	427 429
2006/07	264 438	151 650	416 088
2007/08	271 783	151 650	423 433
2008/09	250 495	129 043	379 539
2009/10	250 585	138 391	388 976
2010/11	276 028	137 112	413 140
2011/12	252 871	132 440	385 311
2012/13	260 740	125 365	386 105
2013/14	266 876	125 015	391 891
2014/15	273 689	151 622	425 311

Interrogating staff and student numbers, the rate of growth is more evident than can be seen in the change in gross internal area. Between 1994 and 2001, the UoS almost doubled in size from 9,000 full-time equivalent (FTE) students to 15,500 in 2001 (Nash and Sherwood, 2002) and increased again to 18,700 in 2015 and 20,500 in 2012 respectively (HESA, 2012).

A number of singular developments between 2006/07-2015/16 are worth noting. A number of campus extensions were made, such as in 2006, when the Archaeology department relocated to a £2.8 million building on the Avenue Campus (purchased by the university in 1993 to facilitate expansion, bypassing restrictive planning laws at the time that would have required a large number of parking spaces in the form of three multi-storey car parks to be incorporated in the Highfield campus expansion plans). In 2013, a new off-site data centre was also developed and brought online to cope with the advancing computing requirements of the university and in 2015, the university constructed a series of halls of residence to increase capacity dramatically. Southampton City Gateway in Swaythling, a 15-storey tower built at a cost of £23.5m is able to house >360 students and includes local amenities such as a pharmacy and GP surgery. Also, halls were constructed nearer the centre of Southampton; Mayflower plaza is a £70m development of three, 8-16 storey accommodation blocks and features space for 1100 students.

Development has been particularly centred on the Highfield and Boldrewood campuses. Figure 24 depicts Highfield Campus and Boldrewood Campus and highlights where significant additions to the campuses have been made. Large areas of land on the Highfield site have been purchased in the northeast corner (where residential houses have been demolished), whilst the Boldrewood site has undergone a complete redevelopment programme.

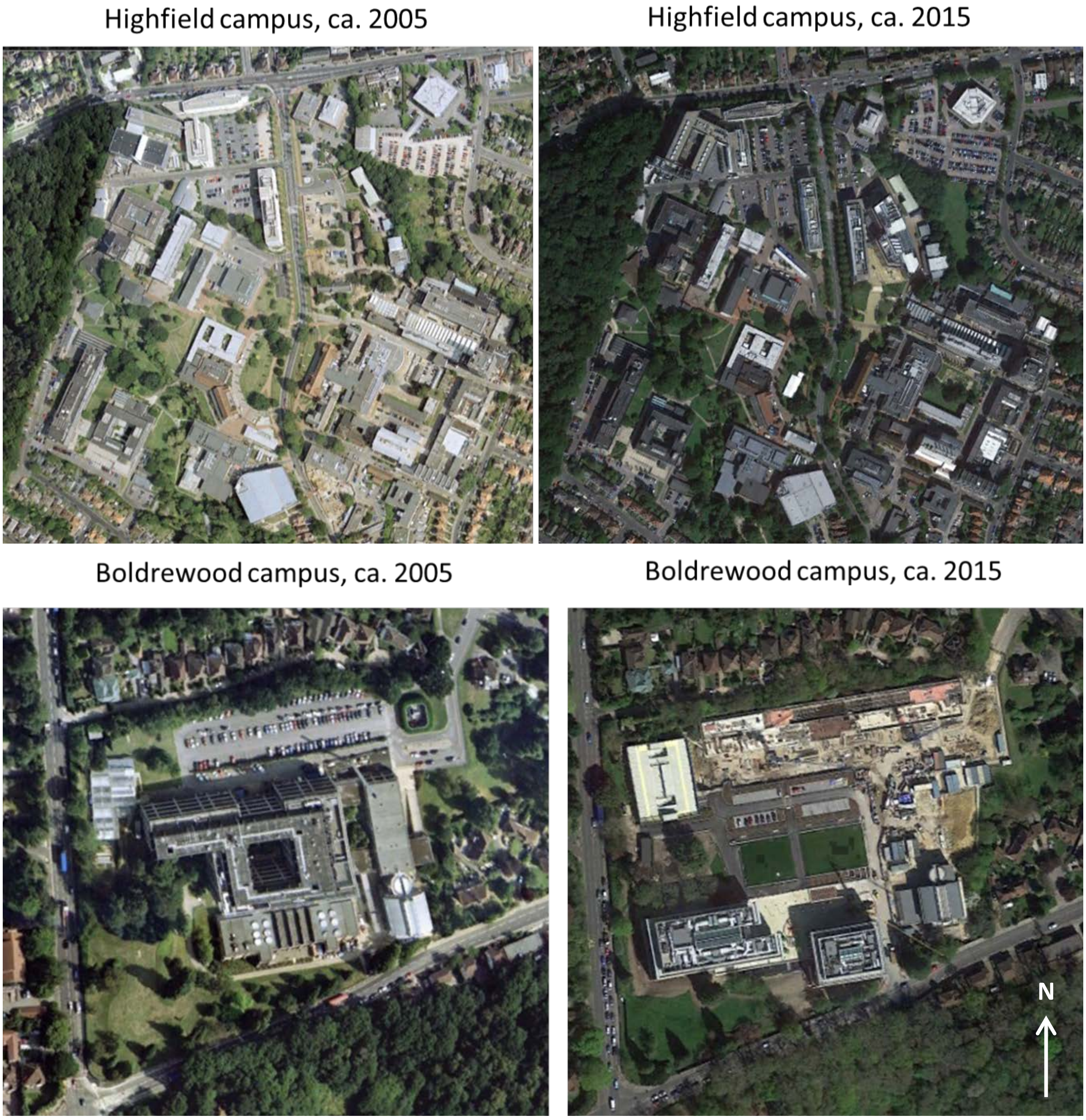

Figure 24: Aerial imagery highlighting the changing and expanding estate footprint. Top row left to right: Highfield Campus in 2005 and 2015. Bottom row left to right: Boldrewood Campus in 2005 and 2015.

In 2007, the £18 million Electronics, Education and Engineering (EEE) building was constructed, which features the UoS' largest lecture theatre with 430 seats. The building features a glass street front to provide natural lighting and ventilation. The Institute of Development Sciences at the Southampton General Hospital and the Institute for Sound and Vibration Research (ISVR) building, incorporating a green roof, were also constructed in the year. In 2008, a temporary building, housing the School of Civil Engineering was erected in the university's 'engineering square' due to the 1960's Faraday Tower being deemed structurally unsafe. In 2010, a £50 million life sciences building was constructed, utilising previously unused space and requiring the demolition of an existing university building and residential housing. The decommissioning and demolition of the Boldrewood campus was also initiated. In 2011, the campus bus interchange, operated and used by 'Uni-link', a bus service funded by the UoS, was rebuilt at a cost of £1.5 million. A refreshments kiosk was installed, along with real-time bus information. In 2014, the construction of a maritime centre of excellence, a £116m redevelopment of the pre-existing Boldrewood Campus, was completed. This is a state-of-the-art facility which is used for maritime research by both the UoS and the Lloyds Register (which has transferred marine activities from London to Southampton). A 32,000m^2 gross external area facility, its features include a 186m towing tank and anechoic chamber, as well as space to house over 400 university academics and an equal number of Lloyds Register professionals. The campus is serviced by a centralised power and heat unit. Additionally, construction of an atrium extension of the R.J Mitchell wind tunnel and the refurbishment of the ship sciences building following the transfer of staff and students to the newly opened Boldrewood campus were also completed. In June 2015, the temporary building housing the Environmental Sciences department was demolished and a landscaped seating area with bike storing facilities was installed. The university also replaced the Chamberlain halls of residence, adjacent to the Glen Eyre halls complex, beginning by demolishing existing halls in 2012; construction was completed in 2015.

6.1.4.3 Future developments

The UoS will continue to grow in the future and a number of large construction and development projects are planned for the near-term. These include the completion of the redevelopment of the Glen Eyre Halls of Residence, the construction of the National Infrastructure Laboratory at the Boldrewood Campus and the construction of the Cancer Immunology Centre, a £25 million development at the University Hospital Southampton NHS Foundation trust site. The UoS has also commenced works to build a new centre for learning and teaching at its Highfield Campus. The building will be located on Salisbury Road, on the combined site of the current Visitors' car park and Building 58a. The new building will include a 250 seat lecture theatre, a range of seminar and teaching rooms, independent study space, a computer suite and a café.

6.1.5 Operational boundary

Auditing the operations of the UoS to establish fully the operational boundary highlights the diverse mix of activities which the institution directly and indirectly influences. The organisational structure was used as the basis for this since it afforded a good understanding of the discrete staff and student groupings and their associated contribution to organisational output. Here, a broad description of the activities identified is given. Building use at the UoS is very mixed and features spaces such as offices, workshops, laboratories, common meeting areas, meeting rooms, computer rooms, libraries, storage/cleaning cupboards and lecture theatres.

6.1.5.1 Campus-based research and teaching

Activities for delivering research and teaching activities on the estate rely on the provision of physical infrastructure and the continual maintenance of this infrastructure. Installed boilers and chillers are required for heating and cooling services. On Highfield campus, this is primarily supplied by two gas turbines in the CHP plant and localised air conditioning units (ACUs). This scheme, installed in 2006, merged two existing campus district energy schemes whilst other buildings were linked and their old local boilers were retired. For instance, linked to this system is the EEE building which contains a 600kW absorption chiller. This utilises the hot water from the CHP plant to provide cooling by generating cold water for circulation through chilled ceilings in the offices, and through a displacement ventilation system in the main lecture theatre (Turner, 2017).

As a mixed-use campus, much of the infrastructure is designed to be multi-functional and adapt to the uses of multiple groups. As a result, the estate is comprised of a wide variety of space in which teaching and research activities are undertaken; from high performance laboratories, to office spaces, performing arts spaces and domestic residences. Table 42 shows an example of some of the largest pieces of equipment listed on-site and their specifications (with data from the UK HE research equipment database funded by the EPSRC). This supports conclusions often made about the energy-intensity of some departments over others (*i.e.* computer science, chemistry and engineering).

Table 42: Examples of large equipment operated by the University of Southampton's researchers.

Building/equipment name	Equipment specification
RJ Mitchell Wind Tunnel	Wind tunnel (3.6m x 2.4m) with an overhead 6-component balance, surface pressure scanner and PIV system.
Facscanto Laser	488nm and 633nm benchtop 6-colour
Coral Reef Laboratory	Multi-compartment aquarium system circulating more than 4200 litres of artificial seawater. Accompanied with a coral reef display tank.
Clean Rooms	Contains equipment for performing focused ion beam (FIB) procedures and field emission scanning electron microscopy.
Doak - Jet facility	Anechoic Laboratory facility, 15m x 7m x 5m and down to 400 Hz. It is used for jet and valve noise and is equipped with an air supply that achieves up to 20 bar pressure.

Not only does the campus serve as a hub for academic activities, but it is also a hub for social activities, sports facilities, and other miscellaneous amenities. In addition to day-to-day operations, the campus hosts many events throughout the year, including public open days, enrolment activities (including inductions and interviews), examinations, and graduations.

The UoS owns an extensive vehicle fleet including four Kubota diesel tractors, one Honda Petrol Quad bike, one Ezgo Petrol Golf buggy, multiple electric adapted milk floats, a Toro petrol lawn mower, more than 40 Diesel Ford/Peugeot/minibuses and vans (up to 3.5 tonnes), and an even greater number of petrol/diesel multi-size passenger vehicles. The latter are used for the transportation of staff and students during field courses, research activities, and Sports club activities (although these tend to be undertaken under the auspices of the Student's Union and therefore these journeys for the purposes of GHG assessment are excludable).

6.1.5.2 Off-campus research and teaching activities

Activities dedicated to the provision of research and teaching activities off-site are numerous and seldom recorded formally. For this reason, understanding which activities are influenced and where data collection efforts should be targeted is a considerable challenge (and one which is characteristic of full GHG assessments). In taking a methodical approach by interrogating the list of courses on offer and the resultant activity types that these generate, a picture of the nature of activities undertaken by and for the institution can be produced The following information sources were interrogated:

- Subject/course list;
- Course programmes;
- UK Quality Code for Higher Education; and
- Enrolment data.

During the course of undergraduate study, many courses may offer off-site fieldtrips, in the UK and internationally. Many subjects also require students to undergo fieldwork or training at external facilities and outdoor sites. During the course of postgraduate research, students will also conduct field investigations; these excursions typically occur on an ad-hoc basis reliant upon the field of study and the individual research project scope. The UoS is also largely involved in public outreach activities nationally as part of a drive to ensure research is of high impact.

The types of staff that are employed by the UoS can be categorised as being either 'administrative and support' staff or 'academic' staff. Both of these groups may attend conferences, workshops and meetings off-site; multi-day off-site excursions typically result in hotel stays. Academic staff are more likely to undertake external business trips and to attend conferences and other institutions, whilst support staff attend meetings and events off-site for shorter periods.

6.1.5.3 Administration activities

The support staff function allows the UoS to conduct its business efficiently. This includes a plethora of activities on-campus including the distribution of mail and ICT support services (covering the operation of the data centre, the installation of hardware, the troubleshooting of ICT issues and the provision of ICT across the institution).

6.1.5.4 Construction, infrastructure and land-based activities

Construction activities are outsourced to contractors. This means that the emissions burden is borne by the contractors themselves during the construction phase. The procurement of materials for construction is conducted through the procurement office. Small building maintenance works are mostly conducted by teams within the institution, unless specialist equipment or expertise is required. Ground maintenance, landscaping, and gardening are all done in-house using university-owned equipment.

6.1.5.5 Off-site non-research and teaching activities

In addition to research and teaching activities which occur off-site, a plethora of other activities are influenced by the institution off-site from the disposal of waste at material recovery facilities (MRFs) to the delivery of procured goods. The UoS also leases external storage facilities.

A specific consideration for institutions when assessing GHG emissions is the role that student domestic-related emissions have on the footprint. Student-related domestic emissions are included in the footprint from institution-owned and operated halls of residence, but are excluded once they (typically) move to privately-rented accommodation. It is important to note that at some institutions, students can expect to be accommodated in university-managed halls for the entire duration of their degree programme. Although a lesser cited issue in the literature, it could be argued that the reason why students require accommodation in the host city is due to the presence of the institution there; there is an interesting debate to be had on whether these emissions should be excluded. Due to considerable data restrictions these emissions are excluded in this research project.

6.2 Pre-study carbon footprint data

Prior to this research project, the UoS undertook a baseline carbon footprinting study based on the HEFCE methodology. Total emissions were found to amount to 144,000 tCO_2e, with scope 3 emissions contributing 110,250 tCO_2e (~76.6%) to the overall footprint (Figure 25).

The assessment focused on collating information regarding procurement emissions, commuter transport, waste and water and was not released publicly at the time due to poor confidence in the methodology used. See Table 43 for the data sources and associated confidence levels.

The notable issues with the output from the emissions assessment that inspired this research project are numerous. The means by which emissions are disaggregated does not follow published conventions: for instance, emissions associated with the consumption of water are: i) reported in a separate category, despite being a constituent of the 'purchased products' category; and ii) include emissions from wastewater treatment, despite this being a constituent of the 'waste' category.

The procurement emissions, which clearly represent the greatest proportion of this footprint and therefore an important element to calculate sufficiently, are calculated using cost code categories to assign conversion factors. This was based on a published methodology developed by the consultancy ARUP for the HEFCE in 2012. Under interrogation, it is evident that the methodology uses a series of concordance matrices to apportion known material emission factors (previously published by the Department Environment, Food and Rural Affairs (Defra) but discontinued in 2014) to a broad (ProcHE) cost code description. There is also a considerable double counting risk; whilst fuel and electricity consumption are rightfully reported as Scope 1 and 2 emissions, the ProcHE codes associated with utilities (fuel, electricity, and water) are included in the procurement spend calculation.

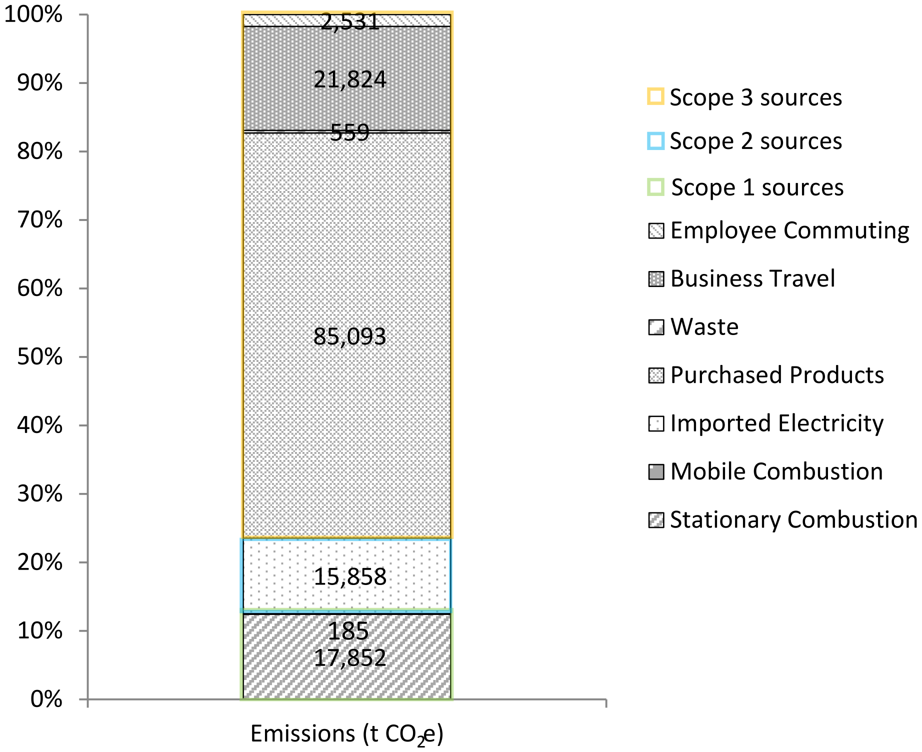

Figure 25: Results of the preliminary GHG assessment undertaken by the University of Southampton Estates and Facilities department in 2013.

Table 43: Origin information of activity data collected to inform the University of Southampton's carbon footprint in 2013.

Emission source	Confidence	Origin
Energy – Gas/Electricity	Good	University Automatic Metering System (AMS) Half-hour metering – reported in EMR
Water	Good	University AMS water data. Includes wastewater (90% of water consumed)
Procurement	Low	Procurement spend from finance department, calculation conducted by the Southern Universities Purchasing Consortium (SUPC)
Waste	Low	Waste mass data, low confidence is attributed to Defra emission factors being the same for most waste treatments
Commuting	Medium	Biennial voluntary transport surveys, determining modal split and trip origin
Business Travel	Low	Travel spend data provided by finance department
Vehicle Fleet	Medium	Fuel card spend provided by finance department

The 2013 GHG assessment allowed for rapid identification and establishment of data streams for the research study presented in this thesis.

6.3 Universal standardised methodology data

Data for use in the study outlined in Chapter 5 were collected as per the methodology outlined in that same chapter. The following section explores further the strengths and weaknesses of the procedure that was followed and provides a greater depth to the somewhat high level analysis already presented for the primary case study institution.

6.3.1 Energy emissions

The UoS has good confidence in the source and supply of energy-related data. As an organisation which consumes greater than 6000 MWh of electricity annually, all electricity and natural gas data is collected through a campus-wide AMS network and reported through the governmental Carbon Reduction Commitment (CRC) scheme.

Energy intensity can vary significantly across the institution's building portfolio due to the intrinsic differences in research and teaching activities that occur there. Interrogation of the raw data for each building meter point administration number (MPAN) for electricity and natural gas reveals that the buildings which accommodate the Chemistry Department, the Computer Sciences Department, and the RJ Mitchell Wind Tunnel are those with the highest energy intensities across the institution. Intensities are calculated by normalising natural gas and electricity usage by the gross internal area (GIA) of the building and made comparable through the use of degree days (to eradicate meteorological bias for natural gas usage). The buildings with the lowest energy intensities include predominantly administrative buildings, Student Services, and smaller outlying buildings in the southeast corner of the campus.

6.3.2 LULUCF/AFOLU emissions and removals

The Rothampstead institute's RothC-26.3 model was used to investigate the influence of agriculture, forestry and other land-use (AFOLU) processes undertaken by the UoS. RothC-26.3 is a model for the turnover of organic carbon in non-waterlogged topsoils that allows for the effects of soil type, temperature, moisture content and plant cover on the turnover process. By creating a baseline calculation of organic carbon stored in biomass and the soil, in the future the institution can use the results to inform future land use management practices and explore the means to offset its emissions through pragmatic use of the estate. Published physical characteristics, including, soil type, open pan evaporation rate, mean air temperature, and the decomposability of incoming plant material (DPM/RPM) ratio were also determined for use in the model: Table 44 shows typical data inputs for the model.

Once soil organic carbon (SOC) was determined, the current store of carbon in biomass (biogenic carbon) in addition to the rate of uptake of carbon were calculated using published rates for UK habitat types, identified on the UoS' estate through aerial survey. A habitat survey was conducted using aerial photography for each of the institution's sites to determine the proportion of the estate by each land use type: see Figure 26.

Table 44: Example data inputs for the Roth-C26.3 model, for improved grassland at the Highfield Campus

Southampton - Improved grassland/agriculture								
Year	Month	Rainfall (mm)	Monthly open pan (mm)	Mean air temp	Clay soil content	DPM/RPM ratio	Bare/ vegetated soil	Soil depth (cm)
1	January	81.4	14.05	5.65	20%	1.44	Vegetated	25
1	February	58.3	20.55	5.6	20%	1.44	Vegetated	25
1	March	60.0	42.47	7.6	20%	1.44	Vegetated	25
1	April	50.7	70.02	9.85	20%	1.44	Vegetated	25
1	May	49.0	110.05	13.25	20%	1.44	Vegetated	25
1	June	50.4	135.71	15.95	20%	1.44	Vegetated	25
1	July	42.0	148.02	18.05	20%	1.44	Vegetated	25
1	August	50.4	124.21	18.0	20%	1.44	Vegetated	25
1	September	60.4	80.60	15.6	20%	1.44	Vegetated	25
1	October	93.8	45.62	12.25	20%	1.44	Vegetated	25
1	November	94.0	20.03	8.55	20%	1.44	Vegetated	25
1	December	89.2	12.76	6.05	20%	1.44	Vegetated	25

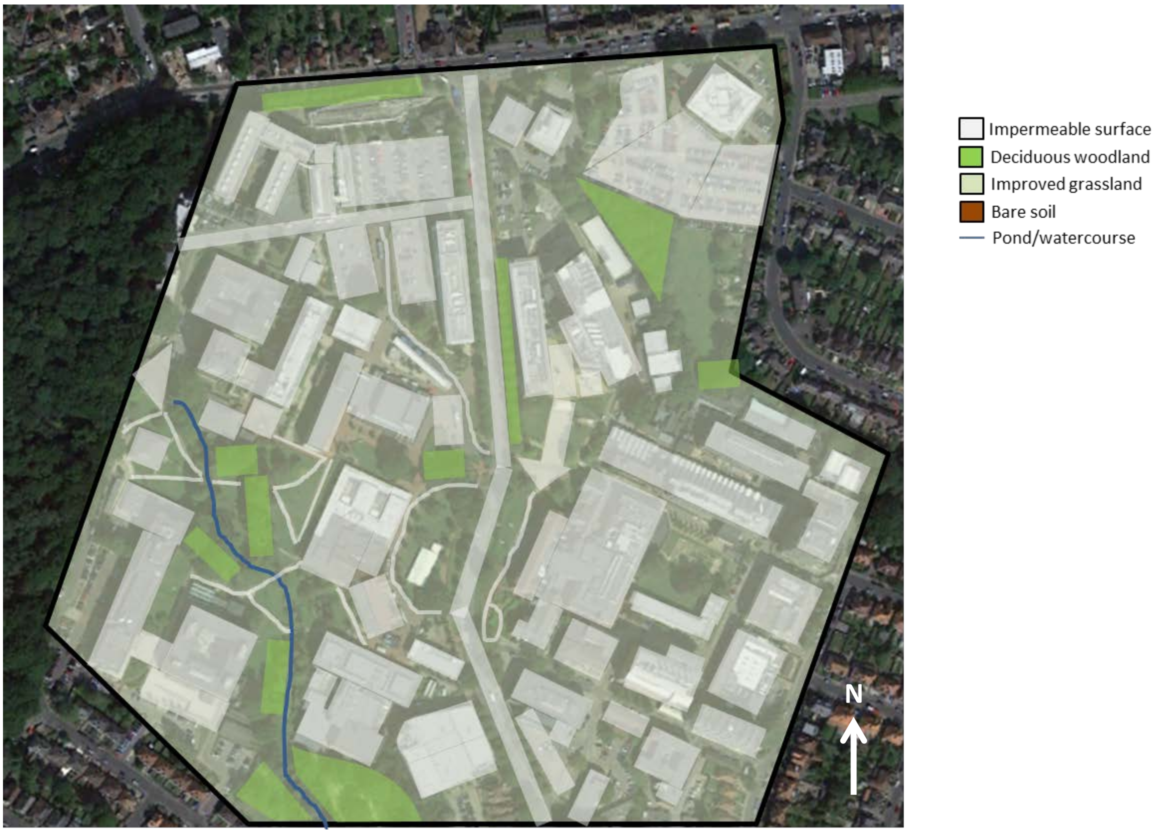

Figure 26: Land-use types on the University of Southampton’s estate, determined through habitat survey using aerial footage.

6.3.3 Commuter car travel

Further detail is provided in latter sections of this thesis on the approach taken to determine emissions from commuter car journeys. The results of an online travel survey, administered with a representative self-selected sample of the staff and student population, were applied to average emission factors and extrapolated in line with the current size and composition of the UoS' staff and student population.

6.3.4 Waste and waste transfers

The management of waste is a key issue for the estate team at the UoS, managed centrally by the waste manager and in close contact with waste contractors and faculty facilities managers. Waste is collected from the campus via numerous streams; in office and shared spaces waste is collected predominantly as mixed municipal waste, comingled recycling, and food waste and additionally from service areas as metals, aggregates, and WEEE.

Some 20 separate licensees operate the waste transfers from the Highfield Campus site alone. Table 45 shows the contractors responsible for the different waste stream and the next-step destination of the waste (in Hampshire this is often an MRF for recyclable materials and an MSW plant for municipal waste).

Table 45: Waste contractors by waste stream: the organisations responsible for disposing of waste arising from the University of Southampton's Highfield Campus.

Waste Stream	Contractor/destination
Mixed Municipal Waste	Sita UK/Wallington Depot, Fareham
Mixed Recyclables	Sita UK/Wallington Depot, Fareham
Metal	Southampton Steel/Timsbury, Romsey
Cooking oil	Wimborne Cooking Oils/ Wimbourne, Dorset
Clinical waste/sharps	SRCL Clinical Services/ Bournemouth waste to energy facility, Bournemouth, Dorset
Garden waste	Veolia E S Hampshire/Stockbridge, Winchester
Batteries	End of Line Services/Maldon, Essex
WEEE	End of Line Services/Maldon, Essex
Food	Eco Food Recycling/Piddlehinton, Dorchester
Hazardous Waste	B&W Waste Management Services, Bedford

Details from waste transfer notes are recorded locally and reported to the UoS' waste manager on an annual basis; the cumulative amount of waste disposed by waste type and treatment type is centrally collated through manual internal reporting practices. Waste transfer notes use the European Waste Catalogue (EWC) coding system to distinguish the waste being sent for disposal which organisations can use as a record (Wilson, 2011). This central database was the primary source of data for the waste calculations, supplemented by the university's waste collection schedule. The waste collection schedule details the planned waste lifts for the 57 waste compounds across the estate. Regular schedules are set for municipal waste, mixed recycling, glass, and food waste, whilst the other waste streams are collected on a demand-basis.

The producers of waste are legally mandated to ensure that their waste carrier is registered to transfer waste and that waste is disposed of responsibly (HM Government, 2017). Beyond this stipulation and an effort to ensure that as much is recycled as possible, the producers of waste have little control over the method of disposal. This is often determined by the waste carrier as the most profitable method. For this reason, the recording of waste treatment is seldom performed. Additionally, existing published emission factors are only released for certain treatment types and materials, thus limiting the resolution with which waste emissions can be investigated. Total derived emissions from the disposal of waste were 3146.50 tCO_2e (as an annual aggregated figure). In total, 56,680 bin lifts were recorded, amounting to 1,087 tonnes of mixed municipal waste and 1,080 tonnes of mixed recycling (a recycling rate of 49.8%). 280 tonnes of compostable food waste, 20 tonnes of wood, 19 tonnes of cardboard, and 72 tonnes of WEEE were generated.

Hazardous and clinical waste is disposed of using a dedicated disposal route direct to the waste treatment facility on an ad-hoc basis. The GHG impacts of the hazardous waste stream are difficult to assess reliably and are thus excluded from the assessment of waste-related GHG emissions for the UoS.

Eq. 7 shows the derivation for the number of journeys made by waste collection vehicles to the UoS for the two major waste streams (mixed municipal waste and mixed recycling) over a single year period. The bins used were standard, 1100 litres, whilst the waste collection vehicles used by the UoS' mixed municipal waste have a gross volume of 15,000 litres. It was also assumed that vehicles will on average fill to 75% capacity before returning to the depot, based on average published figures (Defra, 2013).

$$\sum_{transfers} = \frac{V_{Vehicles}}{V_{Schedules}} * 1.25 \qquad (7)$$

$$V_{Schedules} = (V_{Bin} * n_{Bin}) * n_{Compounds}$$

where, $\sum_{transfers}$ is the number of waste transfers undertaken in a year, $V_{Vehicles}$ is the total volume of the waste collection vehicles and $V_{Schedules}$ is the function of bin size, number of bins, and number of waste compounds on the university estate.

Table 46: Total scheduled waste volume and associated waste transfers for mixed municipal waste collection at the University of Southampton.

	Non-Residential		Residential		Sport	
	$V_{Schedules}$ (litres)	$\sum_{Transfers}$	$V_{Schedules}$ (litres)	$\sum_{Transfers}$	$V_{Schedules}$ (litres)	$\sum_{Transfers}$
Monday	123 200	8.2	59 400	4.0	3300	0.2
Tuesday	77 000	5.1	42 900	2.9	0	0
Wednesday	123 920	8.3	33 000	2.2	2200	0.2
Thursday	19 800	1.3	46 200	3.1	0	0
Friday	55 000	3.7	59 400	4.0	0	0
Saturday	5500	0.4	9900	0.7	0	0
Total	404 420	27.0	250 800	16.7	5500	0.4

Table 47: Total scheduled waste volume and associated waste transfers for mixed recycling collection at the University of Southampton.

	Non-Residential		Residential		Sport	
	$V_{Schedules}$ (litres)	$\sum_{Transfers}$	$V_{Schedules}$ (litres)	$\sum_{Transfers}$	$V_{Schedules}$ (litres)	$\sum_{Transfers}$
Monday	119 900	8.0	115 500	7.7	3300	0.22
Tuesday	77 000	5.1	89 100	5.94	0	0
Wednesday	121 720	8.1	69 300	4.62	2200	0.15
Thursday	64 900	4.3	89 100	5.94	0	0
Friday	130 900	8.7	118 800	7.92	0	0
Saturday	81 400	5.4	9900	0.66	0	0
Total	595 820	39.7	491700	32.8	5500	0.4

The calculated cumulative distance was found to be 2,099,670 km. For waste streams without directly measured data (including battery collections, hazardous waste, and radioactive waste) a factor of 48 was used, calculated as one 'lift' per waste stream, per year for each institutional site. A 'lift' is taken literally here and defined as the instance whereby the waste collection vehicle lifts the bin or container containing the waste material. Technology-specific emission factors were used for calculating emissions from waste disposal vehicles for both recycling and mixed municipal waste streams. Where information about the vehicle type was absent, an average emission for factor for a van was used instead. Cumulatively, emissions from waste transfers amounted to 2774 tCO_2e.

Tables 45 and 46 above demonstrate the number of waste vehicles that would theoretically be needed to dispose of the volume of waste in a single week if all of the scheduled collections were honoured. However, a comparison with the total mass of waste sent for disposal would enable these theoretical calculations to be sense checked. To do this, the measure used for the bins and vehicles (a volumetric value, which in this case is litres) must be converted to mass (often, the information recorded by waste carriers for billing purposes) for both the mixed municipal waste and recycling waste streams.

Using published conversion factors, obtained from Defra (2016a) the calculated volume would account for 3,146.29 tonnes of mixed municipal waste and 5,204.86 tonnes of mixed recycling. In reality, only 1,087 tonnes of mixed municipal waste and 1,080 tonnes of mixed recycling were collected from the institution in the study year. Evidently, this can be attributed to a combination of two influences: i) the full waste schedule is never realised; and/or ii) the collection of waste from the university is not conducted by waste vehicles taking a full load from the campus before returning to the waste facility (even despite the 75% fill rate used in the calculations). In GHG terms, this means emissions attributable to the UoS are undoubtedly exacerbated by the inefficiency of the waste schedule and the frequently half-loaded vehicles. This also means that, in reality, the emissions attributed to the UoS for these journeys could be many orders of magnitude larger than those estimated here (when attributing a single trip from the waste transfer depot to the campus and assuming the vehicles move immediately on to the next customer who at that point becomes responsible for the emissions).

With this information, emissions associated with waste transfers could be reduced by an average of 72.35% for the largest two waste streams alone by optimising waste schedules and increasing the fill rate of vehicles.

6.3.5 **2015-16 aggregated GHG emission results**

In line with the proposed UM, the total calculated GHG emissions of the UoS found in this study were 47,695 tCO_2e. Scope 1 emissions accounted for 38.3%, Scope 2 28.3% and Scope 3 emissions 33.4% of the overall carbon footprint. Figure 27 shows the results of the study and ranks the emission sources in order of their importance through contribution analysis. Despite the proposed universal standard methodology (USM) excluding the majority of Scope 3 sources, in certain cases, data were collected and the associated emission sources were quantified. For instance, the travel survey contains a swathe of data on the commuting habits of the staff and student population on public and private modes of transport that would not be accounted for by the proposed USM. For completeness, these are also shown in the Figure alongside the methodology used to gather the data is detailed in the following sections.

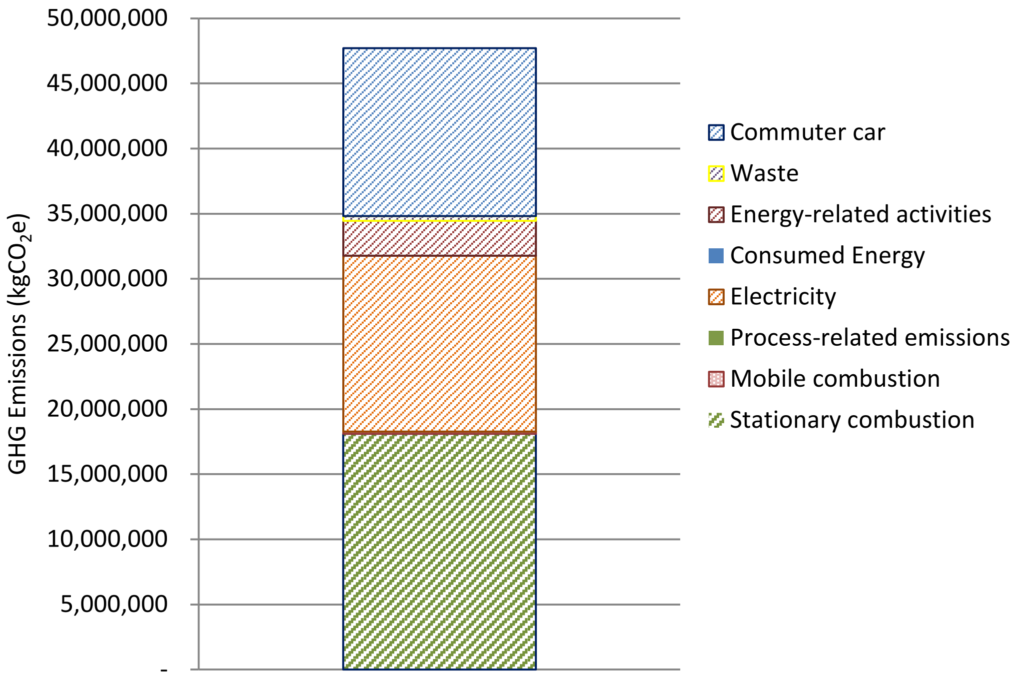

Figure 27: Results of the GHG assessment of the University of Southampton disaggregated by emission source under the proposed USM.

6.4 Assumptions and sources of uncertainty

Whilst the need for assumptions was minimised through the proposed USM, a number of assumptions were still needed during the undertaking to collect activity data to inform the UoS's GHG assessment calculations. The use of assumptions (often an integral part of any GHG assessment), were used in the absence of all required activity data. Whilst the data hierarchy was followed where possible, in many instances caveats and 'rules-of-thumb' were used to extrapolate the raw activity data. This ensured that it was relevant to the characteristics of the institutions. Table 48 records the most common assumptions used. Where assumptions were used, these broadly followed two types: those that supplement empirical data (or used solely for extrapolation purposes) and those used in place of missing or unobtainable empirical data.

Table 48: Assumptions used during the data collection procedure at the University of Southampton and associated citation, arranged by emission source.

Emission Source	Common general assumption	Literature source
Stationary combustion	Constant calorific value of fuels	Baggott *et al.* (2004)
Mobile combustion	Constant calorific value of fuels	Baggott *et al.* (2004)
LULUCF/AFOLU	Constant rate of soil turnover Various model assumptions in the Roth-C model	Coleman & Jenkinson (2014)
Imported electricity	Average CO_2 emissions from the UK national grid. Assumes fuel mix is constant throughout the year.	Department for Business Energy and Indsutrial Strategy (2017)
Waste	Waste categories are homogenous, and analogous to real world waste composition Limited by emission factor resolution	Clavreul *et al,* (2012)
Commuter car journeys	With the exception of the data captured by surveys, it was assumed that all employees and students commenced all journeys from, and returned directly to, their own homes.	

The USM reduces the role that assumptions play in the calculation methodology. However, as is evident, a number of assumptions must still be used to supplement the data collection. Whilst it is clear that there is a case for the use of assumptions, they should be used sparingly, and with purpose. In any case, by clearly stating the assumptions (as they have been here), assumptions can be used without significantly reducing data quality.

6.5 **Standalone studies**

During the course of this research project, there were numerous opportunities to delve further into certain subject areas due to the interdisciplinary and somewhat under-researched nature of the research topic. As a result, a series of standalone studies were undertaken which add flavour to the overall research, albeit without contributing directly to the aims and objectives. Two such projects are outlined in the following section. The data presented in sections 6.4.1 and 6.4.2 was obtained through collaboration with undergraduate students in the Faculty of Engineering and the Environment at the UoS. The questionnaire data in 6.4.1 was collected by Eleni Zardeli under the co-supervision of Oliver Robinson and Professor Ian Williams and the results of which are presented in Table 53, whilst the goods delivery data in 6.4.2 was undertaken by a group completing a design project under the supervision of Professor Tom Cherrett. Whist secondary data is used, the interpretations are that solely Oliver Robinson's.

6.5.1 Targeting commuter travel

6.5.1.1 UoS travel survey

The most recent travel plan published by the Estates and Facilities Department at the UoS announced detailed targets for the modal share of commuter travel modes in 2020 (see Table 49 and Table 50). In order to reach these targets, the UoS, as with all HEIs, understands that continual monitoring of the travel habits of staff and students is required if behavioural change and model shift is to happen. As with most universities, the UoS relies on undertaking a biennial travel survey in order to obtain data about the travel habits of staff and students. Administered via an online survey, biennially and in alternating years the travel survey focusses primarily on those staff and students that travel to and from the Highfield Campus as a commuter journey. This section outlines a study that sought to evaluate the attributes of a good travel survey, standardise it for use across the HE sector and explore the means by which the institutions can use it to achieve its 2020 travel targets.

Table 49: Undergraduate student commuting travel mode targets published in the UoS Travel Plan

Mode	2010-2015 Baseline Data	2015-2020 Baseline	Survey 2015	Target 2020
Single occupancy car	46.5%	35.8%	37.5%	30.0%
Car share	10.0%	11.3%	11.2%	12.0%
Uni-link	4.8%	7.0%	8.4%	8.0%
Bus (other)	1.9%	2.3%	2.8%	3.0%
Walk	17.9%	19.3%	19.6%	20.0%
Cycle	14.2%	15.6%	12.8%	17.0%
Motorcycle	1.0%	1.0%	1.1%	1.5%
Train	3.6%	6.9%	5.7%	7.5%
Other (e.g. taxi, ferry)	1.0%	0.8%	0.9%	1.0%

Table 50: Staff and postgraduate student commuting travel mode targets published in the UoS Travel Plan

Mode	2010-2015 Baseline Data	2015-2020 Baseline	Target 2020
Single occupancy car	10.1%	4.6%	3%
Car Share	6.0%	2.1%	1.5%
Uni-link	22.3%	23.8%	24%
Bus (other)	1.0%	0.8%	1.0%
Walk	47.5%	36.1%	36.5%
Cycle	10.6%	29.1%	29.5%
Motorcycle	0.3%	0.2%	0.5%
Train	1.5%	3.1%	3.5%
Other (e.g. taxi, ferry)	0.4%	0.3%	0.5%

Figure 28 shows the results of the 2015 staff survey and the 2016 student survey. A total of 2003 (40%) staff, 1244 (7%) undergraduate, and 501 (7%) postgraduate responses was recorded.

Extrapolated to account for the entire institutional population, the survey determined that 6416 tCO_2e were attributed to the commuting habits of staff, 5881 tCO_2e to postgraduate students and 6522.36 tCO_2e to the undergraduate students. When normalised against the populations of those groupings (staff n=5635, postgraduate n = 7390 and undergraduate n = 17485) it can be seen that staff possess the highest average carbon footprint at 1.1 tCO_2e per person per annum. Postgraduate students choose more energy intensive modes of travel, on average producing 0.2 $kgCO_2e$ per kilometre.

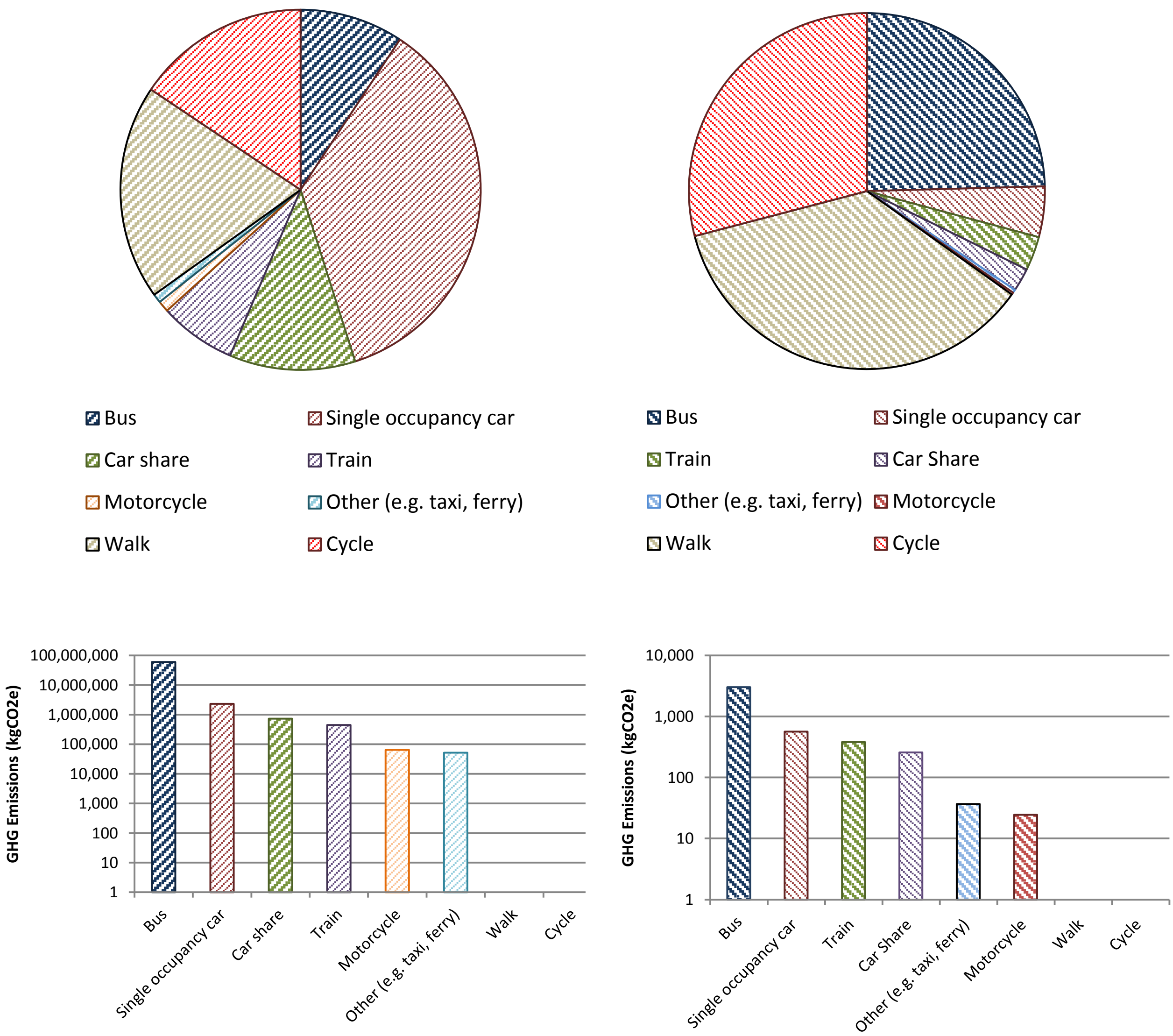

Figure 28: Results of the 2015 staff travel survey and the 2016 student travel survey, administered online for 30 days. Top left: pie chart showing staff modal split in kilometres; top right: quantified extrapolated GHG emissions by staff transport mode. Top left: pie chart showing student modal split in kilometres; bottom right: quantified extrapolated GHG emissions by transport mode.

6.5.1.2 Meeting modal shift targets

The travel survey contributes meaningful information which aids the delivery of the travel plan. Not only for the UoS to be able to meet its 2020 modal split targets, but with the carbon calculations that can be performed with the data that it yields, potentially, future carbon reduction targets can also be introduced. Not only would this have significant benefits to reduce Scope 3 emissions of the institution, but also will have wider implications on the broader economy. Where modal shift may improve local transport-related issues (such as congestion), by quantifying the emissions associated with this emission source, the UoS is able to make tangible improvements to national 2050 CCA target and even non-climate related issues such as local air quality. The generic nature of the proposed travel survey also allows these impacts to be compared amongst institutions.

The implications on the modal split targets on the GHG emissions arising from the act of commuting can be seen in Table 51. The shift to fewer single occupancy cars, a greater number of carbon-neutral NMT journeys (walking or cycling) and increased use of public transport (primarily bus and rail), emissions from the undergraduate cohort will increase 57%. The projection for undergraduates is that reducing the number of car movements is challenging (compared with that for staff) and so the tendency is for a shift from single occupancy cars to multiple occupancy. The increased penetration of public transport by students also contributes to the increased emissions. Conversely, the modal split targets for postgraduates and staff is expected to lead to an emissions decrease of -18%, though both of these predictions exclude the absolute increase in the staff and student population.

Further evaluation of these modal shift targets, with the expected connotations for GHG emissions, will allow the UoS to target specific policies to make significant emission reductions. Whilst there are tangible benefits to promoting the use of public transport and increasing car sharing, currently, the UoS’ travel policy advocates an overall increase in emissions of 50%.

Table 51: Implications to commuter-based GHG emissions by 2020 modal split target

Mode	2010-2015 Baseline	Emissions (tCO_2e)	2015-2020 Baseline	Emissions (tCO_2e)	Target 2020	Emissions (tCO_2e)	Difference (emissions)
Undergraduate							
Single occup. car	46.5%	3033	35.8%	2335	30%	1958	-35%
Car share	10%	652	11%	737	12%	783	+20%
Bus	6.7%	43 700	9%	60 658	11%	71 747	+64%
Walk	18%	0	19%	0	20%	0	-
Cycle	14%	0	16%	0	17%	0	-
Motorcycle	1%	65	1%	65	1.5%	98	+50%
Train	3.6%	235	6.9%	450	7.5%	489	+108%
Other (Taxi/Ferry)	1%	65	0.8%	52	1%	65	-
Total		47 750.16		64 297.38		75 137.53	+57.0%
Staff and Postgraduate							
Single occup. car	10.1%	1242	4.6%	566	3%	369	-70%
Car Share	6.0%	738	2.1%	258	1.5%	184	-75%
Bus	23.3%	2865	24.6%	3025	25%	3074	+7%
Walk	47.5%	0	36.1%	0	36.5%	0	-
Cycle	10.6%	0	29.1%	0	29.5%	0	-
Motorcycle	0.3%	37	0.2%	25	0.5%	61	+67%
Train	1.5%	184	3.1%	381	3.5%	430	+133%
Other (Taxi/Ferry)	0.4%	49	0.3%	37	0.5%	61	+25%
Total		5116		4292		4181	-18%

A number of limitations to the use of travel surveys can be noted and in particular, the resolution of data obtained from them, which can be affected by a number of factors:

1. Question design – open or closed questions, whether they lead the respondent towards an answer;
2. The volume of questions and their order; and
3. The influence of responder fatigue; the tendency for responders to end the questionnaire prematurely, thus avoiding the latter questions.

In many respects, each of these factors is equally important and in considering them mutually, the quality of the survey can be markedly improved. The third point is perhaps the most evident to demonstrate, however, and can be seen in Table 52, the response rate from the UoS' own travel survey. A pro forma questionnaire can be found in Appendix H. As the survey progresses, response rates drop off rapidly. This is somewhat mitigated by the front-loading of the questions deemed more important for influencing travel policies and carbon calculations (primarily, demographic information and the origin and destination of the respondent). Due to the complex nature of transport management at the UoS and the importance of having campuses connected (which in itself places the UoS in a unique situation), a large number of questions are asked and many of these are not central to the emissions calculation; the broad aim of the questionnaire belies the complex and spontaneous nature of individuals, but also the simplicity required of a questionnaire to avoid responder bias.

Table 52: Response rates given for each individual component question in the University of Southampton's 2016 student travel survey.

Question number	No. of respondents answered question	No. of respondents skipped question	% skipped
1	1244	0	0%
2	1244	0	0%
3	1087	157	14%
4	0	0	0%
5	1218	26	2%
6	1218	26	2%
7	1216	28	2%
8	1190	54	5%
9	0	0	0%
10	1176	68	6%
11	0	0	0%
12	1161	83	7%
13	0	0	0%
14	0	0	0%
15	1003	241	24%
16	1153	91	8%
17	1153	91	8%
18	1153	91	8%
19	1153	91	8%
20	343	901	62%
21	12	1232	99%
22	12	1232	99%
23	0	0	0%
24	0	0	0%
25	61	1183	95%
26	61	1183	95%
27	0	0	0%
28	698	546	78%
29	394	850	54%
30	0	0	0%
31	396	848	53%

6.5.1.3 Standardising the travel survey

The websites of 142 universities were interrogated to obtain travel survey questionnaires or travel reports (from which questions could be inferred). Six fundamental themes were obtained from the questionnaires:

1) **Distance**: Often in km, travel surveys must be able to quantify the distance the respondent lives from their destination;
2) **Post code:** In lieu of distance information being provided by the respondent, post code information can be used to enable the calculation of journey distance;
3) **Frequency**: The frequency in the week the trip is made, as well as the number of weeks in the year the trip is made;
4) **Duration:** The amount of time the journey takes, which allows further analysis of the routing of the journey and any traffic encountered;
5) **Opinions**: Information pertaining to the respondent's opinion of the institution's travel provision, in order to better assist in travel management; and
6) **Demographics**: Information about the age, gender, faculty, and position at the institution in order to understand who is answering the questionnaire.

When designing a questionnaire that could be used by the entire sector and which also yields high quality information with limited responder bias, it was necessary to revert to first principles. From this, a number of basic functions that a travel questionnaire must fulfil were derived. The primary function that the travel questionnaire should fulfil is the ability for the assessor to quantify the carbon emissions of the respondents, and second, for them to be able (where understanding of demographic is good) to extrapolate this to derive emissions for the entire institution. Thirdly, the questionnaire should provide a way to act as a tool for fostering a sustainable modal shift in order to meet the targets of the institution, at the same time as staff and students can communicate their thoughts and ideas about the provision and management of travel services, infrastructure, and/or policies at the institution.

The designed questionnaire can be found in Appendix H and consists of eight questions separated into two sections: i) weekly travel patterns; and ii) demographic information. A preliminary study was conducted to test the questionnaire via three ways:

- Contact was established with the Environmental Association of Universities and Colleges (EAUC) network of transport managers for open-ended feedback;
- Reviewed by the UoS transport manager and adjusted to suit the UoS-designed travel survey where appropriate; and
- A planned preliminary trial was undertaken by distributing the questionnaire to 15

students and staff members across faculties.

This final questionnaire was administered online via the internal Southampton University Staff/student Social & Educational Directory (SUSSED) portal for 25 working days for the staff and student body to access. In addition and due to low uptake by staff 200 targeted emails were sent to staff and students in the Faculty of Engineering and the Environment, as well as further reminder emails; 108 student responses and 58 staff responses were recorded.

Cumulative emissions attributed to commuter travel indirectly influenced by the institution were calculated from the results of the questionnaire; Table 53 shows the results as the cumulative distance and corresponding GHG emissions by vehicle mode. The column marked 'extrapolated distance' shows the products of the annual distance results of the questionnaire and the demographic results of the UoS' own travel survey. Extrapolated distance is calculated using Eq. (8) and Eq. (9):

$$CF_{Staff} = (\frac{D_{Staff} * EF}{n}) * 5635$$
$$D_{Staff} = \sum_{Journeys,\ Frequencies} * 45 \tag{8}$$

$$CF_{Stud} = (\frac{D_{Stud} * EF}{n}) * 17485$$
$$D_{Stud} = \sum_{Journeys,\ Frequencies} * 31 \tag{9}$$

where, CF_{Staff} are the GHG emissions of the university employees from commuting, D_{Staff} is the distance travelled by staff per annum as a function of the distance, number of journeys and journey frequency. CF_{Stud} are the GHG emissions of students and D_{Stud} is the distance travelled by students per annum. n is the number of survey respondents.

Table 53: Calculated GHG emissions from the administered questionnaire and extrapolation based on institutional demographics.

Mode	Cumulative distance travelled in a single journey (km)		Annual distance (km)		Extrapolated distance (km)		Cumulative GHG Emissions (tCO_2e)	
	Staff	Students	Staff	Students	Staff	Students	Staff	Students
Bus	64	161	28 832	49789	2 801 129	8 060 763	336	966
Bicycle	65	21	29 385	6603	2 854 905	1 069 014	0	0
Walk	15	60	6809	18 631	661 481	3 016 324	0	0
Car	619	109	278 640	33 666	27 071 317	5 450 463	4956	998
Rail	597	79	26 8776	24 341	26 112 979	3 940 795	1276	193
Total	1361	429	612 441	133 030	59 501 811	21 537 359	6567	2157

An emission factor of zero was applied to non-motorised transportation (NMT) (walking and cycling) since these are considered modes of zero emissions (Massink *et al*., 2011). Some authors do apply an emission factor for cycling to account for the extra calorie intake associated with the physical exertion needed for cycling and the embodied carbon of the metal frame and fixtures (European Cyclists' Federation, 2011); however, this was deemed here to be out of scope.

A clear understanding of emissions of university students' travel behaviour is crucial in order to implement targeted behavioural change policies. Students form an autonomous group which has a considerable freedom in undertaking daily activities such as attending lectures, seminars, social, and physical activities. Due to their fairly complex lifestyle patterns, it is challenging to study and understand their travel behaviour directly. Consequently, institutions undertake annual or biennial travel surveys to obtain a snapshot of student travel habits. The results of this discrete study, casts a different perspective on current strategies at the UoS and highlights a number of areas for improvement.

6.5.2 Quantifying goods inwards deliveries for Highfield Campus

A second standalone study was conducted, which attempted to quantify the number and frequency of goods deliveries at the UoS. This was of particular interest due to the suspected frequency of deliveries, associated inefficiencies in delivery, and therefore, suspected to be a significant contributor of greenhouse gas emissions from the institution. This study is included here despite emissions associated with purchased goods and services having not been included in the USM methodology and therefore excluded from reporting in the results presented earlier in this chapter. The decision to include this study was taken so that it could be presented to the estates and facilities department at the UoS in order to be considered in future policy decisions and to highlight an example of another emission sources that the UoS is indirectly responsible for.

A complex undertaking, the Highfield Campus was chosen as the sole focus of study for a number of significant reasons, including an assumption that since university operations were concentrated there it could be appropriately deemed that deliveries there would be most numerous and would contribute most significantly to the overall institutional carbon footprint.

6.5.2.1 UoS' goods ordering system

The process of ordering goods at Highfield Campus is decentralised, lacks automation, and is only generally lightly controlled by financial checks throughout the entire institution. For large capital expenditures, goods are ordered through a dedicated procurement team. For items of lower value, individual budget holders are able to order goods direct from suppliers or commercial outlets. Goods are only recorded once an order has been made and budget is required from an allocation, identified by a unique code identifier created by Unit 4's Agresso software. Budgets are either held by the faculty or personally; requisitions are raised and must be authorised by the budget holder. BMC Remedy is an IT Management System which facilitates organisation through online record keeping. Agresso, which has been used by the UoS since 2007, offers a range of services such as financial management, human resources and payroll management, fiscal budgeting and forecasting. Employing this software has considerably improved the record-keeping associated with ordering goods at the UoS.

The receipt of goods is also unregulated and decentralised with no strict process. The campus utilises a number of 'goods in' delivery points, which handle goods for multiple departments or buildings. Records are kept locally, although the store which handles the largest volume of goods, Hartley Stores, employs the use of 'Planon' software (facilities management software) to record information specific to an incoming parcel; this is only recorded for deliveries for the Faculty of Engineering and the Environment. Other systems used by the subsidiary stores include handwritten log-books or local spreadsheets. Historically the only goods inwards point serving the entire university, Hartley Stores, now serves most faculties and administrative groups on Highfield campus, along with the 'satellite' campuses in Southampton and Winchester, but is supported by a number of other goods inwards points on Highfield, as can be seen in Figure 29. It still remains the sole point for Royal Mail postal deliveries.

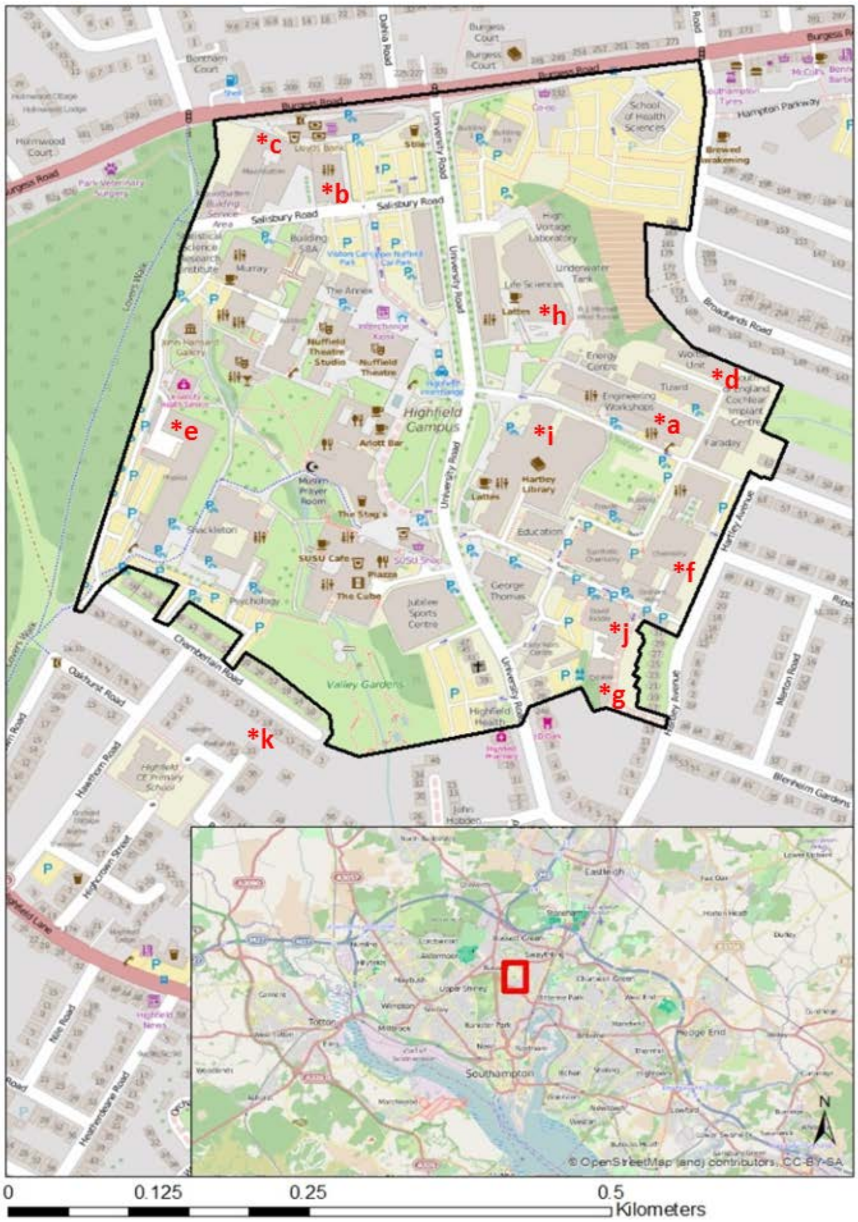

Figure 29: Goods inwards locations at Highfield Campus, University of Southampton: a) Engineering and Design Manufacturing; b) Electronics and Computer Science; c) Optoelectronics; d) Institute of Sound and Vibration Research; e) Physics; f) Chemistry; g) Building 33; h) Building 85; i) Hartley Library; j) Konica Minolta Printing; k) Hartley Stores.

A highly relevant point to consider here is that the delivery of personal mail at university-owned and operated halls of residences is excluded. With more than 6,000 students located in 20 different halls, the potential for many thousands of courier journeys being unaccounted for is highly likely. If each student made a single order, on average once a fortnight, it would result in the generation of 99,000 courier items. A conservative estimate of the number of courier deliveries, assuming that orders would be grouped and efficiencies would be borne by the courier, there could be more than 9,900 movements associated with deliveries to the halls of residences throughout the academic year.

6.5.2.2 Surveying technique and results

A detailed survey on all incoming deliveries was carried out at Hartley Stores over the period of one week in December 2013. The driver survey was created by closely following the methods used in the Regent Street consolidation centre survey example (Transport for London, 2011), in order to collect delivery data of the vehicles and the nature of the consignments at Hartley Store. All of the information regarding the route taken by the vehicle was attained by speaking to the driver on arrival at the stores. To account for the potential to misappropriate the allocation of emissions to the institution as a result of the courier visiting multiple recipients along the route, drivers were also asked about previous drops they had conducted. Future drops were not considered unless they were found to be destined for another UoS goods inward point. Results (Table 54) show the times deliveries were recorded, the average distance travelled by the courier and details of the next drop.

Table 54: Delivery frequency: results of the five-day deliveries survey at the Hartley Stores of the University of Southampton's Highfield Campus.

Time period	Number of deliveries recorded
0700-0800	8
0800-0900	9
0900-1000	20
1000-1100	18
1100-1200	12
1200-1300	12
1300-1400	4
1400-1500	4
1500-1600	8
1600-1700	0
Total	95
Average depot origin distance (km)	36

A total of 1073 items were delivered in 95 separate freight movements during the five-day survey; a slightly higher number of delivery vehicles were recorded on a Friday. This equals an average of 215 items and 19 vehicles per day. There were 19 different depot locations recorded and the majority of the delivery vehicles were from Fareham (26.7km away) and Eastleigh (4.5 km away). The furthest depot was found to be located in Loughborough; a distance of 246 km.

Since the information recorded during the survey was only indicative of activity at the Hartley Stores, extrapolation was required of the data to provide a best estimate of delivery frequencies for the entire campus. Additional datasets were interrogated since a direct extrapolation was not possible without first understanding the percentage of the total freight movements represented by the Hartley Stores. Planon data was used to convert the number of deliveries for the Hartley Stores to an appropriate quantity representative of the Faculty of Engineering and the Environment, for which a factor was derived: see Table 55. For extrapolation, deliveries by Royal Mail were excluded, since the Hartley Stores was the only inward point for daily postal deliveries. Deliveries from Royal Mail arrived between once and twice a day, from one of two depots in Southampton.

Table 55: Delivery records from Planon facilities management software for the Hartley Stores, Highfield Campus.

Week no. (academic calendar)	Quantity of deliveries	Cumulative deliveries
1	51	51
2	53	104
3	41	145
4	48	193
5	48	241
6	54	295
7	62	357
8	60	417
9	46	463
10	No data	463
11	57	520
Average/week	52	

Due to the discrepancy between surveyed data and Planon data, an adjustment was made to ensure that the survey data was representative of the Faculty of Engineering and the Environment, from which the conversion was derived. The reason for the discrepancy is explained by the Hartley Stores accepting deliveries for many other groups on the campus, which are not recorded in Planon. The data was adjusted based on the discrepancy between Planon and survey data, as in Eq. 10.

$$F_{Adjusted} = \frac{n_{Planon}}{n_{Survey}} \qquad (10)$$

$$= 52/95$$

$$= 0.60$$

where, $F_{Adjusted}$ is the ratio between Planon and survey data, n_{Planon} is the number of deliveries recorded in Planon and n_{Survey} is the number of deliveries recorded in the survey.

With the adjusted number of deliveries representing the FEE, Agresso information was used to estimate the total the deliveries for the UoS. This was achieved using an index for each faculty, as a proportional value of Hartley Stores. The dataset obtained was a subset of all Agresso financial data, and included all financial outgoings for equipment, consumables and lab expenses, office expenses and professional fees, and books and periodicals. These four criteria were selected because they were related to the procurement of physical goods which could be delivered to the campus, and would thus give an estimate of proportions of goods arriving for each faculty.

F_{Scaled} = 1:3.067

Using the average dimensions for each category as presented in Transport for London (2011), an estimation of the volume of deliveries coming into Hartley Stores was made:

$$V_{Hartley}(m^3) = (0.0015 * total\ small) + (0.014 * total\ medium) + (0.129 * total\ large)$$

Hence, the estimated total volume of freight arriving at Hartley Stores was 35.87m^3 each week, excluding Royal Mail. From this value, another estimation for the total volume of freight delivered to the UoS as a whole could be made. The estimated volume was calculated under the assumption that number of goods being received by a department was proportional to its spending on physical goods, in the absence of any more useful information about delivery patterns. Hence, the scaled estimation for total University packages was calculated using Eq. (11):

$$V_{University} = F_{Adjusted} * F_{Scaled} * V_{Hartley} \qquad (11)$$

$$= (0.547 * 3.067) * 35.87$$

$$= 60.22m^3\ per\ week$$

where, $V_{University}$ is the volume of deliveries received by the university as a function of the adjusted ratio between Planon and survey data ($F_{Adjusted}$), the ratio of deliveries earmarked for each faculty (F_{Scaled}) and the Volume of freight arriving in Hartley Store ($V_{Hartley}$).

Similarly, the number of deliveries arriving at Hartley Stores was scaled to estimate the total number of vehicles arriving on campus each week. The estimation assumed that the relationship between vehicle number and deliveries was linear (rather than an increased vehicle load) and this was calculated using Eq. (12), hence:

$$D_{University} = F_{Adjusted} * F_{Scaled} * D_{Hartley} \tag{12}$$

$$= 0.547 * 3.067 * Vehicles\ [Hartley]$$

$$= 1.678 * 79$$

$$= 132.5\ vehicles/week$$

where, $D_{University}$ is the total number of deliveries received across the university in a given week.

For the emission calculation, journey distance modelled in ArcMap was applied to an emission factor for the different vehicle characteristics recorded. Vehicle categories were split into either vans distinguished by class (*i.e.* class I, up to 1.3 tonnes; class II 1.3-1.74 tonnes, and class III 1.74-3.5 tonnes) or heavy goods vehicles (HGVs) distinguished between rigid or articulated HGV by weight (>3.5-7.5 tonnes, >7.5-17 tonnes, and >17 tonnes). Emission factors are based on an industrial average payload weight of 50% (Defra, 2013).

In extrapolating the figures for the entire year, a modest estimate was made; since the survey was conducted during a 'business-as-usual' (BAU) date in term-time, consideration must be made that this is not indicative of the non-term time. For this reason, emissions were only calculated for the 31 weeks that the UoS could be considered to be operating at 'BAU'. The results of the GHG assessment show that total CO_2e emissions for the institution from deliveries equals 80,373 kgCO_2e. Using this information can be a powerful tool for future traffic management and carbon management at the institution. With more than 130 vehicle movements per week at the campus, the logistical challenges of receiving these goods is evident especially when considering the setting of the Highfield Campus; surrounded by suburban residential housing adjacent to an SSSI.

A softer option for managing freight movements is route optimisation (Hughes, 1992). As the results affirm, deliveries by couriers are most often not only destined for the institution, but the campus is one feature along a predetermined route from a central depot. Emissions are apportioned by the recipients along the route (Suzuki, 2011), minimising the duration the vehicle is operating over the course of the route yields benefits for all recipients. By ensuring that freight takes the shortest route, which avoids obstacles (either reactionary obstacles such as traffic lights or geographic obstacles such as hills), fuel efficiency is improved and emissions are decreased. In addition, optimising the return journeys of vehicles wherever possible and allowing goods to be back-hauled ensure that the greatest efficiency is achieved in essential journeys.

A number of studies have been conducted on sites in urban settings whereby freight consolidation is a viable option to reduce freight movements, reduce local congestion and in-turn influence emission reduction. Consolidating freight can be considered in a number of forms, including localised consolidation points or through freight consolidation centres and most often consist of strategically located warehouses where freight from multiple suppliers is stored (often out of town) until it can fully load a single vehicle (Allen *et al.*, 2012). Freight consolidation is most effective and commonly employed for 'last mile' movements (Allen *et al*., 2012; Plambeck, 2012).

6.6 **Conclusions**

This chapter has sought to present in-depth the results of the GHG assessment conducted at the UoS, the research's primary case study institution. Whilst a description of methodological approaches accompanied the results returned by the participating institutions, the detailed study of the UoS has revealed more about the likely approaches taken by the nine other participant institutions to collate and report data required for the long-term research study presented in Chapter 5. Whilst the details recounted in this chapter go slightly beyond the scope of the USM, a number of important conclusions assist in improving and contextualising the findings presented in Chapter 6, the results of the USM test.

Much of the data collected by institutions for use in GHG assessments is collected through activities or programmes that inform other estate processes. For instance, the example presented here is the commuter travel survey which aids university travel managers in prioritising nearby travel interventions and on-campus transport policies. Travel surveys are a staple tool used for quantifying GHG emissions and allow practitioners to collect information about the habits of staff and students, including journeys for all common transport modes. The USM now only requires that data on commuter car journeys, which would otherwise involve a need for a redesign, if the information already contained in the travel survey were not highly useful to the institution.

To this end, data collection may remain considerably complex despite the efforts to simplify it. This may also involve further processing than would otherwise be necessary, as additional steps may need to be taken in order to extract it from the superfluous data no longer required by the USM methodology. Despite this, the chapter demonstrates that data collection is relatively straightforward for data sources required for the USM. Additionally, a number of simple methods have been demonstrated here where data can be obtained for calculating emission sources not required under the USM, including emissions from upstream transportation.

The management of Scope 3 sources that no longer require quantifying under the USM can still have significant uses for carbon management at the institution and existing policies. The UoS is still committed to commuter-based modal targets as outlined in its 2015-2020 travel plan and the quantification of the GHGs arising from transport, as demonstrated in this chapter, reveals surprising conclusions about the policy that has been implemented. Whilst emission savings are expected for staff and postgraduate modal targets, undergraduate modal targets are expected to result in an increase in emissions by 2020 (without also accounting for student population growth). Closer consideration of the GHG-related impacts of modal shift targets at the time they were mooted would have altered the course of policy setting and ensure that the institution is responsible for lasting GHG reduction. This highlights the importance of quantifying GHG emissions and the breadth of their use as a policy tool which goes beyond simple reporting and peer benchmarking.

Chapter 7: Carbon management at universities: future trends and shared opportunities

The previous two chapters explored the results of the year-long study undertaken to test the proposed universal standard methodology (USM), as outlined in chapter 4. This chapter now turns attention to address the third research aim outlined in 1.6 concerned with assessing the future of carbon management in HE, under the scenario of a sector-wide adoption of a universal standardised GHG assessment methodology. More specifically, this chapter now addresses objective 3.1 by assessing the HE sector's climate vulnerability and by understanding how this could be improved by adopting a universal methodology. Secondly, it addresses objective 3.2 as it investigates the potential for the decarbonisation of the HE sector to 2050 using best available technologies.

The UK is in transition; the currency by which international success is now measured in this transition is knowledge. Therefore, the UK must prioritise the development of new knowledge and the training of highly technically skilled people in order to maintain its competitive position in the global economy. The third 'digital' industrial revolution, since the late-20th Century, has seen the desire for knowledge grow insatiably, facilitated by the rise of modern forms of communication: mobile telephones, satellite communication and the internet (Barber *et al*., 2013). Consequently, the HE sector is simultaneously undergoing rapid change to ensure that the workforce needed in this transition is equipped to prepare for, and confront, unknown challenges.

Ever-increasingly, UK HEIs are looking to the world for new talent, often for reasons that go beyond simple financial returns. There is also a growing recognition of the need to expand the reach and influence of research and teaching through growth. The impact of this growth on the environment is yet to be understood and quantified, but it is certain that growth must be decoupled from GHG emissions if the sector is to contribute to the decarbonisation required to maintain average surface increases above pre-industrial levels at +2^{o}C (as agreed at the United Nations Framework Convention on Climate Change (UNFCCC) COP in Paris in 2015). There is a dichotomy between an increasing international outlook supported by a broad goal for rapid growth and uncertainty of the climate impacts at home. If there is a solution to be found to this issue, then, in the context of this research, it starts with the concept introduced in Chapter 3 managing what is measured and therefore needing to measure in order to manage.

Once an institution holds itself to higher environmental standards, its global competitiveness is improved and resilience against future challenges strengthened. Thus, in the context of carbon management, following best practice delivers positive multipliers that transcend international borders (CDP & IBM, 2008).

As highlighted in the earlier chapters of this thesis, following best practice is an often imperfect and unattainable goal for many, which hinders the progress of the collective. In the context of carbon management in universities, a sense of best practice is garnered from generalised environmental reporting standards, which are amended and transposed to fit the setting of the institution (Robinson *et al*., 2018). Despite the absence of clear reporting methodologies however, progress is being made (but it should be noted that there are other factors that influence carbon management beyond clear and standardised reporting methodologies). Three key factors have contributed towards the improving standardisation and reliability of data associated with campus energy emissions, which have galvanised the UK HE sector in recent years, including:

i) The introduction of Carbon Management Plans (CMPs) (institutions were threatened with funding reductions if CMPs were not completed on time);
ii) The publication of sectoral guidance; and
iii) The development of the Estates Management Record (EMR)[43] (and associated reporting mechanism) administered by the Higher Education Statistics Agency (HESA).

This has been an important coming together, for HE is a sector that has felt governmental pressure to decarbonise since the introduction of the Climate Change Act (CCA) in 2008. This difficult task has been intensified at a time when funding has been significantly altered and student recruitment has become particularly competitive. Ambitious reduction targets were set to create positive momentum, but these have thus far achieved little progress, except perhaps in the short term with the adoption of CMPs. It is clear that the current paradigm favours prioritising carbon management initiatives on low-hanging fruits over deeper systemic changes. These are prioritised on their economic credentials, as the activities that promise to yield the fastest return-on-investment (ROI) and expose the institution to the least amount of risk. On most governance metrics these can only be lauded as sensible prioritisations. However, a degree more of risk should be promoted by institutions in order to ensure that meaningful and lasting actions are implemented to maintain the level of ambition committed in Paris.

The following section explores the options available to institutions for going beyond superficial savings. Without a clear strategy for the future, the UK HE sector risks exposing itself unduly to

[43] Initiated by the Association of University Directors of Estates (AUDE), the EMR covers a wide range of statistics on the attributes of the university estate. Institutions are expected to report information on 95 mandatory items on an annual basis during a reporting year from 1st August to 31st July. Data are submitted following detailed guidance and using an excel template via an online portal (submit.hesa.ac.uk)

vulnerability caused by climate change and climate-related impacts. Whether deep enough reductions can be made to contribute meaningfully towards society's Paris Agreement obligations remains to be seen. The options presented highlight the numerous opportunities awaiting the sector through delivering best practice carbon management. A thorough assessment of the required efforts needed to meet these obligations is contrasted against likely achievable actions using current technologies and the willingness of the sector. Firstly, a sectoral vulnerability assessment is conducted, which gives perspective to the immediate urgency with which to address impending climate change. This is framed by the adoption of a universally applicable methodology for assessing the carbon emissions of universities.

7.1 Assessing vulnerability of the UK HE sector to climate change

Vulnerability assessments help environmental practitioners to identify, quantify, and prioritise an organisation's vulnerabilities to climate change. This can be done for a number of reasons that allow leaders to understand future scenarios on: i) the attractiveness of investment, ii) the long term and short term financial costs; and, iii) the potential for asset-stranding of the investment portfolio (where the value of a fossil-fuel based commodity or climate-sensitive asset becomes worthless) amongst others (Smit & Wandel, 2006). In the context of preparing for a changing climate, vulnerability is defined as: '*the extent to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes*' (Adger, 2006). The University of Southampton (UoS) is used as an indicator of the HE sector's climate vulnerability: the assessment criteria are presented in Table 56.

Table 56: Criteria descriptors used to calculate vulnerability score for the University of Southampton .

Indicator	Weight Value	Description
Exposure	25%	
Ave. temperature:	Average °C 2001-2010	A higher starting average temperature indicates a greater vulnerability
Temp. changes	% change 1991-2000 to 2000-2010	A higher rate of increase in average temperature suggests a higher vulnerability to changing weather factors
Water availability	% from 1997-2008	A lower water availability *per capita* value indicates a greater vulnerability to climate change factors. A higher negative percentage change of renewable water *per capita* indicates a greater vulnerability
Extreme events	Land adjusted number of events	A high level of extreme events indicates a higher exposure
Change in extreme events	% change 1991-2000 to 2000-2010	A higher rate of change of event indicates an increasing magnitude of climate risk
Impact Sensitivity	25%	
People affected	Number affected by weather events	More people affected reflects a higher vulnerability
Deaths	Number killed by weather events	More people affected reflects a higher vulnerability
Damage costs	USD as a proportion of GDP	Higher damage costs as a proportion of the economy reflect a higher vulnerability to climate change driven weather events
Adaptive potential	25%	
Wealth	Income *per capita* (USDm)	A lower GDP *per capita* indicates a higher vulnerability because of the lower ability to invest to adapt
Budget	Debt to GDP ratio	Higher debt indicates a lower capacity to pay for infrastructure build
Adaptive capacity	25%	
Rule of law	Index to denote perception of confidence in rule of law	Higher rule of law indicates better governance which demonstrates an ability to implement change
Corruption	Index to denote perception of control of governance	Better control of corruption indicates a greater likelihood of proper allocation of funds for adaptation
Education	Ratio of total enrolment to the population officially correspond-ding to tertiary education age	Higher education indicates a higher skills base to change

Source: Adapted from Knight *et al*. (2013).

Each of these indicators is scored on a 1-5 rating system (one describing 'no change' and five describing a 'severe' change, or equivalent):

- Exposure captures the likelihood of vulnerability to climate change impacts, based on current metrics. While it is distinct from vulnerability, exposure is an important precondition for considering a specific vulnerability as key. If a system is neither at present nor in the future exposed to hazardous climatic trends or events, its vulnerability to such hazards is not relevant in the current context. Exposure can be assessed based on spatial and temporal dimensions;

- Impact sensitivity demonstrates the magnitude of disruption from these impacts. Vulnerabilities are considered key when they are persistent and difficult to alter. This is particularly the case when the susceptibility is high and coping and adaptive capacities are very low as a result of conditions that are hard to change;
- Adaptive potential measures the economic resources available to build infrastructure needed to reduce or limit the consequences of climate-related hazards (Birkmann *et al*., 2013). Adaptation is a continuous process that encompasses learning and change of the system exposed, including changes of the rules or modes of governance. Inability to replace losses in the system (or compensate for potential and actual losses and damages *i.e.*, irreversibility) is a critical criterion for determining what is "key". From a financial perspective, organisations with greater cash levels and operating profits should be in better positions to take pre-emptive action to avoid and react to adverse external stimuli; and
- Adaptive capacity defines the capacity of the system to adapt if the environment where the system exists is changing. Conditions that make communities or social-ecological systems highly susceptible to climatic-related hazards such as violent conflict are considered. The methodology considers three indicators here: the rule of law, corruption and education.

The UoS' vulnerability score can be seen in Table 57; an overall score of 2.5 means that whilst the institution is somewhat exposed to the risks of a changing climate, future vulnerability is deemed to be low. For comparison, the results of the vulnerability assessment conducted by Knight *et al (* 2013) on the UK's climate vulnerability places the UK 16th in the G20 with a score of 4.1. The strength of the UoS' position regarding climate change is attributed to its strong financial position, it's positioning in an economically prosperous and politically stable region of the UK and its foundations in research with personnel able to devise the solutions to the future climate-related challenges it faces.

Table 57: The University of Southampton's vulnerability score results, out of 20, the higher the vulnerability score is across each of the vulnerability indicators the more acute the exposure to potential climate change risk.

Vulnerability Indicator	Score (out of 20)
Exposure	4
Impact sensitivity	2
Adaptive potential	2
Adaptive capacity	2
Score	2.5

The favourable position that UK-based institutions, such as the UoS, are in (where vulnerabilities to climate-related impacts are low) may support why the sector's progress to-date has been so limited. This may also add weight to the reasoning that institutions find themselves limiting their ambition, because they simply do not need to take undue risks under current conditions. A note of caution, the security afforded to institutions operating in the UK is not the same in markets around the world in which they operate. Therefore, institutions are increasingly and inadvertently exposing themselves to enhanced climate vulnerability. The adoption by universities of a universal approach to quantifying and reporting GHG emissions will contribute to improving the preparedness of institutions to a changing climate as international growth priorities take precedence over the early decades of the 21st Century.

The UK's ratification of the Paris Agreement represents a move towards aiming for net zero carbon emissions from the 2050s onwards[44] (Committee on Climate Change (CCC), 2016). Referring again to the existing carbon budgets published by the CCC (presented in Table 1), the UK is on a self-committed trajectory to make an 80% reduction in emissions by 2050 (in-line with the CCA). These represent a least-cost trajectory towards the global goal of keeping temperature to around 2°C. The UK's own intended nationally-determined contribution (INDC) committed it to a binding target of at least a 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990. This means that the UK's domestic climate goals are more ambitious than

[44] In accordance with this pledge, each party is required to submit carbon budgets during global stocktakes occurring every five years designed to assess the collective progress towards achieving the purpose of the Agreement and to inform further individual actions. During the stocktake, INDCs are reviewed and redrawn in-line with the individual party's recognised climate ambition and adaptive capacity (Smit & Wandel, 2006).

those set down in the EU's Paris Agreement INDC (though subject to review from 2020). Despite this, the UK's 2050 commitments fall short of the Paris Agreement's upper ambition to keep global temperatures at or close to 1.5°C. This would require the UK to commit to reduction of a least 90% below 1990 levels by 2050 and potentially more ambitious efforts over the timescale of existing carbon budgets.

The CCC has recommended that despite this performance gap, the carbon budgets and targets remain, as they are already stretching and relatively ambitious compared to pledges from other countries. Meeting them cost-effectively will require deployment to begin at scale by 2030 for some key measures that enable net zero emissions (e.g. carbon capture and storage, electric vehicles, low-carbon heat). In theory these measures could allow deeper reductions by 2050 if actions were ramped up quickly[45]. The different sectors of the UK, such as HE, can directly contribute to meeting this target by aligning emission reductions targets with the carbon budget. It is this rationale that spurred the HE sector to set its absolute (combined) Scope 1 and Scope 2 target in 2010.

7.2 A bespoke university carbon management strategy to 2020, and beyond

A universal methodology, which provides a structured and bespoke basis for reporting, establishes a level playing field where GHG information can be calculated and reported in a relatable and traceable way. With an approach that is tailorable to the individual institution, sympathetic to their activities and which recognises competing priorities, a firm basis for GHG emission assessments is established. The benefits of which are described throughout this thesis. Beyond calculation though, the measurement and subsequent reduction of GHG emissions is a considerable ongoing challenge with often high operating costs.

[45] There will be several opportunities to revisit the UK's targets in future as low-carbon technologies and options for greenhouse gas removals are developed, and as more is learnt about the ambition of other countries. In 2018 the IPCC will publish a Special Report on 1.5°C, and there will be an international dialogue to take stock of national actions. In 2020: the CCC will provide its advice on the UK's sixth carbon budget, including a review of progress to date, and nations will publish mid-Century greenhouse gas development plans and in 2023 the first formal global stocktake of submitted pledges will take place.

7.2.1 Decarbonisation of a university in-line with the Paris Agreement: the case of the University of Southampton

Instituting a clear strategy, which outlines the pathway to decarbonisation, is an imperative that institutions should develop without delay. Further delay would act to stall progress even more and worsen the current climate change threat; consensus follows that fewer of the worst climate impacts are expected if immediate action is taken to curtail GHG emissions from 2020, begin carbon removal from 2030 and fully decarbonise around 2050-2060 (UNFCCC, 2015).

It was shown in chapter 3 that a target-setting culture can hinder meaningful emissions reductions if rhetoric is favoured over action. In chapter 4, a scope 3 sectoral target was found to be unfavourable to practitioners over activity-based performance-based targets and strategies[46] (Robinson *et al.*, 2016). This does not detract however from the urgent need for a collaborative and universal goal to be set on emissions reduction as a sector in order to meet the Paris Agreement commitment.

The more pragmatic of methodologies used to develop sectoral decarbonisation strategies takes a 'sectoral contribution' approach. This advocates the setting of a collective GHG reduction target for a discrete economic sector, whilst its constituent organisations calculate their own reduction contributory emission reduction 'wedge'. Individual targets are a function of emissions baseline, size, and growth trajectory of the organisation or institution.

The Sectoral Decarbonisation Approach (SDA)[47] is one such example and is a subsector-level methodology designed to allow simple medium- and long-term scenario modelling of the decarbonisation pathway. This methodology is based on the 2°C scenario from the IEA's 2014 Energy Technology Perspectives report (IEA, 2014), which uses the least-cost technology mix available to meet final demand for industry, transport, and buildings services to budget to the year 2100. The budget used is consistent with the representative concentration pathway (RCP) 2.6 scenario from AR5 (IPCC, 2013), which gives the highest likelihood of staying within the global target temperature of less than 2°C in the year 2100 (p = 0.66) estimated at 1,055 $GtCO_2e$ up to 2050. The SDA is intended to help companies in homogenous, energy intensive sectors with well-defined activity and physical intensity data, including: electricity generation; iron and steel;

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[46] The most common reasons cited for low turnout in submitting data returns for indirect emissions categories include data reliability, data quality issues, and the quality of available guidance. Reporting is currently not mandatory despite an increasing number of reporting items being required in the estates management record; discussion by sector leaders cannot rule out any changes to this situation in the near future, or post-2020.

[47] This is governed and approved by the Science Based Targets Initiative (SBTI), a partnership of global governance bodies including the CDP, UN Global Compact, WRI and WWF.

chemicals; aluminium; cement; pulp and paper; road, rail, and air transport; and commercial buildings. Education is included in the services/commercial buildings subsector.

Based on the baseline emissions results presented in Chapter 5 (a combined Scope 1 and 2 baseline of 31,769 tCO_2e for the academic year 2015), the outputs of the model can be seen in Table 58 and Table 59. The growth of the institution is projected under a number of forecasting procedures which can be seen in Figure 30; the average year-on-year growth projection was chosen for the SDA calculations. The UoS should set an absolute Scope 1 and 2 reduction target of -46% by 2030 and -84% by 2050 below a 2015 baseline. Due to projected estate growth of only 1% year-on-year, significant reductions made to the intensity baseline will also equate to significant absolute savings.

Table 58: Absolute and Intensity GHG emissions reductions in the medium term (to 2030) and long-term (to 2050) required for the University of Southampton to level with sectoral decarbonisation efforts on a 2^{o}C trajectory.

Year	Scope 1 & 2 target emissions (tCO_2e)	Variance
2015 (baseline)	31,769	N/A
2030	17,005	-46%
2050	5,025	-84%

Table 59: Intensity GHG emissions reductions in the medium term (to 2030) and long-term (to 2050) required for the University of Southampton to level with sectoral decarbonisation efforts on a 2^{o}C trajectory.

Year	Scope 1 & 2 intensity target (tCO_2e/m^2 GIA)	Variance
2015 (baseline)	0.075	N/A
2030	0.040	-46%
2050	0.011	-85%

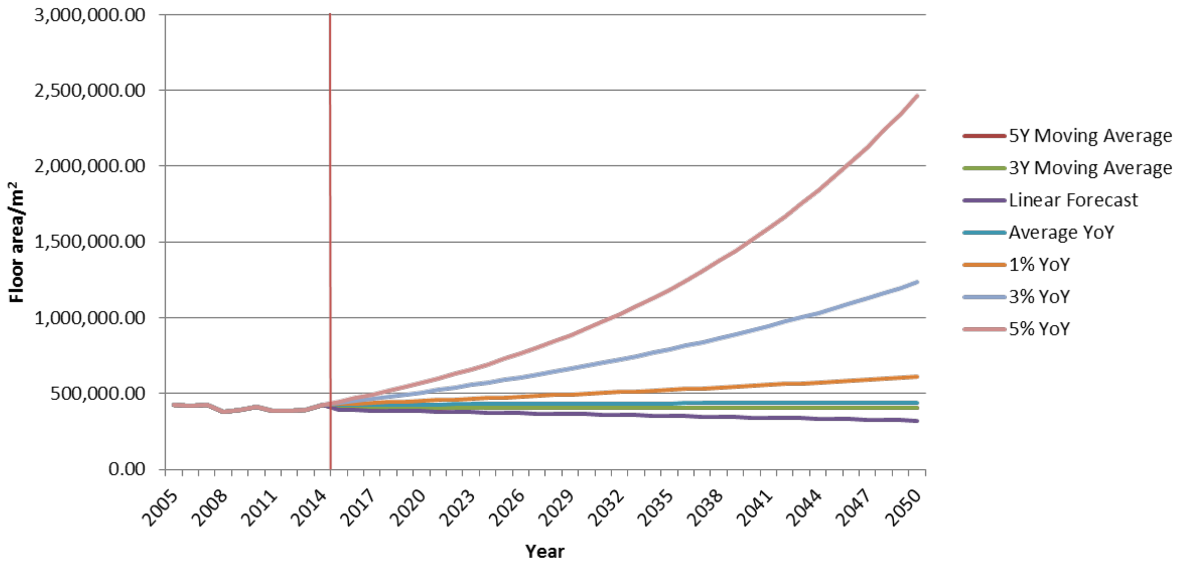


Figure 30: Estate growth projections of the University of Southampton's gross internal area for 2015-2050 under: i) a five-year moving average forecast; ii) a three-year moving average forecast; iii) a linear forecast; iv) the average year-on-year growth from 2005-2015; v) an assumed 1% year-on-year growth; vi) an assumed 3% year-on-year growth; and vii) an assumed 5% year-on-year growth.

Ambitious, long-term Scope 1 and 2 trajectories must be set. Scope 3 trajectories are much harder to project and, in this way, are controlled at the national scale by the UK's GHG inventory. It is clear that there is a role institutions must play in reducing indirect Scope 3 emissions. In using the environmental performance indicators to monitor emissions, many of the significant Scope 3 emission sources are managed by respective institutions (and their supplier organisations). The inclusive Scope 3 environmental performance indicators can also have targets associated with them and in the case of commuter travel, at the UoS, many already do; this is an additional nascent benefit to the adoption of the universal standard methodology (USM).

Notwithstanding the desire for institutions to reduce emissions through energy efficiency measures, behavioural change through engagement, and innovative technological solutions over the course of the next Century, emissions may also be offset sooner through pledges made to be 'carbon neutral'. Currently, PAS2060 is the only standard available to UK organisations in accrediting carbon neutrality (although consultancies do award their own certifications). This relies on possessing good knowledge of all activities, including Scope 3 activities (though there are notable exceptions to this *i.e.* Marks and Spencer) or of the stated portfolio. To comply with PAS2060, the carbon credits need to originate from approved sources and should result in emission removals that wouldn't have happened anyway. Ensuring that offsetting is making a net reduction in emissions, rather than shifting the burden is central to pragmatic carbon neutrality.

To offset emissions and become carbon neutral, institutions would need to purchase carbon credits from a PAS2060 approved scheme *i.e.* the Clean Development Mechanism (CDM) or Joint Implementation (JI).

A high profile example of a large multi-national corporation investing in emissions offsets is Microsoft. Amongst the 23 projects across 15 countries, Microsoft invests in a community reforestation project in Kenya, which aims to offset the emission of releases that are deemed unavoidable, (DiCaprio, 2015). The other projects are focused on myriad land-use issues, such as deforestation of virgin rainforest for the development of palm oil plantations (for instance, in Borneo). Additionally, the company has instituted an internal carbon price to deter influencing greatly emitting activities.

7.2.2 Management options

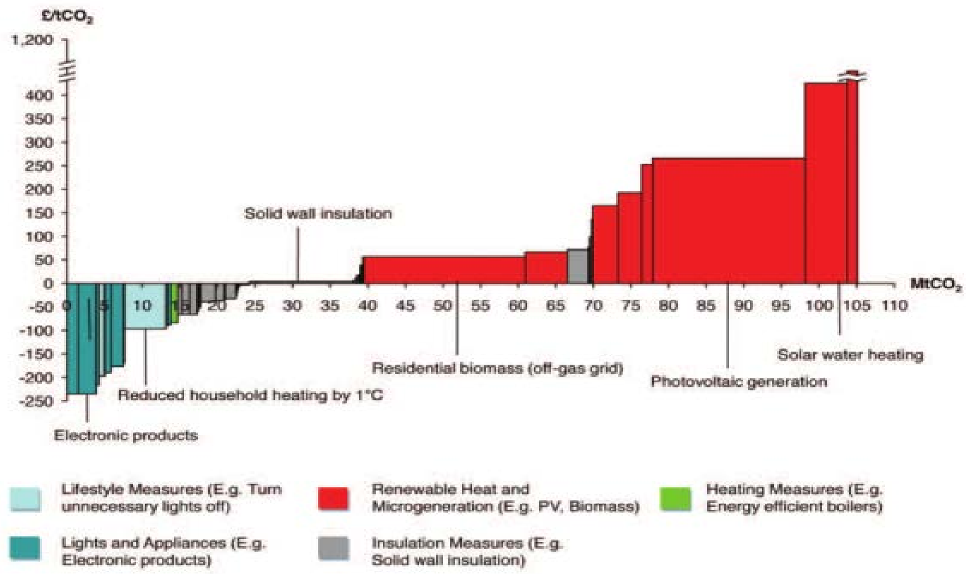
Marginal abatement cost curves (MACC)[48] can assist the practitioner in deciding which policy implementation or technology is the most appropriate, affordable and most likely to assist them in reaching their emission pledge. Well-established in guiding national policies for adapting to climate change, MACC are increasingly being used by the HE sector to prioritise, in-detail, the intended management options for delivering proposed emission reductions. Often composed using a range of technologies, they allow environment managers to select least-cost options and tailor programmes according to the financial abilities of the institution.

Based on the current political momentum aimed at limiting climate change based on direct energy usage emission reductions, sectoral projections to 2050 would see the sector limiting climate change by significantly reducing direct energy usage or switching to zero emission tariffs. Whilst Chapter 5 of this thesis still advocates the quantification of emissions from indirect emissions along the value chain for internal management purposes, in practice, due to the relaxation of the demands for reporting such information, the onus to manage indirect emissions lessens. Should all organisations operate under best practice, this does not represent a significant threat to the wider carbon management agenda. What emerges is the need to improve the operating efficiencies of the buildings occupied by institutions and the wider estate instead. Figure 31 shows MACC curves for residential assets and non-residential assets under a Business-

[48] There are two types of MAC curves: expert-based MACC curves may be used to assess the cost and reduction potential of each single abatement measure based on educated opinions, while model-derived curves are based on the calculation of energy models. Abatement curves based on a societal perspective are recommended by the Green Book (Lowe, 2008) to use a discount rate of 3.5% in the first 30 years of a programme, followed by a schedule of declining discount rates thereafter to reflect society's preference over time, while curves from a private perspective integrate subsidies, taxes and higher interest rates up to 10% and higher to measure the costs faced by private individuals when making investment decisions.

as-usual (BAU) scenario in 2020, published by the UK Government in 2008 as an example of potential campus-based management options available to practitioners.

a)



b)

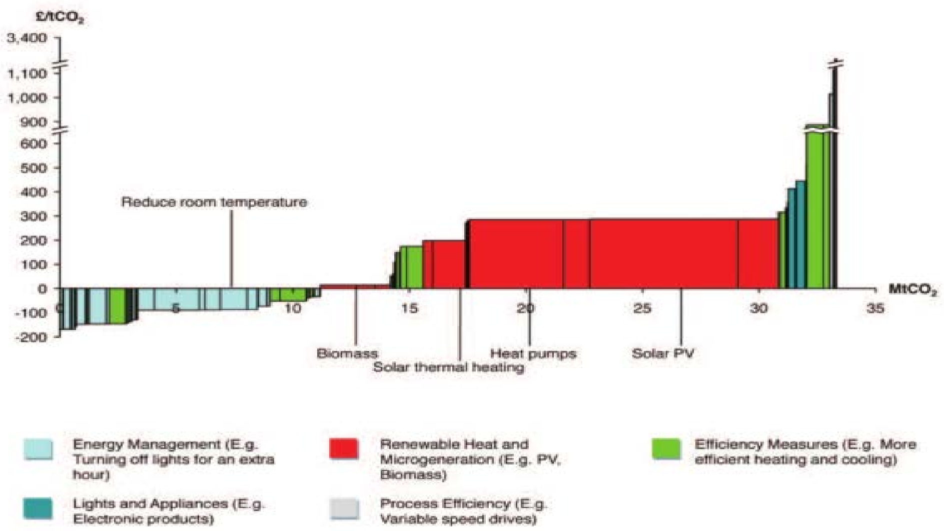


Figure 31: a) marginal abatement cost curves in UK residential buildings; b): for UK non-residential buildings in 2020, under a BAU scenario and a discount rate of 3.5% per annum.

Source: Reproduced with permission from Higher Education Funding Council for England (HEFCE), 2010b.

Industrial sector abatement technologies are generally divided into two distinct categories; End of Pipe (EOP) and Change in Process (CIP). EOP technologies are based upon the treatment of waste, whereas CIP technologies tend to be based upon the prevention of waste production, for example changing raw materials to reduce waste outputs. The CIP measures are generally the most effective and efficient as they prevent the production of potential pollutants, and often save resources, however, they do tend to require significantly more development. The EOP measures are often immediately applicable and cheaper in the short term, but rarely have beneficial financial effects and generally do not prevent the production of waste. The most significant factors affecting the technology applied tend to be capital cost and ease of application.

7.2.3 The realities of ambitious carbon management

As MACC are formulated for the future and cover many technologies, they can be deemed highly uncertain. Although a number of scenarios can be modelled, the assumptions typically embody a particular subjective world view, whilst the available technologies are limited by the practitioner's knowledge of future breakthroughs. Presently, practitioners may not possess the ability to be able to take such long-term views of their institution's carbon management activities. This may be due to a number of reasons: their role does not involve them in new build or refurbishment projects, or that they are occupied in more urgent matters, such as energy management or travel planning.

Invariably, institutional decision makers tend not to be environment managers, whose roles typically occupy the middle of the organisational structure. It must be remembered that the championing of sustainability-related issues may not only come from the estates or environment teams, and as has already been explored in the thesis, Vice Chancellors and decision makers are welcoming the benefits of sustainability. Often however, economic factors will prevail and so developments favoured by Vice Chancellors will tend to be less expensive and more inefficient, instead of low carbon. This happens unless environment managers are able to extoll the virtues of the low carbon alternative through transparent costings and well thought out strategies, of which there are many well-known examples. The UoS itself has been able to make significant improvements across the estate as a result of championing this agenda; including a number of these examples, which featured in their CMP published in 2010. These were short term projects, often standalone developed in order for the institution to meet its 2020 carbon target and included:

1. The installation of a swimming pool cover and appropriate upgrades to air handling plant controls of the sports centre,
2. The installation of energy efficient gas burners to the main district heating boilers to deliver annual carbon savings of 1,134 tonnes and pay back in 4.5 years,
3. New electricity sub meters installed at halls of residences and water meters installed at the main Highfield Campus; and
4. A computer switch-off in conjunction with the implementation of a power management policy.

These examples demonstrate success is possible when projects are assessed and prioritised for their wider sustainability credentials (and this means also developing projects that incorporate social benefits and go beyond carbon and financial savings).

7.3 A future for sustainability in higher education

As has been a recurring theme throughout this thesis, HEIs are stronger and better equipped to face future challenges if carbon management is prioritised alongside all other sustainability activities. As sustainability (and broader, sustainable development) is recognised as business-critical, as is evident in the example of the UoS, the reality of an equitable and environmentally-conscious reality becomes ever more probable.

Different studies have attempted to articulate systematically scenarios for the future of sustainability in higher education, each with distinct approaches. Table 60 shows a summary of studies and details of their future scenarios of sustainability in the HE Sector. Beynaghi *et al*. (2016) outlines three future scenarios for HEIs in regards to the wider ESD context: the socially-oriented university will be an institution committed to advancing equitable and sustainable social and economic development in partnership with its surrounding community and region. The environmentally-oriented universities will be solely devoted to the co-creation of strategies and tools for environmental transformations and the pursuit of sustainability through environmental improvement. The economically-oriented universities will promote sustainability through economic development and entrepreneurialism.

Table 60: Summary of key studies proposing future scenarios for sustainability in higher education institutions.

Author(s)	Format	Scope	Description/focus
McNay, 1992	Book	Global	Diversity and equity, individual and collective identity, freedom and trust, collaboration and community commitment
Conway, 2003	Article	Individual institution	Education, societal values and expectations, local demographic issues, globalization, information technology, financial issues and market needs, environmental issues, government policy
Miller, 2003	Report	OECD countries	Lifelong learning, networking, diversity, tradition and entrepreneurship
Vincent-Lancrin, 2004	Article	OECD countries	Tradition, entrepreneurship, the market, lifelong learning, networks and diversity of learning
Avila & Leger, 2005	Book	Global	Politics, the labour market, the value of education, social demands, and quality
Hashimshony & Haina, 2001	Article	Global	Physical and organisational structures of universities
Ritzen, 2006	Article	Global	Demand for higher education: international talents, lifelong learning
Snyder, 2006	Article	Global	Time in education, fuller education and further education
Vincent-Lancrin, 2006	Article	OECD countries	Funding, administration and market force, national and international trends
Amatariyakul & Tesaputa, 2009	Article	Individual institution	Learning and teaching management, research, academic services, art and cultural maintenance
Azman *et al*., 2010	Article	National (Malaysia)	Economic drivers, democratisation of knowledge, corporatization and the learning environment
Blass *et al*., 2010	Article	National (UK)	Globalization and international students, demographic trends and non-traditional students, digitalization, democratization
Barth *et al*., 2011	Article	Global	Sustainable universities
Stephens, 2011	Article	National (Ireland)	Access, curriculum, management, external environment and assessment
Duderstadt, 2012	Article	Global	Knowledge economy, diversity, technological change, globalisation, demographic change, global sustainability, lifelong learning, market, access
Inayatullah, 2012	Article	Asian-Pacific countries	Globalisation, Virtualisation, democratisation, multiculturalism
Inayatullah *et al*., 2013	Article	Individual institution	Curriculum, learning process, technological change, organisational structure, leadership, campus
Nasruddin *et al*., 2012	Article	Individual institution	Intellectual freedom, learning environment

More often than not, the past is not a good indicator of the future. However, for the HE sector, the past should stand to act as inspiration for the future of sustainability, and by wider definition, sustainable development. The decade 2005-2014 was dedicated by the UN as the international Decade of Education for Sustainable Development. In this time HEIs increased their efforts to support sustainable development in a number of areas. Not only have they significantly improved the provision of campus greening initiatives, they have also acted to embed sustainability in the taught curriculum and research programmes. Additionally, numerous networks have been established in all regions of the world, including: Mainstreaming Environment for Security in Africa, Promotion of Sustainability in Postgraduate Education and Research in Asia-Pacific, COPERNICUS in Europe and *Alianza de Redes Iberoamericanas de Universidades por la*

Sustentabilidad y el Ambiente (Alliance of Ibero-American Networks of Universities for Sustainability and the Environment) in Latin America. More recently, UNEP created the Global Universities Partnership on Environment for Sustainability.

Under the current capacity-building trajectory and with clear foresight to the growing importance of sustainability in HE certainly has a promising future, should momentum continue.

7.4 Main research findings and original contribution

There are significant future risks to business affecting the HE sector in the future as a result of a changing climate. Yet, despite this, the HE sector is falling behind on its own commitment of emissions reduction (as demonstrated in Chapter 3). This is as a direct result of the policy decision that have been taken and the response by the sector to promote a target-setting culture over meaningful and deep emission cuts. In 2016, the UK government released a white paper on the future of policy in HE, which was focussed on funding and provision of facilities and did not mention sustainability issues at all (Department for Business Innovation & Skills, 2016).

Put simply, to be able to manage GHG emission releases in a manner that is supported by evidence, Vice Chancellors, institutional policymakers and sustainability teams require the political willpower, collective momentum, and the tools to put GHG emissions at the top of the agenda. These tools in particular must enable them to compare progress against their peers. Often, the carbon footprint is a tool used by non-experts and must thus be designed for interpretation by a wide audience.

Whilst GHG emissions are inherent to the operations of HEIs, the contribution that UK HE can make to national carbon reduction efforts is noteworthy and gaining momentum. In quantifying carbon emission releases, institutions are able to understand the ‘size of the prize’ regarding emission savings (which is collectively often cited as 11% of public sector emissions) and plan their efforts accordingly. This thesis addressed a number of methods of quantitatively evaluating GHG emissions from the activities inherent to HEIs for supporting decision-making and strategic carbon management.

The existing approaches used to quantitatively assess GHG emissions of HE activities have been critically reviewed (objective 1.1) and a rationale provided for giving prominent study to the HEIs as organisations (objective 1.2). Together, these fulfil research aim one on investigating the extent to which existing greenhouse gas emission methodologies are applicable to HEIs and can be found in Chapter 2, Chapter 3, and Chapter 4. The critical challenges and essential requirements of industrial environmental practitioners have been identified through a long-term institutional study (objective 2.1), which has also revealed the status of data collection systems in HE institutions (objective 2.3). Chapter 5 outlines this research, which also addressed aim two, which sought to develop a practical and realistically applicable method of calculating GHG emissions from the activities of HEIs. Objective 2.3 is addressed throughout Chapter 5 and 6.

Chapter 6 presented an in-depth study of the case study institution, the UoS. The implications of these findings on the proposed universal methodology are also presented. Chapter 7 fulfils objectives 3.1 and 3.2 explores the management options available to UK institutions through a scenario-led analysis to 2020.

The original contribution and significance of this research can be summarised as follows:

- This research represents the first in-depth critical review of the current paradigm for assessing the GHG emissions of HEIs;
- This can be divided into the critical assessment of environmental standards commonly used by environmental practitioners and their subsequent standardisation into an applicable methodology for universities and the review of current methods for collecting and reporting GHG-related information in universities;
- The most extensive collection of GHG-related information of HEIs, conducted using a unique data collection tool over a long time period;
- The development of a series of Environmental Performance Indicators, with which environment managers can use to identify GHG emissions of their activities along the value chain which sympathises with the time and financial cost of traditional GHG assessments, whilst simultaneously ensures high quality and independently verifiable data; and
- An assessment of the future of HE from a carbon management perspective and explores examples of the available pathways to decarbonisation.

This thesis focused on evaluating existing methods and proposing a simplified and pragmatic method for the quantitative evaluation of GHG emissions from the activities of HEIs. With an emphasis on the UK situation and the primary case study, the UoS, the main research findings are summarised:

- Some English HEIs have set very high targets for carbon reduction, the result of an ambitious sector target set by the HEFCE;
- It remains to be seen if self-set Scope 1 and 2 carbon reduction targets will be accomplished within the set time frame to 2020;

- The three most influential barriers to assessing and reporting indirect GHG emissions from upstream and downstream of the organisational boundary of HEIs have been identified as time, cost and data reliability;
- A limited number of institutions have a detailed understanding of GHG emissions associated with all of their directly and indirectly influenced activities;
- The transposition of environmental standards designed to be suitable for all organisation types stifles the reporting of GHG-related information in the HE sector;
- Whilst the virtues of understanding all emissions for which an organisation is responsible are clear for implementing appropriate sustainability initiatives, when reported, inherent double counting undermines conclusions that can be made about entire economic sectors;
- The use of full-scale footprints for internal purposes and the external reporting of production-based emissions overcome all barriers and double counting issues;
- It is possible to reconcile existing emission standards, make a theoretical proposal about what improvements can be made to improve institutional reporting (based on defined parameters) and practically apply it to develop an externally-verifiable universal methodology;
- The UK HE sector is unprepared to make the necessary adaptions required against a changing climate and must begin now to address significant vulnerabilities; and
- Preparations should start with long-term horizon scanning to set an emission reduction trajectory for each institution in-line with sectoral decarbonisation required to meet the terms of the Paris Climate Agreement.

7.5 Research limitations

7.5.1 EEIOA-LCA model limitations

This study has employed the use of various research methods. Primarily, the prevailing method to assess the GHG emissions from activities of organisations and the method chosen in this research study is EEIOA-LCA. Although such techniques are implemented to facilitate meso-scale applicability and overcome the limitations of applying macro-scale EEIOA techniques and micro-scale LCA techniques at this scale, its use does come with certain limitations.

The integrated EEIOA-LCA approach is often lauded for its ability to combine large datasets on micro- and macro-scales to be used at the meso-level. However this means that the detail provided by the former is lost, whilst truncation errors are introduced by the latter. The wide choice of approaches available and the different results that can be garnered from studies of the same activity, process, or product highlights the limitation of integrated EEIOA-LCA. This also demonstrates the innate limitations that are recognised by the research community with conducting GHG assessments, by any means, at any scale. The limitations of the published approaches were detailed in Chapter 2 and carefully considered during the design of the study.

7.5.2 **Chapter 3 limitations: Benchmarking performance in higher education**

Chapter 3 began by selecting the UK Russell Group institutions as the grouping of universities under study for benchmarking. The reason for choosing the Russell Group institution was outlined; the consideration that research intensive universities are the most energy intensive due to significant energy consumption required for ‘research’ i.e. equipment in laboratories and workshops. This premise does not always stand when considering some of the institutions that comprise the Russell Group. The most notable example is the London School of Economics and Political Science (LSE), which is a specialist in social sciences based across a number of buildings in central London. The number of full-time equivalent (FTE) students at LSE exceeds no more than *ca.* 15,000 and meant LSE was the smallest institution in the study by population. Other examples include the ancient universities of Oxford and Cambridge, which together own property worth in excess of *ca.* £3.5 billion. These institutions are by far the largest occupiers and owners of land in the entire HE sector. Additionally, there are as many cases of non-Russell group institutions of high energy-intensity as there are in the Russell Group; oddities such as these highlight the limitations with focussing just on the Russell Group and assuming homogeneity/comparability between institutions.

The chapter moved onto assessing the carbon management plans (CMPs) of the case study institutions using two developed scoring methodologies. The methodologies took two environmental viewpoints that were intended to highlight the disparities between CMPs between institutions and the effect on performance of different perspectives. The chosen perspectives, defined as ‘light green’ and ‘dark green’ have not been cited many times in peer-reviewed publication, and were based on the subjective view of the author (Steffen). Therefore it could be argued that these methodologies were unreliable for use in this study. Although that may have been the case, this specific investigation was not central to the argument set out in the chapter, or more broadly, in this thesis.

The questionnaire undertaken to assess the behaviours of staff and students at the UoS was limited by the number of respondents. This meant that it was not necessarily representative of the entire population of the institution (150 respondents were received, which represented 0.67% of the institution’s combined FTE staff and student population). The means by which the questionnaire was administered (online) meant that it could be easily overlooked. There was also no financial (or other) incentive to entice staff and students to complete it, which certainly hindered the response rate. Administering the questionnaire for longer, at different times in the year and by additional means than the approach selected may have improved the response rate and generally improved the robustness of the chapter.

An additional suggested improvement to the chapter is the exploration of additional KPIs to those selected to present intensity-based metrics (*i.e.* staff and student FTE, gross internal area, and income). Research into other potential KPIs would extend the scope of the research.

7.5.3 **Chapter 4 limitations: Developing a framework for higher education**

Although six of the most popular carbon management standards available in the grey literature were selected for comparison and standardisation in Chapter 4, it should be noted that the choices which practitioners have were not limited just to these. Certainly, the inclusion of standards here was by no means intended as a way to positively 'rate' their effectiveness at calculating and reporting GHG emissions. A fraction of the literature is excluded from comparisons because the focus is on meso-scale models (integrated EEIOA-LCA). These models are somewhat more reliant on data inputs than say, macro-scale models, but offer the practitioner greater insight into process-level emissions.

The focus here was on engaging environmental practitioners at UK-based institutions. It could be argued that their broad role on many aspects of campus sustainability does not allow for building an in-depth knowledge on the academic underpinning of carbon management. Despite this, these personnel were deemed to be a vital resource and the expert on their own institution's reporting structures. The limited geographical spread of institutions as a result of the UK-focused nature of the event which hosted the consultation (the EAUC annual conference at the University of Leeds) can be extended. Consultation results suffered little from induced or preconceived response bias because of the variety of opinions received by respondents and the questionnaire design based on a variety of open- and closed-style questions.

7.5.4 **Chapter 5 limitations: Appraising the proposed universal standard methodology**

Chapter 5 was fundamentally limited by the availability of data and the associated quality of data due to the reliance on colleagues in external institutions. Although regular contact was maintained with study participants, there was an expectation that study participants would be self-sufficient following the initial project briefing. Following direct contact with the participants, it was clear that data availability was a major issue. This was also despite the guidance that was provided and the availability of assistance throughout the year for problem troubleshooting. Often, there was a lack of willingness to ask for help, which was exacerbated by the varied nature of their roles and the many issues competing for their time.

For many institutions, data streams simply did not exist for some emissions sources, making collation almost impossible or requiring long and costly lead-in times (which was unavailable at the time of the study, due to time constraints). Due to the differences in experience at conducting GHG assessment of study participants, it should be acknowledged that not all issues or difficulties could be rectified or were indeed highlighted by the participants. Due to these concerns, the potential was introduced for participants to delimit the organisational boundary to exclude certain entities or activities for which data would be difficult to obtain. In instances where this was a suspected issue, the stated reason for its exclusion was interrogated and agreed upon or disputed.

Although the study was offered to institutions as a means of assisting them develop their carbon management programme, some participants reported that to collect all the information required would be counter-productive and unsupported by staff members internally. Not all institutions had automatic metering systems and relied on more manual methods of data collection; instances like this only compounded the data availability issue but were broadly overcome and simply rectifiable through trial and error. Ultimately, all efforts to minimise, quantify, or explain limitations have been made as far as practicably possible. However, additional work is required to better address these limitations and, thereby, enhance the study's robustness. In doing so, this will enable more informed and less uncertain decision-making pertaining to the outputs of the USM.

It is worth exploring whether the sample size and type of institutions featured in this research study act was representative of the wider UK HE sector. For a number of reasons it was deemed to be representative for a number of reasons that can be explored. Firstly, the sample represented 7% of HE staff (30,000/410,130) and 6% of HE Students (129,000/2,280,830). Secondly, the types of institutions were varied (*i.e.* research-focused, teaching-focused, and vocation-focused) and originated from a variety of UK locations.

7.5.5 Chapter 6 limitations: Production-based university GHG assessments

The limitations of Chapter 6 were mostly attributed to methodological approaches of the standalone studies.

In quantifying emissions from upstream transportation and distribution, a significant source of uncertainty was introduced through the use of Hartley Stores as a proxy for the other campus stores. It was assumed that there is no variation between the nature of the goods received and their relative frequency at this store, however examples were found that showed this not to be the case all the time. For instance, the Institute of Sound and Vibration Research store typically receives a low volume of high value goods whilst the Engineering Design and Manufacturing Centre typically receiving a higher volume of lower value goods.

There is some underestimation of the figures calculated here. Although uncertainty with records made in Agresso is low, Agresso does not exclusively capture all orders made on behalf of the institutional faculties. Some are expensed, whilst personal orders are placed through altogether different routes, delivered to the institution and become assimilated into the internal postal handling system; an estimate puts personal orders at 25% of delivery volume. The ad-hoc nature of ordering goods is exacerbated by the lack of inventory control in Agresso. Optimising the central purchasing of goods internally at a time when a critical stock threshold is reached would ensure that duplicate orders are not placed by different departments at the same time. In addition, the arrival of vehicles sub-optimally loaded with deliveries intended for the institution could be avoided by better ordering policies.

The travel survey study was limited by the survey design limitations and may also have been the subject of unintended bias. Firstly, a number of transport modes were not available for selection in the questionnaire as these were deemed to be immaterial or considered to be a tertiary mode of transport (*i.e.* ferry journeys). Primary and secondary modes of transport were considered (modes of transport used on exclusive journeys), however due to the complexity of questionnaire design required, only primary *journeys* were considered (the mode of transport chosen on the final leg closest to the final destination). Therefore, were members of staff to originate on the Isle of Wight then only journeys from the ferry terminal were captured.

An inherent underestimate is acknowledged in the survey results, exacerbated by the small sample size and the potential introduction of responder bias (from the advertising campaign used to encourage people to take part in the study).

The calculations made to the waste data provided a best-case scenario for the efficiency of waste collections, but there were real world considerations which could not be so easily modelled. Apportioning the waste arising at Highfield to the waste collection vehicle was conducted using figures on the volume of the bins used in the campus' waste compounds. This was used alongside the assumption that the waste collection vehicle would continue its round at university-owned waste compounds until it reached capacity. Therefore, it could collect multiple bins with only making one trip to the university. A further stipulation, that the waste collection vehicle would only empty bins containing comparable waste types was made. This was conducted for mixed municipal waste and mixed recycling; the other waste streams were considered to be collected on an ad-hoc basis, with a vehicle travelling to the campus for the specific purpose; return journeys were excluded as the assumption was made that these vehicles would move on to another collection elsewhere.

7.6 Recommendations

It is anticipated that the development of a universal method for assessing the GHG emissions of HEIs will help to galvanise the sector in order for it to position itself on a trajectory towards decarbonisation. Based on the main research findings, the following section outlines a number of key recommendations for this to be able to happen. These recommendations are intended to apply not only to the case study institution or the study participant institutions, but should serve to be identifiable across the entire sector. The nature of the research presented in this thesis is such that it provides a much-needed critical analysis of the current state of GHG assessment and provides a pragmatic viewpoint on the long-term prognosis for carbon management to 2020 and beyond.

Chapter 3 recommends for caution and pragmatism on GHG reduction targets. If targets are to be set, they must be achievable, use reliable emissions baselines, and take consideration of the individual setting of the institution (through the use of relevant KPIs); these conclusions are very simple, and are almost a given. However, they are worth stating here again since this is one of the most significant fears reported by practitioners (see Chapter 4). The sector must address the impending perfect storm, associated with a collective failure to meet GHG reduction targets. This should help to influence the debate on whether institutions are serious about carbon management and demonstrating leadership in the current difficult socio-economic environment.

The use of the information gathered by institutions to inform these targets and their carbon management policies should be improved (through tougher requirements of disclosures to the EMR record) and this information should be put to better use for their stakeholders and the public alike to use. In this vain, institutions should be encouraged to register on voluntary platforms such as the Carbon Disclosure Project (CDP) to publicly disclose their activities on reducing climate-related impacts; in the commercial sector, investors and customers are demanding organisations make such disclosures, so there is no reason why the HE sector should act any differently.

Reporting of GHG information, based on the proposed cut-off criteria, can also happen rapidly without any considerable difficulty. Changes to the way data are presented, making effective use of the ability to aggregate at the sector level without significant double counting issues means that the HE sector can begin to look strategically together at the means by which emission reductions will be brought about in the future decades.

The proposing of a theoretical USM in Chapter 4 and the critique of existing environmental standard methodologies embodies recommendations for improving the assessing and reporting of GHG-related information in the HE sector. What this research shows is that HEIs should internally manage Scope 3 emissions, but not report on sub-par information which leads to inherent double counting. Multilateral agreement on this an 'official' GHG assessment methodology for the HE sector should now be considered.

In addition, the conclusions of study presented in Chapter 5 advocates a national programme of training and best practice knowledge transfer (for undertaking GHG assessments) should be introduced. This should be a continual process, perhaps adopted in-line with continuing professional development programmes administered by most professional environmental bodies to which environment managers are encouraged to join. If this is not possible within institutions, then this could be contracted out to third parties to provide; whether this would happen in times of financial austerity would be a difficult argument to make. This will eradicate the apparent skills shortfall, whilst enabling environment managers to feel continually supported, share problems and have their questions answered during the annual GHG assessment process currently timetabled (through the EMR record).

Chapter 7 provides the necessary basis for the HE sector, together, to understand and prioritise carbon management efforts at the institutional level. Developing a holistic plan for each institution to 2020 and beyond is critical at this juncture to transition to a trajectory that is in-line with decarbonisation required to comply with the Paris Climate Agreement and the UK CCA. The inherent shortcomings of the current state of carbon management practices (through GHG calculation and project-based carbon reduction) are highlighted. It is concluded that only the individual institutions comprising the sector can apply enough pressure on the relevant governing bodies (*i.e.* the HEFCE and the Department for Business, Energy and Industrial Strategy (BEIS)) and their own internal governing structures for long-lasting grassroots change.

Ultimately, environment managers should engage with those that control the data; either third parties or internal stakeholders. The more assistance there is, the less time and financial resources these activities take to complete. Identifying key stakeholders and setting up automated data return processes with an emphasis on the data that is to be reported should be a priority, but data that isn't reported should also be important.

In addition to this, disclosures on such actions should be prioritised. Just as corporate Chief Executive Officers (CEOs) are beginning to release climate-related disclosures to demonstrate to private investors their degree of future climate-change risk (TCFD, 2017), HE institutions should be planning far in advance of the changes that are projected to occur. This is an area in which institutions are considerably underperforming.

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Chapter 8: Conclusions and further work

8.1 The governance of carbon management in the HE sector

Changes to the value of UK tuition fees in 2010 and the influence that the post-2008 economic downturn has had on budgets and research funding, means that institutions must be more accountable to their students and think of novel ways to stand out in a vastly competitive environment (Dobson *et al*, 2010). Since the publication of the Browne Review, HE has traversed the political maelstrom. The view that HE is a ‘public good’ (articulated through educational judgement and financed by public funds) has softened, and now HE is a lightly regulated market where consumer demand (in this instance in the form of student choice) determines the direction of travel. The Browne Reviews instituted a fundamental change to the financing model for HE, which set a paradigm shift towards students as consumers and the state as the emboldened moderator and regulator (Barber *et al*., 2013)). Under this system, quality (measured by satisfaction) is expected to improve through inter-institution competition (Collini, 2012).

Notwithstanding the issues around funding disparities and student recruitment, institutional sustainability priorities vary widely between institutions. Despite sustainability being regarded as a central issue to the future of HE, there is a risk that this is not the case and therefore there is a tendency for it to fall down on the agenda. Politically, due to the vote in 2016 to leave the European Union, government appetite for pushing carbon management forward is currently lukewarm (Smith *et al*., 2016).

Carbon management could potentially become the first issue neglected should the need for short-term cost reduction be great enough and the long-term view of savings not favoured. Ensuring that fostering sustainable practices remain high on the agenda offers a pragmatic and lucrative opportunity. Those involved with university governance understand the rewards that can be garnered from such activities: namely efficiency savings which result in financial benefits following some initial capital investment, an enhanced external reputation, and a beneficial shift in internal culture. Some English HEIs have set very high targets for carbon reduction, which is the result of an ambitious sector target set by the Higher Education Funding Council for England (HEFCE) in 2010. It remains to be seen if self-set Scope 1 and 2 carbon reduction targets will be accomplished within the set time frame to 2020. A limited number of institutions have a detailed understanding of GHG emissions associated with all of their directly and indirectly influenced activities.

What has not been touched on in great depth is the preparedness of the UK HE sector to make the necessary adaptions required against a changing climate. Whilst the UK HE sector is deemed to be somewhat immune to the potential impacts of a shifting climate (see chapter 7 on the HE sector's climate vulnerability score), futureproofing HE is essential for a number of reasons. Namely, the unpredictability of the future under climate change and the importance placed on HE in maintaining and expanding its strong presence internationally, beside others. Preparations should start with long-term horizon scanning to set an emission reduction trajectory for each institution in-line with sectoral decarbonisation required to meet the terms of the Paris Climate Agreement.

HEI environment managers are preoccupied with the 2020 emissions reduction target that the necessary plan for scope 3 emissions reduction has not yet been developed. There is a fear that institutions will be portrayed poorly if they fail to deliver on direct emission reductions given the wider issues associated with expanding campus estates, increasing student recruitment and persistent political pressure. In reality, the impacts are likely to be short-lived reputational impacts instead of anything more severe (Lang, 2016). The likelihood of prosecutions arising as a result of failing to comply with non-legally binding sectoral target is considerably small. An important example of this is the Energy Performance of Buildings Regulations, which formally introduced Display Energy Certificates (DECs) in 2007. It made it mandatory for public buildings to display a DEC, yet no one has ever been prosecuted for not complying with this piece of legislation. This proves that policy without enforcement is debased and powerless (Warren, 2016).

8.2 Practical applications for theoretical carbon assessment methodologies

Managing activities indirectly attributed to the HEI upstream and downstream along the value chain is a particular challenge for HEIs. The size and complexity of the organisation, varying financial regimes, and devolved purchasing departments are just some of the difficulties associated with understanding all indirectly influenced activities (Epstein & Roy, 2003). The use of full-scale footprints for internal purposes and the external reporting of production-based emissions overcome all barriers and double counting issues. The three most influential barriers to assessing and reporting indirect GHG emissions from upstream and downstream of the organisational boundary of HEIs have been identified as time, cost, and data reliability. The transposition of environmental standards designed to be suitable for all organisation types stifles the reporting of GHG-related information in the HE sector.

It is possible to reconcile existing emission standards, make a theoretical proposal about what improvements can be made to improve institutional reporting (based on defined parameters), and practically apply it to develop an externally-verifiable universal methodology. By streamlining the carbon footprint, that is to say, shortening the boundary and only including the most significant emission sources, the need for obtaining externally-held and non-transparent data is lessened (Lenzen & Murray, 2010). A number of studies that have investigated the significance of emissions along organisational supply chains have found that up to 70% of upstream emissions can be captured from just the top 10 industry suppliers and employee commuting (Huang, Weber, *et al*., 2009). The release of GHGs along the university supply chain has not been studied in any great detail (Baboulet & Lenzen, 2010). Indeed, individual institutional specialisms mark HEI operations as difficult to generalise.

The level of technical expertise required is no longer a hindrance to producing high quality reports of robust science which are simply interpreted. Also addressed is the concept of double counting and employing cut-offs to ensure that emissions are not unduly inflated once aggregated at the sectoral level. Combined, these criteria transpose full EEIOA-LCA based guidance used by the sector at the current time into *production*-based EEIOA guidelines. It becomes production-based due to the “exclusion of paid-for Scope 3 products and services” as these are assigned to the producer. This institutes an official recognition by institutions that they deem their wider influence to be of significant importance, whilst avoiding double counting issues and frees up much needed resources for implementing impactful carbon management projects.

8.3 Benefits of a universal standardised methodology

Standardisation of data collection procedures results in comparable conclusions. Developing a methodology that is to the activities and priorities of HEIs, the most to assessing GHGs can be. Whilst some would see this as a positive shift that may galvanise the sector further, this may be derided by the energy intensive and high consuming institutions that may suffer reputational damage as a result. Whilst the adoption of the universal standard methodology (USM) as a sector standard would require unanimous multilateral support, it is for these reasons that acknowledgement must be made that ubiquitous support may not be forthcoming.

By implementing a universal standard methodology though, wider issues are overcome; for instance, emissions double counting is eradicated. This means, at a meso-level, the full climate contribution of HEIs (and by extension their supplier organisations) as discrete entities can be understood. This knowledge is powerful in informing the development of future decarbonisation pathways and allows institutions themselves an understanding of their vulnerability before expanding their operations internationally. The necessity to combine empirical data with modelled economic data creates certain challenges for environmental practitioners in HEIs, which are broadly overcome by the adoption of the USM. Although there are certain advantages to this method, such as extending the resolution of otherwise data-limited studies and reducing reliance on manual data collection, practitioners should be cautious of potential discrepancies and idiosyncrasies that occur when liberal and interpretive methodologies are prescribed. These considerations are well described in the literature (Townsend & Barrett, 2015). Environment managers are required to collect and report data for fewer emission sources under the USM.

Developing reliable data streams within the institution to enhance the coverage and accuracy of the data they need to report should be a high priority. Identifying and setting up streams to collect good quality, consistent and reliable data that is placed high on the data hierarchy would benefit an institution by saving time and money once initial setup has taken place as dataflow would be consistent. Equally, favouring automatic metering, or methods with little need for human inputs, means that high quality data can be collected with little potential for human error. Resources can instead be diverted to research or teaching activities when fewer human inputs are needed. The USM provides a direction for the development of these data streams; what is needed now is for institutions to invest in systems and infrastructure. Management systems are a pragmatic means of managing these data streams and allow institutions to better monitor continual progression. Energy Management Systems such as ISO50001:2011 specify the requirements for establishing, implementing, maintaining and improving an energy management system, whose purpose is to enable an organisation to follow a systematic approach to achieving continual improvement of energy performance, including energy efficiency, energy security, energy use, and consumption.

At an asset-level, Building Management Systems (BMS) are control systems that are being used increasingly to control and monitor building systems for optimising energy efficiency (by bringing together the building’s mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems). Implementing BMS systems would allow estates managers to automatically retrieve information about an estate’s operations to directly inform GHG calculations. Even data streams typically seen as collected on an *ad-hoc* basis could be made compatible with a management system. For instance, either the regular travel survey procedure could be continued and data fed into the management system, or automated data collection could be developed that could require all staff and students to return data on a more regular basis through online portals. This would require a significant level of engagement of both staff and students in order to prove successful.

Yet to be addressed is a post-2020 framework for institutions to take institutions on a path to decarbonisation. Uncertainty caused by the UK voting to leave the EU by the end of 2019 has drastically shifted political momentum (Smith *et al.,* 2016). However, it is clear that planning and foresight are required now more than ever by the sector's leaders to futureproof climate vulnerabilities and position the sector favourably. The desire for this to be so has been demonstrated through this research. Because of a lack of momentum and pressure from the top, the time for institutions to plan carbon management activities post-2020 is ever-decreasing. For this reason, institutions should be beginning to develop individual medium- and long-term plans now in order to establish a multilateral sectoral agreement.

8.4 Further work

The research presented in this thesis is by no means a final oratory on the future of carbon management in the HE sector. Far from this, this thesis provides the basis for further work needed to position the HE sector favourably to confront the challenges ahead over the coming decades and into the second half of the 21st Century (where sectoral decarbonisation is required to limit the greatest of the climate impacts).

8.4.1 Geographic extension of the scope of work

The development and application of the USM and the Higher Education Institution Carbon Calculator (HEICC) tool was conducted on case study institutions from the UK. Therefore, little regard for its international application has been made or indeed tested. The credibility of the conclusions presented in this thesis could be improved by extension the work, to encompass additional institutions from countries around the world.

The literature highlights large disparities in higher education systems around the world, most notably in the way they are funded[49]. It is these types of nuances that disparately contribute to the overall nature of the institution's activities and thus, climate impact. Therefore, further exploration in this sphere would usefully extend the scope of the research.

8.4.2 Investigation into production and consumption perspectives

The cut-off criteria introduced in Chapter 3 no longer requires environment managers to embark on costly and time consuming full GHG assessments. Little research has been conducted into

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[49] In many Scandinavian countries (such as Norway or Finland), where tax structures are more progressive, students pay very little fee toward their tuition. However, this is often countered by high living costs and income tax. Students studying in countries where tuition fees are high (such as Australia or the Unites States) have almost universal access to financial support (through loans, scholarships and public subsidies), with the exception of Switzerland where very little financial support is available. Despite high fees, the countries with particularly well-funded and advanced financial aid systems (such as the US or UK) have the highest participation rates of any other countries in the OECD (OECD, 2012).

exploring the relationship between production-based and consumption-based methodologies. How representative the production-based EEIOA-LCA assessment perspective is to the consumption-based EEIOA-LCA assessment perspective would be an important addition to this research. Obtaining a 'rule-of-thumb' which would allow institutions to translate production-based footprints into full EEIOA-LCA assessments would also provide streamlined capabilities for internal carbon management purposes and allow environment managers the ability to tailor their external reporting activities to their needs.

8.4.3 **HEICC tool development**

In terms of the features of the HEICC tool in particular, numerous desirable features could be considered in the future. The version that was used in this research study was fairly 'rough and ready', based on simple VBA functions and solely intended to be good enough for the requirements of the study. However, this means there is scope for improvement. For instance, moving the tool online would enable countless other features to be considered. Users could upload information or documents in the front end which could populate through the tool automatically. Users could store their estates information here (*i.e.* the tool would represent the front end of a complex database) and even configure their own AMS systems to collect the data automatically through data flows. The benefit of an online system would mean that data issues, data coverage and other issues would be transparently identified by the user or the administrator (automatic warning systems could also be built in). The fewer inputs required by human users, the less potential there would be for human error.

Appendix A Online behavioural snapshot questionnaire

iSurvey – Online Questionnaire Generation from the University of Southampton 27/04/2012 09:29

Staff Behaviours contributing to the University of Southampton's Carbon Emissions

Section 1. Section 1: About You

Question 1.1

Please select your gender:

- ◯ Male
- ◯ Female

https://www.isurvey.soton.ac.uk/admin/data/print.php?surveyID=3228 Page 1 of 8

Question 1.2

Please select which age category you fall into:

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

Question 1.3

What is your position at the Instition? i.e. Lecturer in Environmental Science, financial administrator etc.

Section 2. Section 2: Activity at University

Question 2.1

How many hours do you spend at university per week?

- < 5 Hours
- 6 - 10 Hours
- 11 - 20 Hours
- 21 - 30 Hours
- 31 - 40 Hours
- > 41 Hours

Question 2.2

How many hours do you spend at a computer or laptop at university per week?

- I do not use a computer or laptop at university
- < 5 Hours
- 6 - 10 Hours
- 11 - 20 Hours
- 21 - 30 Hours

- ○ 31 - 40 Hours
- ○ > 41 Hours

Question 2.3

"When at university, I use electricity for"... (Please select those that apply)

- ☐ Charging Smartphone/mobile phone
- ☐ Charging iPod
- ☐ Charging Laptop/iPad/Tablet
- ☐ Charging Camera
- ☐ Listening to the radio/stereo
- ☐ None of the above
- ☐ Other

Question 2.3b

Please state 'other':

Question 2.4

Which of the following measures have you taken to reduce your personal electricity usage at the university? (On personal appliances i.e. lamps)

- ☐ Do not leave appliances charging overnight
- ☐ Electricity meter
- ☐ Enable standby/sleep function on computer/laptop
- ☐ Energy saving light bulbs
- ☐ Personal Computer or Laptop shutdown when not in use
- ☐ Reduce brightness of screen on LCD monitor/laptop
- ☐ Turn lights off when leaving a room
- ☐ Take stairs instead of elevator
- ☐ None of the above
- ☐ Other

Question 2.4b

Please specify 'other':

Question 2.5

Which mode of transport do you most commonly use to travel to and from university? (Please select one)

- ○ Aeroplane

- Bicycle
- Bus
- Car
- Train
- Walk
- Other

Question 2.5b

Please specify 'other':

Question 2.6

How many hours per week do you spend travelling on University business?

- I do not travel on university business
- < 5 Hours
- 6 - 10 Hours
- 11 - 20 Hours
- 21 - 30 Hours
- 31 - 40 Hours
- > 41 Hours

Which mode of transport do you most commonly use when travelling on university business? (Please select one)

- Aeroplane
- Bicycle
- Bus
- Car
- Train
- Walk
- Other

Question 2.6b

Which mode of transport do you most commonly use when travelling on university business? (Please select one) agreement of this statement.

- Strongly Agree
- Agree
- Niether Agree or Disagree
- Disagree
- Strongly Disagree
- Don't Know

Question 3.2

Which statement best describes your opinion on climate change?

- There is undeniable evidence to suggest climate change is occurring due to anthropogenic carbon emissions and requires immediate action
- There is evidence climate change is occurring and that action should be taken but not immediately
- Climate change is occurring due to natural causes and is not attributed to human activity
- There is a lot of uncertainty and more research is required until action can be taken
- There is little or no evidence to back up claims about climate change
- No Opinion

Question 3.3

The emission of greenhouse gases such as carbon dioxide, contribute to climate change, had you ever heard of climate change before undertaking this questionnaire?

- Yes, I had heard of climate change
- No, I had never heard of climate change
- I Don't know

Section 4. Section 4: Carbon Reduction at the University of Southampton

Question 4.1

What is the University of Southampton's carbon emission reduction target by 2020? (Please select answer you think is correct)

- 10 %
- 20 %
-

30 %
- 40 %
- 50 %

Question 4.1b

Where did you obtain this information? (Please specify if advertised by the university)

Question 4.2

The University of Southampton have adopted an environment and sustainability policy. How would you rate your awareness of this?

- No awareness
- Basic awareness
- Excellent Awareness
- Don't know

Question 4.2b

Where would you find information on this (i.e. Internet)?

Question 4.3

The University of Southampton has set itself a target of 20% reduction below 2005/06 levels in carbon emissions by 2020. "I think that the University is going to meet this target." Please select your level of agreement with this statement.

- Stongly Agree
- Agree
- Neither Agree or Disagree
- Disagree
- Strongly Disagree
- Don't know

Question 4.4

Which are the most important issues faced by UK Russell Group Higher Education Institutions today? Please rank the following nine impacts (N.B. Dynamic ranking will place them in the order you select):

- -- Environment
- -- Funding
- -- National/International Ranking
- -- Quality of Facilities
- -- Student Experience

[--] Standard of Scientific Research and Teaching
[--] Job Prospects

[--] Sustainability
[--] Tuition Fees and Value for Money

iSurvey - Online Questionnaire Generation from the University of Southampton 27/04/2012 09:29

Student Behaviours contributing to the University of Southampton's Carbon Emissions

Section 1. Section 1: About You

Question 1.1

Please select your gender:

- ○ Male
- ○ Female

Question 1.2

Please select which age category you fall into

- ○ < 18
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 - 64
- ○ > 65

Question 1.3

Which of the following best describes you?

- ○ 1st year Undergraduate
- ○ 2nd year Undergraduate
- ○ 3rd year Undergraduate
- ○ 4th year Undergraduate
- ○ MA Student
- ○ MSc Student
- ○ PhD Student

Question 1.4

Which degree course are you enrolled on?

Question 1.5

Year of Graduation?

Question 1.6

Do you live in University-provided halls of residence during term-time?

(If yes, survey proceedes to section 2. If no, survey proceedes to section 3)

- ○ Yes
- ○ No

Section 2. Section 2: Halls of Residence

Question 2.1

How many hours do you spend in your halls of residence per week (excluding time spent sleeping)?

- ○ < 5 Hours
- ○ 6 - 10 Hours
- ○ 11 - 20 Hours
- ○ 21 - 30 Hours
- ○ 31 - 40 Hours
- ○ > 41 Hours

Question 2.2

How many hours do you spend at a computer or laptop at your halls of residence per week?

- ○ I do not use a computer or laptop in halls
- ○ < 5 Hours
- ○ 6 - 10 Hours
- ○ 11 - 20 Hours
- ○ 21 - 30 Hours
- ○ 31 - 40 Hours
- ○ > 41 Hours

Question 2.3

Please select which electrical appliances you own.

- ☐ Camera
- ☐ Games Console
- ☐ iPad/Tablet

- iPod/mp3
- Radio/Stereo
- Smartphone/Mobile Phone
- Television
- None of the Above
- Other

Question 2.3b

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
Camera	○	○	○	○	○

Question 2.3c

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
Games Console	○	○	○	○	○

Question 2.3d

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
iPad/Tablet	○	○	○	○	○

Question 2.3e

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
iPod/mp3	○	○	○	○	○

Question 2.3f

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
Radio/Stereo	○	○	○	○	○

Question 2.3g

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
Smartphone/Mobile Phone	○	○	○	○	○

Question 2.3h

How many hours per week do you use this?

	< 10 Hours	11 - 20 Hours	21 - 30 Hours	31 - 40 Hours	> 41 Hours
Television	◯	◯	◯	◯	◯

Question 2.3i

Please specify 'other':

Question 2.4

Which of the following measures have you taken to reduce your personal electricity usage in your halls of residence? (On personal appliances i.e. lamps)

- ☐ Do not leave appliances charging overnight
- ☐ Enable standby/sleep function on computer/laptop
- ☐ Energy saving lightbulbs
- ☐ Personal Computer or Laptop shutdown when not in use
- ☐ Reduce brightness of screen on LCD monitor/laptop
- ☐ Turn lights off when leaving a room
- ☐ None of the above
- ☐ Other

Question 2.4b

Please specify 'other':

Section 3. Section 3: Activity at University

Question 3.1

How many hours do you spend at university per week?

- ◯ 0 - 5 Hours
- ◯ 6 - 10 Hours
- ◯ 11 - 20 Hours
- ◯ 21 - 30 Hours
- ◯ 31 - 40 Hours
- ◯ > 41 Hours

Question 3.2

How many hours do you spend at a computer or laptop at university per week?

- I do not use a computer or laptop at university
- < 5 Hours
- 6 - 10 hours
- 11 - 20 hours
- 21 - 30 hours
- 31 - 40 hours
- > 41 hours

Question 3.3

"When at university, I use electricity for"... (Please select those that apply)

- Charging Smartphone/mobile phone
- Charging iPod
- Charging Laptop/iPad/Tablet
- Charging Camera
- None of the above
- Other

Question 3.3b

Please state 'other':

Question 3.4

Which of the following measures have you taken to reduce your personal electricity usage at university?

- Enable standby/sleep function
- Personal Computer or Laptop shutdown when not in use
- Reduce brightness of screen on LCD monitor/laptop
- Turn lights off when leaving a room
- Take stairs instead of elevator
- None of the above
- Other

Question 3.4b

Please specify 'other':

Question 3.5

Which mode of transport do you most commonly use to travel to and from university? (Please select one)

- ○ Aeroplane
- ○ Bicycle
- ○ Bus
- ○ Car
- ○ Train
- ○ Walk
- ○ Other

Appendix BSystematic review results

Search terms – Organis(z)ation carbon footprint [*principle*]

Principle	Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]
Emission baseline (benchmark/base year)	Letete & Marquard, 2011; Dragomir, 2012; Mazhar *et al*., 2012; Riding *et al*., 2012; Williamson, 2012; Ozawa-Meida *et al*., 2011; Pelletier *et al*., 2013; Townsend & Barrett, 2015; Robinson *et al*., 2014
Equity share or control boundary-setting approach (organisational boundary)	Young, 2010; Dragomir, 2012; Oludele *et al*., 2012; Scipioni *et al*., 2012; Gao *et al*., 2013; Pelletier *et al*., 2013; Rietbergen *et al*., 2015
Temporal boundary	Moerschbaecher & Day, 2010; Peters, 2010; Wright *et al*., 2011; Oludele *et al*., 2012; Scipioni *et al*., 2012; Williams, Kemp, *et al*., 2012; Güereca *et al*., 2013; Ozawa-Meida *et al*., 2011; Pelletier *et al*., 2013
Emission Scopes: 1, 2 and 3	Awanthi & Navaratne, 2010; Busch, 2010; Moerschbaecher & Day, 2010; Peters, 2010; Sinha *et al*., 2010; Andrew & Cortese, 2011; Lee, 2011; Recker *et al*., 2011; Stubbs & Downie, 2011; Thurston & Eckelman, 2011; Wiedmann & Barrett, 2011; Woodroof, 2011; Wright *et al*., 2011; Dragomir, 2012; Mazhar *et al*., 2012; Oludele *et al*., 2012; Plambeck, 2012; Scipioni *et al*., 2012; Williams, Kemp, *et al*., 2012; Chakraborty & Roy, 2013; Correia *et al*., 2013; Gao *et al*., 2013; Klein-Banai & Theis, 2013; Larsen *et al*., 2013; Matisoff *et al*., 2013; Townsend & Barrett, 2015; Pelletier *et al*., 2013; Almeida *et al*., 2014; Alvarez *et al*., 2014; Rietbergen *et al*., 2015; Robinson *et al*., 2014; Yi-Chun, 2014
Upstream/downstream	Busch, 2010; Lenzen & Murray, 2010; Peters, 2010; Weinhofer & Hoffmann, 2010; Lee, 2011; Lee, 2012; Stubbs & Downie, 2011; Wiedmann & Barrett, 2011; Wright *et al*.,

Principle	Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]
	2011; Scipioni *et al*., 2012; Williams, Kemp, *et al*., 2012; Güereca *et al*., 2013; Ozawa-Meida *et al*., 2011; Pelletier *et al*., 2013; Powell *et al*., 2015; Almeida *et al*., 2014; Robinson *et al*., 2014
Direct emissions from stationary combustion (on-site energy production)	Awanthi & Navaratne, 2010; Sinha *et al*., 2010; Moerschbaecher & Day, 2010; Lee, 2011; Woodroof, 2011; Dragomir, 2012; Lee, 2012; Mazhar *et al*., 2012; Oludele *et al*., 2012; Williams, Kemp, *et al*., 2012; Williamson, 2012; Ozawa-Meida *et al*., 2011
Direct emissions from mobile combustion (vehicle fleet)	Awanthi & Navaratne, 2010; Moerschbaecher & Day, 2010; Sinha *et al*., 2010; Lee, 2011; Letete & Marquard, 2011; Recker *et al*., 2011; Woodroof, 2011; Dragomir, 2012; Lee, 2012; Mazhar *et al*., 2012; Oludele *et al*., 2012; Williams, Kemp, *et al*., 2012; Williamson, 2012; Ozawa-Meida *et al*., 2011; Yi-Chun, 2014
Direct process-related emissions	Sinha *et al*., 2010; Lee, 2011; Dragomir, 2012; Lee, 2012; Oludele *et al*., 2012
Direct fugitive emissions	Moerschbaecher & Day, 2010; Sinha *et al*., 2010; Lee, 2011; Woodroof, 2011; Dragomir, 2012; Lee, 2012; Oludele *et al*., 2012
Direct emissions/removals from Land-use, Land-use Change and Forestry	Pandey *et al*., 2011; Williams, Kemp, *et al*., 2012; Gao *et al*., 2013
Indirect emissions from imported electricity consumed (purchased electricity)	Awanthi & Navaratne, 2010; Moerschbaecher & Day, 2010; Lee, 2011; Letete & Marquard, 2011; Recker *et al*., 2011; Lee, 2012; Oludele *et al*., 2012; Scipioni *et al*., 2012; Williams, Kemp, *et al*., 2012; Gao *et al*., 2013; Larsen *et al*., 2013; Pelletier *et al*., 2013; Yi-Chun, 2014
Indirect emissions from consumed	Sinha *et al*., 2010; Lee, 2011; Recker *et al*., 2011; Lee, 2012;

Principle	Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]
energy imported through physical network (purchased steam, chilled water)	Oludele *et al*., 2012; Williams, Kemp, *et al*., 2012; Pelletier *et al*., 2013; Yi-Chun, 2014
Energy-related activities not included in direct emissions & energy indirect emissions (scope 1 and 2 life-cycle emissions) Upstream emissions of purchased fuels Upstream emissions of purchased electricity Transport and distribution losses Generation of purchased electricity sold to end users	Lee, 2011; Letete & Marquard, 2011; Moerschbaecher & Day, 2010; Stubbs & Downie, 2011; Thurston & Eckelman, 2011; Lee, 2012; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Alvarez *et al*., 2014; Yi-Chun, 2014
Purchased/procured products (Product LCA – cradle-to-gate emissions)	Atherton & Giurco, 2011; Lee, 2011; Letete & Marquard, 2011; Recker *et al*., 2011; Stubbs & Downie, 2011; Thurston & Eckelman, 2011; Lee, 2012; Mazhar *et al*., 2012; Scipioni *et al*., 2012; Trappey *et al*., 2012; Williams, Kemp, *et al*., 2012; Correia *et al*., 2013; Gao *et al*., 2013; Larsen *et al*., 2013; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Almeida *et al*., 2014; Alvarez *et al*., 2014; Mosgaard *et al*., 2013; Yi-Chun, 2014
Production-related procurement	
Non-production-related procurement	
Capital equipment (goods)	Gao *et al*., 2013; Townsend & Barrett, 2015; Yi-Chun, 2014
Waste generated from organisational activities	Moerschbaecher & Day, 2010; Sinha *et al*., 2010; Lee, 2011; Letete & Marquard, 2011; Stubbs & Downie, 2011; Thurston & Eckelman, 2011; Lee, 2012; Scipioni *et al*.,

Principle	Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]
	2012; Williams, Kemp, *et al*., 2012; Larsen *et al*., 2013; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Almeida *et al*., 2014; Alvarez *et al*., 2014; Yi-Chun, 2014
Upstream transport and distribution Transport and distribution of purchased products Third-party transportation and distribution services purchased	Lee, 2011; Thurston & Eckelman, 2011; Lee, 2012; Rizet *et al*., 2012; Scipioni *et al*., 2012; Trappey *et al*., 2012; Mosgaard *et al*., 2013; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Almeida *et al*., 2014; Yi-Chun, 2014
Business travel (staff travel)	Awanthi & Navaratne, 2010; Moerschbaecher & Day, 2010; Letete & Marquard, 2011; Recker *et al*., 2011; Mazhar *et al*., 2012; Matisoff *et al*., 2013; Townsend & Barrett, 2015; Almeida *et al*., 2014; Yi-Chun, 2014
Emissions from business travellers in hotels	Baboulet & Lenzen, 2010; Berners-Lee *et al*., 2011; Stubbs & Downie, 2011; Townsend & Barrett, 2015; Alvarez *et al*., 2014
Upstream leased assets	Townsend & Barrett, 2015; Yi-Chun, 2014
Investments	Yi-Chun, 2014
Client and visitor transport	Williams, Kemp, *et al*., 2012; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015
Downstream transport and distribution	Lee, 2011; Yi-Chun, 2014
Emissions from retail and storage	Rizet *et al*., 2012
Use stage of sold product Direct use-phase emissions Indirect use-phase emissions Maintenance of sold products	Lee, 2011; Stubbs & Downie, 2011; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Yi-Chun, 2014
End-of-life (disposal) of sold product	Lee, 2011; Lee, 2012; Scipioni *et al*., 2012; Ozawa-Meida *et al*., 2011; Pelletier *et al*., 2013; Townsend & Barrett, 2015;

Principle	Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]
	Yi-Chun, 2014
Downstream franchises	Lee, 2011; Dragomir, 2012; Lee, 2012; Yi-Chun, 2014
Downstream leased assets	Lee, 2011; Lee, 2012; Yi-Chun, 2014
Employee commuting	Awanthi & Navaratne, 2010; Sinha *et al*., 2010; Moerschbaecher & Day, 2010; Letete & Marquard, 2011; Recker *et al*., 2011; Stubbs & Downie, 2011; Thurston & Eckelman, 2011; Oludele *et al*., 2012; Williamson, 2012; Larsen *et al*., 2013; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Almeida *et al*., 2014; Yi-Chun, 2014
Land-use	
Emission calculation (activity data x emission factor)	Awanthi & Navaratne, 2010; Hooi *et al*., 2011; Williams, Kemp, *et al*., 2012; Oludele *et al*., 2012; Gao *et al*., 2013; Matisoff *et al*., 2013; Ozawa-Meida *et al*., 2011
Carbon dioxide only	Recker *et al*., 2011; Oludele *et al*., 2012; Trappey *et al*., 2012; Chakraborty & Roy, 2013; Rietbergen *et al*., 2015
Kyoto Basket GHGs - full suite (six gases, CH_4, N_2O, HFC, PFC, SF_6)	Sinha *et al*., 2010; Sundarakani *et al*., 2010; Stubbs & Downie, 2011; Thurston & Eckelman, 2011; Dragomir, 2012; Lee, 2012; Turner *et al*., 2012; Chakraborty & Roy, 2013; Correia *et al*., 2013; Gao *et al*., 2013; Larsen *et al*., 2013; Matisoff *et al*., 2013; Ozawa-Meida *et al*., 2011; Pelletier *et al*., 2013; Yi-Chun, 2014
Air pollutants	
Published emission factors (*i.e.* not from a national database)	Letete & Marquard, 2011; Dragomir, 2012
National emission factors (Defra, Bilan Carbone, IPCC, IEA)	Awanthi & Navaratne, 2010; Chen *et al*., 2011; Letete & Marquard, 2011; Pandey *et al*., 2011; Stubbs & Downie, 2011; Oludele *et al*., 2012; Scipioni *et al*., 2012; Chakraborty & Roy, 2013; Matisoff *et al*., 2013; Ozawa-

Principle	Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]
	Meida *et al*., 2011; Pelletier *et al*., 2013; Townsend & Barrett, 2015; Almeida *et al*., 2014; Alvarez *et al*., 2014
Organisation-specific factors	
Use of data scenarios (best, inter, min)	
Centralised [*data collection*] approach	Thurston & Eckelman, 2011; Yang *et al*., 2014
Decentralised [*data collection*] approach	Burritt *et al*., 2011
[Reporting] Acknowledgement of significant emissions changes	Dragomir, 2012
[Reporting] Assumptions (Standards and methodologies used)	Dragomir, 2012; Matisoff *et al*., 2013
Intensity ratios (normalised)	Dragomir, 2012; Larsen *et al*., 2013; Matisoff *et al*., 2013; Almeida *et al*., 2014; Alvarez *et al*., 2014; Rietbergen *et al*., 2015; Robinson *et al*., 2014
Disaggregated emissions	Berners-Lee *et al*., 2011
[Report] Excluded emission sources	Dragomir, 2012; Matisoff *et al*., 2013
Uncertainty analysis	Peters, 2010; Berners-Lee *et al*., 2011; Milne & Grubnic, 2011; Plambeck, 2012; Ozawa-Meida *et al*., 2011
Base year recalculation policy	Dragomir, 2012; Matisoff *et al*., 2013
Internal performance tracking	Gao *et al*., 2013
Scope 1 and 2 emissions independent of GHG trades, sales, purchases, transfers, banking allowances	Dragomir, 2012
Emissions data separate for each	Dragomir, 2012; Matisoff *et al*., 2013

Principle	**Search term: (Organis(z)ation/corporate/enterprise/institution/higher+ education/firm) carbon footprint [*principle*]**
scope and scope category	
Metric tonnes and in tonnes of CO_2 equivalent	Sinha *et al*., 2010; Berners-Lee *et al*., 2011; Milne & Grubnic, 2011; Recker *et al*., 2011; Thurston & Eckelman, 2011; Wright *et al*., 2011; Dias & Arroja, 2012; Dragomir, 2012; Lee, 2012; Oludele *et al*., 2012; Plambeck, 2012; Scipioni *et al*., 2012; Trappey *et al*., 2012; Williamson, 2012; Chakraborty & Roy, 2013; Correia *et al*., 2013; Güereca *et al*., 2013; Matisoff *et al*., 2013; Ozawa-Meida *et al*., 2011; Townsend & Barrett, 2015; Alvarez *et al*., 2014
Emissions data for direct CO_2 emissions from biologically sequestered carbon (e.g. CO_2 from biomass/biofuels) to be reported separately	Matisoff *et al*., 2013
Set targets/guidelines for target-setting (SMART)	Matisoff *et al*., 2013; Rietbergen *et al*., 2015; Robinson *et al*., 2014

Appendix C Comparative analysis results

Principle	Variable	#	Constituent	Notes	HEFCE Guidelines (2010)	GHG Protocol (2004) Scope 3 (2011)	ISO14064 Standard (2006)	Defra Guide on Measuring and Reporting GHG Emissions (2009)	Global Reporting Initiative Sustainable Reporting Guidelines (2013)	Carbon Disclosure Project (2014)	Reconciled	Robinson *et al.* proposed	Robinson *et al.* with cut-offs
Boundary Setting	Boundary Setting	1	**Emissions baseline**	Full year used to calculate organisation's emissions; used for setting target emissions against	✓	✓		✓	✓	✓	*	*	*
		2	**Equity share**	Organisation accounts for greenhouse gas emissions from operations according to its share of equity in the operation – reflects economic interest (extent of rights a company has to the risks and rewards flowing from an operation, usually aligned with the company's percentage ownership of that operation		✓	✓	✓	✓	✓	*		
		3	**Financial control**	Organisation reports 100% of the greenhouse gas emissions from operations over which it has control with a view to gaining economic benefits from its activities		✓	✓	✓	✓	✓	*	*	*
		4	**Operational control**	Organisation reports 100% of the greenhouse gas emissions from operations over which it has full authority to introduce and implement its operating policies at the operation		✓	✓	✓	✓	✓	*	*	*
		5	**Temporal boundary**	The use of time-dependant variables such as global warming potential, greenhouse gas residence time and treatment of time-lagged greenhouse gases. On-going subjects *i.e.* a household, can be set in-line with existing temporal units (*i.e.* month) but for temporally-limited subject *i.e.* products or events, event-based boundaries should be applied		✓		✓				*	*
Emission Scopes	Emission Scopes	6	**Scope 1 emissions**	Direct greenhouse gas emissions that occur from sources that are owned and controlled by the company	✓	✓	✓	✓	✓	✓	*	*	*
		7	**Scope 2 emissions**	Energy Indirect emissions that occur as a result of consumption of purchased electricity, heat, steam and cooling. These are indirect emissions that are a consequence of the organisation's activities, but which occur at sources the organisation does not own or control	✓	✓	✓	✓	✓	✓	*	*	*
		8	**Scope 3 emissions**	Indirect emissions that are a consequence of the organisation's actions, but occur at sources not owned or controlled by the organisation and which are not classed as scope 2 emissions	✓	✓	✓	✓	✓	✓	*	*	*
		9	**Upstream emissions**	Supplier emissions, indirect emissions from purchased products		✓	✓		✓			*	*

Principle	Variable	#	Constituent	Notes	HEFCE Guidelines (2010)	GHG Protocol (2004) Scope 3 (2011)	ISO14064 Standard (2006)	Defra Guide on Measuring and Reporting GHG Emissions (2009)	Global Reporting Initiative Sustainable Reporting Guidelines (2013)	Carbon Disclosure Project (2014)	Reconciled	Robinson *et al.* proposed	Robinson *et al.* with cut-offs
		10	**Downstream emissions**	Direct and indirect emissions from sold products		✓	✓		✓			*	*
		11	**Reporting company emissions**	Also referred to as 'Out-of-stream' or 'In-stream'		✓	✓					*	*
	Disaggregation of Scope 1 Activities	12	**Direct emissions from stationary combustion**	Emissions arising from on-site combustion of fuel burnt in stationary equipment *i.e.* boilers or furnaces *etc.*	✓	✓	✓	✓	✓	✓	*	*	*
		13	**Direct emissions from mobile combustion**	Emissions arising from fuel burnt in transport equipment owned by the organisation *i.e.* fleet vehicles	✓	✓	✓	✓	✓	✓	*	*	*
		14	**Direct process-related Emissions**	Emissions from biological, mechanical or other activities that are not coming from the direct combustion of fossil fuels or from equipment/storage leaks	✓	✓	✓	✓	✓	✓	*	*	*
		15	**Direct fugitive emissions**	The uncontrolled emission of greenhouse gases		✓	✓	✓	✓	✓	*		
		16	**Direct emissions/removals from Land-use, Land-use Change and Forestry**	Emissions arising as a result of anthropogenic land-use activities (controlled biomass burning, restoration of wetlands, forest management, rice and other agriculture cultivation, animal husbandry) direct land-use change (afforestation, reforestation and deforestation) and managed forests			✓					*	*
	Disaggregation of Scope 2 Activities	17	**Indirect emissions from imported electricity consumed**	Emissions from electricity imported by the organisation due to fuel combustion	✓	✓	✓	✓	✓	✓	*	*	*
		18	**Indirect emissions from consumed energy imported through physical network**	Emissions from the generation of steam, heating, cooling and compressed air consumed by the organisation			✓	✓	✓			*	*
	Disaggregation of Scope 3 Activities	19	**Energy-related activities not included in direct emissions & energy indirect emissions**	Upstream emissions of energy sources (extraction, production, transport, distribution emissions)		✓	✓		✓	✓		*	*
		20	**Upstream emissions of purchased fuels**			✓						*	*
		21	**Upstream emissions of purchased electricity**			✓						*	*

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		22	Transport and distribution losses			✓						*	*
		23	Generation of purchased electricity sold to end users			✓						*	*
		24	Purchased products:	Emissions from goods and services brought into the organisation (embedded carbon)	✓	✓	✓	✓	✓	✓	*	*	
		25	Construction		✓								
		26	Business services		✓								
		27	ICT products		✓								
		28	Manufactured fuels		✓								
		29	Chemicals and gases		✓								
		30	Paper products		✓								
		31	Medical and precision instruments		✓								
		32	food and catering		✓								
		33	Other procurement		✓								
		34	Water		✓	✓						*	
		35	Raw material extraction			✓						^	
		36	Agricultural activities			✓							
		37	Manufacturing, productio and processing			✓						^	
		38	Generation of electricity consumed upstream			✓						^	

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		39	**Disposal/treatment of waste generated upstream**			✓						^	
		40	**LULUCF emissions**			✓						^	
		41	**Transportation of materials and products between suppliers**			✓						^	
		42	**Emissions from other action prior to acquisition by reporting company**			✓						^	
		43	**Production-related procurement**	Purchased goods that are directly related to the production of a company's products		✓						^	
		44	**Non-production-related procurement**	Purchased goods and services that are not integral to the company's products, but are instead used to enable operations		✓						^	
		45	**Capital equipment**	Upstream emissions from the production of capital goods (goods used to manufacture a product, produce a service or sell, store and deliver merchandise) purchased or acquired by the organisation		✓	✓		✓	✓		*	
		46	**Waste generated from organisational activities**	Emissions from the disposal of solid and liquid waste depending upon the characteristics of waste type and its treatment (landfill, incineration, biological treatment or recycling)	✓	✓	✓	✓	✓	✓	*	*	*
		47	**Upstream transport and distribution**		✓	✓	✓	✓	✓	✓	*	*	
		48	**Transport and distribution of purchased products**	Emissions from fuels burnt in mobile sources of combustion not owned or controlled by the organisation		✓						*	
		49	**Third-party transportation and distribution services purchased**			✓						*	
		50	**Business travel**	Emissions from fuels burnt in mobile sources of combustion not owned or controlled by the organisation		✓	✓	✓	✓	✓	*	*	^

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		51	Emissions from business travellers in hotels	and used for business travel		✓	✓					^	
		52	Upstream leased assets	Emissions from the use of assets that are leased (finance lease, operating lease or contract hire) by the organisation		✓	✓	✓	✓	✓	*		
		53	Buildings			✓	✓						
		54	Motor vehicles			✓	✓						
		55	IT equipment			✓	✓						
		56	Machinery			✓	✓						
		57	Emissions from operation of leased assets not already in scope 1 and 2 inventories			✓							
		58	Investments	Emissions due to the operation of equity investments (equity investment refers to the holding of shares of stock on a stock market in anticipation of income from dividends and capital gains.		✓	✓		✓	✓		^	*
		59	Equity investments	Emissions due to the operation of equity investments		✓						^	*
		60	Debt investments			✓						^	*
		61	Project finance			✓						^	*
		62	Managed investments and client services			✓						^	*
		63	Client and visitor transport	Emissions from fuels burnt in mobile sources of combustion not owned or controlled by the organisation and used for client and visitor travel			✓			✓		*	
		64	Downstream transport and distribution	Emissions from fuels burnt in mobile sources of combustion not owned or controlled by the organisation for which the reporting organisation does not pay		✓	✓	✓	✓	✓	*		
		65	Emissions from retail and			✓						*	

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			storage										
		66	**Use stage of sold product**	Emissions from the consumer use of the product		✓	✓	✓	✓	✓	*	^	
		67	**Direct use-phase emissions**	Emissions from products that directly consume energy during use, fuels and feedstock and GHGs emitted		✓						^	
		68	**Indirect use-phase emissions**	Emissions from products that indirectly consume energy during use		✓						^	
		69	**Maintenance of sold products**	Optional		✓						^	
		70	**End-of-life of sold product**	Emissions associated with the end-of-life of all products sold by the reporting organisation		✓	✓		✓	✓		^	
		71	**Downstream franchises**	Emissions from the operation of franchises (a business operating under a license to sell or distribute another organisation's goods or services within a certain location)		✓	✓		✓	✓		^	
		72	**Downstream leased assets**	Emissions from the operation of assets that are owned by the reporting organisation and leased to other entities		✓	✓	✓	✓	✓	*	^	*
		73	**Employee commuting**	Emission from fuel burnt in mobile sources not owned or controlled by the organisation and used by employees to travel to and from the organisation on a daily basis	✓	✓	✓	✓	✓	✓	*	*	^
		74	**Land-use**		✓								
Conceptual Approach	**General Methods**	75	**Emission calculation**	CO_2e = activity data x emission factor	✓	✓	✓	✓	✓	✓	*	*	*
	Greenhouse Gases	76	**Carbon dioxide only**	CO_2	✓								
		77	**Kyoto Basket GHGs - full suite**	CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, NF_3		✓	✓	✓	✓	✓	*		
		78	**Air pollutants**	Ozone Depleting Substances (ODS), oxides of Nitrogen (NOx), oxides of Sulphur (SOx), Persistent Organic Pollutants (POPs), Volatile Organic Compounds (VOCs), Hazardous Air Pollutants (HAPs), Particulate Matter (PM_{10}, $PM_{2.5}$)					✓				
		R1	**Carbon dioxide and Methane**	CO_2, CH_4								*	*
	Emission Factors	79	**Published emission factors**	Origin of published factors open to interpretation	✓	✓			✓	✓		*	*

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		80	**National emission factors**	Published by nationally recognised/government approved bodies *i.e.* Defra Emission Factors in the UK				✓				*	*
		81	**Organisation-specific factors**	Derived from a recognised origin, are appropriate for the GHG source/sink concerned, are current at time of quantification, takes account of uncertainty and are calculated in a manner intended to yield accurate and reproducible results consistent with the intended use of the GHG inventory		✓	✓						
Data Quality	**Data/Methods**	**82**	**Use of data scenarios**	Minimum, intermediate and best scenario data			✓					*	*
		83	**Centralised approach**	Facilities report activity data		✓						*	*
		84	**Decentralised approach**	Facilities report GHG emissions		✓							
Operational Data (Little Manipulation Required)	**Direct Emissions from Stationary Combustion**	**85**	Total quantities of fuel used (collected from energy metres or by fuel bills)		✓	✓	✓	✓					*
		86	An estimate based on organisational setting and energy use behaviours				✓					*	*
		87	All sources identified and quantity of fuel is available. Where fuel used is not known, an estimate of the consumption of fuel related to stationary combustion can be obtained by disaggregation of: Heating of buildings (Floor area and age of building, type of energy used, climatic zone, operating house and use of the building) and machinery (type and size of machine, period of use per year, type of fuel, nominal input power and yield, efficiency and equipment rating)				✓					*	*
	Direct emissions from mobile combustion	**88**	Total quantity of each type of fuel consumed by each transport equipment (metre reading/bills) or vehicle mileage		✓	✓	✓	✓				*	*
		89	Identify each type of transport equipment, with the distinction between vehicles, trucks, ships and aircraft (as a minimum). For each, the total distance travelled is estimated				✓					*	*
		90	Key parameters that should be considered are: Type of energy used: *i.e.* gas/diesel *etc.*) Type of engine (small/large *etc.*) Type of travels: urban/rural *etc.*) Type of use (eco/fast driving) and weight of the vehicle with its load				✓					*	*
		91	If no data is available, assume direct transport emissions account for 1% of total scope 1 and 2 emissions		✓								
	Direct Process-related Emissions	**92**	Exact amount (weight, volume) for each gas is known and based on direct measurement or exact measurements of the activity data and related emissions factor				✓					*	*
		93	Estimate the direct GHG emission by multiplying activity data with relevant emissions factor				✓					*	*
	Direct Fugitive	**94**	For organisations transporting gases, the difference between the amount bought and the amount sold can be calculated. For cooling				✓					*	*

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	Emissions		systems, it can be the quantity of refrigerants needed to refill equipment										
		95	Estimate leakage based on information available about the system (based on formulae from published, peer-reviewed literature)				✓					*	*
		96	Known data is used, and the other data are estimated by disaggregation using such key parameters as: Type of GHG, the technical specificities of the system, age of the system, potential size of the source, power of the equipment				✓					*	*
	LULUCF	97	Biomass per unit area known				✓					*	*
		98	Area estimated, biomass estimated based on land use				✓					*	*
		99	Area known, land use/land cover known, biomass per unit area is estimated by disaggregation using key parameters such as: Type and quantity of biomass, climate, harvested or natural growth				✓					*	*
	Indirect Emissions from Imported Electricity Consumed	100	Exact amount of electricity bought is known, (from electricity metres or bills)		✓		✓	✓				*	*
		101	Amount of energy bought by the organisation is estimated (based on the benchmarking with similar business sectors and should be done separately for small and large electricity consumers				✓					*	*
		102	The organisation knows accurately the amount of electricity bought for large electricity consumers and estimates its electricity consumption either by one of the following approaches: Estimation of electricity consumption by a bottom-up approach (power of each electricity consuming equipment is multiplied by the time the equipment if used and % of available power is used, estimate by consumption ratios of organisations with similar activities				✓					*	*
	Indirect Emissions from Consumed Energy Imported Through a Physical Network	103	The exact amount and type of energy bought by the organisation is known (energy metres, bills)				✓					*	*
		104	Exact amount of each is not known, activity data are estimated separately for need of heating and cooling for: Building processes: cooling or heating, industrial processes				✓					*	*
		105	Organisation knows accurately the amount of heating, steam *etc.* bought for large consumers and calculates it consumption of heating, steam *etc.* by using one of the following approaches: Estimation by bottom-up approach: consumption of each energy item of equipment obtained by multiplying rated power by the time period for which the equipment is used, estimate of heating, steam, cooling *etc.* by consumption ratios of organisation with similar activities (guided by type of organisation, age of installations, activities covered by heating *etc.* and those that are providing energy by other				✓					*	*

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			sources										
Non-operational Data (Processing required and practical constraints are common)	(Fuel and) Energy-related Activities Not Included in Direct Emissions and Energy Indirect Emissions	**106**	Organisation knows exactly the type and origin of the fuels consumed for the generation of electricity *etc.*				✓					*	*
		107	Organisation does not know the origin of fuels consumed for generation of electricity *etc.* Recognised database values used			✓	✓					*	*
		108	Organisation not able to verify process for generation of its imported energy, the organisation disaggregates the data using parameters such as: Origin of fuel, distance from county of origin to place of consumption, type of transport mode, age of technologies, supplier energy consumption and associated mix within the different steps				✓					*	*
	Purchased Products	**109**	Water consumption figures (m^3) from water metre or bill. Only water supplied by water companies, rainwater recycling and borehole extraction should not be included here in this calculation (which is accounted for in scope 2). Calculate residential/non-residential separately		✓							*	
		110	Exact physical amount (weight, volume, number of units) is known for each of the goods and services		✓		✓					^	
		111	When no site-specific data are available, the organisation uses aggregated estimated data. As a minimum, the organisation should disaggregate the data at the level of the product families (e.g. plastics, metals, cleaning services, groundwork and garden services *etc.*)				✓					^	
		112	Estimation based on Best and minimum scenario above is made			✓	✓					*	
		113	Assume water accounts for approximately 1% of scope 1, 2 and 3 emissions		✓								
	Capital Equipment	**114**	Description and number of different items of equipment known and data are site-specific				✓					*	
		115	Only an estimate of the capital equipment life is available. Data are disaggregated between main categories of capital goods, e.g. building, machineries, mode of transport			✓	✓					*	
		116	Capital goods are classified into categories and disaggregated by: All key parameters by category: date of acquisition, assessed lifetime, Specific key parameters by categories: buildings (type of material used, type of construction, total surface area or volume. Machinery (type of material used, type of surface treatments, total weight or volume. Vehicles (engine and carrying capacity of the motor vehicle/truck, fuel type.				✓					*	
	Waste Generated from	**117**	Calculate residential and non-residential separately		✓							^	^
		118	Hazardous waste excluded due to Defra conversion factors unavailable		✓								

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	Organisational Activities	**119**	Construction waste excluded - disposal is likely to be construction contractor's responsibility		✓							*	*
		120	Volume of wastewater multiplied by conversion factor obtained from metre readings. Predicted using factor provided by waste company or 95% of mains water usage		✓	✓	✓	✓				*	*
		121	If no waste water data available assume waste accounts for approximately 3% of scope 1, 2 and 3 carbon emissions		✓								
		122	Quantity of waste and type of treatment (landfilling, disposal in a landfill with landfill gas-to-energy, incineration, biological treatment; aerobic and anaerobic, recovery for recycling, composting and waste-to-energy or energy from waste		✓	✓	✓	✓				*	*
		123	When the amount of waste and the method of treatment and/or disposal are not directly available, estimated date (which can be based on the expenditure for waste treatment or liked to the amount of purchased goods and services. When the specific treatment per category of waste generated is unknown, national/sector average rate of end-of-life treatment (incineration, landfilling, recycling, composting *etc.* is used		✓	✓	✓					*	*
		124	Relevant data disaggregation for each type of treatment in ISO14064				✓						
	Upstream Transport and Distribution	**125**	Distance travelled for each type of transport (rail, road, air and sea) and the type of fuel is known. For the distance travelled by each supplier, the organisation should also know which part of the distance it should allocate to it activities. If a supplier makes a unique journey to the organisation, these round-trip emissions should be allocated to its activities. If a supplier visits a number of clients/customers, the organisation allocates only a part of the travelled distance to it activity based on mass, volume, or economic allocation rules. (To obtain the data, surveys can be made to collect data regarding number of vehicles coming from the supplier and total distance allocated to the organisation, type of vehicle, types of fuel burnt, load rate and return rate)				✓					*	
		126	When the total distance per fuel and type of transport is not directly available, estimated data are used, differentiating the average distance by truck, aircraft, train, and marine craft for the main purchased products. In order to obtain the data, surveys can be made, to identify the number of vehicles entering the site, by each type of transport mode and combined with an estimate of the distance driven by each type of vehicles or from industry average data			✓	✓					*	
		127	For each type of vehicle, the disaggregation of data could be done using such key parameters as: Type of vehicles, engine size in litres, type of travels, suburban, urban, rural, rural periphery				✓						
	Business Travel	**128**	The distance travelled is known for each type of vehicle: Classification e.g. motor vehicle, train, Aircraft *etc.*, characterisation (size, type of technology), location and specification of the type of travel (first class, business class)			✓	✓					*	^

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		129	Number of hotel nights known			✓	✓					^	
		130	Estimated data based on the number of journeys multiplied with the average distance between the office and the destination is used. Data obtained from industry average data. As a minimum, the estimate is disaggregated for motor vehicles, aircraft, and trains. Travel expenses by type of transport can also be used and then converted to km		✓	✓	✓	✓				*	
		131	Organisation should try to quantify distance travelled by aircraft and estimate the distance travelled by motor vehicle				✓					*	
		132	If data is not available, travel surveys can be undertaken		✓							*	
	Upstream Leased Assets	**133**	Organisation classifies all the leased assets into different categories then identifies sources and sinks.			✓	✓					*	
		134	Data based on industry average data			✓	✓					*	
		135	The organisation can set up a survey to collect necessary data: Key parameters: type of leased asset, age of leased asset, used technology, period it is used, geographical location, maintenance and technical control, operational control, behaviour during utilisation				✓					*	
	Investments	**136**	Each investment is individualised, an exact amount for each investment is known and the GHG emissions related to operation of each asset are known and documented				✓					*	*
		137	If only most-significant investments and shares are known the assets' operating economic sectors are roughly known (agricultural, commercial, cement, steel, chemistry *etc.*) allowing the evaluation of the emission factors				✓					*	*
		138	All emissions reported, but only scope 3 emissions, if scope 1 and 2 emissions are included in the scope 1 and 2 emissions of the reporting organisation (if included under financial control boundary for example)			✓						*	*
	Client and Visitor Transport	**139**	The most accurate quantification is when the distance travelled by each type of transport mode can be used as site-specific data and multiplied by a GHG emission factor (GHG per km/miles). Relevant data may be: Mode of transport (bus, train, aircraft), distance travelled, size/spec of vehicle, number of person per unit of transport			✓	✓					*	
		140	When distance travelled in not directly available, estimated data based on number of journeys multiplied by an average distance should be used, disaggregated by motor vehicles, aircraft, trains				✓					*	
		141	The number of clients or visitor transport mode is known, but no data are available about the distance travelled. The conversion between number of journeys and distance unit should be made by an average distance by journey. Surveys can obtain these data, collecting data				✓					*	

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			such as: mode of transport, distance travelled to come, size/spec of vehicle, number of person per unit of transport (this can be organised at the organisation's reception desk, if clients are registered before entering the organisation, the receptionist can ask questions										
	Downstream Transport and Distribution	**142**	Same methodology as upstream transport and distribution - differs by dealing with transport services for which the reporting organisation does not pay			✓	✓					*	
	Use-stage of Sold Products	**143**	Total quantity of sold products is known for the considered period Scenarios of use for processing are defined through a reliable traceability process (based on detailed statistical and consumer behavioural studies)			✓	✓					^	
		144	The organisation hasn't any specific data and the scenarios of use are only defined by big product category. The estimate of emissions associated with the scenarios should as a minimum incorporate an estimate of the energy use and direct emissions of the product during its final consumer use stage. Data based on industry average data			✓	✓					^	
		145	Elaborate scenarios based on: number of sold products, power of the product (electrical appliances), time they were used during a year by an average consumer (based on behavioural surveys), lifetime of the product (based on survey or internal technical information), used technologies and geographical location				✓					^	
	End-of-life Treatment of Sold Products	**146**	Total quantity of sold products is known for the period. End-of-life scenarios are defined through detailed statistical and consumer behavioural studies. Type and performance of waste treatment known			✓	✓					^	
		147	The organisation hasn't any specific data. The organisation has an estimate of the amount of the different products sold or has grouped them in big product families. The end-of-life scenario takes into account the main components of the product and the geographical location of the waste treatment. The performance of waste treatment and the performance of waste treatment and the recycling rate per product are usually linked to geographical location				✓					^	
	Downstream Franchises	**148**	The franchiser has detailed data about each of the franchises. The GHG inventory is known for each downstream franchise Scope 1 and 2 emissions			✓	✓					^	*
		149	The number of franchises is known. An estimated amount of GHG emission is made in order to obtain an estimated emission value (allocation should be calculated by the franchisor if not 100% owned by the organisation				✓					^	*
		150	Organisation calculates GHG emission of the franchisees. The organisation allocates the emissions in this category (if not 100% owned then allocation made by the franchisor. Disaggregation of data by: Size of the franchisee, geographical zone, functionality and type of product,				✓					^	*

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			location										
	Downstream Leased Assets	**151**	The lessor collects the energy use of the leased assets. If the leased assets are emitting other process emissions or fugitive emissions, these should also be taken into account			✓	✓					^	*
	Downstream Leased Assets	**152**	Lessor should group is leased assets by: Buildings, motor vehicles, IT equipment, Lorries (for each, an estimate of the energy consumption and process and fugitive emissions				✓					^	*
	Downstream Leased Assets	**153**	GHG emissions not known - Asset categories are set up based on the disaggregation of data by: Type of leased asset, age of leased asset, used technology, period of use and geographical location				✓					^	*
	Employee Commuting	**154**	Disaggregated by employee and student commuters		✓							*	^
	Employee Commuting	**155**	The organisation should know how many days and how many times a day every employee comes to its workplace during the year – surveys – the organisation knows the transport details for each of its employees. The distance and type of transport are known with its specification: Motor vehicle (type, fuel type), train (county, train type), bus (type *i.e.* inter-city/rural *etc.*)			✓	✓	✓				*	^
	Employee Commuting	**156**	No specific data are available – average distance and the estimation of type of transport are used based on industry average data to estimate the total distance and the type of transport using transport surveys		✓	✓	✓					*	^
	Employee Commuting	**157**	Some specific data are known (distance to work, number of days worked by employees and type of transport). Disaggregation of data could be made by: total worked days per employee, telecommuting, type of travel, type of final energy used (gas/fuel *etc.*), type of engine (small/ large *etc.*), type of travel (urban/rural *etc.*)				✓					*	^
	Employee Commuting	**158**	Student commuting is reported as trips for ‘education purposes’. Calculate UK mileage in this category (multiply mileage per person by population size), divide total mileage by number of people in education, estimate mileage for the institution (multiply individual mileage of people travelling for education purposes by the number of students), apply an average carbon emissions factor for a unit of mileage (km) based on split between car, bus and train		✓								
	Employee Commuting	**159**	Air travel international student data: Emissions arising from students flying to the UK (and back). Two round trips per calendar year should be attributed to EU-25 nationals, and one round trip per year for non-EU-25 nationals. Where the country of domicile is known, institutions should calculate the distance between London and the capital city of the country of domicile. For the remaining students, an average flight distance should be applied. If specific mileage data is not available for air travel, assumptions can be made that a long-haul flight is 4,000 miles and a short-haul flight is 400 miles (one way).		✓								

Principle	Variable	#	Constituent	Notes	HEFCE Guidelines (2010)	GHG Protocol (2004) Scope 3 (2011)	ISO14064 Standard (2006)	Defra Guide on Measuring and Reporting GHG Emissions (2009)	Global Reporting Initiative Sustainable Reporting Guidelines (2013)	Carbon Disclosure Project (2014)	Reconciled	Robinson *et al.* proposed	Robinson *et al.* with cut-offs
		160	Air travel student exchange data: Emissions from air travel of students in English institutions travelling overseas in relation to student exchange programme. Assume one return flight per student based on a London to capital city route. If specific mileage data is not available, assume that a long-haul flight is 4,000 miles and short-haul flight is 400 miles (one way)		✓								
Reporting	**Reporting**	**161**	**Organisation setting**	General description of the organisation goals and inventory objectives	✓		✓	✓	✓			*	*
		162	**Organisational boundary**	Description of the method used to identify the organisational boundary, as well as details of entities included/excluded in the boundary		✓	✓	✓	✓			*	*
		163	**Operational boundaries**	Details of the organisation's activities which are included in the carbon footprint		✓	✓	✓	✓			*	*
		164	**Reporting period covered**	12-month reporting period	✓			✓				*	*
		165	**Acknowledgement of significant emissions changes**	Explanation for any significant emissions changes that trigger base year emission recalculation		✓		✓				*	*
		166	**Report GHGs**	GHGs included in the calculation					✓			*	*
		167	**Assumptions**	Report standards, methodologies and assumptions used during the calculation of the footprint				✓	✓	✓		*	*
		168	**Consolidation approach**	Report the chosen consolidation approach for emissions		✓		✓	✓			*	*
		169	**Intensity ratios**	Report GHG using emissions intensity ratio (*i.e.* appropriate KPIs: Gross Internal Area, FTE employees and Income)		✓		✓	✓	✓		*	*
		170	**Disaggregate emissions**	Report GHGs broken down by business activity/division/country *etc.*						✓		*	*
		171	**Excluded emission sources**	Acknowledgement of emission sources that are excluded from the selected reporting boundary (*i.e.* due to unreliable data *etc.*)		✓		✓	✓	✓		*	*
		172	**Uncertainty analysis**	Acknowledgement of the level of uncertainty associated with the data		✓		✓		✓		*	*
		173	**Source of emission factors**	Report the source of the emissions factors used and GWP ratios				✓	✓			*	*
		174	**Base year recalculation policy**	Recalculation of baseline in the event of significant future changes/growth		✓		✓				*	*
		175	**Internal performance tracking**	The organisation's plan for monitoring progress/performance			✓					*	*
		176	**Data management**	Total scope 1 and 2 emissions independent of any GHG trades, such as sales, purchases, transfers, or		✓			✓			*	*

Appendix C

Principle	Variable	#	Constituent	Notes	HEFCE Guidelines (2010)	GHG Protocol (2004) Scope 3 (2011)	ISO14064 Standard (2006)	Defra Guide on Measuring and Reporting GHG Emissions (2009)	Global Reporting Initiative Sustainable Reporting Guidelines (2013)	Carbon Disclosure Project (2014)	Reconciled	Robinson *et al.* proposed	Robinson *et al.* with cut-offs
				banking allowances									
		177		Emissions data separate for each scope and scope category		✓				✓		*	*
		178		Metric tonnes and in tonnes of CO_2 equivalent	✓	✓		✓	✓	✓	*	*	*
		179		Emissions data for direct CO_2 emissions from biologically sequestered carbon (e.g. CO_2 from biomass/biofuels) to be reported separately		✓			✓	✓		*	*
		180	**Target-setting guidelines**	SMART emissions reduction target-setting	✓			✓		✓		*	*
		R2	**Top Management**	Endorsement of reports and targets by top-management								*	*

Appendix D Practitioner questionnaire

This questionnaire allows you to have your say on what you want to see from a universal and comprehensive set of industry carbon footprinting guidelines. By completing it, you consent to the data you provide being used for this study as outlined in the participant information sheet (13/03/15_2). Your participation is voluntary and you are free to stop filling in the questionnaire at any time and without providing a reason.

Section 1: You and your institution

1) Which region of the UK are you from?

*(Please tick **one**)*

- ☐ Northern Irel
- ☐ Scotland
- ☐ North East
- ☐ North West
- ☐ West Midlands
- ☐ Yorkshire
- ☐ East Midlands
- ☐ West Midland
- ☐ East
- ☐ South West
- ☐ South East
- ☐ London
- ☐ Wales

2) What is the name of your institution/organisation of origin?

3a) Does your institution outsource work to calculate the carbon footprint?

(This includes any work outsourced at any stage to collect or analyse data)

☐ Yes ☐ No

3b) If yes, which company do you use?

4) Please indicate on the scale your attitude towards your institution's ability to calculate its carbon footprint

*(Please make your rating by circling **one** on each scale)*

Adequate Inadequate

4 3 2 1 0

Chaotic Ordered

0 1 2 3 4

Open Secretive

4 3 2 1 0

Complex Simple

4 3 2 1 0

Old-fashioned Modern

0 1 2 3 4

Ineffective Effective

0 1 2 3 4

Innovative Non-innovative

4 3 2 1 0

5) Please rate how much of an impact the following factors have in the calculation of the carbon footprint at your institution

*(Please circle **one** for each statement)*

No Impact *High Impact*

Time constraints	0	1	2	3	4
Budget constraints	0	1	2	3	4
Staff resources	0	1	2	3	4
Staff training requirements	0	1	2	3	4
Support from top management	0	1	2	3	4
Technical knowledge of procedures	0	1	2	3	4
Data reliability	0	1	2	3	4
Other	0	1	2	3	4

If other, please specify:

6a) Does your institution use a published methodology for guidance in calculating emissions?

☐ Yes No ☐

6b) If yes, which methodology is used? *(Please tick **one**)*

☐ HEFCE 2010, carbon management series of guidance documents
☐ IPCC 2006, guidelines for National GHG inventories
☐ GHG Protocol Corporate Accounting Standard 2004 & 2011
☐ ISO 2006, 14064-1 Specification
☐ DEFRA 2009, Guidance on how to measure and report your GHG emissions
☐ GRI 2013, emission guidelines - G4 Sustainability Reporting Guidelines
☐ CDP 2014, Guidance for companies reporting on climate change
☐ Other

If other, please specify:

HEFCE – Higher Education Funding Council for England, IPCC – Intergovernmental Panel on Climate Change, ISO – International Standardization Organisation, Defra – Department for Environment, Food and Rural Affairs, GRI – Global Reporting Initiative, CDP – Carbon Disclosure Project

7) Which emission sources does your institution have a good understanding of?

(Please label the following sources with the appropriate level of understanding at your institution)
0 = not currently calculated; 1 = basic understanding, some data collected but unreliable;
2 = improved reliability of data, but incomplete; 3 = reliable data, calculated fully)

Scope 1Scope 2Scope 3

☐ Stationary combustion (boilers) ☐ Imported consumed electricity ☐ Other energy-related sources
☐ Mobile combustion (vehicles) ☐ Imported energy (heat/steam) ☐ rchased products
☐ Process-related emissions Capital equipment ☐
☐ Fugitive emissions Generated waste ☐
☐ Land-use change/forestry Upstream transport ☐
Business travel ☐
☐ Upstream leased assets
☐ Investments
☐ Client and visitor transport
☐ Downstream transport
☐ In-use stage of sold products
☐ Downstream franchises
☐ Downstream leased assets
☐ Employee commuting

Definitions:

- **Process-related emissions** – Emissions from biological, mechanical or other activities not arising from direct combustion or leaks from equipment/storage systems
- **Fugitive emissions** – Direct uncontrolled emissions of GHGs leaked from equipment/storage systems
- **Other energy-related sources** – Emissions from the extraction, production, transport and distribution stages prior to fuel use/energy consumption
- **Capital equipment** – Emissions from production of capital goods – equipment used by organisation to manufacture a product, provide a service *etc.*

Section 2: expectations of a universal, comprehensive standard

8) Please rate your agreement with the following three statements:

*(Please circle **one** for each statement)*

8a) *"A universal, comprehensive carbon footprinting standard should focus on better data collection"*

Strongly agree Strongly disagree

0 1 2 3 4

8b) *"I should be able to relate a universal, comprehensive carbon footprinting standard to my organisation's own requirements and economic/environmental context"*

Strongly agree Strongly disagree

0 1 2 3 4

8c) *"I require step-by-step instructions to calculate my organisation's carbon emissions"*

Strongly agree Strongly disagree

0 1 2 3 4

9) Please rate your preference for the following:

9a) What is your preference for a universal method which encompasses the greatest extent of emissions but represents the greatest economic and temporal cost?

Cheaper, quicker *Expensive, slower*

0 1 2 3 4

9b) To which extent should the use of technology be employed in a carbon footprinting standard?

Manual *Technological*

0 1 2 3 4

9c) What is your preference for an all-encompassing carbon footprint over one that is less extensive (if the latter were cheaper, quicker and equally comparable)

Bounded footprint *Boundless footprint*

0 1 2 3 4

Section 3: opinions of a universal, comprehensive standard

10) How likely are you to use a universal, comprehensive methodology?

*(Please circle **one**)*

Very likely *Very unlikely*

0 1 2 3 4

11) Please rate your agreement with the following statements:

*(Please circle **one** for each statement)*

11a) *"A universal, comprehensive standard would be beneficial to* my *institution"*

Strongly agree Strongly disagree

0 1 2 3 4

11b) *"A universal, comprehensive standard would be beneficial to* all *UK institutions."*

Strongly agree Strongly disagree

0 1 2 3 4

11c) *"The number of institutions undertaking full-scale carbon footprints will increase as a result of a more universal standard."*

Strongly agree Strongly disagree

0 1 2 3 4

12) Has today's workshop inspired you to adopt different carbon measurement practices?

☐ Yes No ☐ Maybe ☐

13) Are there any other comments you wish to make regarding this research?

(Please continue on the reverse if more space is required)

Appendix D

Would your institution like to participate in an extended study of this research project? If so, please list your email address and a named contact below:

Email address:

____

Name: ____

Institution Address: ____

____

____ Post Code: ___________

Appendix E Treatment of activities attributed to a university estate after applying the universal standard methodology

ISO Designation	Description	Site-specific Activity	Treatment
Direct emissions from Stationary Combustion	Energy/heat Production	Use of boilers	**IN**
		Use of CHP	**IN**
Direct emissions from Mobile Combustion	Use of Vehicle Fleet	Interlibrary book loans	**IN**
		Use of plant machinery	**IN**
		Transport of maintenance personnel	**IN**
		Attendance of international conferences	**IN**
		Attendance of domestic conferences	**IN**
		Outreach activities	**IN**
		Field Trips	**IN**
		Fieldwork	**IN**
Direct Process-related Emissions	Agricultural processes	Livestock	**IN**
		Application of nitrogen fertiliser	
		Putrefaction/fermentation	
	Waste-related processes	Waste treatment	
		Wastewater/sewage treatment	
Direct Fugitive Emissions	Energy-related processes	Natural gas storage	**IN**
		Transportation of Natural gas	
	Miscellaneous	Use of fire CO_2 extinguishers	
		Use of CO_2 in gaseous or solid form	
Direct Emissions and removals from Land-use, Land-use Change and Forestry (excluding combustion)	Grounds Maintenance	Gardening	**IN**
		Tree-cutting	**IN**
		Grass-cutting	**IN**
	Building Works	Building construction/extension	**IN**
		Building demolition	**IN**
	CO_2 Removals	Planting	**IN**
		Soils	**IN**
Indirect Emissions from Imported Electricity Consumed	Use of mains Electrical Equipment	Audio-visual Equipment	**IN**
		Lighting	**IN**
		Digital imaging equipment	**IN**
		MFD printer	**IN**

ISO Designation	Description	Site-specific Activity	Treatment
		White goods *i.e.* kettle, refrigerator, microwave	**IN**
		Water cooler	**IN**
		Computers and peripherals	**IN**
		Laboratory equipment, portable and stationary	**IN**
		Telecommunications	**IN**
		Electronic security and fire safety systems	**IN**
		Elevators	**IN**
		Automatic doors	**IN**
	Use of Rechargeable Battery Powered Equipment	Charging of laptops	**IN**
		Charging of tablets/mp3/mobile phones	**IN**
		Cordless power tools	**IN**
		Electric vehicles	**IN**
Indirect emissions from consumed energy through a physical network	Use of hot water	Wash facilities	**IN**
		Heating	**IN**
	Use of steam	Heating	**IN**
Energy-related Activities not Included in Direct Emissions and Energy Indirect Emissions	Use of Fuels	Extraction of consumed fuels	**IN**
		Production of consumed fuels	**IN**
		Transport of consumed fuels	**IN**
	Use of Electricity	Extraction of fuels consumed in generation of consumed electricity	**IN**
		Production of fuels consumed in generation of consumed electricity	**IN**
		Transport of fuels consumed in generation of consumed electricity	**IN**
		Transmission and distribution	**IN**
Purchased Products	The Arts, Audio-Visual & Multimedia Supplies and Services		**OUT**
	Library-related supplies and services		**OUT**
	Catering Supplies & Services		**OUT**
	Medical, Surgical, Nursing Supplies & Services		**OUT**
	Agricultural/ Fisheries/ Forestry/ Horticultural/ Oceanographic Supplies & Services		**OUT**
	Furniture, Furnishings & textiles		**OUT**
	Janitorial & Domestic Supplies		**OUT**
	Utilities		**OUT**
	Computer Supplies & Services		**OUT**
	Laboratory/Animal House Supplies & Services		**OUT**

ISO Designation	Description	Site-specific Activity	Treatment
	Workshop & Maintenance Supplies (Lab & Estates)		**OUT**
	Printing		**OUT**
	Telecommunications		**OUT**
	Stationery & Office Supplies		**OUT**
	Safety and Security		**OUT**
	Vehicles		**OUT**
	Estates & Buildings		**OUT**
	Miscellaneous		**OUT**
Capital Equipment	Fixed Assets	Server and related items	**OUT**
		Network Equipment Installation	**OUT**
		Telephony/Switchboard Cap Ex >£10,000	**OUT**
		Vehicle Purchase	**OUT**
		Portable and Laptop Computer Purchase	**OUT**
		Agricultural, Fisheries, Forestry, Oceanographic Capital Equipment >£10k	**OUT**
Waste Generated from Organisational Activities	Generation of WEEE		**IN**
	Generation of food waste		**IN**
	Generation of recyclate		**IN**
	Generation of wastewater	Sewerage	**IN**
	Generation of general refuse		**IN**
	Generation of hazardous waste	Clinical and Chemical laboratories	**IN**
	Generation of confidential waste	Accounts, student exam papers	**IN**
Upstream Transport and Distribution	Transport of Purchased Products	As per categories designated in 'purchased products'	**OUT**
	Services, repairs and maintenance of purchased products	As per categories designated in 'purchased products'	**OUT**
	Storage and movement of purchased products	Storage & Warehouse Services	**OUT**
		Archival Services	**OUT**
	Mail Services	Mail Services Overseas/International	**OUT**
		Freight, Carriage & Haulage Services	**OUT**
		Courier Services	**OUT**
	Waste	Waste consignments	**OUT**
Business Travel	Air travel	Attendance of international conferences	**OUT**
		Attendance of domestic conferences	**OUT**

ISO Designation	Description	Site-specific Activity	Treatment
		Attendance of meetings	**OUT**
		Outreach activities	**OUT**
		Field Trips	**OUT**
		Fieldwork	**OUT**
		Consultancy services	**OUT**
	Ferry travel	As per categories designated in 'air travel'	**OUT**
	Taxi hire		**OUT**
	Rail travel		**OUT**
	Mileage (Grey Fleet)		**IN**
	Car hire		**OUT**
	Van hire		**OUT**
	Coach hire		**OUT**
	Boat hire and charter		**OUT**
	Hospitality		**OUT**
Upstream Leased Assets	Hired Products	As per categories designated in 'purchased products'	**OUT**
	Building/Premises/Land - Rent, Lease, Hire, Feu Duties		**OUT**
Investments	Unique to reporting HEI		**IN**
Client and Visitor Transport	Air travel	Attendance of on-site conferences	**OUT**
		Attendance of meetings	**OUT**
		Outreach activities	**OUT**
		Visiting academics	**OUT**
		Consultancy services	**OUT**
	Ferry travel	As per categories designated in 'air travel'	**OUT**
	Taxi hire		**OUT**
	Rail travel		**OUT**
	Mileage (private vehicle use)		**OUT**
	Car hire		**OUT**
	Van hire		**OUT**
	Coach hire		**OUT**
Downstream Transport and Distribution	Not applicable to the HE sector		**OUT**
Use Stage of the Product	Not applicable to the HE sector		**OUT**
End-of-life of the	Not applicable to the HE sector		**OUT**

ISO Designation	Description	Site-specific Activity	Treatment
Product			
Downstream Franchises	Not applicable to the HE sector		**OUT**
Downstream Leased Assets	Leased Products	As per categories designated in 'purchased products'	**IN**
	Building/Premises/Land - Rent, Lease, Hire, Feu Duties		**IN**
Employee Commuting	Air travel	Staff commuting	**OUT**
		Student commuting	**OUT**
	Ferry travel	Staff commuting	**OUT**
		Student commuting	**OUT**
	Taxi travel	Staff commuting	**OUT**
		Student commuting	**OUT**
	Rail travel	Staff commuting	**OUT**
		Student commuting	**OUT**
	Car travel	Staff commuting	**IN**
		Student commuting	**IN**

Appendix F Description of the universal standard methodology and the higher education institution carbon calculator.

A full set of methodological steps were provided to the participants at the beginning of the long-term practical study to test the universal methodology (as outlined in Chapter 5). The instructions contained notes to fulfil a full EEIOA-LCA GHG assessment, since the methodology was developed and refined in parallel; therefore it was deemed sensible to gather more data than was required, instead of less. Instructions are presented here verbatim. F.2 presents a succinct description of the HEICC tool developed to assist with data collection.

F.1 Quantification of GHG emissions and removals for each category:

F.1.1 Direct emissions from stationary combustion

D*ue to on-site combustion of fuel burnt in stationary (fixed) equipment within the organisation boundary of the reporting organisation (i.e. heaters, gas turbines, boilers etc.) to generate heat, mechanical work and steam. The following information is required:*

BEST SCENARIO:

- Total quantity of fuel consumed (your own choice of units can be selected)
- Calculated from meter readings or billed usage
- This information is already returned to HESA via the EMS data return so is easily accessible and already exists for the majority of institutions
- This data has been entered for you based on the most recent EMS returns – please review and update with any more recent existing data

(INTERMEDIATE/MINIMUM: estimated fuel quantity, all sources identified)

F.1.2 Direct emissions from mobile combustion

D*ue to fuel burnt in transport equipment, included within the organisational boundary of the reporting organisation (i.e. motor vehicles, trucks, ships, aircraft etc.). These vehicles are* ***owned*** *by the reporting organisation.*

BEST SCENARIO:

- Total amount of fuel consumed by each transport equipment (your own choice of units can be selected – usually litres)
- Calculated by totalling fuel bills, expense claims and fuel card statements over the period
- This data has been entered for you based on the most recent EMS returns – please review and update with any more recent existing data

(INTERMEDIATE/MINIMUM: Specific information for identified vehicles/Estimated distance travelled for each transport type; at least for motor vehicles, trucks, ships and aircraft)

F.1.3 Direct emissions and removals from Land Use, Land-Use Change and forestry (LULUCF)

Emissions and removals may come from anthropogenic land use activities (such as the controlled burning of biomass, forest management, agriculture), direct land-use change (afforestation, reforestation or deforestation) and managed forests within the organisational boundary.

BEST SCENARIO:

- Site-specific total area and type of land-use within the organisation boundary as well as the land–use changes and practices associated with the land. The amount and type of biomass is quantified.
- This will be calculated retrospectively based on the land-use data you provide. Area of land-use can be calculated from aerial photography/satellite/GIS data using Google Earth

(INTERMEDIATE/MINIMUM: identification of biomass types, estimate of the area/estimate of areas for at least bare land, crops or forests)

F.1.4 Indirect emissions from imported electricity consumed

Emissions from electricity imported by the organisation due to fuel combustion, occurring outside the organisational boundary. Excludes upstream (cradle-to-power plant-gate) emissions of fuels, emissions due to the construction of the power plant and emissions allocated to transmission losses.

BEST SCENARIO:

- Amount of electricity bought by the organisation
- Quantified by obtaining usage data from electricity meters or electricity bills for the relevant period. Institutions consuming more than 6000 MWh will report emissions from

energy to the Carbon Reduction Commitment (CRC) Scheme and can be used here, as well as being regularly reported to the HESA via the EMS return.

- This data has been entered for you based on the most recent EMS returns – please review and update with any more recent existing data

(INTERMEDIATE/MINIMUM: electricity consumption estimated by multiplying the power consumption of each electrical unit by the time used/estimated based on benchmarking with similar sized organisations)

F.1.5 Indirect emissions from consumed energy imported through a physical network

Emissions as a result of the generation of steam, heating, cooling, compressed air consumed by the reporting organisation. Excludes electricity and upstream (cradle-to-power plant-gate) emissions of fuels, emissions due to the construction of the power plant and emissions allocated to transmission losses.

BEST SCENARIO:

- Amount and type of energy bought by the organisation
- Quantified by obtaining from meters or energy bills for the relevant period.
- This data has been entered for you based on the most recent EMS returns – please review and update with any more recent existing data

(INTERMEDIATE/MINIMUM: estimated by multiplying the rated power of each piece of energy-consuming equipment by the time used/estimated based on benchmarking to organisations with similar activities)

F.1.6 Energy-related activities not included in direct emissions and energy indirect emissions

The upstream emissions released as a result of the consumption of fuels and electricity by the reporting organisation.

- If the data for the previous category follows the best scenario, there will be no requirements of you for this category. National figures for cradle-to-power plant-gate and well-to-tank can be used to calculate these emissions based on your input for the previous relevant categories; this will auto-populate the spreadsheet

----

F.1.7 Purchased products

Emissions from goods and services brought into the organisation (embedded emissions) from Tier one suppliers

BEST SCENARIO:

- o Supplier-specific method; detailed cradle-to-gate emissions of the goods and services bought and consumed

INTERMEDIATE/MINIMUM:

- o The Hybrid method; uses a combination of supplier-specific data and secondary data (scope 1 and 2 emissions from suppliers and secondary data of upstream emissions of products and services *i.e.* published category emission factors)
  - ▪ Your institution may already collect detailed information on the incoming products and services based on ProcHE codes
  - ▪ If not, a procedure should be implemented which captures the ordering behaviours of relevant budget holders across the institution
- o Spend-based method; an estimate of emissions is obtained by collecting data on the economic value of goods and services purchased and multiplying by relevant emission factors (industry average per unit spend)
  - ▪ Your institution may already collect detailed information on the incoming products and services based on ProcHE codes
  - ▪ If not, a procedure should be implemented which captures the ordering behaviours of relevant budget holders across the institution

- Here, we have decided to focus on the spend-based method as a proxy for emissions associated with purchased products. If you have specific GHG emissions statistics for the products your institutions buys, please include these.

F.1.8 Capital Equipment[50]

Upstream emissions from the production of capital goods purchased or acquired by the reporting organisation

[50] Capital equipment are goods which have an extended life and are used by the organisation to manufacture a product, provide a service or sell, store and deliver merchandise without being transformed nor sold to another organisation/consumer.

- Methods available are the same for the above category; purchased products

F.1.9 Waste Generated from organisational activities

Emissions from the disposal of solid and liquid waste arisings in waste treatment facilities owned or operated by third parties. Waste treatment activities include:

- Disposal in landfill
- Disposal in landfill with landfill gas-to-energy (LFTGE)
- Recycling
- Incineration
- Composting
- Waste-to-energy (WTE) or Energy-from-waste (EfW)

BEST SCENARIO:

- The amount of waste per waste treatment is known.
- Waste mass obtained from waste transfer notes/internal records, whilst waste treatment type can be obtained from waste carrier
- Additionally, volume of wastewater can be obtained from sewerage bills

(INTERMEDIATE/MINIMUM: Expenditure for waste treatment, converted to mass)

F.1.10 Upstream Transport and Distribution

Emissions from the transport and distribution of purchased product between the reporting organisation's tier 1 suppliers[51] *in vehicles not owned or operated by the reporting organisation.*

BEST SCENARIO:

- Distance travelled for each type of transport (rail, road, air, sea) and fuel type
- Surveys to determine the number and origin of deliveries/services should be made, or alternatively, recording origin data during the ordering process
- If the organisation is just one stop on a continuous journey by the supplier, this trip should be allocated to the organisation using GIS/Google Earth (based on shortest distance) or requested from transportation supplier.

[51] Tier 1 suppliers are companies with which the reporting organisations has a purchase order for goods/services.

(INTERMEDIATE/MINIMUM: the amount of money spent on delivery, combined with national/regional average distance by journey for each supplier)

F.1.11 Business Travel

Emissions from transportation of employees for business-related activities in vehicles owned or operated by third parties

BEST SCENARIO:

- Distance travelled for each type of transport (rail, road, air, sea), characterisation of vehicle and location
- Calculated by totalling, expense claims over the period (distance should be collected through the expense claims process)
- Number of Hotel nights and the allocated Scope 1 and 2 emissions (Here, hotel spend can be inserted, which will be multiplied by a known average emission factor)

(INTERMEDIATE/MINIMUM: Estimated data based on the number of journeys multiplied by the average distance between the organisation's location and the destination, disaggregated by motor vehicles, aircraft and train journeys.)

F.1.12 Upstream Leased Assets[52]

Emissions from the use of assets leased by the reporting organisation in the reporting year

BEST SCENARIO:

- Asset-specific fuel and energy-use data (scope 1 and 2 emissions)
- Allocation of utility costs attributed to leased asset based on calculations using Scope 1 and 2 methodology data

[52] The term 'lease' has a number of different meanings/types:

- Finance leasing – Long-term over the expected life of the equipment (usually 3 years+), although not owned by the leasing company, it is responsible for maintaining and insuring it, shown on balance sheet – common for buildings
- Operating leasing – short-term, leasing company takes the asset back at the end of the lease and is responsible for maintenance and insurance, not shown on the balance sheet
- Contract hire – short-term hire, not shown on balance sheet, leasing organisation takes some responsibility for maintenance (repairs and servicing)

(INTERMEDIATE/MINIMUM: survey of leased assets which exist in the reporting organisation including type, age, time period used and location/disaggregated by buildings, motor vehicles, IT equipment and machinery.)

F.1.13 Client and visitor transport

Emissions from vehicles not owned or controlled by the reporting organisation for the (attributable) transport of clients and visitors to the reporting organisation

BEST:

- Distance travelled by each transport mode
- Calculated by capturing data on visitors, either by staff reporting or at the point of arrival

(INTERMEDIATE/MINIMUM: estimate based on the number of journeys multiplied by average distance/surveys to obtain number and distance of journeys in a sample)

F.1.14 Employee (and student) Commuting

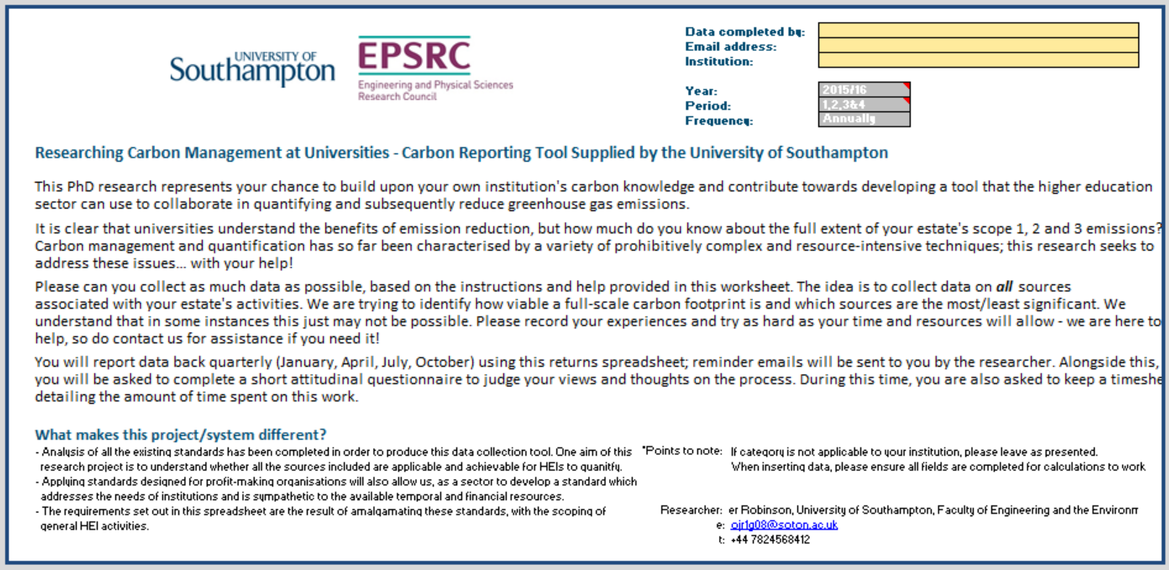
E*missions from the transportation of employees between their homes and worksite*

BEST SCENARIO:

- Distance travelled by each transport mode and classification
- Calculated through regular staff (and student) surveys or regular data capture at the point of arrival
- Emissions associated with Teleworking (Scope 2 emissions of the home as a result of working hours) through regular staff reporting; the adoption of a data capture procedure may need to be implemented if this data is not already collected

(INTERMEDIATE/MINIMUM: average distance and transport type used to estimate the total distance/survey to identify post code and travel type combined with total days worked per employee.)

F.2 Higher education institution carbon calculator


Data completed by:
Email address:
Institution:
Year: 2015/16
Period: 1,2,3&4
Frequency: Annually

Researching Carbon Management at Universities - Carbon Reporting Tool Supplied by the University of Southampton

This PhD research represents your chance to build upon your own institution's carbon knowledge and contribute towards developing a tool that the higher education sector can use to collaborate in quantifying and subsequently reduce greenhouse gas emissions.

It is clear that universities understand the benefits of emission reduction, but how much do you know about the full extent of your estate's scope 1, 2 and 3 emissions? Carbon management and quantification has so far been characterised by a variety of prohibitively complex and resource-intensive techniques; this research seeks to address these issues... with your help!

Please can you collect as much data as possible, based on the instructions and help provided in this worksheet. The idea is to collect data on ***all*** sources associated with your estate's activities. We are trying to identify how viable a full-scale carbon footprint is and which sources are the most/least significant. We understand that in some instances this just may not be possible. Please record your experiences and try as hard as your time and resources will allow - we are here to help, so do contact us for assistance if you need it!

You will report data back quarterly (January, April, July, October) using this returns spreadsheet; reminder emails will be sent to you by the researcher. Alongside this, you will be asked to complete a short attitudinal questionnaire to judge your views and thoughts on the process. During this time, you are also asked to keep a timeshe
detailing the amount of time spent on this work.

What makes this project/system different?
- Analysis of all the existing standards has been completed in order to produce this data collection tool. One aim of this research project is to understand whether all the sources included are applicable and achievable for HEIs to quantify.
- Applying standards designed for profit-making organisations will also allow us, as a sector to develop a standard which addresses the needs of institutions and is sympathetic to the available temporal and financial resources.
- The requirements set out in this spreadsheet are the result of amalgamating these standards, with the scoping of general HEI activities.

*Points to note: If category is not applicable to your institution, please leave as presented.
When inserting data, please ensure all fields are completed for calculations to work

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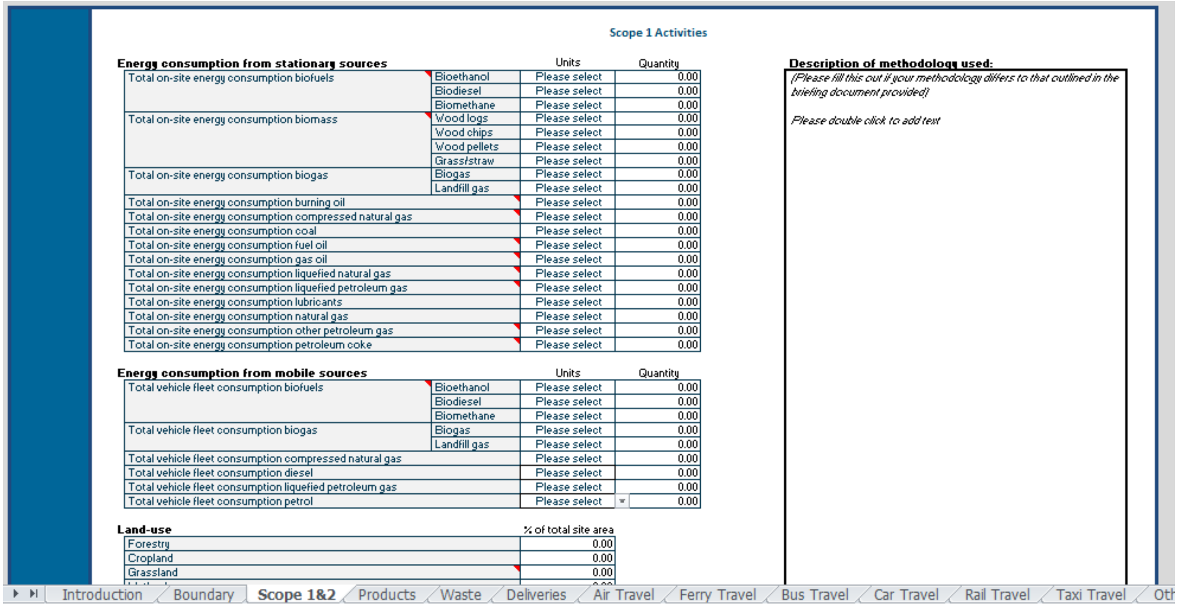
t: +44 7824568412

The HEICC was developed as a means of gathering standardised data from the participants of the long-term methodological test study described in Chapter 5. This was a macro-enable Microsoft excel spreadsheet, which featured 12 data input tabs and five informational/output tabs.


Scope 1 Activities

Energy consumption from stationary sources

		Units	Quantity
Total on-site energy consumption biofuels	Bioethanol	Please select	0.00
	Biodiesel	Please select	0.00
	Biomethane	Please select	0.00
Total on-site energy consumption biomass	Wood logs	Please select	0.00
	Wood chips	Please select	0.00
	Wood pellets	Please select	0.00
	Grass/straw	Please select	0.00
Total on-site energy consumption biogas	Biogas	Please select	0.00
	Landfill gas	Please select	0.00
Total on-site energy consumption burning oil		Please select	0.00
Total on-site energy consumption compressed natural gas		Please select	0.00
Total on-site energy consumption coal		Please select	0.00
Total on-site energy consumption fuel oil		Please select	0.00
Total on-site energy consumption gas oil		Please select	0.00
Total on-site energy consumption liquefied natural gas		Please select	0.00
Total on-site energy consumption liquefied petroleum gas		Please select	0.00
Total on-site energy consumption lubricants		Please select	0.00
Total on-site energy consumption natural gas		Please select	0.00
Total on-site energy consumption other petroleum gas		Please select	0.00
Total on-site energy consumption petroleum coke		Please select	0.00

Energy consumption from mobile sources

		Units	Quantity
Total vehicle fleet consumption biofuels	Bioethanol	Please select	0.00
	Biodiesel	Please select	0.00
	Biomethane	Please select	0.00
Total vehicle fleet consumption biogas	Biogas	Please select	0.00
	Landfill gas	Please select	0.00
Total vehicle fleet consumption compressed natural gas		Please select	0.00
Total vehicle fleet consumption diesel		Please select	0.00
Total vehicle fleet consumption liquefied petroleum gas		Please select	0.00
Total vehicle fleet consumption petrol		Please select	0.00

Land-use

	% of total site area
Forestry	0.00
Cropland	0.00
Grassland	0.00

Description of methodology used:
(Please fill this out if your methodology differs to that outlined in the briefing document provided)

Please double click to add text

Introduction | Boundary | Scope 1&2 | Products | Waste | Deliveries | Air Travel | Ferry Travel | Bus Travel | Car Travel | Rail Travel | Taxi Travel | Oth

The majority of the sheet was locked to prevent inadvertent data entry, or alteration of the formulaic cells. In-built on an open tab were the relevant up-to-date GHG emission factors published by Defra. This tab was open (*i.e.* not locked) so that users can update in the future with the newly published emission factors. The workbook was developed in such a way that, using a series of ‘IF’ statement, GHG emissions could be calculated as the user would input data into the input tabs.

Appendix F

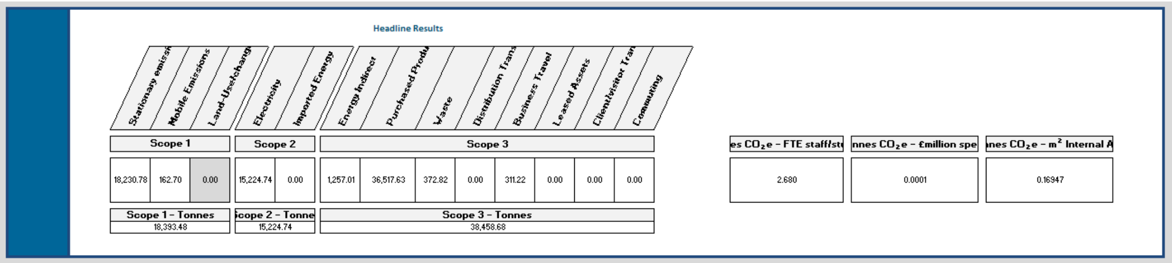
Energy consumption from mobile sources		kgCO$_2$e/litre	kgCO$_2$e/GJ	kgCO$_2$e/kg	kgCO$_2$e/m^3	kgCO$_2$e/tonne	kgCO$_2$e/kWh
Total vehicle fleet consumption biofuels	Bioethanol	0	0	0			
	Biodiesel	0	0	0			
	Biomethane		0	0			
Total vehicle fleet consumption biogas	Biogas			0			0
	Landfill gas			0			0
Vehicle fleet consumption CNG		0		0			
Total vehicle fleet consumption diesel		162700.4313		0			
Total vehicle fleet consumption LPG		0		0			
Total vehicle fleet consumption petrol		0		0			

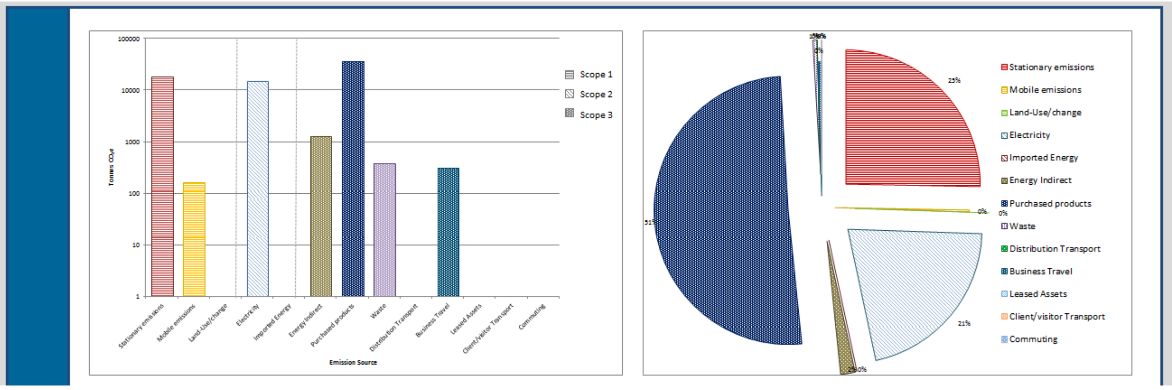
	kgCO$_2$e/litre	kgCO$_2$e/GJ	kgCO$_2$e/kg	kgCO$_2$e/m^3	kgCO$_2$e/tonne	kgCO$_2$e/kWh
UK Grid electricity						15224742.89
Photovoltaic						
Wind						
Other renewables						
Steam and heat						0
Water supply				165331.904		
Water treatment				323262.888		

		kgCO$_2$e/litre
Total vehicle fleet consumption biofuels	Bioethanol	=IF('Scope 1&2'!$N$28="Litre (l)",'Scope 1&2'!$
	Biodiesel	=IF('Scope 1&2'!$N$29="Litre (l)",'Scope 1&2'!$
	Biomethane	
Total vehicle fleet consumption biogas	Biogas	
	Landfill gas	
Vehicle fleet consumption CNG		=IF('Scope 1&2'!$N$33="Litres (l)",'Scope 1&2'!$
Total vehicle fleet consumption diesel		=IF('Scope 1&2'!$N$34="Litres (l)",'Scope 1&2'!$
Total vehicle fleet consumption LPG		=IF('Scope 1&2'!$N$35="Litres (l)",'Scope 1&2'!$
Total vehicle fleet consumption petrol		=IF('Scope 1&2'!$N$36="Litres (l)",'Scope 1&2'!$

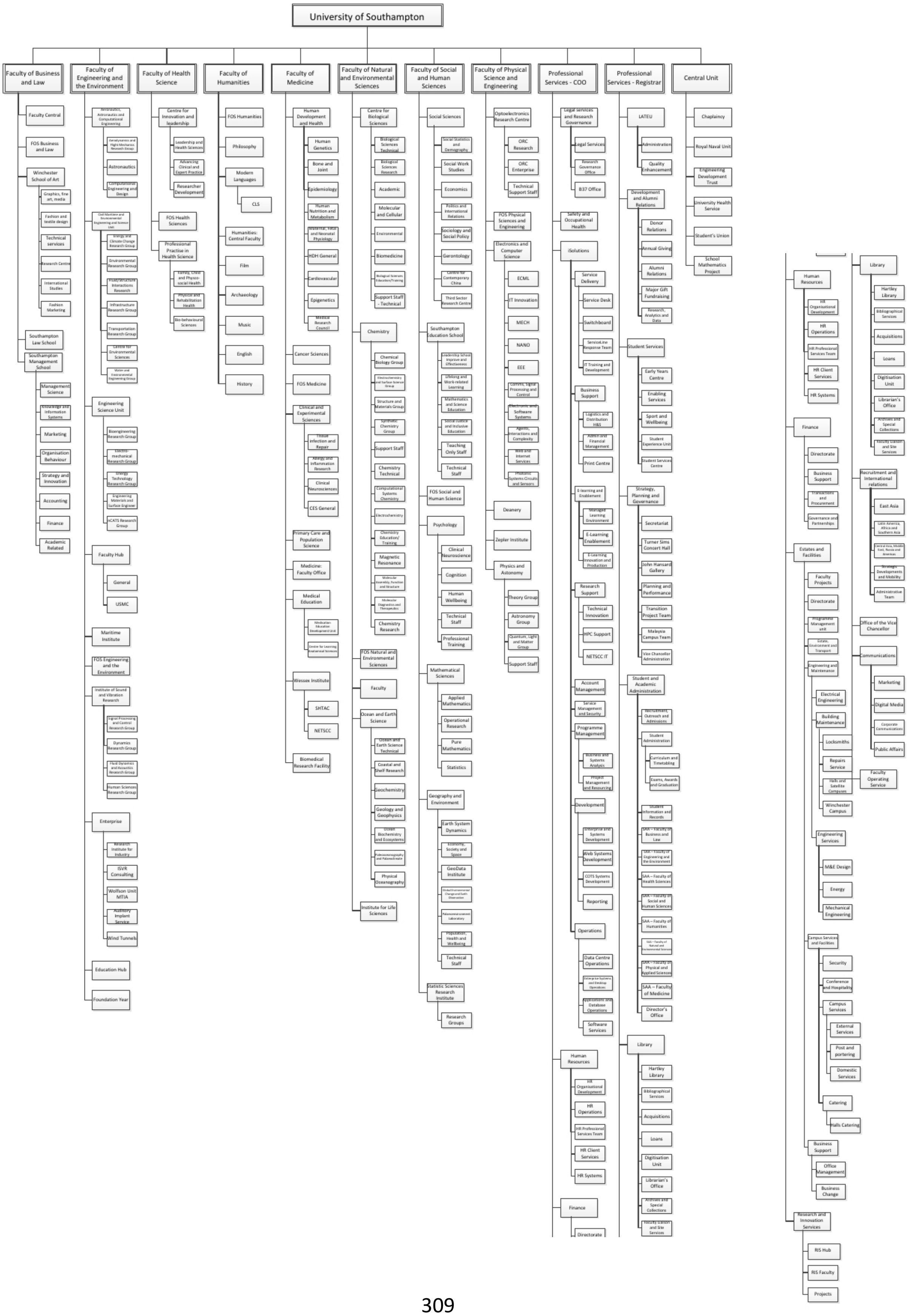
	kgCO$_2$e/litre
UK Grid electricity	
Photovoltaic	
Wind	
Other renewables	
Steam and heat	
Water supply	
Water treatment	

GHG emissions were calculated in kgCO$_2$e in the calculations tab. Through additional 'IF' statements, the output tab was able to capture the calculated GHG emissions and present the data in a means useful to the participant. Data in the output tab was converted to tonnes CO$_2$e and then provided using intensity ratios.





Appendix G Organisational structure of the University of Southampton, 2016



Appendix H Standardised university travel survey

Presented below is a constituent output of the research presented in 6.4.1. This is a collation of the common themes seen in the travel surveys of 143 UK institutions and represents a minimum standard required for travel surveying in order to provide the necessary information with which to calculate the respondent's journey-based GHG emissions.

<u>**Your Journey to the Institution:**</u>

1.) Please enter your term-time postcode:

2.) Please give details of the particular institutional facility that you are visiting more often (campus, building etc.):

3.) On which days are you usually on campus? (*Please select all that apply*)

a.) Monday
b.) Tuesday
c.) Wednesday
d.) Thursday
e.) Friday
f.) Saturday
g.) Sunday
h.) No fixed Pattern

4.) What is your PRIMARY commuting method?

a.) Car (single occupancy)
b.) Car (multiple occupancy)
c.) Scooter/moped/motorbike
d.) Bus
e.) Bicycle
f.) Walk
g.) Other (please specify)

5.) **Do you sometimes travel to the University by another mode of transport? Please indicate the average number of days per month that you travel to the campus using different modes of transport:**

6.) On average, how many minutes does it take to get to your institution and return home?

<u>About You - Staff:</u>

This survey is anonymous and all responses will be treated as strictly confidential. This final section will help us to analyse the results in more detail.

1.) **Are you full-time or part-time?**

2.) **Do you have flexibility in scheduling your work hours? (yes/no)**

3.) **How many days per month do you work from home?**

<u>About You - Students:</u>

This survey is anonymous and all responses will be treated as strictly confidential. This final section will help us to analyse the results in more detail.

1.) **Are you full-time or part-time?**

2.) **Which best describes you:**
   - a.) **Undergraduate**
   - b.) **Postgraduate**
   - c.) **PhD**

Appendix I Robinson, Kemp and Williams, 2015

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Carbon management at universities: a reality check

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ABSTRACT

Carbon dioxide emissions from the higher education sector are globally significant. This study compares the performance of 20 institutions in English research-intensive universities to their self-set targets, using three key performance indicators. Emissions increased for all but two institutions and consequently, targets are extremely ambitious and almost certainly unachievable. Observations are supported by a 10-point appraisal that measures the environmental value of each carbon management plan and a 'reality check' equation to classify them as either pragmatic or ambitious. A paradox is highlighted: institutions that set realistic but relatively low targets can be penalised in league tables and lambasted for apparent lack of ambition even when they may be more likely to succeed in delivering environmental improvements. The results of a staff and student questionnaire at the University of Southampton suggest that increasing awareness on impacts of energy usage will promote a cultural shift towards becoming more energy efficient to reduce emissions. Current carbon management plans are not a good indicator of future performance. The English higher education sector has underestimated the challenge of carbon emissions reduction. Pledged targets seem unlikely to be met by English universities and the likely environmental costs may jeopardise the global competitiveness of the sector. Methods for assessing Scope 3 emissions need refining and standardizing, given they are likely to be the most significant portion of a typical university's carbon footprint. The use of appropriate key performance indicators to foster action and promote realistic target-setting is required at sector-level to achieve the 2020 goal.

1. Introduction

1.1. Rationale

There is little doubt in the scientific community that significant and reliable evidence reveals that anthropogenic Greenhouse Gases (GHGs) directly influence the climate system (IPCC, 2007; Hoffman et al., 2009; Collins et al., 2010). The United Kingdom's (UK) Climate Change Act 2008 is the world's first carbon-related regulation and drives the UK towards an 80% reduction in scope 1 and 2 carbon emissions by 2050; each sector of the UK must be committed to emission reduction in order to attain this. Scope 1 emissions are direct emissions within the organisational boundary from sources the organisation owns or controls i.e. combustion of fuels and scope 2 emissions are emissions from purchased electricity which occur as a result of its activities and are not directly owned or controlled (Ranganathan et al., 2004; Pino et al., 2006).

There is a clear need to reduce the emissions of the United Kingdom's Higher Education (HE) sector; carbon emissions have increased steadily from 1.78MtCO_2 in 1990 to 2.05MtCO_2 by 2005 (HEFCE, 2010b). With more than 2.4 million students (Williams and Ongondo, 2011), 380,000 staff (HESA, 2012) and 129 universities (Universities UK, 2013), the HE sector contributes 11% of the UK's public sector emissions (Ward et al., 2008). In response to this and external government pressure, responsibility for carbon management within the English HE sector has fallen on the Higher Education Funding Council for England (HEFCE), which has prescribed a sector target of 34% reduction below 1990 levels in scope 1 and 2 emissions by 2020, equating to a reduction of 43% of the 2005/06 baseline (HEFCE, 2010a). How these targets will be met remains to be seen and forms the focus of this paper.

This study compares the carbon performance of the English Russell Group[1] institutions by creating an emissions baseline and

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0959-6526/

[1] The Russell Group represents 24 UK (England, Wales, Scotland and Northern Ireland) institutions dedicated to world-leading research and teaching. Member institutions garner 80% of the HEFCE's research funding (Lipsett, 2009), produce over 80,000 graduates and contribute £22.3 billion to the UK economy per annum (Russell Group, 2011).

using the University of Southampton (UoS) as a case study to identify emission-generating behaviours. The study also critically reviews the HEFCE's carbon strategy and its likely effectiveness as a way to initiate carbon reduction in HE and appraises institutional carbon management plans (CMPs), with a special focus on their self-imposed targets and the likelihood of success. The Russell Group is of particular interest as it comprises institutions that have the greatest challenge in altering behaviour, being among the UK's highest-emitting as a result of energy-intensive research programmes (University of Cambridge (2010); Williams, 2011).

Table 1 shows the targets proposed by the Russell Group Institutions up to 2020. An average reduction of 35.6% has been pledged, although 14 institutions have proposed targets that fall considerably short of the overall sector target. A number of notable examples considerably exceed the HEFCE requirement i.e. London School of Economics (LSE), Warwick and York. The remaining three, Durham, Kings College and Newcastle proposed targets that will match emissions with the sector requirements.

Universities are big business: the UoS for example is the largest HE institution (HEI) by student numbers in south-east England. The institution boasts a student population of 16,805 undergraduate and 7325 postgraduate students, 5510 staff, and a £437.8 million income through its teaching, research and enterprise activities in the academic year 2011/12 (HESA, 2014). Although seen traditionally as preserved for the social elite, universities are now open to all (Anderson, 2009), benefitting the global community/economy through the training of highly qualified professionals across a myriad of disciplines, in addition to the development of new academic ideas (Collini, 2012).

1.2. Themes in Institutional Carbon Footprinting

Carbon footprinting is an emerging subject area and it is only recently that a widely-accepted definition and standards for applying it to various applications i.e. a city boundary, have furthered the discipline (e.g. Wright et al., 2011; Publicly Available Specifications 2050, 2070). Very few papers have focused on emissions from HEIs and their management approach.

Table 1
Targets pledged by the 20 English Russell Group Institutions to be met by 2020.

Higher education institution	Carbon reduction target 2020/21 (%)	Baseline year	Notes
University of Birmingham	20	2005/06	
University of Bristol	35	2005/06	
University of Cambridge	34	2005/06	
University of Durham	43	2005/06	
University of Exeter	28	2005/06	
Imperial College London	20	2008/09	30% incl. growth
King's College London	43	2005/06	
University of Leeds	35	2005/06	
University of Liverpool	30	2006/07	
London School of Economics and Political Science	57	2005/06	
University of Manchester	40	2009	
University of Newcastle upon Tyne	43	2005/06	
University of Nottingham	34	2005/06	
University of Oxford	33	2005/06	
Queen Mary, University of London	34	2005/06	
University of Sheffield	20	2005/06	by 2016/17
University of Southampton	**20**	**2005/06**	
University College London	34	2005/06	
University of Warwick	60	2005/06	
University of York	48	2005/06	
Mean ± Standard Deviation	35.55 ± 11.4		

Previous studies that have been conducted on HEI carbon footprinting have primarily focused on scope 1 and 2 emissions, largely because they are easiest and cheapest to assign and calculate (Bastianoni et al., 2004). Riddell et al. (2009) identified that electricity consumption accounted for 40% of the direct emissions of Rowan University in the United States of America (the rest attributable to steam and heat production), with emissions amounting to 4 tonnes CO_2 per full time student per annum. Larsen et al. (2013), using the Norwegian University of Technology and Science (NTNU) as a case study, found that an annual footprint of 4.6 tonnes CO_2 per full time student was emitted per annum. Scope 3 emissions, the remaining indirect proportion of the carbon footprint result from the upstream (indirect emissions from purchased/acquired goods and services) and downstream (indirect emissions from sold/distributed goods and services) activities of the organisation, are inherently more challenging to quantify as a wide variety of primary and secondary data sources, as well as modelled, extrapolated and proxy data need to be researched and combined (Peters, 2010). Few studies have addressed this, although it has been suggested that scope 3 emissions account for at least 80% of an organisation's carbon footprint (Ranganathan et al., 2004; Lee, 2011; Ozawa-Meida et al., 2013). The methods of calculating Scope 3 emissions need refining and standardizing (Turner et al., 2012) so early research conclusions must be treated with caution.

Presenting reported organisational emissions is a contentious issue for many authors, with literature presented on both sides of the argument. Basing targets on appropriate key performance indicators (KPIs), a business/financial metric i.e. revenue, employees or floor space (Defra, 2009) ensures fairness across different institutional settings (Weber, 2008), whilst representing a more practical methodology due to inertia present in university-sized organisations (Samarasekera, 2009). However, issues such as operating hours, endowment and efficiency of floor space can all influence and be obscured by KPIs (Reidy and Daly, 2010; Klein-Banai and Theis, 2013). The sector target reductions are based on absolute emissions and the implications of this will be discussed further in this paper.

1.3. ESD and university institutions

The importance of analysing different education and research activities in terms of carbon management in HEIs should not be underestimated, as an understanding of the carbon intensity of different activities is important in the development of institution-specific strategies. Larsen et al. (2013) demonstrated the greater carbon contributions of teaching and research in science, engineering and medicine compared to the humanities and social science. Klein-Banai and Theis (2013) provided an account of the environmental implications of different academic activities and sizes of HEIs, showing that office and teaching areas have lower emissions than laboratory and research spaces. This can allow targeted and holistic emission reduction strategies to be implemented in HEIs (Disterheft et al., 2012), and is of particular relevance to the research and equipment intensive English Russell Group Universities.

The relevance of education to carbon management goes further than the identification of the relevant carbon consumption of different academic study areas and equipment usage. Education for Sustainable Development (ESD) is considered critical for altering values and behaviours to move towards sustainable universities (Lozano, 2006), especially in the context of HEI carbon management (Barth et al., 2013; Williams and Kemp, 2013). In order for sustainable development and the carbon consequences of decision making to be understood by students, an interdisciplinary approach to learning and teaching is required due to the multidimensional

Appendix I

nature of ESD (Karatzoglou, 2013). The difficulty is that institutions are better designed to teach others than teach themselves (Stephens and Graham, 2010).

A desire to learn about sustainable development is prevalent in HEIs, as demonstrated by the three-year longitudinal analysis conducted in the UK by the National Union of Students (NUS) and Higher Education Academy (HEA). This study has consistently shown that over 80% of students believe their institutions should actively incorporate and promote sustainable development, and over two-thirds believe it should be covered by their courses (Drayson et al., 2013). This demand for the establishment of ESD in the curriculum would ensure all students have some environmental awareness (Fien, 2002) even if economic issues have taken precedence over environmental issues since the recession in 2008 (Kahn and Kotchel, 2010) leading to an imbalance in sustainable development from a learning and teaching perspective. Factors affecting behaviour change from ESD are beginning to be understood and addressed; a study by Polonsky et al. (2011) found that even if people have knowledge regarding carbon-related issues, it is rarely acted upon due to being based on complex science they do not understand or agree with.

The continual expansion of information technology into everyday life globally (Acre, 2003; Sadorsky, 2012) has had unintended consequences for university carbon management. The use of computing equipment is a highly energy-intensive activity and the associated rise in use for teaching and research purposes increases institutional emissions (Ang, 1999; Soytas et al., 2007). Personal 'gadgets', (i.e. MP3 players, tablets, laptops and smartphones) are now ubiquitous in the daily lives of students, and are increasingly embraced by lecturers to enrich the learning experience and to engage with students outside the classroom. The numbers and intensity of use of personal 'gadgets' has surged amongst the student population with resultant increases in per student capita carbon consumption through using and charging devices on campus, increasing the carbon challenge for HEIs. An irony is inherent in that innovative teaching methods are needed to engage students from across academic disciplines (as necessitated in the multi-disciplinary field of ESD). However, these can lead to increased energy consumption and carbon emissions from a HEI, creating a paradox for ESD as a driver to more sustainable universities.

Universities are seen as key drivers of sustainable development (Velazquez et al., 2006; Lozano et al., 2013a); as breeding grounds for responsible research into the technologies and ideas that will be required for the future of sustainable production and consumption (SPC) (Waas et al., 2010), and as the potential vehicle for creating the sustainability leaders and change agents of the future (Lozano et al., 2013b) by weaving ESD through curricula and extra-curricular activities. They possess the ability to influence governance at the local, national and international level as a result of their population size, scope and affluence (Sedlacek, 2013). Wilk (2002) found that sustainable consumption in universities could be tackled through understanding how students can learn to consume resources sustainably, whilst Savagaeu (2013) proposed greater active and passive participation in the decision making process. Whilst reducing emissions is important, it cannot be at the expense of the academic and economic merits they provide (Williams et al., 2012); practitioners must develop the innovative solutions to succeed, and it is clear that ESD plays a critical role in tackling both current HEI and future global industrial carbon emissions.

2. Methods

The HEFCE requires each Russell Group institution to produce a CMP based on their intended carbon reduction strategy (HEFCE, 2010b). A set of 10 questions were developed to analyse the CMPs for their environmental credentials (Table 2). In order to identify appropriate target-setting, the analysis needs to assign scores to: the institutional target, whether normalised or absolute data has been used, whether interim targets and monitoring has been proposed, agreement with sector targets and if commitment is shown by high-level management.

Table 2
Questions used to appraise the institutional carbon management plans.

Number	Question
1	Percentage reduction?
2	Year of emissions baseline
3	Absolute or normalised data used to calculate emissions?
4	Any interim targets proposed?
5	Will strategies outline in CMP result in a net carbon reduction?
6	How does this target compare with the HEFCE's?
7	Pledge to reduce scope 3 emissions?
8	Full responsibility assigned to a relevant and qualified member of staff?
9	Is the CMP agreed by top management (i.e. Chancellor, Vice Chancellor) of the institution?
10	Is continual monitoring of emissions proposed?

A rank of carbon targets was produced by defining outcomes to the questions above and assigning scores using definitions of 'light' and 'dark' green environmentalism[2] defined by Steffen (2011); see Table 3. Scores were intended to represent the closest fit to the light/dark green definitions as possible and explains the subtle differences in the assigned score. This method assumed that all Russell Group institutions would be able to meet their intended target by 2020 (a view that is shared by the institutions themselves) and for this reason a 'reality check' was applied to identify how realistic the targets were. We proposed a more realistic target of 10% reduction in absolute emissions by 2020, with the equation x-10 being applied to check alignment.

To test the likelihood of institutions reaching these targets, an emissions baseline was produced. Consumption rates of electricity and vehicle fleet fuel usage data for all institutions were obtained through the Higher Education Statistics Agency (HESA) (HESA, 2010), namely the HE Estates Management Statistics (EMS). Emissions factors were applied, which convert activity data (i.e. litres of fuel used) into carbon emissions. Here, energy usage (kWh) was converted, using factors provided by the UK Government Department for Environment, Food and Rural Affairs (Defra) (Defra, 2009). Data were chosen for the period 2005–2010 to show how emissions altered over the period since the baseline year and whether positive or negative progress towards the 2020 target was made. Three KPIs: gross internal area, full-time equivalent (FTE) staff and student numbers and institutional income, were utilised to compare normalised emissions, following the conventions prescribed by Defra on reporting guidelines for business using KPIs (Defra, 2006); also obtained from the EMS dataset.

An online snapshot questionnaire was administered to FTE staff and students at the UoS (via www.isurveysoton.ac.uk) and accessed through the Southampton University Staff/student Social

[2] Dark green ideology stipulates that environmental issues are inherent to industrialised capitalism and the current economically driven political setting that gives rise to consumerism and resource depletion. Consequently, targets claiming a greater overall emissions reduction were assigned higher scores, despite the uncertainty in using 1990 data (Ellerman and Joskow, 2008) and growth omitted in absolute targets. Light green ideology views environmentalism as a personal lifestyle choice that exhibits cynicism towards politically-driven motives. Higher scores were thus assigned to targets that aligned with the HEFCE and those beyond were lower as the ideology stipulates that personal carbon management should drive emissions down (Steffen, 2011).

Table 3
Answers and assigned scores for CMP appraisal for Dark and Light Green viewpoints.

Question	Dark green environmentalism		Light green environmentalism	
	Answer/outcome	Assigned score	Answer/outcome	Assigned score
1	71–100%	10	31–50%	10
	51–70%	8	71–100%	8
	31–50%	6	51–70%	6
	16–30%	4	16–30%	4
	1–15%	2	1–15%	2
	0	0	0	0
2	1990	10	2011	10
	1991–2000	7	2001–2010	7
	2001–2010	4	1991–2000	4
	2011	1	1990	1
3	Absolute	10	Use of both absolute and KPIs	10
	Use of both absolute and KPIs	7	Normalised (KPIs)	7
	Normalised (KPIs)	4	Absolute	4
4	4 or more interim targets	10	4 or more interim targets	10
	3 interim targets	8	3 interim targets	8
	2 interim targets	6	2 interim targets	6
	1 interim target	4	1 interim target	4
	No Interim targets	0	No Interim targets	0
5	Net Carbon Reduction	10	Net Carbon Reduction	10
	No change	5	No change	5
	Net Carbon Gain	0	Net Carbon Gain	0
6	Surpasses the HEFCE Target	10	Meets the requirements of the HEFCE target	10
	Meets the requirements of the HEFCE target	5	Surpasses the HEFCE Target	5
	Fails to meet requirements of the HEFCE target	0	Fails to meet the requirements of the HEFCE target	0
7	Yes	10	Yes	10
	No	0	No	0
8	Yes	10	Yes	10
	No	0	No	0
9	Yes	10	Yes	10
	No	0	No	0
10	Yes	10	Yes	10
	No	0	No	0
Maximum total		100	Maximum total	100

& Educational Directory [SUSSED]) in order to gain a picture of self-reported behaviour that generated emissions. A preliminary trial was undertaken with a group of 10 staff and students in October/November 2011 with questions altered to reduce the risk of misinterpretation, an important consideration when surveying (Oppenheim, 1992).

3. Results

3.1. Carbon emissions and targets

The rank order of institutions for both methods outlined in 2.1 is shown in Table 4. Newcastle and York were consistently high for both tests in the light/dark green analysis, with Nottingham and Bristol scoring consistently low. The difference between the two tests is apparent; institutions that scored highly in the light green and dark green appraisal ranked lowly when the "realistic" scenario was applied. In the latter case, the UoS is ranked joint first, along with a number of institutions that ranked in the mid-ranges for the light/dark green tests i.e. Birmingham, Imperial College and Sheffield. LSE and the University of Warwick were ranked 19th and 20th respectively.

The overall emissions of each institution were compared in order to review performance against their 2020 targets. In Fig. 1 it is clear that Imperial College had by far the highest overall emissions at 84,437 tonnes CO_2 p.a in the baseline year and was one of only two institutions where emissions decreased over the study period (−0.7% to a level of 83,836 tonnes CO_2 p.a by 2009/10); the University of Birmingham being the other.

Large increases in emissions to 2009/10 were experienced by a number of institutions i.e. Manchester, Nottingham, LSE and UCL posted rises of 17.7%, 40%, 143% and 91% respectively. Manchester increased sufficiently to overtake Imperial College as the Russell Group's largest emitter of absolute emissions. The emissions

Table 4
Outcomes of the carbon management plan appraisal and application of a 'reality check'.

Higher education institution	Carbon management plan appraisal method					
	Light green	Rank	Dark green	Rank	x-10	Rank
University of Birmingham	58	16	58	15	10	1
University of Bristol	41	20	40	20	25	12
University of Cambridge	65	9	74	2	24	8
University of Durham	75	4	69	7	33	15
University of Exeter	61	14	55	18	18	5
Imperial College London	65	9	64	9	10	1
King's College London	71	6	65	8	33	15
University of Leeds	65	9	64	9	25	12
University of Liverpool	65	9	59	14	20	6
London School of Economics and Political Science	77	3	71	6	47	19
University of Manchester	61	14	60	13	30	14
University of Newcastle upon Tyne	81	1	75	1	33	15
University of Nottingham	51	19	41	19	24	8
University of Oxford	71	6	61	11	23	7
Queen Mary, University of London	71	6	61	11	24	8
University of Sheffield	55	17	58	15	10	1
University of Southampton	**55**	**17**	**58**	**15**	**10**	**1**
University College London	75	4	74	2	24	8
University of Warwick	64	13	72	5	50	20
University of York	78	2	73	4	38	18

Appendix I

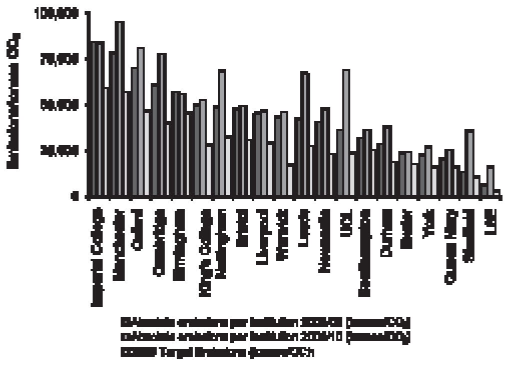

Fig. 1. Comparison of English Russell Group absolute emissions in 2005/06–2009/10 against 2020 targets.

baseline for the UoS in 2005/06 was 31,983 tonnes CO_2 p.a and like a number of institutions rose significantly by 2010; up 13.3% to 36,228 tonnes CO_2 per annum. A consequential reduction of 29% would be needed to meet their 2020 target, which amounts to 25,586 tonnes CO_2 per annum.

The implication of these increases in the group's total emissions is shown in Fig. 2, compared against the 2020 target level. Emissions increased from 856,560 tonnes CO_2 per annum in 2005/06 to 1,043,824 tonnes CO_2 per annum in 2009/10; the 2020 target would bring emissions to 484,959 tonnes CO_2 per annum (based on 43% reduction below 2005/06 levels for the group's total emissions). The pledged reductions, based on the institution's own self-imposed targets would bring the Russell Group's emissions to 570,484 tonnes CO_2 per annum, meaning that the reductions pledged by the individual institutions will significantly fail to meet the collective target. To put this into perspective, the overall sector aim is to reach emissions of 690,000 tonnes CO_2 by 2020, thus the Russell Group contributes a significant proportion of the HE sector's emissions. The 20 institutions comprising the English Russell Group alone exceeded the 2020 sector target considerably in 2010.

Fig. 3 shows the normalised emissions of each institution by staff and student numbers. Imperial College emitted by far the most per staff and student than any other institution in the group. Some institutions reduced their normalised emissions, whilst increasing absolute levels over the time period e.g. Exeter and Queen Mary, University of London. Only two institutions had fewer emissions per staff and student than the UoS in 2009/10 (accounted for 1.37 tonnes per person in 2005/06, rising slightly to 1.41 tonnes in 2009/10) which was Exeter and Sheffield at 1.27 and 1.36 tonnes CO_2 emitted p.a. per staff and student respectively.

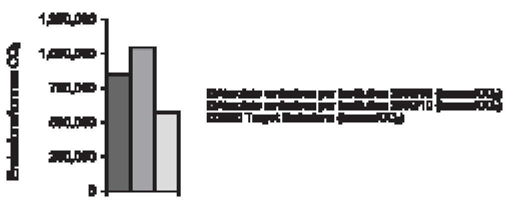

Fig. 2. The rise in total English Russell Group emissions from 2005/06–2009/10 against 2020 target emissions.

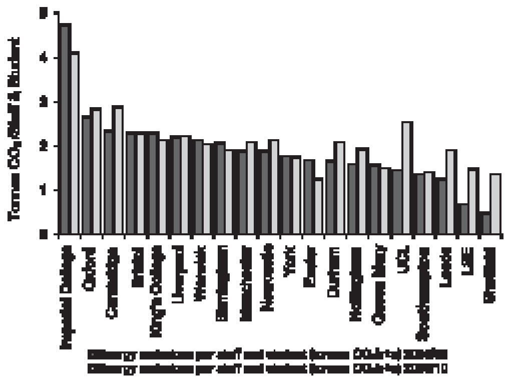

Fig. 3. Emissions per staff and student at English Russell Group institutions from 2005/06–2009/10.

Linear regression analysis was carried out to identify the relationship between income and emissions at the UoS. In 2005/06, the UoS emitted 0.103 tonnes CO_2 per million pounds of income, which declined to 0.1 tonnes CO_2 per million pound of income by 2009/10 (09/10 value corrected for the retail prices index) (RPI); found to be highly significant at $p < 0.001$. The independent variable, income was perhaps unsurprisingly significant in determining CO_2 emissions. Nottingham featured top with an emission of 0.134 tonnes CO_2 per million pounds of income in 2009/10, having reduced from 0.142 tonnes CO_2 per million pounds of income in 2005/06. In fact, most institutions reduced their normalised emissions by income, with only a few exceptions (Leeds, LSE and UCL).

At the UoS, emissions per gross internal area were among the lowest of the Russell Group at 0.07 tonnes per m^2 in 2005/06, but rose to 0.09 tonnes per m^2 in 2009/10. Over the study period, the UoS's income increased, whilst internal area decreased and staff and student numbers were roughly equal. This meant that emissions per income decreased and emissions per internal area and staff and student increased.

3.2. *Staff and student behaviour*

A total of 155 responses were recorded for both staff and student individuals (students: 85% 18–24 years old, 66% female; staff: 75% 25–54 years old, 58% female). Staff reported spending more time at university than students, 60% spending 31–40 h there. The responses were more evenly spread for students, with the majority (30%) spending 11–20 h at university per week. Staff also reported using computers for a longer duration each week than students; 81% using them for longer than 20 h per week as opposed to 38% of students using computers for the same period. Mobile phone and laptop charging accounted for the majority of personal energy consumption (Fig. 4).

Simple strategies, such as turning lights off when leaving rooms and taking the stairs instead of the elevator were reported by respondents to reduce their energy consumption. For student respondents in halls of residence, 35% reported spending >41 h at their halls. 100% of respondents used a computer or laptop for longer than five hours per week, with two respondents in particular exceeding 41 h per week of computer use.

When asked about the UoS's carbon emission target, 40% of staff and 47% of students knew the correct target for 2020. On whether this target would actually be met (i.e. yes/no/maybe) there was no

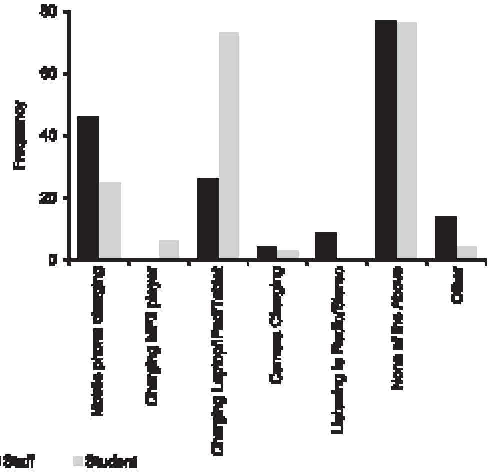

Fig. 4. Personal energy consumption of staff and students at the UoS; results from the snapshot questionnaire.

significant difference found between the difference in staff and student opinions (35% of staff and 40% of students agreed). A Wilcoxon Rank Sum Test was performed to identify significant differences between staff and students' views of carbon emissions and climate change which was found to be not significant; a large proportion of respondents in both categories held the opinion that climate change was undeniable and occurring. Environmental issues did not rate very highly for either staff or students when individuals were asked to rate the greatest issues faced by HE institutions with institutional funding ranked number one by respondents the most frequently (42% of staff and 33.5% of students). "Tuition fees", "student experience" and "standard of scientific research and teaching" were also among the top rated.

4. Discussion

4.1. Target-setting culture

In recent years, a target-setting culture has become prevalent in the UK. Whilst this has become a common-place mechanism to direct change and bring about improvements in organisations during a specific time period (O'Neil and Drillings, 1994) and is often seen as a positive first step towards addressing environmental issues, target-setting is not always appropriate. Targets should not be set in circumstances when e.g. an organisation has limited ability to affect an outcome, when achieving the target is not a real priority, when the cost of measurement outweighs the benefit, or when there are no resources for delivering it. Simply setting a target does not guarantee that a positive change will occur (Harris and Crane, 2002); rhetoric is no substitute for real action. It could be argued from the results in this paper that target-setting in the UK HE sector is incentivised (through high league table results) and praised, sometimes to the detriment of realistic activities by individual HEIs and to the benefit of those who have placed words before actions.

The publication of CMPs has galvanised the sector to take the carbon issue seriously; HEIs are considered important facilitators of change (Sedlacek, 2013), however a danger is that having unachievable targets, senior managers will lose interest and support for their hard-pressed energy and environment managers. In terms of environmental management, high targets often have a low likelihood of success. A paradox for HEIs that set realistic but relatively low targets is that they can be penalised in league tables and lambasted by critics for an apparent lack of ambition when in fact they may be more likely to succeed in delivering regular, incremental environmental improvements than those who set wildly unrealistic targets (Lozano, 2006; Velazquez et al., 2006). Setting high targets for emissions reduction and then not making a realistic attempt to achieve them should be dismissed as "greenwash[3]". It could be embarrassing for individual HEIs if their approach to target-setting turns out to be either i) a cynical, short-term strategy devised to improve upon league table positions in order to e.g. improve recruitment or ii) simply ill-considered and poorly thought out.

Our results suggest that many of the targets set by Russell Group institutions are extremely ambitious and almost certainly unachievable; compare the University of Warwick's target of 60% reduction to the UoS's 20% target. We anticipate that it will take a significant, sustained and concerted effort to achieve a 20% reduction at the UoS and regard the target as optimistic at current rates of energy consumption and estate growth. We argue that to retain credibility, the HEFCE must ensure that institutions which set realistic, proactive targets are rewarded whilst greenwash is actively discouraged.

The HEFCE have proactively taken a lead on carbon management in the UK HE sector, raising the profile of carbon reduction and placing it, and ESD in general, firmly on the agenda's of HEIs across the country (Karatzoglou, 2013). Many institutions have responded well to instructions so far, as demonstrated by the publication of CMPs, even if this is as a result of the threat of penalties. It should be noted that the HEFCE's remit, following the 2010 general election and subsequent changes to tuition fees has changed since the adoption of carbon targets. From being a HE regulator and funder, the focus is now on becoming a 'champion of the student'. As a result, the future of directly linked funding and emission reduction is in doubt, with wider connotations for the sector as a result of limited impetus to meet targets in 2020. Now there is no 'stick' that will drive HEIs towards reduction and so the 'carrot' (financial savings etc.) must be prioritised. Once aware of this, the delivery of targets will most certainly become a lower priority business activity for senior personnel.

Even though the drivers for carbon management in the HE sector seem clear, the details in the delivery of this plan are becoming lost; unrealistic target-setting and environmental rhetoric is being rewarded in practice to the detriment of real action and leadership. This problem could be addressed through the use of more appropriate KPIs. Further, interim targets should be included as a requirement of the HEFCE guidelines, which will allow institutions to identify future difficulties in reaching their target, allowing early action to be taken.

4.2. Key performance indicators and institutional growth

Targets should be based on appropriate KPIs in order to ensure fairness across different institutional settings (Weber, 2008) and to allow comparisons between institutions for the sector to collaborate on future reductions. Significantly, many institutions are

[3] Greenwash occurs when an organisation promotes pro-environmental initiatives but actually operates in a fashion that may be damaging to the environment or in an opposite way to the goal of stated initiatives (Banerjee, 2004). It can also include misleading people about environmental benefits and unsubstantiated claims.

expanding in terms of student and estate size and this is seldom taken into account. A number of HEIs lacked consideration of their emissions at the time their targets were set and HEIs that have posted an emissions increase of more than 1% between 2005 and 2012 are at risk of missing the 2020 target altogether unless drastic action is taken (HEFCE, 2010b); this is a reality check for 90% of institutions in this study.

The UoS for example intends to continue to grow; a new Life Sciences building, opened in 2012 and the redevelopment of the Boldrewood Campus as a Maritime Centre of Excellence, to be opened in 2014, are some recent examples of campus expansion that must be considered when developing an institutional CMP in order to meet the requirements of the Climate Change Act 2008.

Reducing normalised emissions so far has worked to the benefit of institutions, with a recent example being financial incentives from the HEFCE Capital Investment Framework (CIF),[4] which supports one-off expenditures in institutions. This is the same fund from which institutions would have been penalised if not having prepared a CMP by 2011 (CIF round one). CIF two has imposed penalties on four institutions for failing to reduce normalised emissions (Leeds, LSE, Sheffield and UCL) during this round of funding.

Internationally, organisations set targets through corporate social responsibility (CSR) policies using both KPIs and specific, measurable, attainable, relevant and time-sensitive (SMART) targets (Doran, 1981). These are meant to be manageable, comparable and attainable, allowing continuing progress and further targets to be set. The HEFCE may have created an unintentional barrier to carbon management as a result of stipulating that targets should be set on absolute reductions, rather than reductions based on KPIs. Normalised emissions are useful in order to find out the intensity of emissions per KPI (Defra, 2009), which is a more practical method of target-setting due to institutional inertia which masks progress (Samarasekera, 2009).

4.3. Electricity usage

Electricity usage has the greatest effect on direct emissions at university institutions and is likely to increase in future as the demand for power increases, which supports findings by Ang (1999) and Soytas et al. (2007). ICT consumption has rapidly increased (Acre, 2003; Sadorsky, 2012) with personal 'gadgets' now being ubiquitously used daily. The results here have shown that electricity usage is a large part of the emission-generating activities of a university, with 81% of staff and 38% of students at the UoS using a computer for longer than 20 h per week.

Little consideration is made for institutions with differing electricity base loads, which is where significant emission reductions can be made whilst being noted that engineering and sciences-based institutions have higher energy requirements than humanities-dominated institutions (Klein-Banai and Theis, 2013; Larsen et al., 2013). Inefficient infrastructure is a major cause even though simple actions can be taken to address this. For example, significant savings have been made through the installation of a swimming pool cover to reduce heat loss and a combined heat and power (CHP) system to the base load at the UoS. Studies have shown that in the School of Chemistry, a particularly energy intensive department, the base load (overnight measurements) can be as high as 50% of daytime peak electricity usage and so to demonstrate the importance of electricity usage on carbon emissions, and generate awareness, the UoS undertook the first annual 'Blackout' in 2012. This engaged staff and students in a mass-switch off of all non-essential electrical equipment in order to raise awareness of the amount of electricity wasted as a result of leaving equipment switched on unnecessarily. The UoS Blackout in 2012 demonstrated the savings that can be made through changing behaviour and regularly switching off non-essential equipment. The switch-off reduced weekend electricity consumption by 6%, saving 16,000 kWh of electricity and seven tonnes of CO_2 as well as £1600 in electricity cost (Fig. 5) (University of Southampton (2012)). The second annual Blackout in April 2013 featured 300 students and two additional campuses.

4.4. Staff and student engagement/awareness

Activities such as the UoS Blackout demonstrate that staff and student engagement is a very important and effective way to permanently change the culture of an institution (Barth et al., 2013). Student societies are an important way to increase engagement across the student population, with national groups such as Transition and initiatives like Student Switch Off representing fun and interactive activities that all students can participate in. Student Switch Off in particular focusses on students in their halls of residences; providing incentives for students to reduce their electricity usage, usually extremely problematic due to electricity being essential, free and unsupervised. Additionally, when on campus, staff and students may over-consume electricity for the same reason; it is "free" and (apparently) inconsequential to do so.

To this end, improving awareness of sustainability issues is needed to address personal carbon management on the university premises. Raising awareness on the impacts of electricity usage should be made more apparent to staff and students alike, in order

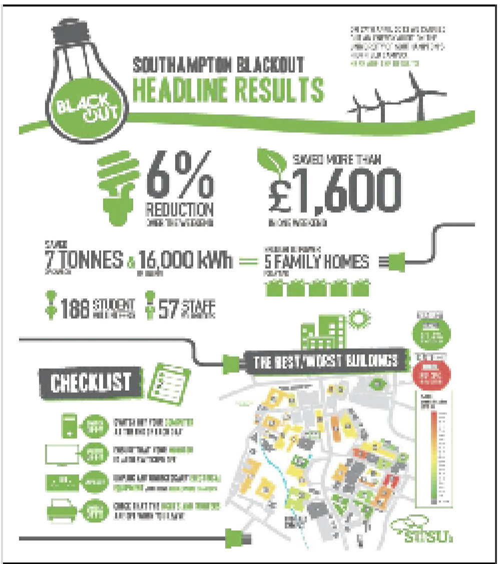

Fig. 5. Headline results of the 'Blackout' undertaken at the University of Southampton in 2012 (University of Southampton (2012)).

[4] The Capital Investment Framework was introduced by the HEFCE in 2008 to foster academic excellence in universities through good quality infrastructure, equipment and information communication technology (ICT) and has so far allocated £598 Million in funding for 2011/12–2014/15 (HEFCE, 2012).

for the increased participation of energy efficient activities (i.e. switching lights off, appliances on standby etc. etc.) (Wilk, 2002; Savagaeu, 2013). This will also highlight the need to reduce the charging of peripheral appliances (smart phones etc. etc.). Raising awareness of the carbon reduction targets by means of advertising, to promote a community-based involvement is the key to develop a holistic approach to carbon management (Disterheft et al., 2012), which are much more likely to be met through a joint bottom-up approach than a disjointed, expensive top-down strategy (Lozano, 2006; Stephens and Graham, 2010). Increased staff engagement is also important since the staff population is less transient than the student population (Saks, 2006), whilst praise and encouragement is needed for those already undertaking strategies to reduce emissions, as well as incentives for those currently not undertaking such activities to alter behaviour.

Increasing awareness and education on the potential impacts of climate change will also assist in boosting the profile of the environment as a major issue affecting HEIs in the 21st century (Fien, 2002); issues that were not rated very highly in the snapshot questionnaire, although they are generally understood to be matters that students want to learn about (Drayson et al., 2013). The removal of individual (increasing individual knowledge) and social barriers (i.e. distrust among social groups of politicians and climate change evidence) is seen to improve awareness (Lorenzoni et al., 2007). Communication must be clear and understandable; otherwise those targeted will not act on the information and enact a substantial and everlasting change (Polonsky et al., 2011). Efforts should be directed to sustained awareness campaigns that force behaviour through choices staff and students make. The agents of change should be focussed on in order to produce long-term change. Staff and student behaviours are complex, with more interdependent factors than wider sector policy, it still promises to deliver the biggest gains in terms of actual carbon reductions.

The results here suggest that the majority of staff and students feel that issues other than environmental matters currently take priority at the UoS (42% and 33.5% respectively selected institutional funding). Whilst this is understandable, institutions must ensure that environmental issues do not fall far down the agenda since future impacts are potentially devastating for the sector as a whole, the UK and the World. Climate change awareness however, is particularly positive (100% of respondents had heard of climate change).

4.5. *Measurable is manageable*

The activities and funding methods for HE are changing and so this will inevitably bring greater challenges in the future of carbon management at HEIs (Barber et al., 2013; HEFCE, 2013). What is certain however is that the issue of carbon management is becoming more important, with the HE sector looking to academia for more answers. Although studies have traditionally focused on scope 1 and 2 emissions, methods for assessing Scope 3 emissions urgently need refining and standardizing given they are likely to the most significant portion of a typical university's carbon footprint. The scale of the issues relating to carbon management will only ever be tackled once the true scale is identified: 'what is measurable is manageable'. HEIs must work hard to reduce errors when quantifying their emissions, at which point reduction can take place. For this reason, the methods that are currently carried out to obtain data required for carbon footprinting, as well as the footprinting methods themselves need adapting in order to become truly effective and uniformly implemented (Turner et al., 2012).

Further international collaboration is needed to ensure that HE carbon management is addressed ubiquitously so that the targets adopted by the HEFCE are attainable for the entire sector. Whilst it seems that time is running out for institutions to meet their targets within a decade, this is still enough time for concerted, collaborative and holistic actions to be taken.

5. Conclusions

Some English HEIs have set very high targets for carbon reduction, the result of an ambitious sector target set by the HEFCE, governmental and external pressures. We have demonstrated for the first time that current carbon management plans are not a good indicator of future carbon management performance and represent a clear underestimate of the challenge of carbon emissions reduction by all institutions, the degree to which has been demonstrated through a 'reality check'. This is supported by the trends in institutional emissions which are fast-growing, not only hindering the institutions in delivering higher education in the future as they confront the inevitable environmental costs, but this also stands to jeopardise the competitiveness of the English HE sector on the global stage if it is not addressed (Ellis, 2013). This issue is likely to become exacerbated since there is little evidence of this slowing at the present.

To this end it certainly remains to be seen if such targets will be accomplished within the set time frame to 2020. Despite this, pledged targets are calculated to significantly fall short of the sector-set targets and represents an issue that must be addressed before the time for action has passed. The HEFCE and HEIs alike have made little provision to account for individual institutional setting in target guidelines and carbon management plans. By utilizing three KPIs; FTE staff and student numbers, gross internal area and income, simple comparisons can be made regardless of institutional size and scope which means the HE sector could better monitor progress on emissions reduction in the future. These findings can also benefit the strategies used in carbon management practices at all organisations, which has fallen victim to a target-setting culture that has little regard for the semantics of achieving targets. We have highlighted the disparate nature of target setting on paper against real-life applications of emission reduction strategies and it is here that this paper makes significant contributions to the fields of ESD and carbon management. Understanding that emission reduction must be achieved without hindering the business-critical practices of the university makes it all the more difficult to see how targets will be reached.

Computer usage contributes to a significant proportion of emissions, and is without question the greatest source of individually-controlled contributions by staff and students. More specific factors, such as lecture hall usage, wind tunnel and research machinery i.e. 'shared activities' have not been investigated and could provide greater understanding of energy use. By reducing overnight power usage and the electricity base load, it has been demonstrated that electricity consumption reduction, coupled with emissions reduction can be achieved in a short timescale. An increased awareness of staff and students to the impacts of electricity usage at university is needed in order to achieve a culture change in HEIs. Furthermore, greater engagement will act to completely change the way HE is delivered in the future.

The implications of these findings can have contributions to institutions across Europe and the world as HE carbon management is a pressing issue for leaders in HEIs globally. It is also vital to maintain dialogue on the strategy of institutional carbon management so that complacency is avoided and continual improvement is fostered. It is here that this paper makes a significant contribution to the field of carbon management. Understanding the role that staff and students have in carbon management is important, but further than this; institutions should take lessons from the carbon-

Appendix I

management-through-target-setting culture that is prevalent in the UK. Contextualising the UK's HE sector on a global setting would be valuable in identifying it as a leader or a laggard in institutional carbon management and although this study has focussed on the English Russell Group as a sample of the English HE sector, it would be pertinent to extend this to encompass all institutions in England for which data is available. A non-Russell Group sample could be tested in order to verify if trends outlined in this paper are ubiquitous through HE in England.

An important consideration for institutions in the near future are scope 3 emissions, which are soon to become an integral part of the HEFCE target (institutions able to report these emissions in the 2013/14 EMS data). Institutions will need to prepare for any targets that develop to control these emissions and even though they prove difficult to quantify and assign, they represent the greatest source of emissions reduction due to their large proportion of an organisational carbon footprint (Ranganathan et al., 2004).

Highlighting transport, this looks to be a future important scope 3 source that can be investigated, as this currently accounts for 24% of the UK's overall carbon emissions (Department for Transport, 2009); addressing the issues of calculating the emissions associated with scope 3 emissions, particularly transport, will be a pertinent extension of this paper. Transport emissions can also be simply addressed through improved local public transport schemes which are more efficient than personal transportation (Hoornweg et al., 2011).

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Towards a universal carbon footprint standard: A case study of carbon management at universities

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ABSTRACT

Organisations of all types are significant contributors to international greenhouse gas emissions. The business case for supporting low-carbon practices is gathering pace, alongside the regulatory demands imposed through carbon emission compliance reporting. Despite this, guidance for generating carbon footprints through hybrid environmentally extended input-output analysis is under-developed and under-researched. Higher Education Institutions are key components of education systems across the globe, transcending international borders, socio-political regimes and economic systems. As an internationally significant sector beginning to address climate issues through carbon reduction policies on and off the estate, very few research articles have been published that document emissions arising from all directly and indirectly attributable activities. This study outlines a number of key elements to standardise the organisational carbon footprinting process by reconciling and evaluating the methodological steps in six selected internationally reputable guidelines (published by the Global Reporting Initiative, the Carbon Disclosure Project, the United Kingdom's Government Department for Environment, Food and Rural Affairs, the Greenhouse Gas Protocol, the International Standardisation Organisation and the Higher Education Funding Council for England). A systematic review is undertaken which relates the four principles of carbon footprinting (boundary-setting, identification of activities, collecting of data and reporting/verification) to the academic literature. Then, via consultation with university environment managers, a number of recommendations are made to address and improve i) the potential to avoid double-counting, ii) the financial and resource cost of carbon footprinting and iii) the reliability and comparability of data compiled by institutions. We introduce a methodology for a universal, standardised footprinting standard for higher education (that could also apply to all organisations regardless of sector or region) with cut-off criteria that excludes paid-for products and services typically included in the 'Scope 3' proportion of the footprint. In proposing this methodology, carbon footprinting is made more applicable to higher education institutions (since existing standards are designed for generality and for profit-driven organisations) and the practical issues, associated with externally owned data and non-expert staff, are broadly overcome.

1. Introduction

1.1. Organisational carbon footprinting

There is a global research agenda towards identifying sources and sinks of greenhouse gas (GHG) emissions across a breadth of scales. Many examples have emerged that aim to understand emission profiles; for products (i.e. Publically Available Specification (PAS) 2050/GHG protocol product life cycle standard), individuals, urban areas (e.g. PAS 2070) and entire nations (i.e. Intergovernmental Panel on Climate Change (IPCC) national GHG inventory), which differ by the sources of emissions encompassed in them. A product carbon footprint typically measures life-cycle emissions (from cradle-to-grave). An individual carbon footprint normally measures consumed goods and activity-related GHGs. National inventories generally measure emissions associated with the consumption of goods & energy and the imports & exports of

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goods and services at a country-wide scale (Gao et al., 2013).

Guidance for generating organisational carbon footprints is less developed than that for other forms (Pelletier et al., 2013). Nevertheless, the need for addressing this issue is pressing; organisations of all types are significant contributors to global GHG emissions. In 2013, direct emissions from the 500 largest companies in the world amounted to 3.6 Gigatonnes CO_2e (The Carbon Disclosure Project, 2014); 7% of total releases from anthropogenic sources (at 49 ± 4.5 $GtCO_2e$ (IPCC, 2014)). Differing standards of environmental regulation (as well as living standards and wage expectations), combined with pervasive rates of consumerism has caused a shift Eastwards of manufacturing industries now deemed too 'dirty' to exist in the West (Shapiro, 2012). Pollution at the price of convenience inhibits the global shift towards a low-carbon economy (Stearns, 2006).

In Europe, organisations have been governed by environmental legislation for some decades and some notable examples have changed the outlook of business to become more carbon-accountable (e.g. the European Union emissions trading scheme [EU ETS]). The United Kingdom's (UK) Climate Change Act 2008[1] was instrumental to the adoption of mandatory carbon reporting for all UK companies in 2013 and was the first dedicated piece of carbon-related legislation in the world. The combination of 'hard' approaches such as these, with 'soft' approaches (for example, through activities set out in corporate social responsibility (CSR) policies) encourages this shifting paradigm (Barth et al., 2013). As a consequence, organisations are increasingly measuring success on a triple bottom line (Norman and MacDonald, 2004).

Assigning and accounting for the entire range of emissions attributable to an organisation's activities is complex and difficult (Bastianoni et al., 2004; Department for Environment Food and Rural Affairs, 2009). Whilst Scope 1 (direct emissions from sources owned or controlled by the reporting organisation) and Scope 2 (from purchased electricity) are the simplest to assign and calculate, Scope 3 emissions (the remaining indirect emissions from purchased and sold goods and services) are seldom quantified in their entirety (Ranganathan et al., 2004; Huang et al., 2009). Guidance has often favoured the emission sources for which data is readily available. Despite a compelling case for quantifying Scope 3 emissions, up to 80% of a carbon footprint can be attributed to unreported indirect emissions (Ozawa-Meida et al., 2011). This issue is compounded by the complex nature of activities performed by organisations and the varying scales in which they operate (Williams et al., 2012a,b).

To mitigate the uncertainties and practical issues experienced by practitioners, environmental standards are developed. These interpret highly theoretical peer-reviewed literature into readily accessible technical notes (Auger, 1994). The number and variety of competing methodologies has the potential to introduce an unacceptable degree of discrepancy; organisations operating under one system are incomparable and may perform better than those favouring a different system (Kenny and Gray, 2009). Examples of this occur frequently and is not limited to organisational carbon footprinting; Dias and Arroja (2012) outline the differences in estimations for office paper between ISO14040, PAS 2050 and Confederation of European Paper Industries (CEPI) frameworks at 4.64 g, 4.74 g and 4.29 g CO_2e per A4 sheet respectively, whilst Turner et al. (2015) cite the methodological considerations made in calculating emission factors for waste materials as a predominant source of discrepancy.

Ensuring data are collected using analogous methodologies means that footprints are comparable (Rypdal and Winiwarter, 2001), reliable (Dragomir, 2012) (referring as much to the conclusions that can be drawn as the potency of the procedures in place to collect information) and robust (Kasah, 2013). Despite challenges, the business sector is beginning to capitalise on the low carbon economy emerging as carbon management tools and methods improve (Chakraborty and Roy, 2013) (in regards to their access/ubiquity, their value to consumers and their overall accuracy). The use of carbon footprinting tools has more importantly allowed organisations to: i) 'hotspot' areas of highly emitting activities (Minx et al., 2009); ii) streamline their supply chains (Sundarakani et al., 2010); and, iii) develop legitimate low-carbon products (Scipioni et al., 2012).

1.2. *The higher education sector*

Globally, the higher education (HE) sector exceeds 207 million people (United Nations Educational Scientific and Cultural Organization, 2014a) (around 34% of the global university-age demographic [United Nations Educational Scientific and Cultural Organization, 2014b]) and continues to undergo unprecedented change. There are estimated to be ca. 17,000 Higher Education Institutions (HEIs) worldwide, distributed among most nations, on every continent (except Antarctica) (Altbach et al., 2009). The number of students attending university since the year 2000 has grown exponentially; a trend likely to continue under most business-as-usual (BAU) scenarios, which estimate a rise to 262 million by 2025 (Goddard, 2011). Although in developed nations efforts have been made to enact moves towards low-carbon HE systems (Roy et al., 2008), the divide between less economically developed countries (LEDCs) and more economically developed countries (MEDCs) remains considerable (Drori et al., 2014).

In the United Kingdom (UK), the HE sector is extremely significant in terms of population, economic contribution and societal influence and therefore represents an important sector for long-term carbon management. With more than 318,000 staff and 1.7 million students in 160 institutions, the total economic value per annum equals £39.9 billion (Universities UK, 2015). As a result, HE is one of *the* largest occupiers of building space, occupying 27 million m^2 and is responsible for some 10,600 ha of land (HESA, 2014). It is well documented that HEIs are influential players in both local and national policymaking, both informing society through research and educating graduates (Etzkowitz, 1998). In addition, they are also successful incubators for innovation, from which many sustainability initiatives have originated (i.e. Blackout (University of Southampton (2012)), Student Switch off (Jones, 2012)).

It is widely recognised by university vice chancellors that prioritising carbon reductions not only yields environmental benefits but also promotes financial savings and increases competition (Epstein and Roy, 2003; Dangelico and Pujari, 2010). Sustainability reporting has been proven to help deliver these benefits (Lozano and Huisingh, 2011) as well as assist university leaders in directing on-campus operations and sustainability projects (Townsend and Barrett, 2015). The benefits manifest in substantial utility cost reductions (due to their size and scale) and an improved international reputation (Barber et al., 2013). Universities are now also finding that by incorporating sustainability education into the curriculum, they can add value to the quality of education students receive, as well as fostering cultural change within the organisation (Lozano, 2006; Savageau, 2013). This is important because the future challenge lies in reducing campus emissions whilst simultaneously expanding student numbers, extending their range of activities and remaining commercially competitive (Cronin et al.,

[1] The UK Climate Change Act 2008 legislated the UK towards an ambitious 80% reduction in direct (Scope 1 and 2) emissions below a 1990 baseline by 2050.

[2] Operational data is defined by the author as data that is directly transposable into the organisation's carbon footprint without much required processing.

2010). The recruitment rate of students has increased dramatically in the last 25 years, despite a turbulent period of UK government policy (i.e. the opening up of HE places preceding 1990, the expansion of the number of institutions in 1993, the introduction of tuition fees in 1998 and subsequent rise in 2004) and more institutions are understanding that students want to engage on such issues. The removal of the tuition fee cap in 2010 at the recommendation of Lord Browne did little to dent this trend (Wyness, 2010). The year 2015 saw a record number of students recruited at 532,000, a 3.1% increase on the previous year (Universities and Colleges Admissions Service, 2015).

1.3. A universal carbon footprint methodology for higher education

The Higher Education Funding Council for England (HEFCE) published a number of guides in 2012 with the aim of assisting institutions to report and reduce emissions. These focussed primarily on direct emissions (institutions have mandatory targets to reduce their Scope 1 and 2 emissions by 34% below a 2005/06 baseline by 2020) or on a limited number of Scope 3 sources (i.e. water and waste (HEFCE, 2010), transport (HEFCE, 2012b) and procurement [Arup et al., 2012]). Although no specific international standard for HE carbon footprinting exists, it is common for practitioners to adapt methodologies from those designed predominantly for profit-making enterprises. This is often conducted with limited success alongside the unrestricted use of assumptions and caveats to complicate their interpretation (Almeida et al., 2014). The hybridisation of input-output analysis and life cycle assessment theories (EEIOA-LCA) (Peters, 2010) are favoured here because they generate assessments in greater detail, absent of aggregation errors (Berners-Lee et al., 2011; Ozawa-Meida et al., 2011). Baboulet and Lenzen (2010) used input-output analysis (IOA) informed with readily-available financial expenditure information of an Australian university as a means of assessing supply chain emissions of universities without any addition informational inputs. These can measure *total* environmental impacts of institution's activities (Mattila et al., 2010), whilst broadly hot-spotting areas for improvement along the supply chain.

There is a notable absence of empirically supported full-scale EEIOA-LCA institutional footprints in the literature. Growing pressure to reduce emissions means that institutions are in danger of falling behind on pledged targets for direct emissions (Robinson et al., 2015), which subsequently lessens the probability of successfully managing and reducing Scope 3 emissions. The priorities currently favoured by universities in terms of promoting growth and economic fortune can conflict with the importance they assign to carbon management (Lozano, 2013); estate growth disproportionately magnifies scope 3 emissions occurring upstream and downstream of the organisational boundary (Sharp, 2009).

Universities serve a number of functions, influencing the activities they undertake and the GHG emission releases for which they are responsible. Specifically, the four major functions which universities serve (and from which, all other activities emanate) are in education, research, governance (Stephens et al., 2008; Sedlacek, 2013) and enterprise (Rae, 2010). Teaching perhaps influences the greatest number of activities and as a result, HEIs need not only be providers of physical learning facilities (such as lecture theatres, libraries, ICT equipment etc.), but a whole host of other amenities in order for students to thrive (such as health and wellbeing services; sports and social services; retail, food and drink outlets). For this reason, a comparison with small towns is often made (Zhang et al., 2011). The concentration of these amenities is highly disparate, with some universities based on a single location (a campus), multiple sites or scattered around cities. A rise in internet access means that traditional universities are moving activities online through distance-learning courses (Roy et al., 2008) and Massive Open Online Courses (MOOCs) (Barber et al., 2013) (examples include the Open University, Coursera and Kahn Academy).

Diverse infrastructure plays a key role in the delivery of degree programmes, which adds to the complexity of HEI carbon footprinting. Also, the nature of research programmes has also been seen to have a direct correlation with the energy-intensity of activities, often being cited as one of the primary reasons for contention when research-intensive institutions are compared to teaching-intensive institutions (Klein-Banai and Theis, 2013) and *vice versa*. The varying specialisms of universities, their demographic composition and financial leverage are additional contributors to this incongruence.

The reason for examining university carbon management in particular is to continue the debate of the role of HE on sustainability over the 21st century, whilst allowing institutions to position themselves favourably in tackling the future challenges associated with a changing climate (Barber et al., 2013). Universities play an influential role in providing technical solutions to climate-related issues (Sedlacek, 2013). Moreover, they are a pertinent case study organisation for assessing the relevance and applicability of carbon management standards. Their central role in education systems in all societies of the world transcend political regimes and economic systems (Meyer and Schofer, 2007). This presents a form of organisation that can be studied *anywhere* and understood *everywhere*.

This paper aims to make four key contributions to the literature: first, through highlighting the considerable disparities between carbon management standards designed for organisations; second, by identifying the key requirements for practitioners tasked with interpreting these standards; third, by proposing a universal methodology for universities as a surrogate for a generalised global organisational methodology and, fourth, by adapting and overcoming ubiquitous problems associated with data collection. This research focusses on UK HEIs but can be used as a barometer for present issues in campus sustainability departments in institutions across the world. A qualitative comparative analysis (QCA) (Gao et al., 2013) is conducted using a selection of frequently used organisational carbon footprinting standards, in-turn evaluated for their relation to the published literature through a systematic review. By combining these results with the results of a practitioner consultation, a framework for conducting organisational carbon footprints for universities is proposed. By accounting for the requirements of university environmental practitioners themselves, a series of recommendations are made which are sympathetic to the role that universities play and the activities they conduct.

2. Materials and methods

2.1. Systematic review: inclusion criteria

A systematic review was carried out to identify the theoretical underpinning of key ideas. Research papers were selected following a pre-determined set of criteria which amounted to (i) being written in English; (ii) featuring state-of-the-art knowledge, i.e. published on or after 1st January 2010 and not superseded by additional research; and (iii) being specific to the carbon footprint of organisations *and/or* HEIs. Often, elements of organisational carbon footprinting are research streams in their own right and are only applied to organisations retrospectively. In these instances, inclusion of papers was based on the importance of all search terms being present.

Search criteria were based on selecting papers that exhibited the terms 'organis(z)ation', 'carbon', 'footprint', and a selected additional 'search term'. Here, the 'search term' refers to any one of the 55 phrases outlined in Table A.1 that describes procedural elements categorised by individual actions. The development of these used a methodology founded in Grounded Theory (GT); the individual constituent elements of pre-existing carbon management standards were coded and categorised into these phrases (Corbin and Strauss, 1998). This highlights the interconnectedness of the systematic review with latter sections of this paper, in particular the review of grey literature outlined in the proceeding Section (2.2). Papers included in this research study were full research articles; therefore, conference proceedings, reviews, and editorials were discarded.

2.2. Review of grey literature

To analyse the uniformity of existing standard guidelines, five of the most widely-used methodologies were chosen using the results from the annual Carbon Disclosure Project (CDP) survey on carbon strategies as outlined in Matisoff et al. (2013). These findings show the respective proportion of reporting organisations using carbon footprinting standards (See Table 1) and include: The GHG Protocol corporate accounting and reporting standard (2004) & corporate value chain (Scope 3) accounting and reporting standard; the DEFRA guidance on how to measure and report on corporate GHG emissions (2009); the ISO 14064-1 quantification and reporting of GHG emissions for organisations (2013) and the GRI G4 sustainability reporting guidelines (2013). The CDP guidance for companies reporting on climate Intergovernmental Panel on Climate Change (2014) was included due to the CDP's global significance in organisational carbon reporting; the HEFCE guides to good carbon management practice (2012) were also selected as a matter of course. A description of the authorities accountable to these standard guidelines is outlined in Table 2.

These methodologies were selected on the basis that they all have origins in the GHG protocol methodology developed by the WRI and WBCSD in 2004. This is regarded as the *de facto* standard for carbon accounting for organisations (Ascui and Lovell, 2012). Each has been somewhat successful in fostering action on emission reporting for corporate profit-driven organisations in its own right. For instance, the CDP is now the world's largest repository solely for carbon reporting, annually collating information for 1500 companies which contribute 26% of global anthropogenic emissions (Dragomir, 2012).

2.3. Consultation: UK university environmental practitioners

A workshop was undertaken at the 19th annual Environmental Association of Universities and Colleges (EAUC) conference at the University of Leeds in March 2015. A focus group was deemed the most direct method for collecting information about practitioner experiences of carbon management. Time pressures and venue limitations were among the push factors in preferring this method, whilst relative simplicity and the potential for shared-learning (Krueger, 1998) were significant pull factors.

The aim of the session was to understand the apparent gulf between the theoretical application of carbon standards and the real-world issues faced by staff at universities; participants were self-selected (as conference delegates). For many UK institutions, issues arise as a result of attempting to complete the annual estates management statistics (EMS) returns to the higher education statistics agency (HESA). Further investigation of these issues allowed for the identification of key requirements for a universal carbon footprinting standard for HEIs (known as user-sensitive inclusive design [Newell and Gregor, 2000]). A 40-min focus group discussion aimed at highlighting a series of broad-scale issues was followed by the administering of an individual questionnaire, designed with a series of Likert and semantic differential scale questions for classifying attitudinal attributes. The aim of both questioning methods was to answer four research questions:

Q1 Which emission sources are the best understood in HEIs?
Q2 Have difficulties been experienced to calculate data needed for the carbon footprint and if so, what can be improved?
Q3 Do you think sector targets should be introduced which push institutions to calculate and subsequently reduce Scope 3 emissions?
Q4 Would a universal standard methodology lead the sector closer in reaching carbon management goals?

Table 1
Implementation of standards by firms tested by the Carbon Disclosure Project (adapted from Matisoff et al., 2013).

Year	WBCSD/WRI[a]	DEFRA[b]	ISO[c]	GRI[d]	EU ETS[e]	IPIECA[f]	EPA[g]	CCAR[h]
	Percentage implementation by UK organisations (%)							
2007	41.1	10.7	1.3	1.6	3.6	1.3	0.0	0.0
2008	47.7	12.8	4.2	3.0	3.6	1.6	0.0	0.4
2009	54.7	20.0	10.0	6.9	5.9	2.4	0.2	1.2
2010	66.8	23.7	8.3	5.7	5.1	1.9	0.8	0.4

[a] WBSCD/WRI – World Business Council for Sustainable Development/World Resources Institute.
[b] DEFRA – Department for Environment, Food and Rural Affairs.
[c] ISO – International Standardisation Organisation.
[d] GRI – Global Reporting Initiative.
[e] EU ETS – European Union Emissions Trading Scheme.
[f] IPIECA – International Petroleum Industry Environmental Conservation Association.
[g] EPA – Environmental Protection Agency.
[h] CCAR – Californian Climate Action Registry.

2.4. Limitations

The limitations of this work must be noted. Although we have selected six of the most popular carbon management standards available in the grey literature for comparison and standardisation, the choices which practitioners have are not limited just to these. Certainly, the inclusion of standards here is by no means intended as a way for the authors to positively 'rate' their effectiveness at calculating and reporting GHG emissions. A fraction of the literature is excluded from comparisons because the focus is on meso-scale models (hybrid IOA-LCA). These models are somewhat more reliant on data inputs than say, macro-scale models, but offer the practitioner greater insight into process-level emissions.

Here we focus on engaging environmental practitioners at UK-based institutions. It could be argued that their broad role on many aspects of campus sustainability does not allow for building an in-depth knowledge on the academic underpinning of carbon management. Despite this, we deem these personnel to be a vital resource and the experts on their own institution's reporting structures. Consultation results suffer little from induced or preconceived response bias because of the variety of opinions received by respondents. The limited geographical spread of institutions can be extended, however the origins of the modern HEIs (based predominantly on the models set by the earlier institutions such as Cambridge, Oxford and the London Colleges) would suggest significant commonalities exist globally (Collini, 2012).

3. Findings

3.1. Appraisal of standards

The combined results of the systematic review and comparative analysis are found in the supplementary material. In total, 57 publications were interrogated, highlighting the considerable academic interest in organisational carbon footprinting methods since

Table 2
Descriptions of the authorities included in this study, which governs the use of carbon management standards for organisational carbon footprint assessments.

Authority	Description
World Resources Institute World Business Council for Sustainable Development	The WRI is a research organisation that seeks to promote the sustainable use of natural resources. The WBCSD is a CEO-led organisation of forward thinking companies that galvanises the business community to create a sustainable future for business, society and environment.
Department of Environment, Food and Rural Affairs	DEFRA is a government department responsible for environmental protection, food products and standards, agriculture, fisheries and rural communities in the UK.
International Standardisation Organisation	The ISO is an international standard-setting body composed of representatives from various national standards organisations.
Global Reporting Initiative	Non-profit, promotes sustainability reporting as a way for organisations to contribute to sustainable development.
Carbon Disclosure Project	The CDP is an organisation that works with shareholders and corporations to disclose the GHGs of major corporations, amounting to some 3000 organisations.
Higher Education Funding Council for England	The HEFCE is a non-departmental public body of the Department for Business, Energy and Industrial Strategy (BEIS) that distributes public money to HE providers in England. It is mandate to ensure funding is used to deliver maximum public benefit.

2010. Organised by the four main principles of carbon footprinting identified in the peer-reviewed literature (boundary-setting, identification of activities, collecting of data and reporting/verification), these are further categorised into 32 variables and are in-turn disaggregated into 180 'constituents'. The grey-scale coding represents the degree of coverage exhibited by each constituent across all standards, ranging from 22% for the CDP standard to 60% for the ISO standard (see Table 3).

3.2. *Results of the consultation*

The questionnaire yielded 35 respondents from 31 individual institutions, representing a response rate by attendees of 66.04% (n = 53); an example can be found in Appendix A. Nevertheless, the sample is deemed sufficiently representative because 19% of the HEIs in the UK were represented (corresponding to a combined student population of 323,000). Questioning provided supporting information for the four original research questions:

Q1 Which emission sources are best understood?

The emissions categories reportedly calculated by each respondent can be seen in Fig. 1. Respondents were able to rate each emission source (as outlined in the ISO14064 standard) to reflect their institution's ability to fully quantify them with reliable data. This was based on four options: 'reliable data, calculated fully', 'improved reliability but incomplete', 'basic understanding, some data collected but unreliable' and 'not currently calculated'. In the figure, data are arranged in descending order by emission sources rated as 'not currently calculated' by the respondent. Stationary combustion, mobile combustion, imported electricity, imported energy and waste were the most commonly calculated fully with the most reliable data (supported by more than half of respondents). Of these, stationary combustion and imported electricity (Scope 1 and Scope 2 emission sources) were found to be the best understood with the highest number (77%, n = 27) of responses.

Unsurprisingly, the majority of Scope 3 emission sources were not quantified with any certainty. For many, these sources have yet to be tackled and for reliable data to be obtained. For 91.4% (n = 32) of the respondents, both in-use stage of sold products and downstream leased assets were the least understood. In fact, responses for 10 of the Scope 3 categories reflected the inability of practitioners to quantify the impact of activities ranging from in-use emissions (from sold products) to upstream/downstream leased assets by more than 50% of respondents. This was only typical for two Scope 2 sources and for zero Scope 1 sources. The Scope 3 sources found to have been quantified with more reliability were: generated waste, business travel and employee commuting. These received the fewest 'not currently calculated' responses.

Q2 Have difficulties been experienced and if so, what can be improved?

Fig. 2 shows the results of a semantic differential question posed about attitudes towards the carbon footprint of the respondent's institution. The mean respondent's score is shown for each of the bipolar adjective pairs: adequate-inadequate; chaotic-ordered; open-secretive; complex-simple; old-fashioned-modern; ineffective-effective, and innovative-non-innovative. From this analysis, respondents exhibited a somewhat optimistic view of their institution's carbon footprint with a slight skew towards 'ordered' and 'effective'. The strongest attitude overall was identified in the open-closed pairing which fell significantly in favour of 'closed'. Although fewer negative connotations were identified, respondents also favoured 'inadequate' over the more positive alternative.

Respondents were asked to rate the factors that most influenced the quality of their institution's carbon footprint (see Fig. 3). Data reliability, staff resources, and time constraints had the highest rate of high impact responses, with the former two receiving 16 responses apiece. Whilst a mixed spread of responses was recorded, four of the eight factors recorded a response for 'no impact'; namely budget constraints, staff training requirements, top management support and technical support (albeit from between one and three respondents only). Budget constraints and staff training requirements were less influential and received most responses in the 'medium impact' categories.

A number of specific issues were identified about data collection and reporting. Respondents expressed the view that they were often left to 'fend for themselves' when identifying the correct type

Table 3
Coverage of constituents from the six standard methodologies tested.

	GHG Protocol (2004) Scope 3 (2011)	DEFRA Guide on Measuring and Reporting GHG Emissions (2009)	ISO14064 Standard (2006)	Global Reporting Initiative Sustainable Reporting Guidelines (2013)	The Carbon Disclosure Project (2014)	HEFCE Guidelines (2012)
No. of constituents	98	47	107	45	39	51
Total constituents	180					
Coverage percentage (%)	54.44	26.11	59.44	25.00	21.67	28.33

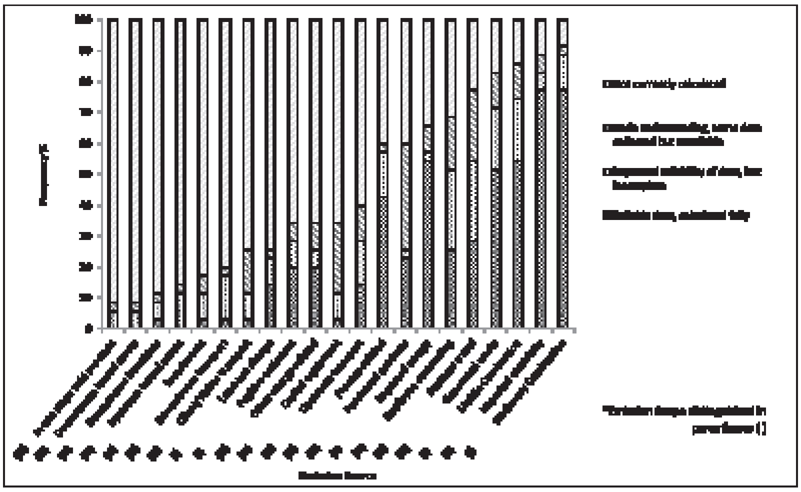

Fig. 1. The frequency of emissions sources calculated at the institutions represented by respondents. Emission source categories available for selection were based upon those in the ISO14064-1 standard.

of data sources. By following the guidance set by industrial bodies, respondents found the detail for data collection lacking. Where it was sufficient, this was limited to emissions sources where reliable data was already obtained, making the guidance somewhat irrelevant in places and directly attributable to their omission in returns to HESA.

Often, practical limitations caused data reliability issues. Access to data was restricted because of the complicated and external nature of some calculations. For instance, some institutions attempted to collect environmental information regarding purchased products directly from suppliers (citing the methodology which utilised financial "spend" data to be insufficient) but struggled to identify them or receive the information:

"… Getting data from suppliers is the most difficult for us …"

"Scope 3 calculation for procurement is very difficult to calculate as we purchase from tier 1, 2 and 3 suppliers. We don't always know where products are manufactured."

Doubt was expressed about the ability to quantify emission sources accurately. Individuals sometimes have to physically measure and/or obtain data from other employees across the estate and supply this to environment managers who are typically the focal the point for data and responsible for compiling reports. Respondents felt they had to scrutinise information from these sources particularly closely, citing the absence of a vested interest in ensuring the data supplied was authoritative and consistent.

"… The sources of information need to be managed better."

Often miscommunication between these employees was

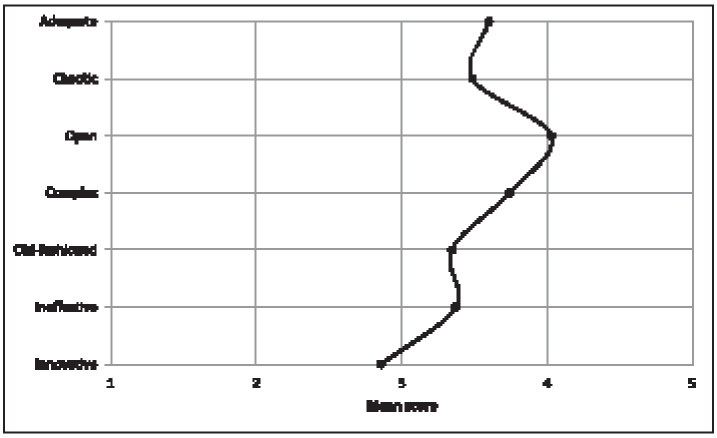

Fig. 2. Results of the semantic differential questions; respondents were asked to rate where their attitude placed along a continuum of adjective pairs.

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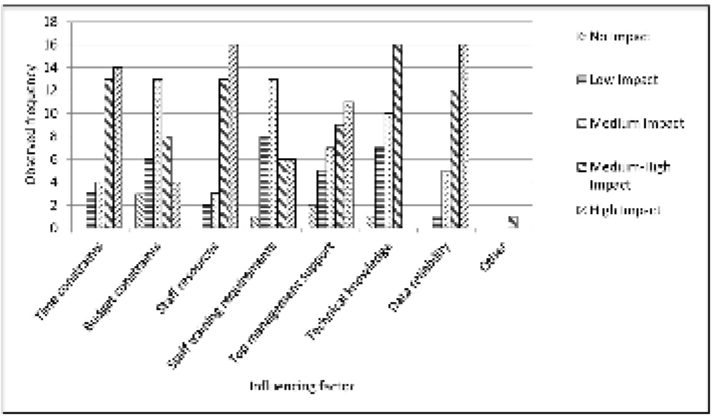

Fig. 3. Impact rating of factors influencing the full-scale calculation of the carbon footprint at the institutions represented by respondents.

experienced due to the number of people involved. In addition, respondents found that besides the lack of reliability in data discouraging the ability of HEIs to compare between peers, gaps in data exacerbated this problem:

> *"Simplify data collection to minimise gaps so that everyone has comparable data."*

As a result, practitioners exhibited desire for a simplified process, in which obtaining a full data set was more likely. The practical-focus of responses meant that no respondents provided contrary answers regarding *extending* the current scope of mandatory reporting metrics.

Q3 Do you think sector Scope 3 reduction targets should be introduced?

It was clear that the level of preparedness required for pragmatic reduction targets was not yet in place. Respondents saw the current lack of Scope 3 emissions reporting to be a barrier to implementing targets in the short-term. Without good baseline years to inform targets, the strength of future reduction efforts was perceived to weaken. Time would be needed for institutions to produce reliable datasets, whilst further consultation and research would result in a more carefully designed set of objectives supportive of the needs of all institutions.

> *"If targets are based on years of high-volume construction or 'acts of god' then targets become irrelevant and lose the support of institutions."*

Respondents were concerned with the probability of being portrayed unfairly as a result of differential reporting. The heterogeneity of the data reported by institutions was deemed significant enough to deter them from wanting performance-based targets associated with Scope 3 emissions. Whilst an institution might have taken responsibility for, and reported all indirect emission sources, respondents foresaw the potential for their institution to receive negative publicity. This forms a paradox when comparing institutions with those reporting lower emissions (as a result of understanding fewer emission sources across the estate); on the surface, the latter institution 'performs' better in the eyes of the media, funders and peers. As a result, these actions were predicted to lead to potential reputational damage:

> *"Institutions would only report on Scope 3 emissions if everyone else was doing it!"*

Respondents also suggested that a lack of control over emission sources was a factor in not supporting Scope 3 targets. Ultimately, if such targets were necessary, then being disaggregated by activity type was favoured. An all-encompassing target was criticised because it would be impractical for the majority of institutions; even the most experienced institutions would struggle to manage the full breadth of activities in the short term. Indirect targets, based on behavioural change, were deemed highly favourable to influence emission reduction. Institutions already manage their waste, have a travel plan and a procurement policy, and so focussing on areas where they currently direct efforts through sustainability measures were regarded as more sensible.

> *"In reality, if this was to be introduced, it would have to be a target broken down for each of the emission sources in order to be meaningful and attainable."*

Despite a general feeling against the introduction of Scope 3 targets, it was clear that all respondents shared a desire to manage emissions arising from indirect activities. In addition, all respondents supported the notion that the reporting of these sources should be mandatory and coupled with a published management plan:

> *"Reporting and having a plan to manage Scope 3 should be mandatory, but not carbon targets!"*

> *"It is important that reporting is mandatory."*

This is somewhat contradictory of answers gleaned from Q2 and evidently, a fine balance between oversimplifying the GHG assessment process and dismissing ethical and altruistic responsibilities and the abilities of overstretched environmental practitioners was highlighted.

Q4 Would a universal methodology improve the *status quo*?

Practitioners reported a desire to prioritise carbon management as it was *"seen as the right thing to do for responsible organisations"*. The respondents demonstrated a general positive reaction to the idea for a universal methodology, believing that this would lead to an increased number of institutions fully reporting emissions for the full breadth of activities. Forty percent (n = 14) agreed that a universal, comprehensive standard would be beneficial to their home institution. Thirty-one percent (n = 11) strongly agreed that the number of institutions undertaking full-scale carbon footprints would increase, as there was a perception that if all institutions followed the same method, better comparability would instil the confidence to report emissions.

A number of points were outlined that advocated a universal methodology for reducing the influence of a number of perceived issues. For instance, many practitioners found that prescriptive and standardised guidance could reduce the loss of knowledge that can occur when individual staff members depart the institution:

> *"A universal standard for HEIs would go a long way to solving issues around members of staff leaving and taking certain methodologies that have taken years to produce with them …"*

For institutions with very small environment and sustainability teams, this was found to be an even more significant consideration. However, the key to switching current approaches and adopting any of the proposals outlined was university leaders seeing the financial benefits, suggesting that the decision was not theirs to take:

> *"The number of institutions using a universal carbon footprint would depend on the financial situation of the HEI."*

When asked about the likelihood of their institution using a universal methodology, a skew towards 'very likely' was evident (34% (n = 12) of respondents made that selection). In addition, there were calls for this methodology to be used in urging the HEFCE to change its stance on carbon management in favour of something designed *'by the sector, for the sector'*.

4. Discussion

4.1. The organisational carbon footprinting process

Organisational carbon footprinting is typically a four-step process (Gao et al., 2013), characterised by: (i) setting the organisational boundary (identifying the facilities that should be accounted for); (ii) establishing the operational boundary (the activities for which the organisation deems itself to be responsible for); (iii) quantifying the carbon footprint (through collection of appropriate activity data); and, (iv) reporting and verifying the result (Dragomir, 2012; Gao et al., 2013; Pelletier et al., 2013). The methodologies involve the practitioner identifying the activities they are responsible for in separate emission Scope categories upstream and downstream of their organisation's operations. This is based upon a hybridisation of methods used in [*environmentally-extended*] input-output analysis and life cycle assessment (EEIOA-LCA) (Peters, 2010); two well-established fields of carbon assessment at opposite scales.

A number of key pieces of literature identified in the systematic review have highlighted recent augmentations to the organisational carbon footprinting process. For example, Pelletier et al. (2013) attempted to develop a new methodology for the European Commission (EC) based on a number of criteria, aiming for a new method which was: inclusive of the lifecycle emissions across the supply chain; reproducible; comparable (as opposed to flexible); and physically realistic. Others, have vocalised the need for Scope 3 methodologies (Stubbs and Downie, 2011) and established preliminary research that can be taken forward in making this a reality. A few examples of full-scale Scope 3 carbon footprints have arisen, but these changes have not yet proved radical enough to increase the number of organisations reporting Scope 1, 2 & 3 carbon footprints; our search criteria identified only three examples (see: Larsen and Hertwich, 2009; Letete and Marquard, 2011; Ozawa-Meida et al., 2011). Often, the choices that make such methodologies applicable to a wide audience are removed in the hope of maintaining simplicity (Pandey et al., 2011). However in the process, truncation errors are introduced and the Scope is narrowed without sufficient explanation.

Some would argue that little progress has been made since the publication of the first GHG protocol in 2001, which had been hailed as a major breakthrough in environmental advocacy and widely adopted and accepted since (Green, 2010). There has been little in the way of developing this methodology to account for the changing need of carbon reporting in the intervening 15 years; a time of rapid adoption of environmental legislation (Tews et al., 2003; Jordan et al., 2013). As a consequence, the scope for change is equally and simultaneously significant in its potential, but encumbered by well-established methodologies.

By clearly delineating the steps required in conducting an organisational carbon footprint, the process can be understood in its entirety and evaluated for its functionality. The commonalities identified as a result of our analysis means that we can build upon this relationship to propose Fig. 4 as a more complete description of the organisational carbon footprinting process. These four steps are supported by the themes 'scoping', 'conceptualising' and 'communicating', which help to distinguish the individual actions required of the environmental practitioner. 'Scoping' incorporates two steps: the setting of the organisational boundary and the identification of the organisation's activities (conducted using a control approach or equity share approach). 'Conceptualising' refers to the collection of activity data (itself categorised into operational[2] and non-operational[3] data) and the application of the carbon equation. 'Communicating' describes the reporting of carbon information to key stakeholders in an understandable format, which is externally verified, to ensure reliability and maintain rigour. Additionally, an initial theoretical reconciliation is made to the constituents by accepting those with coverage greater than 66.6% (as can be seen in the column in the Supplementary Material marked 'Reconciled'); this captures 24 of the 180 constituents (13.3%) i.e. 'setting an emission baseline' and 'defining the organisational boundary'.

Combining these initial changes with the results of our analysis, a number of interrelated issues are identified. These are listed below alongside simple corresponding improvement solutions:

- i a There is no guidance on clearly deciding whether activities are to be included or excluded, leading ultimately to a high level of double counting. When EEIOA-LCA footprints are reported, double counting is unavoidable since these activities overlap with many other organisations;
- i b Potential solution: The implementation of simple cut-off criteria would allow the user to make a definitive in-out decision of activities along the supply chain.

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- ii a There are deficiencies in time, cost and staff resources in organisations, which means that the process cannot be

[3] Non-operational data is defined by the author as data that requires manipulation in order to obtain an emissions profile.

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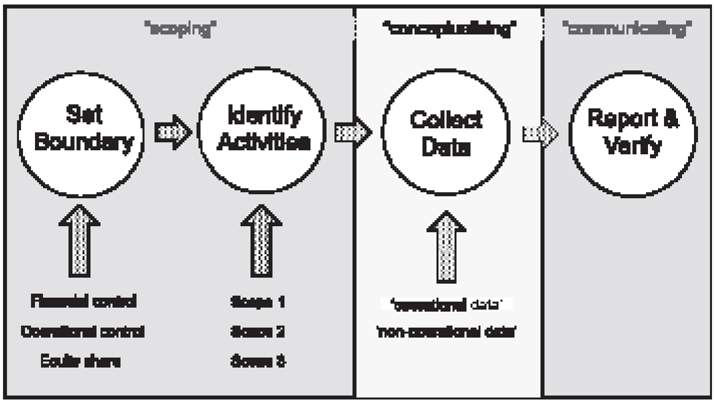

Fig. 4. The relationship between the seven principles of organisation carbon footprinting.

conducted to the 'end' (defined by the standards or the reporting organisation);

ii b Potential solution: Minimise the number of actions required by environmental practitioners.

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iii a The description of data collection methods is not clear nor prescriptive, making reliable or useful inferences from data impossible;

iii b Potential solution: Introduce guidance outlining methods for the robust activity data collection, which is appropriate for the resolution and aim of the footprint.

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iv a The GHGs included are inconsistent, potentially leading to false reporting and high margins of error.

iv b Potential solution: Standardise the GHGs included in the footprint.

A second column is added to the Supplementary Material labelled 'Robinson et al. proposed'. This incorporates reconciled constituents with additional ones that are deemed imperative to the functioning of the methodology (n = 77). Sixteen constituents are made 'dependent', where their inclusion is subject to certain considerations, and dismissing them outright would be inappropriate. For example, constituents referring to the manufacture or use of products for sale or the operations of franchises may not be applicable to all universities but the scope for their inclusion cannot be disputed, when considering that the activities of universities are highly variable.

A number of constituents have been omitted, following decisions to ensure parity with the suggested improvements (supported by the systematic review); three instances can be highlighted. Previously, practitioners had been given the option to choose which approach they took to setting the organisational boundary. Now, only the entities through which the organisation can enact meaningful carbon reduction measures are considered (through the allocation approach based on financial or operational control) (Pelletier et al., 2013). Secondly, through the use of data scenarios, an illustration of the best, minimum and intermediate quality data is provided (British Standards Institute, 2013). Ensuring all footprints conform to an acceptable degree of accuracy has become a central idea, controlled much more closely through the verification process. Finally, the GHGs included are aligned with those outlined in Wright et al. (2011), who formed a definition inclusive of only two GHGs (CO_2 and CH_4) based on their contribution to global anthropogenic emissions. This standardisation is important owing to the variability found in all standards and the literature; with authors favouring solely the accounting of CO_2 (such as Recker et al., 2011; Chakraborty and Roy, 2013; Rietbergen et al., 2015), or the seven Kyoto basket GHGs (referred to as a 'climate footprint') (Dragomir, 2012; Williams et al., 2012a,b; Matisoff et al., 2013).

4.2. *Cut-off criteria*

The difficulty in assigning responsibility for emissions has been well documented and still remains a highly divisive topic in the literature (Bastianoni et al., 2004; Stubbs and Downie, 2011). For internal use, carbon footprints that detail the emissions arising from all activities under the influence of the reporting organisation are a highly useful decision-making tool (Lenzen, 2008) that allow organisations to exert a greater degree of control over their activities which impact on the environment (Dragomir, 2012). Upon aggregation of multiple organisations comprising a sector, the resulting figure is artificially inflated and the accuracy undermined (Dragomir, 2012), therefore proving to be less effective for carbon management on a sector-wide scale (Andrew and Cortese, 2011). Cut-off criteria establish a set of rules that assist the environmental practitioner in deciding which activities should be included and which should be excluded in their footprint (after organisational and operational boundaries are set (Dias and Arroja, 2012)). Thus, they offer a potential way of improving the accuracy and usability of reported figures and assist in addressing [i a] and [ii a] in the list of issues outlined above.

Simple criteria comprise: i) the exclusion of paid-for Scope 3 products and services (as these are the Scope 1 or 2 emissions of another organisation); ii) the exclusion of activities with any potential to be counted elsewhere and iii) include the business-critical and geographically significant activities (i.e. Scope 1 and 2).[4] The potential for double counting is eradicated because only emission-releases

[4] These are included as default, due to a robust assigning methodology being already widely accepted by the academic community.

arising from production-related[5] activities would be reported by organisations and aggregated by sector. Activities along the supply chain are assigned to the producer, meaning that time and financial savings can also be realised for the reporting organisation. The consequences of introducing cut-offs can be seen in the final column in the Supplementary Material; the number of constituents now equals 90. Yet, fully removing the ability for organisations to understand climate impacts at this scale would be counter-productive due to their usefulness in aiding policymaking decisions. Therefore, we propose that two figures should be produced by organisations: i) a 'catch-all' figure that is used for internal strategic carbon management planning; and ii) a 'minimum standard' that details emissions through the employment of the cut-off criteria.

Certainly, the use of cut-offs isn't without controversy and have been dismissed in the past for their tendency of being arbitrary and for producing inconsistencies (Huang et al., 2009; Pelletier et al., 2013). Whilst this isn't the only proposed solution to double-counting of aggregated organisation emissions (shared responsibility, has been shown to be an effective compromise [Gallego and Lenzen, 2005 & Lenzen et al., 2007]), our proposal for three well-defined instructions addresses assumptions and streamlines the process from beginning to end. This is advantageous because often, the greater the time spent collecting and preparing information for organisational carbon footprints, the costlier the process becomes (whilst improvements to accuracy are negligible) and the less accessible it is (Plambeck, 2012). Eventually, a threshold is reached beyond which the cost to the organisation exceeds the exploitable benefits ('the law of diminishing returns' [Shephard and Färe, 1974]). Therefore this methodology, which prioritises directly influenced and production-based emissions, removes barriers to carbon footprinting by ensuring organisations remain far removed from any threshold.

With the number of environmental carbon standards growing, the introduction of a new methodology could 'muddy the water' of an already complex field. Despite this and the disadvantages noted by some on the use of cut-offs, there is a global market for process standardisation which supports a move towards a universal approach presented here. This is demonstrated by the existence of organisations such as ISO (which in-turn is comprised of representatives from 162 national standard-setting bodies), ASTM International and the International Electrotechnical Commission, whom combined, are responsible for setting more than 50,000 standards worldwide. It is important that standards are fit-for-purpose and therefore, challenging and promoting the adoption of new approaches, designed and chosen by users themselves is wholly advantageous.

Beyond the more immediate regulatory measures which organisations are governed by, having a clear understanding of environmental impacts allows for better contingency plan and improved recognition of emerging risks (of operations and financial investments) (Hoornweg et al., 2011). This allows organisations to be better placed in contributing to society's climate adaptation in the coming decades (Hulme, 2003; Linnenluecke and Griffiths, 2010), whilst facing up to the increasing significance placed on business resilience through good carbon management (Williams et al., 2012a,b). The appetite for honest environmental claims has never been greater, coupled with a growing popularity of conscious consumerism (Sullivan and Gouldson, 2012). Organisations fail to engage on this agenda at their peril, as failing to do so would mean missing out on a vast swathe of potential customers and revenues.

[5] Production-based emissions are allocated to the organisation that generated them, whilst consumption-based emissions are allocated to the organisation whose consumption caused the emission (Hoornweg et al., 2011).

4.3. *University carbon footprints: practical realities*

Evidently, a 'one-size-fits-all' approach is common across all of the environmental standards interrogated. However, it remains to be seen how suitable this approach is in promoting pragmatic carbon management in the real world. Arguably, the lack of GHG reporting of Scope 3 activities by organisations is indicative of deficiencies in the methodology. For universities in particular, funding pressures and time constraints are the reasons most cited for avoiding or underperforming on carbon management, which is exacerbated by the changing influence of policymakers. Currently, the sector is facing a lack of direction on carbon-related policies, especially in regards to the management of Scope 3 emissions. The issues arising from this are only just starting to be realised. For instance, there are early indications that predict a collective failure on targets enacted in 2010 to reduce Scope 1 and 2 emissions by 2020 (where 2015 represented the halfway point) (Robinson et al., 2015). The lack of cohesion and clear direction is having tangible and potentially damaging consequences, whilst the bodies that control both the direction and pace of progress, have seen their influence wax and wane through concurrent UK government shake-ups over the last decade (Universities UK, 2015).

A streamlined and prescriptive methodology, based on empirical evidence, emerging out of a sector-wide collaboration is a logical first step in addressing these issues. Whilst it cannot be said that scientific expertise is lacking or governments have been inactive in this field (in fact, DEFRA itself commissioned an input-output assessment of UK emissions (Wiedmann et al., 2009); data which organisations can use to support IOA-based footprints), the knowledge within universities needs nurturing. Similarly, a perception that collecting data (internally and from external suppliers/organisations) is an obstacle to developing reliable GHG assessment has emerged, despite readily accessible financial accounts, with which detailed upstream footprints can be calculated (Wiedmann et al., 2009; Townsend and Barrett, 2015). Now more than ever, there is a requirement for clarity in a time of significant change for carbon management in the sector. With the introduction of new funding policies and universities playing an increasingly key role in local and national policymaking, the traditional outputs of universities (the intellectual 'assets' [Collini, 2012]) are being tested and developed. HEIs are under increasing demands to demonstrate their direct financial contributions to the economy (Etzkowitz et al., 2000) and as a result, growth and expansion have been inevitable. Although wholly welcome by those responsible, the impact on indirectly influenced emissions is unknown and for these reasons, the future for Scope 3 carbon management in particular remains uncertain.

Universities act to transfer knowledge between industry, government and the public (described by Etzkowitz (1998) as the triple helix model) and for this reason, can also act as good influencers of carbon management in wider society and other organisations (Lozano et al., 2013). Rapidly changing estates, transient populations and different academic specialisms mean that the variety and intensity of activities are in constant flux (with timings dictated by the structure of the academic year) (Flint, 2001). Critically, they find themselves needing to fulfil certain mandatory responsibilities and activities, which are driven by their research, teaching and innovation-based agendas. Consumption-based activities dominate the emission profile, whilst activities such as travel, procurement or construction are inherently strategic, important and thus, unavoidable (Ozawa-Meida et al., 2011). Those that work and study at university will spend a large majority of their lives there and so, investing in sustainability initiatives at the grassroots level through HE, can and will have wide reaching benefits to students and staff for the rest of their lives (Zsóka et al., 2013); and not forgetting the

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societal benefits too. To add to the significance of Scope 3 emissions, the emerging commodification of HE has promoted institutions to establish campuses internationally, in order to cater for and exploit the demand in HE around the world (Universities UK, 2012); such as in South East Asia (Altbach et al., 2009).

4.4. *University carbon footprints: scoped-out activities*

Table B.1 shows site-specific activities listed under each of the ISO-designated emission categories and the treatment applied under the proposed methodology. Some may argue that the treatment of these activities could provide a case for universities to abstain on carbon management because the majority of Scope 3 sources are excluded. Likewise, the shifting responsibility of emissions from the HEI to their suppliers could enable institutions to continue their current trajectory of growth and increasing consumption without due regard for environmental consequences (Jackson and Knight, 2011). Whilst this may hold some weight, the reason this has been allowed to flourish already can in-part be attributed to the policy situation already described. The methodology outlined here considers these issues in a number of ways and allows institutions to address them individually. Firstly, universities are still held to account because of the emphasised importance of developing full-scope carbon footprints for *internal* use (to aid carbon management) and secondly, the reporting has been made easier for GHGs *within* their organisational boundary.

A responsibility now falls onto the various agencies that govern the HE sector to foster collaboration on understanding an individual institution's carbon management needs. Ensuring that institutions are able to report data (currently controlled by HESA using the Higher Education Information Database for Institutions (HEIDI) and are compared fairly (by using carbon intensities to compare similar-sized institutions) removes the many unwanted barriers that can pose a threat. In addition, this study should serve as a wakeup call to policymakers and institutions that more work needs to be done to decouple growth from emissions (Pelletier et al., 2013). This joins those from other academic research and grassroots movements (such as the global divestment movement and rootAbility's Green Office initiative). Whilst universities should retain the right to grow nationally and internationally, new ways of delivering HE with a lower environmental impact must be a priority, whether managing the estate more efficiently or challenging the traditional methods of teaching to favouring distance-learning and offsite degree courses (Barber et al., 2013; Roy et al., 2008).

The use of carbon footprinting can assist in creating better ownership by individuals in organisations like HEIs (Paterson and Stripple, 2010). As individual stakeholders of HEIs, getting staff and students to take a more central role in contributing to carbon management is important in fostering significant reductions. A cost for carbon, in-line with the published figure of the social cost of carbon (the cost to society as a result of environmental damage caused by anthropogenic GHG emissions) could be introduced by manufacturers and purveyors of services. This would negate any possibility of allowing staff and students *carte blanche* on highly-consuming behaviours. Consequently, the cost of emissions is borne by the consumer and so a potential win-win scenario is presented. This influences the behaviour of the consumer through selecting products and services with the least environmentally damaging credentials. In-turn, the provider adapts favourably to remain competitive and maintain market-share; Grote et al. (2014) considered this in an example of the aviation industry - by increasing ticket prices for flights as a means to reduce aviation emissions, considerable emissions savings could be predicted. However, the low probability that strong policy decisions will be taken offers little certainty about the future trajectory of carbon reduction.

5. Conclusions

Scope 3 emissions represent the largest proportion of the organisational carbon footprint, but are seldom the priority in carbon management policies (Ozawa-Meida et al., 2011). The three most influential barriers to assessing and reporting indirect GHG emissions from upstream and downstream of the organisational boundary of HEIs have been identified as time, cost and data reliability. HEIs transpose key theories from guidance notes, intended to be suitable for all organisation types. Along with inconsistencies in the grey literature, a limited number of institutions have a detailed understanding of GHG emissions associated with all of their directly and indirectly influenced activities.

A universal methodology which takes a consistent and transparent approach for practitioners in assessing the carbon footprint of HEIs is proposed. The input of environmental practitioners themselves during its development has sought to ensure this methodology is user-friendly. We have shown that whilst the virtues of understanding all emissions for which an organisation is responsible are clear for implementing appropriate sustainability initiatives, when reported, inherent double-counting undermines conclusions that can be made about entire economic sectors. Therefore, the use of full-scale footprints for internal purposes and the external reporting of production-based emissions are proposed. With the latter, cut-offs that exclude paid for services are outlined to reduce the financial and temporal cost associated with reporting and data collection. We think that our approach and universal methodology would be suitable for adoption by all types of organisations, regardless of region or sector.

The year 2015 represented the halfway point between the setting of institutional targets in 2010 to reduce Scope 1 and 2 emissions by 2020 (HEFCE, 2010). The interest and desire to manage indirect GHG emissions exists in the HE sector today, but the tools in order to do this are yet to be put in place. Carbon management will be a cornerstone for institutions aspiring to grow internationally at a time when advocating sustainability and low-carbon production is high on the list of priorities (Lozano et al., 2013). Clearly, the time to act is now.

This paper forms the basis of efforts to improve Scope 3 GHG emission reporting rates for HEIs. Future work aims to investigate the current practices that HEIs undertake to assess their GHG emissions using these techniques in order to build upon the findings presented here. Identifying exactly which of the barriers recognised by practitioners can be addressed through employing a streamlined carbon footprint methodology will extend the scope of this research. In particular, the degree to which this method fosters more efficient use of the time and financial resources available to non-technical personnel (such as the university environment managers that formed the basis of this research) will be the subject of further study.

Acknowledgements

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Appendix A

Carbon management at universities: towards a universal method for calculating scope 3 emissions

This questionnaire allows you to have your say on what you want to see from a universal and comprehensive set of industry carbon footprinting guidelines. By completing it, you consent to the data you provide being used for this study as outlined in the participant information sheet (13/03/15_2). Your participation is voluntary and you are free to stop filling in the questionnaire at any time and without providing a reason.

Section 1: You and your institution

1) Which region of the UK are you from?

(Please tick one)

- ☐ Northern Ireland
- ☐ Scotland
- ☐ North East
- ☐ North West
- ☐ West Midlands
- ☐ Yorkshire
- ☐ East Midlands
- ☐ West Midlands
- ☐ East
- ☐ South West
- ☐ South East
- ☐ London
- ☐ Wales

2) What is the name of your institution/organisation of origin?

3a) Does your institution outsource work to calculate the carbon footprint?

(This includes any work outsourced at any stage to collect or analyse data)

- ☐ Yes
- ☐ No

3b) If yes, which company do you use?

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4) Please indicate on the scale your attitude towards your institution's ability to calculate its carbon footprint

(Please make your rating by circling one on each scale)

Adequate				Inadequate
4	3	2	1	0
Chaotic				Ordered
0	1	2	3	4
Open				Secretive
4	3	2	1	0
Complex				Simple
4	3	2	1	0
Old-fashioned				Modern
0	1	2	3	4
Ineffective				Effective
0	1	2	3	4
Innovative				Non-innovative
4	3	2	1	0

5) Please rate how much of an impact the following factors have in the calculation of the carbon footprint at your institution

(Please circle one for each statement)

	No impact				*High impact*
Time constraints	0	1	2	3	4
Budget constraints	0	1	2	3	4
Staff resources	0	1	2	3	4
Staff training requirements	0	1	2	3	4
Support from top management	0	1	2	3	4
Technical knowledge of procedures	0	1	2	3	4
Data reliability	0	1	2	3	4
Other	0	1	2	3	4

If other, please specify:

6a) Does your institution use a published methodology for guidance in calculating emissions?

☐ Yes ☐ No

6b) If yes, which methodology is used? *(Please tick one)*

- ☐ HEFCE 2010, carbon management series of guidance documents
- ☐ IPCC 2006, guidelines for National GHG Inventories
- ☐ GHG Protocol Corporate Accounting Standard 2004 & 2011
- ☐ ISO 2006, 14064-1 Specification
- ☐ DEFRA 2009, Guidance on how to measure and report your GHG emissions
- ☐ GRI 2013, emission guidelines - G4 Sustainability Reporting Guidelines
- ☐ CDP 2014, Guidance for companies reporting on climate change
- ☐ Other

If other, please specify:

HEFCE – Higher Education Funding Council for England, IPCC – Intergovernmental Panel on Climate Change, ISO – International Standardization Organization, DEFRA – Department for Environment, Food and Rural Affairs, GRI – Global Reporting Initiative, CDP – Carbon Disclosure Project

7) Which emission sources does your institution have a good understanding of?

(Please label the following sources with the appropriate level of understanding at your institution)

0 = not currently calculated; 1 = basic understanding, some data collected but unreliable; 2 = improved reliability of data, but incomplete; 3 = reliable data, calculated fully)

Scope 1	Scope 2	Scope 3
☐ Stationary combustion (boilers)	☐ Imported consumed electricity	☐ Other energy-related sources
☐ Mobile combustion (vehicles)	☐ Imported energy (heat/steam)	☐ Purchased products
☐ Process-related emissions		☐ Capital equipment
☐ Fugitive emissions		☐ Generated waste
☐ Land-use change/forestry		☐ Upstream transport
		☐ Business travel
		☐ Upstream leased assets
		☐ Investments
		☐ Client and visitor transport
		☐ Downstream transport
		☐ In-use stage of sold products
		☐ Downstream franchises
		☐ Downstream leased assets
		☐ Employee commuting

Definitions:

- Process-related emissions – Emissions from biological, mechanical or other activities not arising from direct combustion or leaks from equipment/storage systems
- Fugitive emissions – Direct uncontrolled emissions of GHGs leaked from equipment/storage systems
- Other energy-related sources – Emissions from the extraction, production, transport and distribution stages prior to fuel use/energy consumption
- Capital equipment – Emissions from production of capital goods – equipment used by organisation to manufacture a product, provide a service etc.

Section 2: expectations of a universal, comprehensive standard

8) Please rate your agreement with the following three statements:

(Please circle one for each statement)

8a) *"A universal, comprehensive carbon footprinting standard should focus on better data collection"*

Strongly agree				Strongly disagree
0	1	2	3	4

8b) *"I should be able to relate a universal, comprehensive carbon footprinting standard to my organization's own requirements and economic/environmental context"*

Strongly agree				Strongly disagree
0	1	2	3	4

8c) *"I require step-by-step instructions to calculate my organization's carbon emissions"*

Strongly agree				Strongly disagree
0	1	2	3	4

9) Please rate your preference for the following:

9a) What is your preference for a universal method which encompasses the greatest extent of emissions but represents the greatest economic and temporal cost?

Cheaper, quicker				Expensive, slower
0	1	2	3	4

9b) To which extent should the use of technology be employed in a carbon footprinting standard?

Manual				*Technological*
0	1	2	3	4

9c) What is your preference for an all-encompassing carbon footprint over one that is less extensive (if the latter were cheaper, quicker and equally comparable)

Standard footprint				*Boundless footprint*
0	1	2	3	4

Section 3: opinions of a universal, comprehensive standard

10) How likely are you to use a universal, comprehensive methodology?

(Please circle one)

Very likely				Very unlikely
0	1	2	3	4

11) Please rate your agreement with the following statements:

(Please circle one for each statement)

11a) *"A universal, comprehensive standard would be beneficial to my institution"*

Strongly agree				Strongly disagree
0	1	2	3	4

11b) *"A universal, comprehensive standard would be beneficial to all UK institutions."*

Strongly agree				Strongly disagree
0	1	2	3	4

11c) *"The number of institutions undertaking full-scale carbon footprints will increase as a result of a more universal standard."*

Strongly agree				Strongly disagree
0	1	2	3	4

12) Has today's workshop inspired you to adopt different carbon measurement practices?

☐ Yes ☐ No ☐ Maybe

13) Are there any other comments you wish to make regarding this research?

(Please continue on the reverse if more space is required)

Appendix J

Would your institution like to participate in an extended study of this research project? If so, please list your email address and a named contact below:

Email address: ______________________________

Name: ______________________________

Institution Address: ______________________________

____

______________________________ **Post Code:** ____________

Table A1
Procedural elements of organisational carbon footprinting used as search terms in the systematic review.

Emission baseline (benchmark/base year)	Equity share or control boundary-setting approach (organisational boundary)	Temporal boundary	Emission Scopes 1, 2 and 3
Upstream/downstream	Direct emissions from stationary combustion (on-site energy production)	Direct emissions from mobile combustion (vehicle fleet)	Direct process-related emissions
Direct fugitive emissions	Direct emissions/removals from Land-use, Land-use Change and Forestry	Indirect emissions from imported electricity consumed (purchased electricity)	Indirect emissions from consumed energy imported through physical network (purchased steam, chilled water)
Energy-related activities not included in direct & energy indirect emissions (Scope 1, 2 life cycle emissions) Upstream emissions of purchased fuels Upstream emissions of purchased electricity Transport/distribution losses Generation of purchased electricity sold to end users	Purchased/procured products (Product lifecycle assessment (LCA) – cradle-to-gate emissions)	Production-related procurement	Non-production-related procurement
Capital equipment (goods)	Waste generated from organisational activities	Upstream transport/distribution Transport and distribution of purchased products Third-party transportation and distribution services purchased	Business travel (staff travel)
Emissions from business travellers in hotels	Upstream leased assets	Investments	Client and visitor transport
Downstream transport and distribution	Emissions from retail and storage	Use stage of sold product Direct use-phase emissions Indirect use-phase Maintenance of sold products	End of life (disposal) of sold product
Downstream franchises	Downstream leased assets	Employee commuting	Land-use
Emission calculation (activity data x emission factor)	Carbon dioxide only	Kyoto Basket GHGs (six: CH_4, N_2O, HFC, PFC, SF_6)	Air pollutants
Published emission factors (i.e. not from a national database)	National emission factors (DEFRA, Bilan Carbone, IPCC, IEA)	Organisation-specific factors	Use of data scenarios (best, inter, min)
Centralised [*data collection*] approach	Decentralised [*data collection*] approach	[Reporting] Acknowledgement of significant emissions changes	[Reporting] Assumptions (Standards and methodologies used)
Intensity ratios (normalised)	Disaggregated emissions	[Report] Excluded emission sources	Uncertainty analysis
Base year recalculation policy	Internal performance tracking	Scope 1 and 2 emissions independent of GHG trades, sales, purchases, transfers, banking allowances	Emissions data separate for each Scope and Scope category
Metric tonnes and in tonnes of CO_2 equivalent	Emissions data for direct CO_2 emissions from biologically sequestered carbon (e.g. CO_2 from biomass/biofuels) reported separately	Set targets/guidelines for target-setting (SMART)	

Table B.1
Treatment of activities attributed to a university estate after applying the methodology proposed in this research paper.

ISO Designation	Description	Site-specific Activity	Treatment
Direct emissions from Stationary Combustion	Energy/heat Production	Use of boilers	IN
		Use of CHP	IN
Direct emissions from Mobile Combustion	Use of Vehicle Fleet	Interlibrary book loans	IN
		Use of plant machinery	IN
		Transport of maintenance personnel	IN
		Attendance of international conferences	IN
		Attendance of domestic conferences	IN
		Outreach activities	IN
		Field Trips	IN
		Fieldwork	IN
Direct Process-related Emissions	Agricultural processes	Livestock	IN
		Application of nitrogen fertiliser	
		Putrefaction/fermentation	
	Waste-related processes	Waste treatment	
		Wastewater/sewage treatment	
Direct Fugitive Emissions	Energy-related processes	Natural gas storage	IN
		Transportation of Natural gas	
	Miscellaneous	Use of fire CO_2 extinguishers	
		Use of CO_2 in gaseous or solid form	
Direct Emissions and removals from Land-use, Land-use Change and Forestry (excluding combustion)	Grounds Maintenance	Gardening	IN
		Tree-cutting	IN
		Grass-cutting	IN
	Building Works	Building construction/extension	IN
		Building demolition	IN
	CO_2 Removals	Planting	IN
		Soils	IN
Indirect Emissions from Imported Electricity Consumed	Use of mains Electrical Equipment	Audio-visual Equipment	IN
		Lighting	IN
		Digital imaging equipment	IN
		MFD printer	IN
		White goods i.e. kettle, refrigerator, microwave	IN
		Water cooler	IN
		Computers and peripherals	IN
		Laboratory equipment, portable and stationary	IN
		Telecommunications	IN
		Electronic security and fire safety systems	IN
		Elevators	IN
		Automatic doors	IN
	Use of Rechargeable Battery Powered Equipment	Charging of laptops	IN
		Charging of tablets/mp3/mobile phones	IN
		Cordless power tools	IN
		Electric vehicles	IN
Indirect emissions from consumed energy through a physical network	Use of hot water	Wash facilities	IN
		Heating	IN
	Use of steam	Heating	IN
Energy-related Activities not Included in Direct Emissions and Energy Indirect Emissions	Use of Fuels	Extraction of consumed fuels	IN
		Production of consumed fuels	IN
		Transport of consumed fuels	IN
	Use of Electricity	Extraction of fuels consumed in generation of consumed electricity	IN
		Production of fuels consumed in generation of consumed electricity	IN
		Transport of fuels consumed in generation of consumed electricity	IN
		Transmission and distribution	IN
Purchased Products	The Arts, Audio-Visual &Multimedia Supplies and Services		OUT
	Library-related supplies and services		OUT
	Catering Supplies & Services		OUT
	Medical, Surgical, Nursing Supplies & Services		OUT
	Agricultural/Fisheries/Forestry/Horticultural/Oceanographic Supplies & Services		OUT
	Furniture, Furnishings & textiles		OUT
	Janitorial & Domestic Supplies		OUT
	Utilities		OUT
	Computer Supplies & Services		OUT
	Laboratory/Animal House Supplies & Services		OUT
	Workshop & Maintenance Supplies (Lab & Estates)		OUT
	Printing		OUT
	Telecommunications		OUT
	Stationery & Office Supplies		OUT
	Safety and Security		OUT
	Vehicles		OUT
	Estates & Buildings		OUT
	Miscellaneous		OUT
Capital Equipment	Fixed Assets	Server and related items	OUT

Appendix J

Table B.1 (*continued*)

ISO Designation	Description	Site-specific Activity	Treatment
		Network Equipment Installation	OUT
		Telephony/Switchboard Cap Ex >£10,000	OUT
		Vehicle Purchase	OUT
		Portable and Laptop Computer Purchase	OUT
		Agricultural, Fisheries, Forestry, Oceanographic Capital Equipment >£10 k	OUT
Waste Generated from Organisational Activities	Generation of WEEE		IN
	Generation of food waste		IN
	Generation of recylate		IN
	Generation of wastewater	Sewerage	IN
	Generation of general refuse		IN
	Generation of hazardous waste	Clinical and Chemical laboratories	IN
	Generation of confidential waste	Accounts, student exam papers	IN
Upstream Transport and Distribution	Transport of Purchased Products	As per categories designated in 'purchased products'	OUT
	Services, repairs and maintenance of purchased products	As per categories designated in 'purchased products'	OUT
	Storage and movement of purchased products	Storage & Warehouse Services	OUT
		Archival Services	OUT
	Mail Services	Mail Services Overseas/International	OUT
		Freight, Carriage & Haulage Services	OUT
		Courier Services	OUT
	Waste	Waste consignments	OUT
Business Travel	Air travel	Attendance of international conferences	OUT
		Attendance of domestic conferences	OUT
		Attendance of meetings	OUT
		Outreach activities	OUT
		Field Trips	OUT
		Fieldwork	OUT
		Consultancy services	OUT
	Ferry travel	As per categories designated in 'air travel'	OUT
	Taxi hire		OUT
	Rail travel		OUT
	Mileage (Grey Fleet)		IN
	Car hire		OUT
	Van hire		OUT
	Coach hire		OUT
	Boat hire and charter		OUT
	Hospitality		OUT
Upstream Leased Assets	Hired Products	As per categories designated in 'purchased products'	OUT
	Building/Premises/Land - Rent, Lease, Hire, Feu Duties		OUT
Investments	Unique to reporting HEI		IN
Client and Visitor Transport	Air travel	Attendance of on-site conferences	OUT
		Attendance of meetings	OUT
		Outreach activities	OUT
		Visiting academics	OUT
		Consultancy services	OUT
	Ferry travel	As per categories designated in 'air travel'	OUT
	Taxi hire		OUT
	Rail travel		OUT
	Mileage (private vehicle use)		OUT
	Car hire		OUT
	Van hire		OUT
	Coach hire		OUT
Downstream Transport and Distribution	Not applicable to the HE sector		OUT
Use Stage of the Product	Not applicable to the HE sector		OUT
End of Life of the Product	Not applicable to the HE sector		OUT
Downstream Franchises	Not applicable to the HE sector		OUT
Downstream Leased Assets	Leased Products	As per categories designated in 'purchased products'	IN
	Building/Premises/Land - Rent, Lease, Hire, Feu Duties		IN
Employee Commuting	Air travel	Staff commuting	OUT
		Student commuting	OUT
	Ferry travel	Staff commuting	OUT
		Student commuting	OUT
	Taxi travel	Staff commuting	OUT
		Student commuting	OUT
	Rail travel	Staff commuting	OUT
		Student commuting	OUT
	Car travel	Staff commuting	IN
		Student commuting	IN

Appendix B. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclepro.2017.02.147.

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