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*Review*

# Carbon Management in UK Higher Education Institutions: An Overview

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**Abstract:** The paper presents a review of carbon management in relation to UK Higher Education Institutions (HEIs), forms part of a wider study on the ongoing reliance on fossil fuels in Scotland's public sector with a focus on Universities and Local Government Authorities. It compares the CF (carbon footprint), emission sources, and the fossil fuel contribution to the CFs reported in 3 identified articles relating specifically to the estimation of CF for HEIs. The consumption of fossil fuels results in human induced climate change however, fossil fuels boosted the industrialization process and remains the dominant source of global energy consumption. Action in tackling climate change has led to organizations coming under increasing pressures to monitor and report their CFs. HEIs have a key role to play in reducing its reliance on fossil fuels and reducing GHG (greenhouse gas) emissions through delivery of scientific research and innovative carbon management solutions, increase in its uptake of renewable energy technologies, educating and training future leaders, and raising public awareness, in contribution to a sustainable society. This paper highlights the need for a shift of focus to reducing fossil fuel reliance in response to climate change and demonstrates how HEIs can impact GHG reductions.

**Keywords:** public sector; higher education institutions; carbon management; carbon footprint; greenhouse gas emissions



**Citation:** Idundun, E.; Hursthouse, A.S.; McLellan, I. Carbon Management in UK Higher Education Institutions: An Overview. *Sustainability* **2021**, *13*, 10896. https://doi.org/10.3390/su131910896

Academic Editor: Wen-Hsien Tsai

Received: 10 August 2021
Accepted: 27 September 2021
Published: 30 September 2021



## 1. Introduction

It is recognized that climate change, and its associated issues, is a global environmental and social concern, impacting our mental health and well-being, poorer nations, and economic growth [1,2]. The Intergovernmental Panel for Climate Change (IPCC) is confident that the observed warming since the mid-20th Century is a consequence of anthropogenic influence [3], responsible for the retreating glacier and estimated to be responsible for global warming of about 1.09 °C above pre-industrial levels [4]. The issues associated with fossil fuel use continue to be a global growing concern, with the burning of fossil fuels as the largest known contributor of Greenhouse gas (GHG) emissions to the atmosphere [5], and the apparent continued global reliance on fossil fuel energy sources [6]. Large-scale use of fossil fuels determined the process of industrialization; its continued use has major environmental implications such as acid rain and deposition, loss of plant and animal ecosystems and global warming [7,8]. Fossil fuels remain the principal source of global energy consumption today with oil (33.1%), coal (27.0%), and gas (24.2%) having the largest shares in global primary energy consumption in 2019 [6], and the European Union (EU) relies on fossil fuels, importing oil (68%), gas (28%), and hard coal (4%) estimated at approximately €266 billion in 2017 [9].

Public sector organizations like Higher Education Institutions (HEIs) consume fossil fuels directly or indirectly in their day-to-day activities. They often face however the dichotomy between maintaining organizational standards and ethos and reducing organizational emissions. The use of fossil fuel energy sources within HEI buildings for space heating, cooling, and electricity, and its persistent reliance for transportation evidence reliance on fossil fuels [10–12],. For example, motorized forms of transportation for road and air travel are overwhelmingly reliant on fossil fuels [13], like petrol, diesel, jet fuel and LPG. This is likely to be the case for some time yet particularly when considering air travel is a fundamental part of how HEIs organizations operate. However, the COVID-19 pandemic forced HEIs to online delivery of education provisions [14], and whilst this presents the potential opportunity for HEIs to reduce emissions associated with business travel, there are the issues of education inequalities [15] and the carbon implications of working and studying from home [14].

There is therefore an increasing need to reduce the reliance on fossil fuels and to reduce drastically GHG emissions, for example, the 'basket of six' highlighted within various IPCC reports [4]: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride ($SF_6$). The fossil fuel industry is well established within societies globally; reducing reliance on fossil fuels will clearly be challenging however is non-negotiable [16] and requires a systematic approach through concerted action to address the issue and avoid climate tipping points [17–19].

The recognition of human induced climate change has led to international progress in addressing climate change and its associated issues. Figure 1 shows a timeline of some international actions taken by way of reports and conferences since the establishment of the IPCC in 1988.

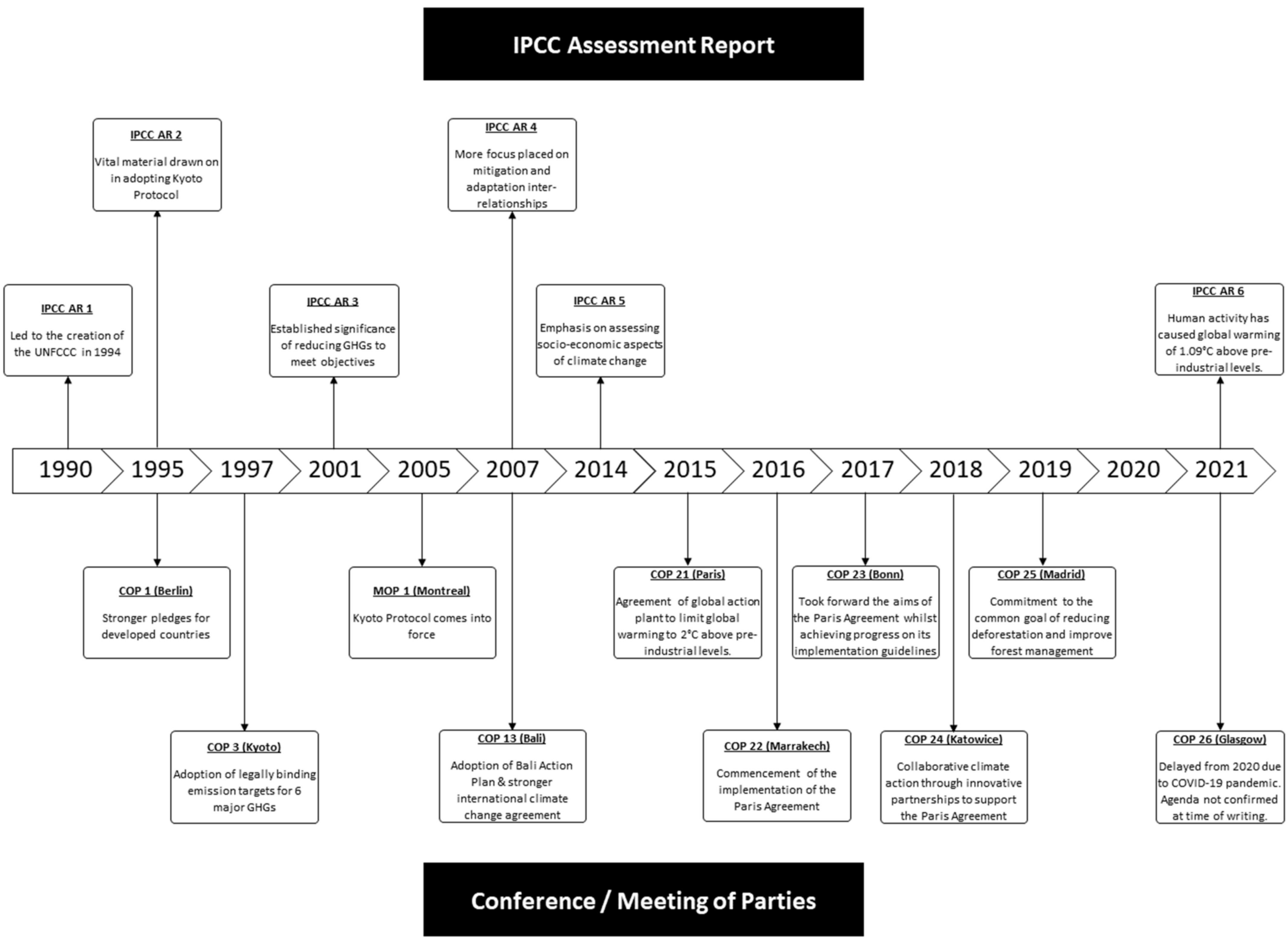


**Figure 1.** Timeline of reports and conferences on Climate Change showing international action (post creation of IPCC in 1988). (AR—Assessment Report, COP—Conference of Parties, MOP—Meeting of Parties to the Kyoto Protocol; [20–27].

This paper therefore highlights the reliance on fossil fuels by HEIs and questions how and why HEIs can impact GHG reductions given the significance of its position within society and the leadership expectations bestowed on it as demonstrated by its spontaneous adaption to the COVID-19 pandemic.

*Legislative Framework for GHG Emission Reductions*

The EU requires member states to participate and contribute to its initiatives to reduce GHG emissions whilst acting to achieve reduction targets and increase the efficiency and use of renewable energy. Some of these initiatives include: (i) EU Emissions Trading System (EU ETS), (ii) Renewable Energy Directive, (iii) Energy Efficiency Directive, (iv) New car and van $CO_2$ targets, (v) 2030 Climate & Energy Framework [28–33]. However, it is important to note that at the time of writing the UK ceases to be a member state of the EU as of January 2020 however, the UK governments aim is that all current legislation is transposed and will still be applicable post Brexit. For example, the statutory instrument 'The Greenhouse Gas Emissions Trading Scheme Auctioning Regulations 2021' which came into force in April 2021 to ensure that emissions from sectors covered by the EU ETS remain covered by a carbon pricing policy post Brexit [34].

The UK Climate Change Act 2008 regulates the reduction of net GHG emissions with targets to reduce emissions to Net-zero GHGs by 2050 based on the 1990 baseline [35]. The Act places the onus on the Secretary of State, Scottish Ministers in the Climate Change (Scotland) Act 2009 [36], to achieve reduction targets. Whilst there are no specific targets set for public sector organizations like HEIs within the Act, and no direct provision for measuring or targeting reduction of fossil fuel emissions within the Act(s), the HEI sector aspires to exceed its sector-level targets [37]. The Act covers all the United Kingdom however Wales, Northern Ireland and Scotland have dedicated reduction targets. The Committee on Climate Change (CCC) recommended new targets following the assessment of the UKs long-term emission targets of net-zero greenhouse gases by 2050 for the whole of the UK [38].

The UK Government, and Devolved Administrations, have taken several actions in its bid to reduce GHG emissions and meet its reduction targets and EU targets. They include but not limited to: (i) setting climate change targets to achieve net-zero emissions by 2050, (ii) incorporation of international aviation and shipping emissions into the Carbon Budget for consistent accounting, (iii) generation of 50% of electricity from low carbon sources, (iv) ambitious strategies to support decarbonization in polluting industries, (v) being the first G7 country to action support for a transition to clean, green energy in the oil and gas industry's (50% reduction by 2030), and (vi) launch of 'Together For Our Planet' campaign, calling on all to take action on climate change [39].

## 2. Carbon Management

The role of the HEIs is pivotal in carbon management, seen as neutral and trusted, with the capacity to raise public awareness, educate and train future leaders, deliver scientific research and innovative carbon management solutions to combat climate change [40–42]. More so with the contribution of academics across the world in contributing to scientific knowledge through IPCC reports. Although climate change is a global concern, its impacts are very much experienced locally. This re-emphasizes the need for public engagement to foster partnerships, collaborations, and transformation in behavior in response to climate change, and HEIs are well positioned to deliver on this requirement [42–44]. There is growing popularity within organizations for 'carbon management' policies, largely due to the perceived contribution they can make in reducing global emissions [45], in reducing and improving their GHG emissions [46], opportunities for financial savings through energy efficiency measures [47], as a result of stakeholder pressure [48].

Carbon management policies, procedures and practices focus on the processes of developing solutions to reduce carbon emissions. Focusing on the 'basket of six' GHGs, carbon management relies on careful carbon accounting (e.g., measuring organizational carbon footprint), reduction in energy use, raw material consumption and waste generation [46,49–51]. Implementing carbon management policies and strategies would ultimately result in the reduction of carbon emissions and yield cost savings for organizations. For example, improving energy efficiency in buildings will decrease the building's energy consumption, operating costs, and its carbon footprint [52]. Other reasons for organizations to implement carbon management protocols are those which cut across the triple bottom line (i.e., social, economic and environmental): (i) to reduce organizational impacts, (ii) to reduce public health risks resulting from air pollutants, (iii) to improve the public image of a business, (iv) to comply with, and prepare for, legislation [49,53–55].

Businesses have brought to the fore of their agendas the need for reducing GHG emissions, ultimately putting pressure on organizations to implement carbon management policies and practices. Carbon Management involves reducing GHG emissions, the efficient use of energy, investing in research and technology to develop and capitalize on alternative renewable and low carbon energy sources, including carbon capture and storage, and accountability through measurement and reporting [44,49,50,56,57]. Lee [58], classifies six categories of carbon management activities in addressing climate change at corporate level as: emission reduction commitment; product improvement; process and supply improvement; new market and business development; organizational involvement and external relationship development. Wade, Dargusch, and Griffiths [59] and Wade, and Griffiths [60] identified best practice carbon management (BPCM) attributes namely: compliance; culture and values; knowledge creation and sharing; monitoring, reporting, and energy efficiency; resource allocation and R&D; networking/stakeholder engagement; strategy; and target setting.

### *2.1. Measuring GHG Emissions*

Purman [61] and Pandey et al. [62] suggest that emissions are measured, either directly or by using emission factors or models to calculate emissions. To reduce GHG emissions, an organization must understand its emissions profile (i.e., identify sources of emissions resulting from its operations, including measuring, and recording the corresponding emissions) and establish a baseline from which subsequent emissions can be measured against. Whilst organizations are under increasing demand to measure their carbon footprint, there is a lack of academic definitions of the term 'carbon footprint' within studies or how it should be calculated [62,63]. Carbon footprints are often used to describe emissions associated with $CO_2$ or the other GHGs in $CO_2$ equivalents [62,64,65], based on their Global Warming Potential (GWP). The range of GHGs and GWPs pose potential difficulties an organization can have when calculating their carbon footprint [66].

Adding to the complexity is Wiedmann and Minx [63], who state that carbon footprints should measure $CO_2$ emissions only and other GHGs should not be included; where other GHGs are included, it should be termed 'climate footprint'. They argue that some GHGs are not carbon based and are difficult to quantify due to lack of data; any conversions to $CO_2$ which is based on assumptions will likely increase uncertainties and errors in footprint calculations. Whilst there is a valid argument for the collective measure of GHG emissions to be termed Climate Footprint [67], current carbon footprint reporting of $CO_2$ and other GHGSs in $CO_2$ equivalents is well established. They form the basis of baseline measurements for organizations and as such the term 'carbon footprint' encompassing other GHGs in $CO_2$ equivalents is used within this paper.

There are various environmental audit systems used for assessing environmental management impacts at different levels (micro, meso and macro), examples include Environmental Accounting (EAc), Life Cycle Assessment (LCA), Life Cycle Costing (LCC), Environmental Auditing (EA) and Environmental Management Systems (EMS) [68]. Arena and de Rosa argues that LCA is the only comprehensive and legitimate method accepted by the scientific community for assessing the environmental impacts of products and services through their life cycle [69]. LCA plays an important role in tracking emissions of an entire supply chain, carbon footprint calculations and in the establishment of protocols and guides for GHG accounting [62,63,70]. Carbon Trust identifies four main types of carbon footprint for organizations as follows: (i) organizational (based on GHG protocol and must include scopes 1 and 2 emissions; with flexibility for reporting scope 3 emissions), (ii) value chain, (iii) product (based on PAS 2050) and (iv) supply chain carbon footprints [71]. Figure 2 shows the different boundaries of organizational, product and supply chain footprints.

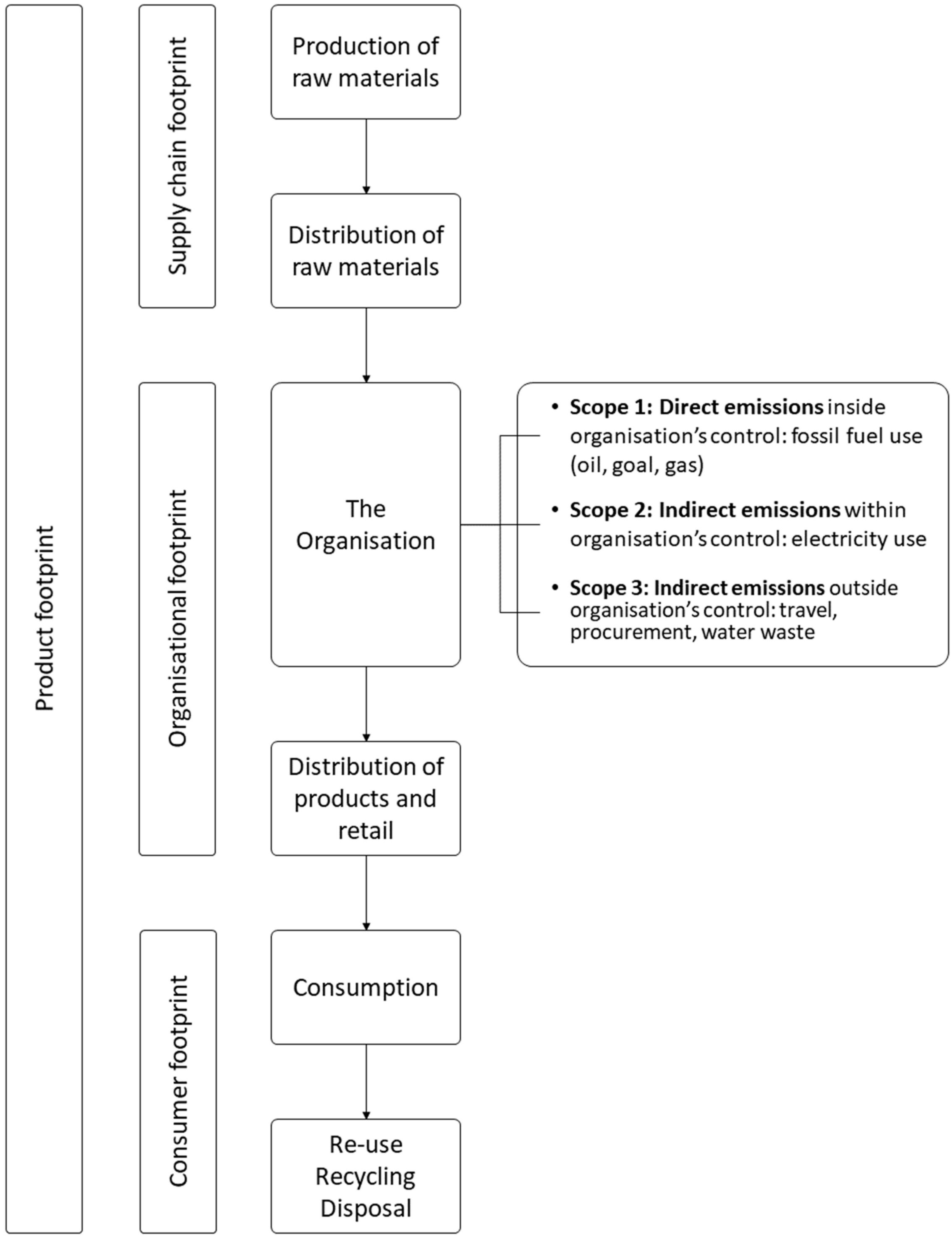


**Figure 2.** Boundaries of organizational, product and supply chain footprints (Adapted from Carbon Trust [71]).

Whilst the methods for calculating carbon footprints are evolving, two main approaches to performing LCA for carbon footprints are: bottom up or process analysis (PA) and top down or input-output analysis (IO) are currently being used [62,63,70]. In some cases, a combination of both approaches also referred to as a hybrid approach is also utilized (for example: [62,63,72]. The IO analysis has variations including economic input-output (EIO) analysis [62,70,73], environmental input-output (EIO) analysis [65], environmental extended input-output (EEIO) analysis [72,74,75] and environmentally extended multi-region-input-output (EEMRIO) analysis [76]. Much research has been conducted on bottom up and top down approaches and there are advantages and disadvantages to both approaches, (Table 1). The variation in methodologies used to calculate carbon footprints, along with their operational scope, population, emission sources reported, contribute to the complexity of comparing carbon footprints of HEI [74–76]. However, in practice, organizations are now using carbon footprint results to identify opportunities to reduce costs associated with their operations [77], for example reducing utility costs through energy efficient operations, consuming less energy and use of more energy efficient machinery and equipment.

**Table 1.** Comparison of Bottom-up and Top-down approaches for carbon footprint estimation [63,78].

| PA—Bottom-Up Approach | IO—Top-Down Approach |
|---|---|
| Better suited for micro systems like an individual product or service, or relatively small groups of products and particular processes (cradle to grave estimation) | Better suited for meso (sector level) and macro systems (aggregate of meso systems) like industrial sectors, individual businesses, households, larger product groups and governments (comprehensive and robust estimation) |
| Suffers from a system boundary problem—only on-site (mostly first-order, and some second-order impacts) | Accounts for higher order impacts and sets the whole economic system as boundary (at the expense of site-specific detail) |
| Not suitable for calculating footprints for macro systems | Limited suitability for calculating footprints for micro systems |
| Potential for specific and dedicated strategies and incentives to reduce emissions in a micro system | Potential for overall efficiency gains across meso/macro systems |
| Site specific accuracy of data | Utilizes aggregated data which may not accurately represent site specific conditions |
| Non-standardized measurements with potential to differ from site to site | Standardized measurements |
| Requires more staffing resources to for estimation | Requires fewer staffing resources for estimation |
| Limited data sources and potential to utilize a top-down database as proxy for missing data | Availability of a range of data sources |
| Difficult to achieve consistency in reporting due to lack of control systems | Consistency of reporting system due to effective control systems |

Private and Public Sector Roles

The need for collaboration between various sectors, industries, governments, and stakeholders as never been more important in addressing climate change and its impacts. Walker and Cass suggest that the social organization of renewable energy technologies is evolving as a heterogeneous category of energy supply and highlight the need to consider the social and geographical implications of this evolution [79]. They characterized five modes of renewable energy implementation in the UK, including 'private supplier mode' which emerged post, the energy utilities, and infrastructures privatization in 1989. From the 1990s, the private sector continues the transition from the traditional 'rule-taker' role to a more engaging role as a 'rule-maker' in relation to the governance of global climate and energy, achieved through private regimes and a hybrid governance regime built on public-private partnerships [80]. Pattberg and Stripple consider global climate governance approaches to include international and public sources of authority, public–private interventions and private interventions [81].

The Kyoto Protocol in a bid to assist involved parties achieve emission targets, whilst also encouraging the private sector and developing countries to contribute their quota, included emissions trading, clean development mechanism (CDM) and Joint Implementation (JI) as market-based mechanisms [82]. CDM is heavily reliant on the private sector which itself involves different types of actors such as CDM project advocates, consultants, brokers, investment funds, Departments of Environment, and private initiatives; like mitigation projects, and to create carbon-trading systems, such as the World Bank's Prototype Carbon Fund (PCF) [80,81].

Talukdar and Meisner suggest a link between countries that allow a greater private sector involvement in economic activities, foreign direct investment and well-developed capital markets, and positive impacts on their environment [83]. That private sector appears to be in transition to the role of 'rule-maker', plays an active role in implementing climate change mitigation mechanisms, and plays a significant role in global decision-making with respect to multi-stakeholder participation. However, their lack of legitimacy poses problems in decision-making; Andrade and Puppim de Oliveira [80], argue that the current architecture should guarantee that the private sector does not hijack global climate and energy governance decisions.

There is a lack of enough private sector investment in low carbon technologies for several reasons, including gaps in research and policy making, and financial gaps. Bradford and Fraser suggest that Small and Medium Enterprises (SMEs) make up a large portion of private sector economic activities and likely a major contributor to GHG emissions in the UK [84]. They highlight the gap in research and policymaking from UK Government and local authorities in relation to SMEs and recommend policy options for local authorities to facilitate significant reductions in energy consumption and GHG emissions.

There is a growing acceptance of the role to be played by public sector in leading by example, promoting energy efficiency improvements, influencing private sector organizations, and acting as a catalyst for action in reducing GHGs across society [85,86]. However, to go beyond aspiring to achieve or exceed legislative targets, taking lead on climate action to set good examples and act as a catalyst for reducing emissions across society, the public sector needs to strengthen its contributions, increase its pace of change, improve the poor energy efficiency of its buildings, and overcome the challenges and barriers of national austerity and investment deficiencies [85–88].

The role of public sector support in addressing financial gaps that occur when finance suppliers are unable to meet business demand for long-term low carbon investments is explored by Owen et al. [89]. They highlight the financial gaps as an institutional barrier; however, suggest that public sector support can limit the gaps through suitable finance ecosystem approach for low carbon investments by government. It was estimated that around $5.7 trillion of annual investment in green infrastructure by 2020 was required, largely in today's developing world, to ensure investments needs are met beyond 2020 the growth of private and public funding levels require to be sustained [90]. Multilateral development banks, a principal source of public funding, committed $2.9 billion to energy efficiency programs in 2015 representing 14% of all mitigation investments, with renewable energy receiving double that amount [91]. In the UK over £92 billion has been invested in clean energy since 2010, this figure includes investments totaling £12 billion from the Green Investment Bank since its establishment in 2012 alongside private sector and third-party investment partners [92].

## 3. Carbon Management in HEIs

The UK HEI sector, like other business sectors of the UK, is committed to reducing GHG emissions resulting from their operations in order to contribute to achieving net zero emissions by 2050 as set by The Climate Change Act 2008 [36]. The sector is also required to comply with other EU-induced frameworks like the EU ETS. The Climate Change (Duties of Public Bodies: Reporting Requirements) (Scotland) Order 2015 [93] requires HEIs to annually report on compliance with climate change duties. Furthermore, there are sector specific requirements, such as CRC, carbon reduction requirements for the Higher Education Funding Council for England (HEFCE), and those set by the Universities and Colleges Climate Commitment for Scotland (UCCCfS). Requirements to contribute to achieving UK reduction targets; vast operational scope of the HE sector; circa 2.5 million enrolled students in the UK [94]; 223, 525 academic staff working across 197 UK HE providers [95]; and over £37 billion annual operating expenditure [96], all indicate that the sector has a key part to play in contributing to achieving UK emission targets. This subsequently justifies the need for HEIs to take the lead in reducing emissions within the sector. Through UK legislation on climate change and sector specific requirements UK HEIs (and indeed other public sector organizations) have developed and implemented CMPs (Carbon Management Plans) [97].

However, Robinson et al. demonstrated through a 'reality check' that current CMPs are not a good indicator of future performance and underestimates the challenges faced by HEIs in reducing carbon emissions [98]. Some HEIs, however, have embedded the results of their carbon footprint into their CMPs and agreed carbon emission reduction action plans [75,97]. Despite the focus on carbon management at HEIs, a report reveals that 13% of HEIs do not have a carbon reduction plan [98], with few institutions having a grasp of their GHG emission profile resulting directly and indirectly from their activities [99]. Reports of recent surveys reveal overall sector emissions have increased in recent years in Scotland [100] and decreased by 7% in English Universities in 2015/16 [100], however most UK Universities are not on track to meet their reduction targets [100–102]. It is worth highlighting the potential implication of the HEIs forced move to online delivery on emission, and although Filimonau et al., found the carbon footprint of a mid-sized UK University to have reduced during the COVID-19 lockdown, they suggest the implications of this move be considered carefully [14]. Although the recent surveys suggest evidence of carbon reductions for some UK HEIs, they corroborate the identified needs for a uniform approach to carbon reduction across the sector, and organizational shift in shared responsibilities for carbon management [100,101].

The benefits of carbon management strategies include: carbon emission reduction, public health and quality of life improvements, meeting climate change mitigation targets, potential for financial savings, organizational credibility particularly in enhancing recruitment for example of staff or students, limiting risks associated with in-action on climate change [103,104]. These should motivate HEIs to do much more particularly with the increasing physical size of many HEIs resulting from student population growth [105]. However, this increase in physical size of HEIs is likely to bring about an increase in its energy use and travel requirements, which are reliant on fossil fuel energy sources, further highlighting the need to increase investment in, and uptake of renewable sources of energy in HEIs to reduce reliance on fossil fuels and carbon emissions. Although emissions associated with fossil fuel sources for example fuels like diesel and petrol for transportation, and natural gas are often reported, they are reported individually. There appears to be a lack of reporting and monitoring of emissions associated with the collective use of fossil fuel sources which is required to monitor progress in reducing reliance on fossil fuels and ultimately aid planning and decision making on fossil fuel issues and policies within HEIs. For carbon management in HEIs to be worthwhile it is vital to overcome the barriers of time, cost and data reliability in assessing Scope 3 emissions [99], financial and staff resources [98], and focus on reducing fossil fuel associated emissions through the uptake of renewable energy technologies, and divestment to end financial support to the fossil fuel industry [106].

## 4. Carbon Footprint of HEIs

### *4.1. Introduction*

HEIs should be motivated to do much more in developing methods for quantifying emissions associated with their vast operations and annual expenditure and take action to reduce fossil fuel emissions to contribute to achieving UK reduction targets, particularly with the increasing physical size of many HEIs resulting from student population growth [105].

Several studies cutting across continents of the world have been carried out to assess, estimate, or calculate GHG emissions, or carbon footprints of HEIs [107], for examples: Letete et al. estimated the carbon footprint of the University of Capetown, South Africa [108]; Gómez et al. calculated the carbon footprint of the University of Castilla-La Mancha, Spain [72]; Butt measured GHG emissions for Massey University, New Zealand [109]; Varón-hoyos et al. quantified the carbon footprint of the Technological University of Pereira, Colombia [110]; Ridhosari and Rahman measured the carbon emission associated with electricity, transportation, and waste generation only, for the generated at the Universitas Pertamina, Indonesia [111]; Larsen et al. investigated the carbon footprint of the Norwegian University of Technology and Science, Norway [74]; and Clabeaux et al. assessed the carbon footprint of Clemson University, United States [112], to mention a few. This section briefly looks at the reported carbon footprints of 3 UK HEIs and compares emission sources, footprint by Scope, and fossil fuel contribution to emissions where this can be identified from the list of emission sources reported within the articles.

### 4.2. Method

Using the ScienceDirect database and Google Scholar to search for literature, there are limited studies focusing on the calculation, estimation, or assessment of carbon footprints specifically for UK HEIs. The search terms used in ScienceDirect database are 'carbon footprint, University' and 'greenhouse gas', University, including 'carbon footprint' and 'university' as keywords to ensure results focus on the carbon footprint of UK HEIs. These search terms yielded 7 and 6 article results, respectively, of which only 2 articles were specifically related to the carbon footprint of a UK HEI, with the remainder being duplicates. Google Scholar was used in a bid to supplement the focused article results sought from ScienceDirect database. The search term used in Google Scholar was 'carbon footprint, UK Universities', whilst this yielded excessive number of articles, a quick review of the article titles (and abstract is several cases) for the first 20 pages of results, sorted by relevance, resulted in only 1 other focus article, bringing the total number of articles found to 3. Gu et al. quantified the carbon footprint of the University of Keele, Staffordshire [113]; Ozawa-Meida measured the carbon footprint for De Montfort University, Leicester [75]; and Townsend and Barrett derived the carbon footprint of the University of Leeds, Leeds [114].

The 3 articles relating specifically to estimating the carbon footprint of UK universities are reviewed with respect to the estimated carbon footprints and where possible the fossil fuel contribution to this, and emissions sources reported within the articles. The following section presents the findings of the review of these articles and a comparative table of the findings.

### 4.3. Findings and Discussion

The use of ScienceDirect database and Google Scholar search engine indicates that there are limited number of studies that have been undertaken to estimate the carbon footprint of UK HEIs within the context of academic literature and highlights the need for more academic studies of carbon footprints of UK HEIs.

The carbon footprints reported in the reviewed articles were calculated for different academic sessions and periods. Consumption-based methodology using LCA approach was employed in the calculations of the carbon footprint reported by Gu et al. for 2010/11 (Keele University) [113] and Ozawa-Meida et al. for periods 2005/06 to 2008/09 (De Montfort University) [75]. However, Townsend and Barrett used EEIO analysis based on financial data to derive the 2010/11 carbon footprint (Leeds University) [114]. In terms of corresponding actions to reduce their carbon footprints, some examples specified include onsite electricity generation by solar PV, installing building management systems, upgrading to energy efficient lighting, switch to electric vehicle fleet, and sustainable procurement measures [75,113,114].

The emission sources reported within the articles cover Scope 1, Scope 2, and Scope 3 emission sources. Whilst Gu et al. and Ozawa-Meida et al. reported identical Scope 1 and Scope 2 emissions, the breakdown of Scope 1 and Scope 2 emissions is not reported by Townsend and Barrett [75,113,114]. The review highlights the range of Scope 3 emissions reported within the articles particularly with the use of financial expenditure data as the basis for the EEIO analysis [114] and with procurement emissions [75]. The corresponding percentages of the different Scopes (1–3) vary considerably across the reviewed articles possibly due to a combination of the variations in methodology, period, or year for which the carbon footprint was calculated, and the operational boundaries unique to each HEI.

The contribution of fossil fuel associated emissions to the total reported carbon footprints within the reviewed articles was derived from the emission sources reported within the articles and include travel related emissions and use of natural gas for building heating. This was possible for the articles which used the consumption-based methodology which allowed for easy identification of fossil fuel related emission sources however, in the case of the EEIO methodology it this was not possible due to the range and merging of emission source categories based on institution spend. The fossil fuel share of emissions, 47% in the case of Gu et al. [113], and 36% in the case of Ozawa-Meida et al. [75] suggests the extent of reliance on fossil fuels within the affiliated HEIs. Table 2 compares the emission sources and carbon footprint of the reviewed articles, including the fossil fuel contribution where applicable, and the per student carbon footprints.

**Table 2.** Comparison of UK HEI Carbon Footprint Assessment.

| **Article** | **Emission Sources** | | | **Footprint** | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Scope 1** | **Scope 2** | **Scope 3** | **Scope 1 (%)** | **Scope 2 (%)** | **Scope 3 (%)** | **Fossil fuel Share (%)** | **Total ($tCO_2e$)** |
| Gu et al. [113] | Natural gas, Owned transport | Grid electricity, on-site generated electricity | Water supply, Wastewater treatment, waste disposal, Food procurement | 47 | 39 | 14 | 47 (Natural gas & Owned transport) | 14,393 (1.5/student) |
| Ozawa-Meida et al. [75] | Gas use & Owned fleet | Grid electricity | Procurement, Travel | 6 | 15 | 79 | 36 (Travel-related emission & Gas use) | 51,080 (2.4/student) |
| Townsend and Barrett [114] | None reported | None reported | Raw materials & chemicals, Food & drink, Paper & publishing, Manufactured products, Machinery & computers, Utilities & construction, Transport & communication, Business services, Public services. | 18 | 31 | 51 | None identified | 161,819 (5.3/student) |

The per student carbon footprint estimated in Table 2 was derived by dividing the carbon footprints by the student population as reported within the articles. Whilst this offers a means of comparing emissions per student it should be dine with caution considering that different methods of estimating carbon footprints, the vast scope of operational boundaries and emission sources reported, and the size of the HEI to mention a few. The per student carbon footprint for the reviewed articles show a range of 1.5 $tCO_2e$/student to 5.3 $tCO_2e$ highlighting the impact of student population on estimating carbon footprints.

## 5. Conclusions

The large-scale use of fossil fuels boosted industrialization and today it remains the principal source of energy consumption. Since inception of IPCC in 1988 it continues to be key in the growing acceptance of human induced climate change resulting mainly from burning fossil fuels. International action in addressing climate change and its associated issues led to global agreements such as the ‘Paris Agreement’. The UK regulates net reduction of GHG emissions through ambitious targets set by the Climate Change Act and other initiatives such as investment in low-carbon technologies and setting national policies and strategies. HEIs need to capitalize on their unique position at the center of global societies in raising awareness and in addressing the issues of reliance on fossil fuels causing climate change, to contribute to carbon emission reductions.

The role of carbon management practices in reducing GHG emissions to meet climate change targets is becoming increasingly necessary. Organizations are under increasing pressure to measure, record and report their carbon footprint. In practice, organizations use carbon footprint results to identify opportunities to reduce operational costs. LCA play an important role in carbon footprint calculations and two main approaches to performing LCA for carbon footprints currently being used are: bottom up (PA) and top down (IO). PA is better suited to micro systems such as individual or small groups of products or services but suffers from system boundary issues, i.e., site-specific, and a lack of consistency in reporting due to lack of control systems. IO on the other hand is better suited for meso (sector level) and macro systems, accounts for higher order impacts at the expense of site-specific detail and provides consistency in reporting due to effective control systems. The hybrid of both approaches is also often used for robust and comprehensive analysis and increases the reliability of carbon footprint estimates. However, HEIs can do more to improve carbon footprint estimations particularly those associated with Scope 3 emissions, and establish standardized models for accounting, measuring, monitoring, and reporting on fossil fuel emissions, in collaboration with other stakeholders.

The public sector has a pivotal role in reducing reliance on fossil fuels and GHG emissions through carbon management practices or enabling sustainable private companies through grants to reduce GHGs. Public sector organizations like HEIs have significant influence in research, education, and the social, economic, and environmental wellbeing of society. They equally are expected to be responsible as well as lead by example in reducing energy consumption, reducing reliance on fossil fuels, and tackling climate change to enable sustainable societies. Through legislation on climate change and sector specific requirements these organizations have implemented CMPs and emission reduction action plans. However, the appears to be an imbalance across the HEI sector as only a few of these organizations have a grasp of their GHG emission profile resulting from their operations and most face difficulty in achieving their reduction targets. Whilst HEIs differ in size and function, a uniform approach to carbon reduction across the sector in collaboration with the private sector, Government(s), and wider society, is necessary. The COVID-19 pandemic presents opportunities for HEIs to reconsider the model of how education is delivered taken account of potential issues that may arise, for example inequalities associated with online education delivery, and transfer of emissions from workplaces to homes.

As renewable energy technologies evolve with various modes of implementation, they are an important element in reducing GHG emissions and tackling climate change. Global climate and energy governance approaches include international and public sources of authority, public-private interventions, and private interventions. The private sectors role in global decision making with regards multi-stakeholder participation raises concerns of its potential autonomy in climate governance decisions in some quarters, citing lack of their legitimacy in decision making. Gaps in financing, research and policy making limit private sector investment in low carbon technologies. The public sector needs to strengthen its contributions in times of austerity and investment deficiency, improve its poor energy efficiency buildings, and limit financial gaps through a suitable finance ecosystem approach for low carbon investment by government. The UK Government recently demonstrated its commitment to accelerating green financing through the release of its first Green Finance Strategy with sets out how this ambition will be achieved however, sustained annual investment is required to bridge the financial gaps in green infrastructure investment.

**Author Contributions:** Conceptualization, Investigation and Writing—Original draft preparation: E.I., Writing—Review and editing: A.S.H. and I.M. Supervision: A.S.H. and I.M. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

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