University of Southampton

Faculty of Environment and Life Sciences

School of Geography and Environmental Science

Development of Culturally, Economically, Environmentally and Socially Acceptable Personal Carbon Budgets (4D-PCB)

by

Alice Brock

Thesis for the degree of Doctor of Philosophy

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Abstract

Climate change is a globally recognised crisis. Climate change is an emergency of such severity that efforts to reduce carbon emissions must come from all levels, government, industry, and individuals must all seek to reduce their emissions to combat climate change.

In the United Kingdom households are the largest contributors to carbon emissions, however current UK policies are ‘top down’ targeting businesses and industry but putting no limit on individual carbon consumption. Behaviour change is required in the public to reduce their carbon emissions. Several Personal Carbon Budget (PCBs) policy interventions have been proposed to reduce personal carbon emissions.

This thesis compared and analysed three main existing proposed models through a PESTLE framework alongside a newly proposed model in this thesis, Personal Carbon Allowance. The new model PCA was found to be the most appropriate model to reduce carbon emissions and ensure all individuals could meet their distinct needs. The similar Personal Carbon Trading model, due to its trading aspect is a regressive model, where those on higher incomes have an advantage. Carbon taxation is a regressive tax and both carbon taxation and carbon labelling have no ‘cap’ on emissions so cannot guarantee the required levels of carbon reduction.

A Multi-Criteria Decision-Making conjoint analysis study was undertaken to identify public preferences on carbon reduction behaviour across demographics and attitudes. Regardless of demographics or degree of ‘green’ attitude the public showed considerable preferences for ‘easier’ options that had lower potential to reduce emissions, than more burdensome changes such as changing their diet or personal travel which have higher potential to reduce emissions. Without an intervention the public seem unlikely to change their behaviour to the degree required to reduce their personal carbon emissions significantly.

A mixed methods carbon reduction behaviour diary study was undertaken to identify the motivations, barriers and challenges people encountered when attempting to reduce their carbon emissions. This study was based on the findings of the PAPRIKA study and using the same categories of behaviour. A new model was developed the CABDI model (CArbon Behaviour DIary model) to facilitate this study. Findings from this study showed the key barriers and challenges were convenience, habit, and consumerism rather than aspects outside of people’s control such as infrastructure. Education and awareness interventions were shown to only have short term effects on participant behaviour. Participants were concerned and anxious about climate change but showed minimal changes in behaviour across the period. However, participants reported a decrease in their carbon footprints from before and after the diary period, demonstrating that a self-monitoring intervention may have influence on carbon reduction behaviour.

As this thesis shows the public are unwilling to change the behaviours that would make the most significant emission reductions with a value-action gap between their stated green attitudes and behaviour. To change public behaviour a ‘bottom up’ policy may be required that enforces changes in behaviour. The only policy intervention identified that is socially just, does not have economic impacts on people on lower incomes, does not create barriers to certain goods or services, whilst delivering the required emissions reductions is the proposed new model Personal Carbon Allowance. As this model includes a hard cap on emissions, provided the cap is appropriate this model could reduce emissions significantly and become a key weapon in the fight to tackle the climate crisis.

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Research Thesis: Declaration of Authorship

Print name: ALICE BROCK

Title of thesis: Development of Culturally, Economically, Environmentally and Socially Acceptable Personal Carbon Budgets (4D-PCB)

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

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:-

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Definitions and Abbreviations

CL .... Carbon Labelling

CO_2 .... Carbon Dioxide

CO_{2e} .... Carbon Dioxide Equivalent

CT .... Carbon Tax

EDI .... Equality Diversity and Inclusion

ETS................................. Emissions Trading Scheme

G20 .... Group of 20 (intergovernmental forum of countries)

GHG .... Greenhouse Gas

GWP................................ Global Warming Potential

MCDM .... Multi Criteria Decision Making

NDC .... Nationally Determined Contributions

PAPRIKA .... Potentially All Pairwise RanKings of all possible Alternatives

PCA................................. Personal Carbon Allowance

PCB................................. Personal Carbon Budget – used to indicate personal carbon policy interventions for brevity in this thesis

PCT .... Personal Carbon Trading

SDG................................. Sustainable Development Goal

TEQ .... Tradable Emission Quota

UN................................... United Nations

List of Thesis-Related Outputs

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Guest on the BBC World Service Radio Programme 'The Climate Question' to discuss topic based on research published from thesis https://www.bbc.co.uk/programmes/w3ct5bk2

1. CHAPTER 1: INTRODUCTION

1.1. Thesis Structure and Signposting

This thesis is a research paper thesis, with three chapters presented as a published or publishable research paper, there may be content overlap in the introductory sections of these chapters.

The structure of this thesis is as follows:

Chapter 1. Introduces the subject matter and central challenges surrounding the climate crisis and personal carbon emissions alongside the policy and sustainability context of the thesis.

Chapter 2:. This chapter reviews the existing literature, provides justification for this study, and states the aims, objectives and originality of this thesis.

Chapter 3. “A PESTLE Review of Personal Carbon Budgets”

This chapter presents a PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis and review of existing personal carbon budget models and the proposal of a new model which is also compared and analysed. This chapter identifies and evaluates key features of the three currently proposed models and the new model, alongside reviewing the literature surrounding personal carbon budgets. Criteria were developed for analysis of each factor of the PESTLE framework and systematically applied to each model for critical analysis and evaluation.

This chapter was published as an article in a peer reviewed journal.

Chapter 4. “I’ll Take the Easiest Option Please’ Carbon Preferences of the Public”

This chapter presents an analytical hierarchy survey and attitudes survey utilising the PAPRIKA (Potentially All Pairwise RanKings of all possible Alternatives) method to the public exploring the preferences of the public in relation to changing their carbon emitting behaviour with analysis of their preferences in relation to their climate change awareness, attitudes, and their personal demographics.

This chapter was published as an article in a peer reviewed journal.

Chapter 5. “Understanding the Barriers and Challenges In Reducing Personal Carbon Emissions Using a Mixed Methods Approach”

This chapter presents a carbon diary study where participants recorded their behaviour over 28 days whilst attempting to reduce their carbon emissions, followed by a reflective piece by participants to explain their behavioural choices and trends. Before and after the behaviour recording activity participants took identical attitude and knowledge surveys based around personal carbon emissions and their perceptions of carbon reduction. Participants also completed a personal carbon footprint before and after the recording period. A new model of gathering and analysing environmental behaviours was developed the CABDI Model (CArbon, Behaviour, DIary Model) based on a mixed methods approach.

This chapter is currently undergoing the submission process to peer reviewed journals.

Chapter 6. This chapter presents a discussion and synthesis of findings from the three studies and literature review. This chapter identifies the key outcomes and the relation of these findings to the existing literature.

Chapter 7. This chapter presents the conclusions of this thesis and proposes future work to be done following this thesis.

Aims and Objectives of the thesis can be found in Section 2.10 in Chapter 2 following the review of the literature and explanation of the rationale of the thesis to provide context for the aims and objectives identified.

1.2. The Global Climate Change Crisis and Sustainable Development

Over 99% of the peer reviewed literature and all climate scientists agrees that anthropogenic climate change is real, based on comprehensive evidence that human activities are generating greenhouse gas emissions which is causing global warming and thus climate change (Calvin et al., 2023; Lynas et al., 2021; Oreskes, 2018). Global surface temperature ranged from 0.95 – 1.2°C higher in 2011 to 2020 than 1850 to 1900 with surface temperature increasing since 1970 to 2020 faster than any fifty-year period over the last two thousand years according to the most recent reporting by the International Panel on Climate Change (Calvin et al., 2023). Increasingly it is becoming apparent that there is no aspect of life on Earth, no life-giving system that will not be impacted by climate change and many are already being heavily impacted (United Nations Environment Programme, 2023). Human decisions, attitudes and behaviour around their consumption is having a direct impact on the rise of global greenhouse gas emissions, to bring emissions down to levels projected to limit the impacts of climate change there must be changes at all levels of responsibility (Chichilnisky and Heal, 1994; United Nations Environment Programme, 2023, 2020).

The term 'greenhouse gases' encompasses a multitude of gases, all greenhouse gases have the potential to contribute to global warming by absorbing heat in the atmosphere, usually in the form of solar radiation, instead of allowing it to be reflected out of the atmosphere. The most notable of these gases is carbon dioxide as globally this is the most emitted GHG although other gases may have higher global warming potential (Department for Environment Food & Rural Affairs, 2020; Intergovernmental Panel on Climate Change, 2018; National Statistics, 2020). Carbon dioxide is of such global importance as a GHG all other are measured as CO_ee (carbon dioxide equivalent). In 2019 the concentrations of CO_2 in the atmosphere were higher than any time in the previous two million years with methane (CH_4) concentrations at their highest in at least 800,000 years (Calvin et al., 2023).

It is estimated that the global GHG emissions in 2019 were 59.1 gigatons CO_2e a rise from previous years, and an above average percentage rise, from 2010 the average rise in emissions has been 1.4%, over 2019 the rise was 2.6%, this has been attributed to the high number of forest fires due to climate change (United Nations Environment Programme, 2020). There has been variability in global emissions during the COVID-19 pandemic, with reductions in global emissions, however it is widely projected that emissions began to return to previous trends (United Nations Environment Programme, 2023). For a limit of a 1.5°C temperature rise the

United Nations Environment Programme (2023) project global emissions need to be reduced to twenty-five gigatons annually CO_2e, a reduction of over half all-global emissions reaching net zero by 2050.

To develop sustainably GHG emissions need to reduce but with consideration of the impacts this may have on different nations and peoples. Emissions are not distributed equally across nations, currently or historically, and they vary in intensity across different demographic groups (Calvin et al, 2023.)

1.2.1. Greenhouse Gas Emission Sources and Climate Justice

Global greenhouse gas emissions are not equally distributed across nations. The global average per capita GHG emissions in 2019 was 6.9 tons (Calvin et al., 2023). In 2019 35% of the global population lived in countries with per capita GHG emissions of more than 9 tons, 41% lived in countries with less than 3 tons per capita GHG emissions and least developed nations emit an average of 1.7 tons GHG emissions (Calvin et al., 2023).The measurement of per capita emissions is complex and depends on if a consumer or producer methodology is used (United Nations Environment Programme, 2023). It is argued that nations which may produce high emissions through the production of goods that are exported to other end consumers should not bear responsibility for those emissions (Munksgaard & Pedersen, 2001; Vetoné, 2011). China has the highest contribution to GHG emissions; however, China holds 18% of the world population and has a high level of manufacturing (United Nations Environment Programme, 2023). The United States of America is the second highest emitter of greenhouse gases, emitting 11% of global emissions for 4% of the global population, by comparison India has 18% of the population but 7% of global emissions (United Nations Environment Programme, 2023). The United Kingdom is part of the G20 and territorially emits 1.1% of global emissions despite having 0.8% of the population, this is without the inclusion of emissions from goods imported for use and consumption (United Nations Environment Programme, 2023). 46.6% of the UK's overall carbon footprint comes from greenhouse gas emissions from imported goods (Department for Environment Food & Rural Affairs, 2024; Office for National Statistics, 2023; United Nations Environment Programme, 2020a, 2023). Therefore, the UK, whilst a small nation in terms of its population emits considerable per capita emissions.

The impacts of climate change globally are well documented, and the impacts of climate change are present in all global regions, however communities with historically low emission contributions are affected disproportionally, such as Small Island Developing Nations (Calvin et al., 2023; Dietz and Rosa, 1997; United Nations Environment Programme, 2023, 2020).

Examples of the impacts of climate change include reduced human health and wellbeing, heatwaves, droughts, tropical cyclones, food and water insecurity, ocean warming and acidification, glacial retreat, and mass mortality rates in species in the sea and on land (Calvin et al., 2023; Doherty and Clayton, 2011; Hunt and Watkiss, 2011; Pörtner et al., 2019; United Nations Environment Programme, 2023, 2020b).

Global climate change and carbon reduction polices generally recognise the varied contributions of nations to the climate change crisis in terms of historic and current emissions, setting differing targets in relation to a nation's assessed contribution to greenhouse gas emissions and responsibility. This is reflected in the assignment of countries to different annexes in policies such as the Paris Agreement (see sections 1.2.2.1 and 1.2.2.4).

Alongside variability in the general emissions driven by nations the distribution of contribution to greenhouse gas emissions is unequal across socioeconomic divides. The wealthiest 1% of the global population are responsible for 17% of the world's annual emissions (Stockholm Environment Institute, 2024). The wealthiest 10% are responsible for 50% of global emissions (Stockholm Environment Institute, 2024).

This imbalance of emission generation raises broad questions around where responsibility lies for reducing carbon emissions, globally and at the individual level. For those who already have benefited from considerable global emissions it is posited that they should bear far greater responsibility for emission reductions and contribute more heavily to aiding efforts to reduce emissions and supporting a just transition to a low carbon society and adaptation and mitigation to and of climate change.

1.2.2. International Climate Change Policy

International climate change policy has developed since the mid 20th Century, initial policy concerns focused on environmental issues with climate change and greenhouse gases less prevalent. Climate change was not a key topic of conversation and discussion on the First Environmental Summit in 1972. until discussions became more notable in the late 1970s leading to the formation of the Intergovernmental Panel on Climate Change in 1988.

A timeline of key events, conferences, bodies being established, and global policies can be found in table 1.1., this is not a comprehensive list of all global climate and environmental conferences.

Table 1-1 Timeline of relevant climate and environmental global policies and conferences

YEAR	
1972	First International Environmental Summit (Stockholm, Sweden)
1972	Establishment of United Nations Environment Programme
1979	First World Climate Conference (Geneva, Switzerland)
1988	Toronto Conference on the Changing Climate (Toronto, Canada)
1988	Establishment of the Intergovernmental Panel on Climate Change
1990	Publishing of the Intergovernmental Panel on Climate Change’s first assessment report
1992	UN Framework Convention on Climate Change opened for signatures
1992	UN Conference on Environment and Development (The Earth Summit) (Rio de Janeiro, Brazil)
1992	Annual Conference of Parties established
1994	UN Framework Convention on Climate Change enters into force
1997	Kyoto Protocol opened for signatures
2001	UN Millenium Goals Established
2005	Kyoto Protocol enters into force
2012	Adoption of Doha Amendment
2015	UN Sustainable Development Goals Established
2015	Adoption of The Paris Agreement

1.2.2.1. United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change was signed by 154 states in in 1992, at the UN Conference of Environment and Development. It is an international treaty which forms the UN's process for negotiation concerning limiting climate change. In 2022 the UNFCCC had 198 parties signed to the treaty.

The intent of the treaty is defined in Article 2:

"stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [i.e., human-caused] interference with the climate system"

(UN, 1992.)

The treaty was developed following the Intergovernmental Panel on Climate Change's First Assessment report, this report was published in 1990 and outlined the consensus of experts at the time on the threat of climate change.

Parties to the convention meet annually at the Convention of Parties.

The United Nations Framework Convention on Climate Change categorised countries into 'annexes' in relation to their responsibility related to greenhouse gas emissions they can be defined as the following:

Annex I: Industrialised countries, and countries defined as having economies in transition (changing from centrally planned to market).

Annex II: A subset of Annex I, this group includes the industrialised countries that had membership of the Organisation for Economic Co-operation and Development (OECD) in 1992 but largely not those with economies in transition. These countries are expected to lead on emission reductions due to their historic and current contributions to greenhouse gas emissions. Annex II countries are required to supply financial resources to developing countries to take emission reduction actions and to assist them in adapting to the impact of climate change. Alongside this they are expected to promote the transfer and development of relevant technologies to countries with economies in transition and developing countries

Non-Annex I: The majority countries are defined as 'developing' . Non-Annex I countries that have been classified by the UN as Least Developed Countries (LCDs) have special consideration under the Convention due to their limited capacity to adapt to the impacts of climate change. The Convention urges other parties to take account of this circumstance in relation to funding and technology transfer.

The United Kingdom is an Annex II country.

(UN, 1992).

Annex I countries are expected to contribute most highly to emissions reductions due to their historic and current responsibility for greenhouse gas emissions.

1.2.2.2. Intergovernmental Panel on Climate Change and Assessment Reports

The Intergovernmental Panel on Climate Change (IPCC) provides science-based assessments and recommendations on climate change, they publish regular assessment reports, each assessment report is developed during a cycle, during that cycle additional reports may be released. The IPCC was established in 1988 by the UNEP and the World Meteorological Organisation (WMO) and then endorsed by the UN (Intergovernmental Panel on Climate Change, 2024). The organisation consists of governments that are members of the UN or WMO, currently there are 195 member nations of the IPCC (Intergovernmental Panel on Climate Change, 2024).

The IPCC has four main groups:

i) The Task Force on National Greenhouse Gas Inventories
ii) Working Group I: The Physical Science Basis of Climate Change
iii) Working Group II: Climate Change Impacts, Adaptation and Vulnerability
iv) Working Group III: Mitigation of Climate Change

There are additional Task Groups that can be established to work on a specific area for a designated period of time by the IPCC (Intergovernmental Panel on Climate Change, 2024).

Assessment reports are authored by experts volunteering their time to assess the existing literature and summarise the drivers, impacts and future risks of climate change alongside information about adaptation and mitigation. IPCC reports do not include research conducted by the IPCC but are a synthesis and summary of existing scientific works. Experts are selected following nomination by governments and observer organisations, composition of author teams are carefully considered to ensure a wide range of scientific, technical and socio-economic backgrounds are reflected, alongside gender and seniority (Intergovernmental Panel on Climate Change, 2024).

At the time of writing six assessment report cycles have taken place with six assessment reports produced. The cycles of reporting vary but are often between six and seven years, the panel selects experts from across the globe to contribute to each report.

The Assessment Reports are considered the most comprehensive scientific reports on climate change. The IPCC is an advisory body to governments with no direct policymaking pathways; however, the assessment reports play crucial roles in supporting policy, the fifth assessment report (AR5) informed the Paris Agreement, and the targets set. Additional special reports, methodology reports and technical papers are also produced by the IPCC, the IPCC special report on Global Warming of 1.5 ºC published in 2018 had a global impact on reframing the depth of the challenge and influencing policy and international, national and local targets and goals.

1.2.2.3. The Kyoto Protocol and Doha Amendment

The international treaty the Kyoto Protocol committed parties to the reduction of six initial greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6). The later Doha amendment amended the list of greenhouse gases to include nitrogen trifluoride (NF_3).

The Kyoto Protocol's first commitment period was 2008-2012, the Doha Amendment was the commitment to a second period 2013-2020. Following negotiations on future commitment periods the Paris Agreement was developed, signed and came into force, rather than the development and commitment to a new period of the Kyoto Protocol.

Despite the targets set through the Kyoto Protocol and Doha Amendment greenhouse gas emissions have risen globally.

1.2.2.4. The Paris Agreement

The Paris Agreement is the largest and most recent global international treaty relating to climate change, and the only international treaty on climate change that is a legal instrument, however there is no direct enforcement to ensure compliance with the treaty, raising questions regarding its strength as the primary mechanism to tackle global emissions (Sanderson et al. 2016). The Paris Agreement sets the goal to limit:

"…the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels."

(UNFCCC, 2021).

Signee nations to the treaty submit plans for GHG reductions termed nationally determined contributions (NDCs), alongside the NDCs nations are expected to have submitted long-term low greenhouse gas emission development strategies (LT-LEDS) to frame efforts for the long-term goal of temperature reduction (UNFCCC, 2021). The Paris Agreement has a five-year cycle, with NCDs submitted for each five year period. Each NDC is intended to be more ambitious than the last (UNFCCC, 2021). Table 1-2 outlines the details of these commitments.

Table 1-2 Table outlining commitment structures of the Paris Agreement

COMMITMENT	DETAIL
NATIONAL DETERMINTED CONTRIBUTIONS (NDCS) **MANDATORY**	- Countries communicate the actions they intend to take to reduce their GHG emissions, with the view to achieve the targets of the Paris Agreement. NDCs also set the intended actions by countries for the actions they intend to take in order to develop their resilience to adapt to climate change and its impacts. (UNFCC, 2021). - NDCs are expected to become more ambitious each five year period under the Paris Agreement 'Rachet Mechanism'* where setting a new NDC previous efforts and the current context must be considered to set a new more ambitious goal. *Note it is not referred to as the Rachet Mechanism in the Agreement itself but is a term used in other publications and within the relevant sectors and bodies.
LONG TERM LOW GREENHOUSE GAS EMISSION DEVELOPMENT STRATEGIES (LT_LEDS) **VOLUNTARY**	- Countries are invited to submit strategies with a long term view of reducing their carbon emissions. - These are not mandatory for signatories unlike the NDCs.

Signee nations define their own NDCs and LT-LEDS, but it is expected that these targets will be realistic in terms of temperature reduction and reducing GHG emissions. Not all nations are signees to the treaty with only seven countries currently unsigned.

Current modelling however indicates that even with existing plans and commitments that the global temperature is expected to rise by 3.2^{o}C and more stringent commitments are required to meet the Paris Agreement's targets (Höhne et al., 2017; Sanderson et al., 2016; Tanaka and O'Neill, 2018; United Nations Environment Programme, 2020). Greater targets and more ambitious actions than the Paris Agreement are often proposed by climate scientists and activists to reduce GHG emissions to an acceptable level, with criticism that the agreement will not achieve its goals (Kühne, 2019; Rogelj et al., 2016; Sanderson et al., 2016).

Whilst the Paris Agreement is a legal agreement it lacks methods of enforcement or repercussions. Some nations may have codified their contributions in law, but this is not a requirement of the treaty, as such the treaty relies upon pressure from other nations and the public to keep nations on target (UNFCCC, 2021). The lack of enforcement, and NDCs that are currently not deep enough to cut emissions to keep temperatures below 2^{O}C has led to suggestions in the literature that further policies should be developed, both global and national to reduce emissions (Kühne, 2019; Rogelj et al., 2016; Sanderson et al., 2016).

Every five-year period the Paris Agreement Global Stocktake Outcome is completed, this mechanism provides information on the progress towards the Paris Agreements targets. It allows parties to take inventory of the efforts made to that point and reflect on the trajectory those efforts set us upon in relation to the targets. Information submitted to the stocktake includes NDCs, case studies and reports.

1.2.2.5. United Nation Sustainable Development Goals

The seventeen United Nations Sustainable Development Goals were created as a call for global peace and prosperity through sustainability and came into force in 2015 (United Nations, 2020). These goals span a huge array of global concerns, from human wellbeing to climate change, each with specific targets and aims. The goals were set with the intention all goals and targets would be achieved by 2030. The sustainable development goals (SDGs) are a set of ambitions and targets for UN member nations based on the initial Millennium Development Goals. Following the adoption of the outcome document 'The Future We Want' in 2012 at the United Nations Conference on Sustainable Development (Rio+20) the process to develop the SDGs was initiated (United Nations, 2020). In 2015 'Transforming our world: the 2030 Agenda for Sustainable Development' was adopted, this agenda included the seventeen SDGs as a principal component of the document (United Nations, 2020).

Each goal presents an overall area of sustainable development and then each goal has a series of associated targets to achieve each SDG, each target has clear official indicators of progress on each target. The SDGs are not legally binding, there are no penalties for not complying with the goals or the spirit of the goals or reaching targets or indicators. As shown in table 1-4 the Sustainable Development Goals span all dimensions of sustainability and across all goals have 169 unique targets covering a vast range of sustainability challenges (United Nations, 2020). Each nation reports annually on their progress towards their targets and indicators with annual reports generated on global progress.

1.3. The United Kingdom and Climate Change

Greenhouse gas emissions can arise from numerous sources and demands, consumer expenditure is the largest contributor to GHG emissions in the UK (Figure 1-2). Any reduction in carbon emissions will need to include reductions in the general public's consumption alongside any other policies that target industry. In Figure 1-2 household emissions are included under consumer expenditure alongside personal transport, consumer expenditure emissions have remained consistent over the depicted time period (Office for National Statistics, 2024), despite reductions in the energy and transport sectors.

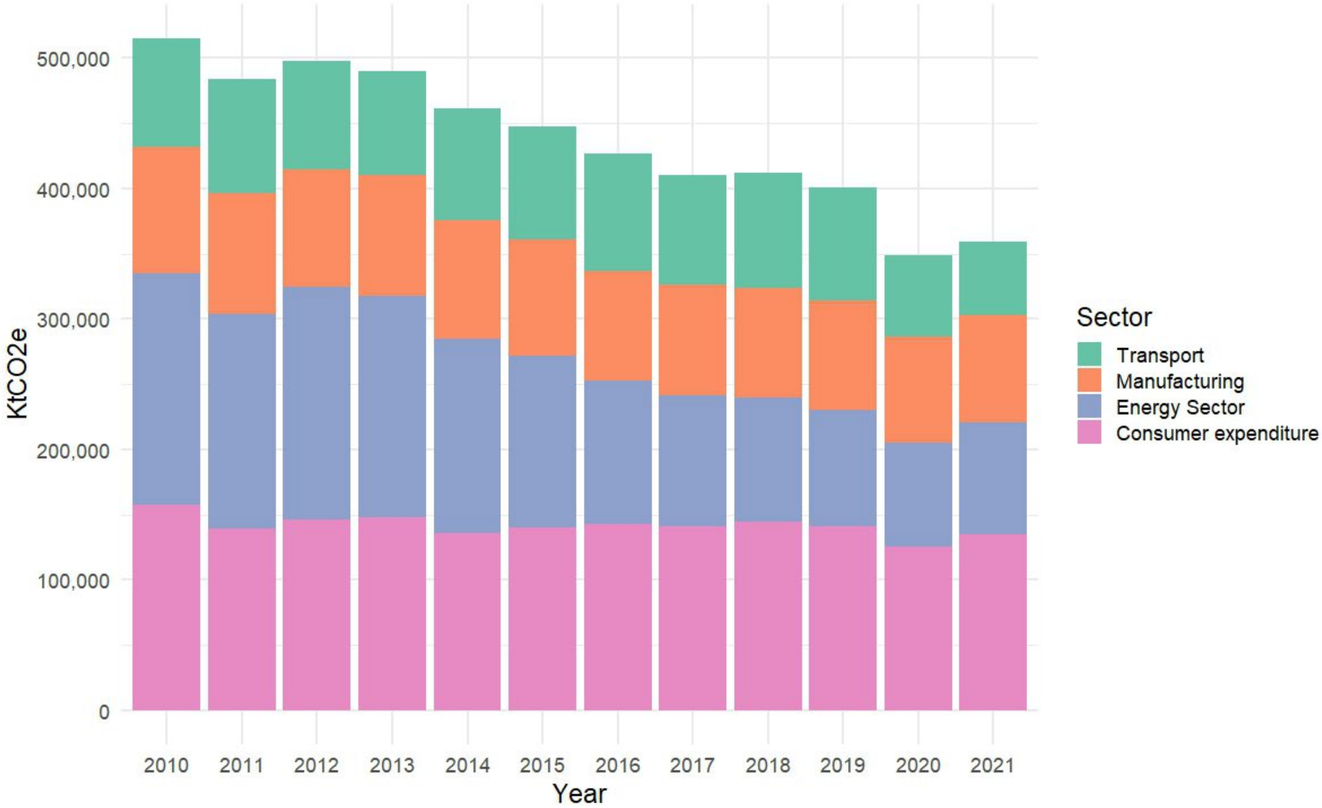

Figure 1-1UK GHG emissions 2010 – 2021 by sector data from Office for National Statistics, (2024).

As households are the biggest contributor to carbon emissions in the UK it is vital to comprehend the sources of these emissions to develop policies by which they can be reduced. The biggest sources of personal/household emissions are household heating and energy demands, transport (personal and public) and food and drink, although other sources such as personal electronics and household equipment purchasing show considerable GHG emissions (Department for Environment Food & Rural Affairs, 2020). Waste disposal, collection and processing is estimated to generate 5% of the UK's GHG emissions (Department for Business Energy and Industrial Strategy, 2020). Some GHG emissions are unavoidable, such as those generated by hospital services or education, and the burden of aiming for GHG reduction in these services would fall to the government rather than personal reductions. However, many emissions can be directly influenced by the public and changes in their consumption behaviour, especially those within the household (United Nations Environment Programme, 2023).

1.3.1. UK Carbon Policy

The United Kingdom is a signatory and participant in the global policies outlined in section 1.2.2. although these are not policies with penalties and non-compliance is not punished. However, the targets, agreements and NDCs the United Kingdom is party to inform its policy and policy development.

The United Kingdom submitted a NDC in accordance with the Paris Agreement of a 68% reduction in greenhouse gas emissions from 1990 levels by 2030. This commitment potentially shapes the ambitions and policies of the government leading up to the target year.

In 2024 the Prime Minister of the UK stated the reduction target for the United Kingdom is 81% emissions by 2035 compared to 1990 levels. This was announced during COP29 and before the UK submitted its next, and more ambitious, NDC. This figure was announced following correspondence between the UK government and the Climate Change Committee who recommended the NDC (Climate Change Committee, 2024). This target does not include international aviation or shipping (Climate Change Committee, 2024).

Within the United Kingdom there are several key policies, targets, schemes and strategies that outline the United Kingdom's government's approach to climate change and reducing greenhouse gas emissions.

1.3.1.1. UK Climate Change Act 2008

The Climate Change Act (2008) sets the UK's approach and agenda for its response to climate change, it sets requirements for greenhouse gas reductions and adaptations to climate change impacts (Parliament of the United Kingdom, 2024). The Climate Change Act establishes the UK's current planned 'pathway' to achieving its emission reduction targets. A central part of the

Act is the establishment of the Climate Change Committee, this committee is in place to ensure all targets are assessed independently and evidence based, the committee provides advice on climate change risks and monitoring and assessment on adaptation actions and progress within the UK (Parliament of the United Kingdom, 2024). The act requires the UK government to set carbon budgets for every five years, these are legally-binding budgets which cap the amount of GHGs to be emitted in the UK over the five year period. However, the budgets themselves are set at least twelve years before the budget start, allowing time for implementation of strategies, policies, and adaptations to achieve the budgets (Parliament of the United Kingdom, 2024).

A UK Climate Change Risk Assessment is required by the Act to be produced every five years, assessing risks both present and future, alongside the requirement for a National Adaptation Programme to be produced for England (devolved nations produce their own versions of this programme) (Parliament of the United Kingdom, 2024).

The Climate Change Act of 2008 had the original target of an 80% reduction in emissions from 1990 levels by 2050, with The Climate Change Act 2008 (2050 Target Amendment Order) 2019 becoming the legal act that commits the UK government to the reduction of GHG emissions by at least 100% of the levels of emissions in 1990 by 2050 (Net Zero by 2050).

The Climate Change Committee propose recommended pathways in Carbon Budget Reports, these are advisory reports, the government is not under legal obligation to undertake the proposed budget (Parliament of the United Kingdom, Climate Change Committee 2019). The most recent proposed budget is the 6th Carbon Budget which advised a 78% reduction in emissions from 1990 levels by 2035, it also recommended key steps to take to reach this target:

- Low Carbon Solutions – the adoption by the public and businesses of lower carbon options such as electric vehicles, renewable energy use across the grid, the replacement of gas boilers and the capture and storage of carbon.
- Expansion of Low Carbon Energy Supplies – an increase in wind power and low carbon hydrogen scale-up.
- Reduce Demand for High Carbon Activities – insulation of homes, dietary change and a reduction of meat consumption, fewer car miles and less flights.
- Greenhouse Gas Removal – a change in the agricultural system, a significant increase in woodland and restoration and maintenance of peatlands.

(Climate Change Committee, 2020).

Many of these changes are cross-sectoral, requiring changes to infrastructure, services, industry and public behaviour and consumption.

1.3.1.2. UK Net Zero 2050

In 2019 the UK Government signed into law the requirement to bring its emissions to net zero by 2050. Net zero means that considering sources and sinks the UK emissions would be recorded at zero, this is not the same as zero emissions due to the usage of sinks or offsetting (Climate Change Committee, 2019).

The previous target was a reduction of at least 80% reduction from 1990 levels. In 2021 the UK Government published its Net Zero Strategy in two parts ; 'Net Zero Strategy: Build Back Greener' and 'Net Zero: Powering Up Britain', these documents outline the strategy, targets, and framework for the UK's plan to achieve Net Zero emissions by 2050 (Department for Energy Security and Net Zero, 2023; UK Government, 2021). To meet this target various strategies have been implemented, such as an end date on the sale of new petrol and diesel cars, support for alternative home heating and commitments to increased renewable energy capacity (Department for Energy Security and Net Zero, 2023; UK Government, 2021).

1.3.2. UK Carbon Valuation

The UK government agrees a set of carbon values to be used in policy and updates the short term traded carbon values using market data and assumptions, these figures are used in modelling related to the UK Emissions Trading Scheme. Valuing carbon also allows the UK government to understand the impacts of policy interventions on greenhouse gas emissions (Department for Energy Security and Net Zero, 2021). These carbon values are used in appraisals of policy interventions including cost – benefit analyses.

Values are updated annually and the approach taken when assessing and updating the UK carbon values must fulfil four criteria:

- Consistent with UK's national and international climate commitments
- Simple and transparent
- Evidence-based
- Pragmatic values and allow for effective decision making

(Department for Energy Security and Net Zero, 2021).

In 2009 the method of updating the values was moved from a 'social cost of carbon' approach to a 'abatement cost' or 'target consistent' cost, the social cost of carbon was tied in part to the European Union Emissions Trading traded carbon costs (as the UK was then part of the European Union) in sectors under the EU-ETS, and non-traded cost for those that did not fall under this scheme (Department for Energy Security and Net Zero, 2021).

The target-based approach allows for carbon values to be directly tied to the commitments made by the UK, such as the Paris Agreement commitments and NDCs, domestically the carbon values can be tied to targets set under the Carbon Budget Levels.

Carbon values are based on a variety of evidence sources, evidence from internal governmental modelling and IPCC modelling and evidence, the carbon values are based on global abatement costs not UK specific abatement costs (Department for Energy Security and Net Zero, 2021). It is important to note that despite using internationally evidenced data set on modelling that underpins the IPCC assessment reports there is reasonable uncertainty in the modelling and different approaches to the modelling produces different carbon price trajectories, different assumptions, different future impacts such as population growth or economic instability lead to a range of predicted carbon price trajectories which are not in full alignment with the UK's climate commitments (Department for Energy Security and Net Zero, 2021). A fully accurate carbon value or price that will guarantee the achievement of the UK's climate targets is not currently possible under the modelling currently undertaken.

Actual carbon prices in the UK fluctuate depending on the market, demand and supply through the UK Emissions Trading Scheme.

1.3.3. UK Emissions Trading Scheme (UK- ETS)

Following the United Kingdom's exit from the European Union its participation in the EU ETS was withdrawn and a UK ETS developed, Northern Ireland remains in the EU ETS. The UK ETS came into force in 2021, and is established through The Greenhouse Gas Emissions Trading Scheme Order 2020 (Department for Energy Security and Net Zero, 2024). Emissions allowances for certain sectors are auctioned annually, and traded between participants, with the cap on allowances decreasing each year in an effort to reduce emissions generated, if allowances are exceeded the organisation will be fined per tonne over the allowance (Department for Business Energy and Industry Strategy, 2024). A portion of emissions allowances are allocated for free to stationary installations based on these installations submitting applications for free allowances (Department for Business Energy and Industry Strategy, 2024)

The UK ETS applies to;

i) Energy intensive industries

ii) The power generation sector

iii) Aviation

iv) Activities involving combustion of fuels in installations with a total rated thermal input exceeding 20MW (except in installations for the incineration of hazardous or municipal waste).

v) Activities in Schedule 1 (for Aviation) and Schedule 2 (for stationary installations) of the Greenhouse Gas Emissions Trading Scheme Order 2020.

(Department for Business, 2020; Department for Business Energy and Industry Strategy, 2024; Department for Energy Security and Net Zero, 2024).

If an organisation carries out an activity that falls within the UK ETS scope, they must hold a relevant greenhouse gas emissions permit. Hospital permit, small emitter permit for installations or have an emissions monitoring plan, these permits are distributed by UK ETS regulators (Department for Business Energy and Industry Strategy, 2024).

Caps on allowances of emissions are set each year and under review and consultation to ensure allowances trajectory is consistent with commitments to emission reductions within the UK (Department for Business Energy and Industry Strategy, 2024). The effectiveness of the UK-ETS in reducing emissions relies on the calculation and setting of the emissions cap and that it is developed with the UK's climate commitments fully considered.

Volatility in the carbon market may have impacts on the efforts of companies to decarbonise, if a price crashes they may be decentivsed to reduce emissions to then sell surplus credits, this may also impact government revenue if prices are low.

Changes to the UK-ETS have been proposed, with the UK-ETS Authority putting forward its intent to move the maritime sector into the scope of the UK-ETS, two other key proposed changes is the potential to recognise non-pipeline transport for carbon capture and storage, and to remove excess free allowances for businesses that cease activity (only in their final year of activity).

1.3.4. UK Behavioural Insights Team

In the UK in 2010 The Behavioural Insights Team (BIT), also known unofficially as the Nudge Unit, was established by the Government to develop Nudge Theory based projects (The Behavioural Insights Team, 2020). Interventions devised by this Team have been used across different United Kingdom strategic aims and has been considered a viable methodology by policymakers in 2020 to adjust public behaviour as a less intrusive policy intervention.

Nudge Theory has been applied to environmental goals by the BIT, BIT alongside other partners published a guide to providing green nudges on university campuses (United Nations Environment Programme et al., 2020). This included suggesting fees for using disposable coffee cups or sustainability commitment pledges for students, these nudges are either voluntary or provide some kind of incentive or minor penalty, such as a nominal cost for using a disposable cup.

1.4. Policy Instruments

There are several key types of policy instrument that are utilised in policymaking and design. Table 1-3 summarises several types of policy instrument commonly used.

Table 1-3 Summary of policy instrument mechanisms

POLICY INSTRUMENT	SUMMARY	SOURCES
PURSUASIVE/ INFORMATIONAL	- Informational instruments provide information this may be the government providing information to another body or the body providing information to the government. - Low implementation cost - When economic incentives are lacking informational instruments are less effective.	Bengtsson et al, 2010, Sterner, 2003
MARKET BASED	- Market based instruments create market based incentives to comply with certain practices and behaviours such as economic incentives. - Can include adjusting resource prices to reflect the societal and environmental costs to reduce potential overuse due to cost. - May include tradable permit schemes and deposit-refund schemes. - Changing behaviour/ activity is not mandatory but incentivised. - Different bodies may be impacted differently depending on unique circumstances. - Impacts can be unpredictable as there are not regulatory standards on change.	Bengtsson et al, 2010, Stavins, 2000
COMMAND AND CONTROL	- Command and control instruments have been present in the policy landscape for a considerable time. - Many environmental policies are command and control instruments, mandating or prohibiting certain actions, activities or behaviours (i.e discharge of untreated waste water into certain water courses). - There is often a regulatory body that manages compliance and mechanisms for monitoring and punishing or sanctioning non-compliance. - Industry is often hesitant to support or submit to command and control policy instruments and argue they do not take the specifics of each unique company into account. - There are three general categories of command and control instruments: Quality Standards, Technical/ Emissions Standards and Restrictions and Bans.	Bengtsson et al, 2010, Stavins, 2000, Stavins 2003
VOLUNTARY INSTRUMENTS	- Voluntary instruments promote change through voluntary engagement and action - These may be voluntary agreements these may be unilateral agreements, private agreements or negotiated agreements	Bengtsson et al, 2010

Selecting the appropriate policy instrument for a policy ambition is imperative to achieving the desired result as each instrument may lead to different engagement and outcomes.

Environmental and carbon emission policies span the range of the different policy instrument models. An intervention such as monitoring the discharge of untreated water with a penalty for violating set levels would be a command-and-control intervention, the UK-ETS is a market based intervention.

1.5. Carbon Accounting

Greenhouse gas emissions for goods, services and processes are measured to represent the overall 'footprint' of the subject. The term footprint does not mean an area of land or tangible physical space, but has come into common parlance as a term for the overall emissions or impacts of a good or service. Carbon Footprinting is based on life cycle assessment principles, that an audit of the inputs and outputs of a good, service or process must be accounted, and these inputs and outputs analysed for their environmental impacts (Williams et al., 2012; Wright et al., 2011).

(Wright, Kemp and Williams, 2011) propose three distinct definitions for different types of GHG account or inventory.

i) The carbon footprint which includes CO_2 and CH_4,
ii) The climate footprint that includes the Kyoto Basket GHGs,
iii) The GHG inventory which includes all GHGs and other air pollutants such as particulate matter and aerosols.

1.5.1. Carbon Footprinting

(Wright, Kemp and Williams, 2011) define a carbon footprint as:

"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_2e using the relevant 100-year global warming (GWP100)."

This definition only includes the two most common carbon based GHGs rather than the broader collection of GHGs, these gases contribute the majority of GHG emissions in the UK, 11% of UK GHG emissions are CH_4, 81% are CO_2 (National Statistics, 2020). Globally GHG emissions follow this pattern with these two gases being the main GHG gases emitted annually (United Nations Environment Programme, 2020). A carbon accounting method that captures these two gases alone would account for the majority of global GHG emissions.

Calculating a carbon footprint requires decisions to be made around the required scope for the purpose of the carbon footprint, such as which emissions Scopes should be included, particularly with consideration of the challenges surrounding gathering Scope 3 emissions data (Liora et al., 2023; Williams et al., 2012; Wright et al., 2011). This will depend on the purpose of the carbon footprint, the data and resource availability. A carbon footprint can be calculated simply using estimates, for example miles travelled in a vehicle multiplied by an emissions factor for the unit of distance travelled for that class of vehicle (Williams et al., 2012). Online carbon footprinting tools employ this type of methodology, using generalised information to give an approximate and comparable footprint which requires low resources and unspecific data (WWF, 2021). A carbon footprint can also be calculated using specific data, directly measured emissions from the vehicle by a monitoring device over the journey in the scope of the footprint, giving a highly specific footprint for that individual activity (Williams et al., 2012). Carbon footprints are used across varying scales, from footprints created for an individual to footprints generated for entire nations.

1.5.2. Climate Footprinting

A climate footprint incorporates additional gases to a carbon footprint, including further greenhouse gases: hydroflurocarbons, nitrous oxide, perflurocarbons and sulphur hexafluride (Williams et al., 2012; Wright et al., 2011). A climate footprint requires more comprehensive emission data than a carbon footprint, requiring a higher level of monitoring equipment, expertise, and calculation.

1.5.3. GHG Inventory

A GHG inventory includes all GHGs and any other airborne pollutants that may have some influence on climate change or air quality such as particulate matter or contrails (Wright et al., 2011). A GHG inventory is the most comprehensive air pollution accounting model, however due to its expansive scope gathering reliable data for all included pollutants would be costly and complex (Wright et al., 2011). Some pollutants included are present in the atmosphere in incredibly low amounts or are only relevant for specific goods or processes (for example some goods will generate no contrails due to involving no air travel) (Wright et al., 2011).

1.6. Carbon Pricing

Carbon pricing is when a financial (or other) cost on greenhouse gas emissions is created, it uses market mechanisms to put the cost of emitting greenhouse gases onto those who are responsible for their emission. This aligns with the 'polluter pays' principle, that the body who caused the pollution or emission is responsible for it and its impacts. The UK-ETS is an example of a carbon pricing instrument.

Currently there are three main identified carbon pricing instruments, a carbon tax, cap and trade and hybrid methods that combine the two former policies. Additional to these policies are voluntary schemes like carbon offsetting, or schemes such as Green Certificates where participants pay for energy generated by renewable technologies. There are varying levels of implementation across these instruments globally, and varying degrees of political will towards adoption of them globally.

1.6.1. Carbon Tax

A carbon tax is most frequently a tax per weight of carbon emitted in production of a good or service by a firm, although there may be other methods of calculation on how the carbon tax is calculated. This tax is paid 'upstream' by the fuel extraction companies, the tax costs may then be passed on to consumers (Sorrell, 2010). A carbon tax is a simple method of carbon pricing, the intention of a carbon tax policy is to reduce carbon emissions by increasing the price of carbon intensive fuels and thus reducing the demand for them (Akkaya and Bakkal, 2020).

1.6.2. Cap and Trade

Cap and trade (emissions trading systems) is at the 'other end of the scale' from a carbon tax. An emissions trading system (ETS) has an overall cap on emissions emitted, usually annually, this cap is either on the overall weight of emissions or intensity of emissions emitted (Narassimhan et al., 2018). On a global scale this may be measured as emissions of GHGs per unit of GDP. The GHGs included can vary, for some there is a wide inventory of GHGs, others focus only on carbon dioxide (Aldy and Stavins, 2012; Narassimhan et al., 2018). Once a cap has been established, a government will allocate or auction allowances to firms, these can be allocated for free, but a for-pay auction system can also be used to distribute all or some of the allowances equal to the cap (Aldy and Stavins, 2012). There is also trading permitted between firms, often this is only during a set period and any remaining allowances are surrendered back to the government (Aldy and Stavins, 2012; Narassimhan et al., 2018).

Domestic Tradable Quotas (also known as Tradable Emissions Quotas), a form of cap-and-trade scheme proposed by Dr David Fleming (1997), has carbon credits allocated to all adult individuals and organisations rather than one or the other (Fleming, 1997; Fleming and Chamberlin, 2011; Starkey and Anderson, 2005). Organisations must purchase carbon credits, adults are allocated them for free and can trade surplus credits to other individuals on a central carbon market (Starkey and Anderson, 2005). Fleming and Chamberlin (2011) in their report to the All-Party Parliamentary Group on Peak Oil assert that using a TEQ framework means CO_2 emissions would not need to be measured, carbon emissions would be accounted for by the carbon attributed to certain goods and services whose use would be recorded.

TEQ models propose a set countrywide carbon budget set by the government, usually a relevant independent statutory government body – such as the Climate Change Committee (CCC) in the UK, this budget would then be divided into permit/ credit allocation for the public (Entitlement) and for industry/ other organisations (Tender) (Fleming and Chamberlin, 2011). Tender would be auctioned to banks and brokers on behalf of industry/ services/ Government, revenue from the auction would be claimed by the government and could be invested in reducing fossil fuel dependence and funding ‘green' energy solutions (Fleming and Chamberlin, 2011; Starkey and Anderson, 2005).

These emissions trading systems have been implemented in several countries, cities, and states/ counties, these span across Europe, Asia, and America (Betsill and Hoffmann, 2011). In the early 2010s it had been hoped and anticipated that cap and trade would become a central part of global carbon reducing policy, however various roadblocks hindered this, including widening political divisions in the American Senate (Betsill and Hoffmann, 2011). However, some states in America have adopted cap and trade policies despite an overall lacklustre response to them nationally. Following the failure of legislation relating to cap and trade nationally, California adopted limits on GHGs and a cap-and-trade model (Barringer, 2011). This cap-and-trade legislation was extended in 2017.

California's cap and trade model includes free allocation and an auction system, the free allocation was a focus in the earlier part of the program transitioning to an auction system particularly for large industrial facilities (California Environmental Protection Agency, 2015). The cap amount is set to decline by a set amount each year compared to the projected GHG emissions for the state. Trading is allowed as is banking of allowances to protect against shortages and price swings (California Environmental Protection Agency, 2015). Carbon offsetting is also included in California's model, allowing up to 8% of a facility's emissions to be offset, offsets are limited to those in the USA and must be independently verified (California Environmental Protection Agency, 2015). California's cap and trade model is an example of this policy working outside of a national context, the policy has found moderate success with a 5% reduction in GHG emissions between 2013 and 2017 (Centre for Climate and Energy Solutions, 2020).

Issues have arisen in discussions around regional cap and trade programs and policies, this can be in the form of 'leakage,' the import of electricity to a region under a cap-and-trade program from an area which does not have such a program or limit (Caron et al., 2015). Imports of other goods or services could also result in such leakage, the state or region may be causing more GHG emissions than the cap allows due to imports from other areas (Caron et al., 2015). The Californian model of cap and trade includes imported electricity in its cap, this is likely to reduce leakage significantly even allowing for the import of goods from unregulated regions (Caron et al., 2015).

Hybrid methods of carbon pricing combine cap and trade and carbon taxation, this may mean the cap and trade program has a carbon price floor or ceiling (Goulder and Schein, 2013). Another hybrid method would be a carbon taxation policy in place alongside a cap-and-trade program, integrating the two policies so a financial cost is paid, and a body is still assigned or purchases a cap on emissions (Narassimhan et al., 2018).

1.6.3. Carbon Offsetting

Carbon offsetting is a scheme that exists for those who generate carbon emissions through their consumption and energy usage to 'repay' the carbon emitted by paying for carbon emission reduction or sinks through another organisation. This may consist of actions such as paying a company to plant trees that would function as a carbon sink for the equivalent amount of carbon as that one generated (Araña and León, 2013; Hyams and Fawcett, 2013; Lovell et al., 2009).

Carbon offsetting is utilised by parties such as businesses or companies that must comply with GHG reduction targets, they may generate the same emissions but then theoretically lower these emissions with offset credit purchasing equivalent to their emissions (Corbera et al., 2009). Individuals can also use offsetting and various organisations offer it as a service to customers as a feature, for example stating their product is carbon neutral due to their involvement with an offsetting scheme.

Carbon offsetting is criticised for several key reasons.

i) Concerns over accuracy of the emission reductions promised and monitoring and reporting of these reductions

ii) Concerns on if promised carbon offsetting actions would take place, of if credits assigned are ‘ghost’ credits with no true emission reducing action taking place

iii) Carbon offset may not be equivalent to carbon emitted (i.e temporally or geographically)

iv) Carbon offsetting may encourage the public and industry to maintain ‘business as usual’ and not pursue carbon reducing changes to behaviour or processes

v) Carbon offsetting practices are inconsistent and not standardised across the industry

vi) Socioeconomic impacts are often not adequately addressed by scheme methodologies, particularly in forest offsetting schemes

(Anderson, 2012; Cavanagh and Benjaminsen, 2014; Corbera et al., 2009; Dhanda and Hartman, 2011; Hyams and Fawcett, 2013; Johnson et al, 2024, Lovell and Liverman, 2010; Pan et al, 2022 Watt, 2021, Wittman and Caron, 2009).

Whilst the current peer reviewed literature landscape has considerable criticisms of carbon offsetting and recent scandals related to the overstatement of emissions offset by large scale schemes carbon offsetting has been noted to have some beneficial applications depending on implementation (Jones et al, 2024, Johnson et al, 2024, Watt, 2021). Carefully managed carbon offsetting schemes do lead to carbon sequestration, although this varies in cost per tonne sequestered some methods of implementation can be as low as £0 per tonne (Jones et al, 2024). Carbon offsetting can improve biodiversity and create long term carbon sinks depending on the methods, location and management (Pan et al, 2022). The intention of carbon offsetting is often considered a reasonable one, to increase the potential sinks and stores of carbon globally as part of the effort to reduce carbon emissions (Anderson, 2012, Pan et al, 2022m Watt, 2021). It is the implementation, advertising and potential behavioural impacts that are often critiqued and a cause for concern (Hyams and Fawcett, 2013, Johnson et al, 2024).

1.6.4. Tradable Green Certificates

Green certificates are not a carbon pricing scheme however they are proposed to fulfil an equivalent purpose. Where a scheme like TEQs imposes a cost on carbon emission, green certificates encourage the generation of energy by renewable sources by payment by a company or organisation for a certificate of proof of renewable energy generation (Amundsen and Bergman, 2012; Bertoldi et al., 2005; Nielsen and Jeppesen, 2003). These certificates would function as proof that a company or organisation has paid out for a certain amount of renewable energy, as renewable energy when generated and fed into a national grid cannot be separated from other energy. Green certificates are often implemented in nations where requirements are placed on companies and organisations to have a certain quota of energy they use come from renewable sources (Nielsen and Jeppesen, 2003). Trading is frequently done via brokers or a centralised hub as with TEQs models.

1.7. Sustainability

Sustainability relates to sustainable development; sustainable development is an ongoing process aiming towards resilience, a state, where a system or society can maintain itself.

The most enduring definition of sustainable development is from ‘Our Common Future’ also known as the Brundtland Report (1987):

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

In the past there have been identified three pillars of sustainability (economic, social, environmental) although the origins of these pillars is hard to discern (Purvis et al., 2019). We have added the additional ‘cultural’ dimension to the existing three pillars, this allows further assurances that inequality can be appropriately addressed and that cultural differences can be respected and preserved.

Recent literature has begun to examine the role of culture in sustainability, two landmark reports on the role of culture in sustainability were published by The British Council (2020, 2023) ‘The Missing Foundation: Culture’s place within and beyond the SDGs ” and “The Missing Pillar: Culture's Contribution to the UN Sustainable Development Goals ”. Both these reports highlight the multiple perspectives on the role culture can play in sustainable development and discuss culture’s oft overlooked place in sustainability (The British Council, 2023, 2020).

Tylor, (1871) defined culture as:

““…the complex whole which includes knowledge, belief, art, law, morals, custom, and any other capabilities acquired by man as a member of society.”

This definition has endured and is still often used in modern literature, although it is agreed that culture by its nature is difficult to define with clarity, but it is widely agreed that culture encompasses; behaviour, social norms, customs, arts, laws, habits found in human societies (Bennett, 2015; Goldstein, 1957; Kroeber and Kluckhohn, 1952; MacDonald, 1991; Mironenko and Sorokin, 2018; Tylor, 1871; White, 1959). As such the culture is entwinned with all other dimensions of sustainability and the impacts any sustainable development policy or action may have culturally should be considered, additionally culture itself will change how individuals engage with sustainability and may give unique benefits and challenges across the cultural spectrum (Soini and Birkeland, 2014).

These dimensions of sustainability can be framed by the United Nations Sustainable Development Goals, the Goals seek to encompass all aspects of sustainability as a holistic framework for sustainable development (United Nation, 2021). Several SDGs span across multiple dimensions of sustainability, SDG 17: Partnerships for the Goals impacts all dimensions of sustainability both directly and indirectly. Table 1-4 maps the UN SDGs to the four dimensions of sustainability using the targets and indicators of each goal and their mention of relevant factors to assign the goals to each dimension.

Table 1-4. The UN Sustainable Development Goals mapped to the dimensions of sustainability.

DIMENSION OF SUSTAINABILITY	RELEVANT SUSTAINABLE DEVELOPMENT GOALS
SOCIAL	SDG 1: No Poverty SDG 2: Zero Hunger SDG 3: Good Health and Wellbeing SDG 4: Quality Education SDG 5: Gender Equality SDG 6: Clean Water and Sanitation SDG 7: Affordable and Clean Energy SDG 8: Decent Work and Economic Growth SDG 9: Industry, Innovation and Infrastructure SDG 10: Reduced Inequality SDG 11: Sustainable Cities and Communities SDG 16: Peace, Justice and Strong Institutions SDG 17: Partnerships for the Goals
CULTURAL	SDG 8: Decent Work and Economic Growth SDG 10: Reduced Inequality SDG 11: Sustainable Cities and Communities SDG 16: Peace, Justice and Strong Institutions SDG 17: Partnerships for the Goals *But Underpins all SDGs.*
ECONOMIC	SDG 7: Affordable and Clean Energy SDG 8: Decent Work and Economic Growth SDG 9: Industry, Innovation and Infrastructure SDG 12: Responsible Consumption and Production SDG 17: Partnerships for the Goals
ENVIRONMENT	SDG 12: Responsible Consumption and Production SDG 13: Climate Action SDG 14: Life Below Water SDG 15: Life on Land SDG 17: Partnerships for the Goals

1.7.1. Social Sustainability

Social sustainability considers the aspects of sustainability that are human-centric such as equality, health and wellbeing, poverty, food security, democracy, and overall quality of life.

There are numerous definitions of social sustainability due to how many aspects of human life could fall under the concept. Eizenberg and Jabareen, (2017) propose that the core framework of social sustainability includes: equity, safety, sustainable urban forms (i.e. physical places and communities) and sustainable production and consumption to meet individual needs. Vallance et al. (2011) states that social sustainability has three components: Development Sustainability, Bridge Sustainability and Maintenance Sustainability. The definitions of each of these components are as follows:

"…development sustainability' addressing basic needs, the creation of social capital, justice and so on; (b) 'bridge sustainability' concerning changes in behaviour so as to achieve bio-physical environmental goals and; (c) 'maintenance sustainability' referring to the preservation – or what can be sustained – of socio-cultural characteristics in the face of change, and the ways in which people actively embrace or resist those changes."

(Vallance et al., 2011)

All proposals of a social sustainability definition include equity, social justice and the ability to meet an individual's basic needs, alongside the understanding that social sustainability is entwinned with environmental sustainability and there are requirements to ensure natural environments and ecosystem services are preserved (Eizenberg and Jabareen, 2017; Missimer et al., 2017; Vallance et al., 2011; Virtanen et al., 2020). As seen in table 2-2 a wide range of the Sustainable Development Goals are aligned with social sustainability.

Social Justice forms a central part of social sustainability, social justice is the concept that all humans have equal rights that should be applied in all parts of life, that all diversity should be respected and there should be fairness across society (Buettner-Schmidt et al., 2012; Jost and Kay, 2010; Walster and Walster, 1975). Within the Sustainable Development Goals over half of the goals carry a direct social justice aim, from Goal 1. No Poverty, to Goal 10 Reduced Inequalities to Goal 16 Peace, Justice, and Strong Institutions. Other goals such as Goal 7 Affordable and Clean Energy may appear to concern technology and energy innovation but crucially include the aims that the energy generated must be affordable, reliable and accessible to all, accessibility to energy is a social justice issue. Social sustainability frequently hinges on the necessity for fairness and equal distribution of goods, services, and the benefits of sustainable development. Access to water, food and energy are considered a human right, denial of these resources is often considered a social injustice (Boström, 2012; Dempsey et al., 2011; Eizenberg and Jabareen, 2017; Missimer et al., 2017; Vallance et al., 2011).

Social sustainability is different from public acceptability, if the majority accepts something that does not make it socially sustainable or just (Rasinski, 1987; Wolsink, 2018). Social sustainability is beyond just what the public may want but reaches to what the public and society as a whole need to continue to function. However, social acceptability is considered important for exploring and analysing social sustainability and the implementation of sustainable practices, ensuring people have an opportunity to express their believes, opinions and attitudes around a potential intervention or concept (Wood et al., 2016).

1.7.2. Cultural Sustainability

Culture makes up who we are, it is the place we are in, culture isnot just the arts but heritage, cultural beliefs, and practices (Tylor, 1871). Culture impacts different people's concepts of sustainability, and their limitations. For example, diet composition, travel conventions, how we care for those around us are all shaped by cultural impacts and experiences. Cultural sustainability is complex, including a range of political ideologies and exists across spatial and temporal scales (Soini and Birkeland, 2014). Culture is a part of every individual's life and influences their worldview and attitudes. Cultural sustainability is an emerging field within sustainability science and research and definitions of cultural sustainability vary across the literature, the peer reviewed literature on the topic is limited with discussions developing on how culture can be utilised and preserved in relation to sustainability (Soini and Birkeland, 2014; The British Council, 2023, 2020).

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) positions culture at the core of sustainable development, stating it underpins all of the Sustainable Development Goals and impacts all aspects of sustainability (UNESCO, 2023, 2022, 2021, 2016, 2014).

The UNESCO Hangzhou Declaration: Placing Culture at the Heart of Sustainable Development Policies specifically states the importance of culture in public policy development, and calls on member states of UNESCO (the UK is a member) to consider culture as a driver and fundamental enabler of sustainability (UNESCO, 2013). The Declaration states:

'The cultural dimension should be systematically integrated in definitions of sustainable development..."

(UNESCO, 2013.)

When considering the development of sustainable development the cultural aspects require consideration and recognition, despite their frequently intangible nature. Cultural sustainability may be entangled with other forms of sustainability and inform the views of those developing sustainability theories and definitions.

Capturing culture and how it impacts and is impacted by sustainability does not currently have a standard methodology or set of indicators, culture spans all aspects of life and cuts across various other forms of sustainability, such as the social and economic, it also has great influence over the political decisions a government may make, depending on the overriding culture of the nation they govern (The British Council, 2023, 2020),

In 2014 UNESCO developed thematic indicators for culture for the 2030 agenda, with each of the four themes directly linked to Sustainable Development Goal Targets (UNESCO, 2014). The targets aligned with the themes span the full breadth of the SDGs and demonstrate the cross-cutting nature of culture as an aspect and driver of sustainability (UNESCO, 2014).

The thematic indicators identified are:

- Environment and Resilience
- Prosperity and Livelihoods
- Knowledge and Skills
- Inclusion and Participation

The report aligns each thematic indicator with targets and indicators of the Sustainable Development Goals and the report on the indicators also notes that the cultural indicators contribute unilaterally to SDG 5: Gender Equality and SDG 17: Partnerships for the Goals.

UNESCO, 2014.

This highlights the broad range of areas culture influences and is a factor in, assessing culture, cultural significance and influence is widely agreed to be difficult, each individual's cultural makeup is different and the different cultural groups they are part of will have varying degrees of influence (The British Council, 2023, 2020). Additionally culture is deeply entwined with sustainability and the targets of the Sustainable Development Goals, beyond SDG 11: Sustainable Cities and Communities Target 11.4 'Strengthen efforts to protect and safeguard cultural and natural heritage'.

1.7.3. Economic Sustainability

Economic sustainability is fundamentally tied with environmental sustainability, both consider the depletion and loss of environmental resources (natural capital) as an unwanted outcome and a failing of sustainability. Economic health has long been defined by growth and GDP (gross domestic product) the measure of an economy on any level is based on if it continues to grow, to keep producing greater and greater amounts. (Ward et al., 2016) states:

"…growth in GDP ultimately cannot plausibly be decoupled from growth in material and energy use, demonstrating categorically that GDP growth cannot be sustained indefinitely."

Continual growth as it is measured now is considered unsustainable by many eco-economists, the depletion of resources at current rates compromises the ability of future generations to meet their needs if GDP growth continues to be the measure of economic success (Barca, 2018; Raworth, 2017). Environmental economists, and those concerned with sustainable economies look at numerous factors outside of growth, these economists instead look at wellbeing as a measure of a thriving economy (Barca, 2018; Kallis, 2011; Kallis et al., 2012; Raworth, 2017, Sandberg et al., 2019). The life systems the planet provides are fundamental to the continuation of human life, but it is argued current economic models ignore the needs of the environment, alongside ignoring the importance of human wellbeing and safety (Goodland, 1995; Kallis, 2011; Ward et al., 2016).

The current economic climate is criticised for its focus on growth and idealisation that to fulfil people's socioeconomic needs growth is the required solution (Raworth, 2017, Hickel and Kallis, 2020, Schwartzman, 2012). Newer theories of economics position economics as not a purely growth driven and financial consumption-based field but one that considers global resources with greater importance and the importance of their maintenance, preservation and renewal. These newer schools of thought that include green and sustainable economic theories tend towards alignment with the Brundtland definition of sustainability, that meeting the current needs of people should not impinge upon meeting the needs of future generations.

The theory of 'Doughnut Economics' states current economic thinking and teaching considers the public as 'consumers' rather than 'citizens' and only considers the financial aspects of people's contributions to society (Raworth, 2017). The theory argues there is a great deal of unpaid caring labour and other social work done without financial incentive or payment, she argues current economic models are flawed as they look only at GDP and growth, rather than development and wellbeing. The theory of Doughnut Economics states that society must balance its wellbeing with the ecological ceiling of putting too great a pressure on Earth's life giving systems (Raworth, 2017). Other economists argue that it is possible to avoid decoupling or degrowth, that what is required is to move to a services-based economy supported by circular economy thinking or claim degrowth or decoupling the economy from growth is impossible (Hickel and Kallis, 2020; Schwartzman, 2012; Van Den Bergh and Kallis, 2012).

Planetary boundaries, which are incorporated into Raworth's Doughnut Economics model, are a framework of the limits of human pressure on life giving systems on the planet, for example the limit of air pollution in the atmosphere before air quality becomes too detrimental to life (Steffan et al, 2015).

There are nine identified planetary boundaries:

- Climate change
- Change in biosphere integrity (biodiversity loss and species extinction)
- Stratospheric ozone depletion
- Ocean acidification
- Biogeochemical flows (phosphorus and nitrogen cycles)
- Land-system change (for example deforestation)
- Freshwater use
- Atmospheric aerosol loading (microscopic particles in the atmosphere that affect climate and living organisms)
- Introduction of novel entities

(Rockström et al, 2009, Steffan et al, 2015, Richardson et al, 2023).

Exceeding the planetary boundaries means that the boundary or resource in question is being overused or degraded at a rate where it cannot be replenished or may be irreparably damaged, impairing its ability to meet the needs of the planet at the time it was exceeded or for the future (Steffan, et al, 2015).

The complex relationship between economic and financial concerns have been framed as what is referred to as the Sustainable Development Goal 'Wedding Cake', this framing positions the relationship between the different goals which are grouped as 'society', 'biosphere' and economy (Philippidis et al, 2020). These layers have trade offs and synergies, and conflict in fulfilling the needs of the societal and economic layers against deprivation of the biosphere (Philippidis et al, 2020).

Despite the varying views of economists' economic sustainability concerns the use, reuse or conservation of resources, the health of the economy and its ability to function and ensure the population can meet its needs.

1.7.4. Environmental Sustainability

The environmental dimension of sustainability concerns aspects such as climate change, resource use, land use, land use change and forestry, human wellbeing, and numerous other aspects. It does not only concern wildlife, flora, and fauna but everything around, and including, us. Whilst these aspects may be considered mostly in terms of their importance as life giving systems, access to green spaces and areas is considered vital to human wellbeing, the value of the environment concerns a far broader spectrum of benefits than simply maintaining life (Goodland, 1995; Heritage Fund, 2022; Virtanen et al., 2020).

In 'The Concept of Environmental Sustainability' Robert Goodland (1995) puts forward that environmental sustainability hinges on the maintenance of natural capital. Natural capital is such resources as clean air to preserved forests to any other ecological or natural resource in our environment. Goodland (1995) emphasises that Natural Capital should not be considered equivalent to some kind of monetary value in part as this is near impossible to do accurately, we cannot understand the financial value of the resources we have as we do not understand the impacts of them being degraded or destroyed. Therefore, this natural capital should be maintained and preserved as it is.

The concept of natural capital is aligned with the concept of public goods, also known as collective goods, multiple people use public goods, and or lifeforms, such as the air we breathe or the oceans (Bergstrom and Goodman, 1973; Oakland, 1987; Ostrom and Ostrom, 2019). Public goods have no clear owners and are often natural resources that are needed by humans to survive; therefore, their preservation is critical. Hardin, (1968) discussed the concept of 'The Tragedy of the Commons', this concept puts forth that if everyone has unrestricted access to a resource it will be overused and depleted, making it unusable for all and for future generations. This concept can be applied to subjects such as air quality, the use and pollution of water and the use of non-renewable energy. Hardin, (1968) posits that even when some show restraint in using resource, or are unable, others will replace them and continue to use the finite public good. Environmental sustainability seeks to avoid the overuse of resources, even those which are considered public goods which all have access to, and many could deplete at the expense of others.

Environmental sustainability is intrinsically tied to all other forms and concepts of sustainability, it is the natural resources we use that must be used in a way that does not deplete them and reducing future generations' ability to benefit from them.

1.8. Reducing Personal Carbon Emissions

There is considerable discussion on who holds the highest responsibility for reducing carbon emissions however the literature often indicates that a degree of change is required in individual behaviours particularly in high consumption nations with high historic contributions to climate change and greenhouse gas emissions (UNEP, 2023).

There is great deliberation on the appropriate methods to reduce personal carbon emissions and where responsibility lies to reduce personal carbon emissions, whilst households can be identified as a key source of emissions it is critical to understand why and how this occurs. If high household emissions are due to behaviour and personal choices of individuals or if there exist barriers to reducing emissions, such as service provision or infrastructure different methods and policy interventions would be required.

1.9. Revisiting Personal Carbon Interventions in the United Kingdom

As outlined carbon emissions must be reduced to slow climate change and its impacts, the emissions from households, and therefore the public are responsible for a key area to address (Department for Environment Food & Rural Affairs, 2020; Ivanova et al., 2016; National Statistics, 2020). The United Kingdom is an Annex II party and therefore within the global policy context is considered to have a higher responsibility to reduce its greenhouse gas emissions.

As stated in the 6th Carbon Budget Report by the Climate Change Committee to reach the 78% from 1990 levels emission reduction required to reach net zero by 2050 behaviour change may be inevitable (Climate Change Committee, 2020). There remains little in the way of direct policy interventions on public emissions and high carbon intensity public behaviour and consumption. To meet the UK budgets to reach net zero by 2050 consideration of the political instruments required to reduce personal carbon emissions needs to take place with appropriate policies identified.

As carbon-based emissions are the highest emitted and often associated most heavily with household emissions, they are most frequently the area of focus in climate change reduction and mitigation policies (Calvin et al., 2023; United Nations Environment Programme, 2023).

Numerous methods of reducing carbon emissions have been put forward globally such as carbon storage and capture, creating more efficient technology and changing our energy sources, but the overwhelming priority globally is to reduce emissions generated with haste (Intergovernmental Panel on Climate Change, 2018; Letcher, 2018). The International Energy Agency (2021) report that whilst there are still pathways to reach the net zero emissions by 2050 these pathways are narrow, challenging and require all stakeholders from governments to individuals. As noted, households are responsible for a high percentage of emissions, yet often emission reduction methods take a 'top down' approach focusing on industry and regulation, whilst little is done to enforce public emission reductions. The public is often encouraged to reduce their emissions by their governments through nudge theory campaigns and awareness raising (Carter, 2014; Committee on Climate Change, 2018; Hansen & Jespersen, 2013), but there are no limitations on carbon emissions an individual may be responsible for generating. Industries will continue to supply customers with high GHG emitting goods and services if they are demanded and paid for.

For the public to reduce their personal carbon emissions current behaviours would be required to change alongside any 'top down' regulations on industry. Personal emissions under the direct influence of the public such as household heating, diet and personal transport require change due to the considerable associated emissions (Brand & Boardman, 2008; Department for Business Energy and Industrial Strategy, 2020b; Moult et al., 2018; Office for National Statistics, 2023; Preston et al., 2013; Scarborough et al., 2014; WRAP, 2016). However, instigating behavioural change is complex, requiring changes in often deeply held attitudes to facilitate long term 'green' behavioural shifts (Gralton et al., 2004; Environment & Change Committee, 2022; Whitmarsh et al., 2021). Arguments have been made by international bodies, national governments and within peer-reviewed literature that to modify personal carbon emissions policy interventions must be developed (Bailey & Rupp, 2004; DEFRA, 2008; Elkins & Baker, 2002; Fawcett, 2010; Lane et al., 2008; Rondoni & Grasso, 2021; United Nations Environment Programme, 2020a, 2020b, 2023; Wintour, 2006). However, the nature of such policy interventions is a topic of considerable discussion and research with no clear consensus on the appropriate approach, and with the consideration of considerable public resistance to policies that seek to limit lifestyle choices (Carattini et al., 2018; Elkins and Baker, 2002; Glover, 2014; Marek et al., 2018; Parag and Strickland, 2009; Sumner et al., 2011; Zheng et al., 2014).

Further investigation and analysis are required to identify policies that could deliver viable and impactful emission reductions whilst considering the needs, attitudes, and behaviours of the public. Any policy that seeks to change the behaviour of the public sustainably must consider all dimensions of sustainability, ensuring any policy is equitable and allows individuals to meet their needs whilst achieving the required cuts to global emissions.

2. LITERATURE REVIEW IN RELATION TO PERSONAL CARBON BUDGETS AND CLIMATE BEHAVIOUR

To explore if the different models of personal carbon emission interventions a review of the existing literature has been conducted. Section 2.1 discusses climate behaviours and theories of behavioural change.

Section 2.2 considers and evaluates the existing methods of evaluating personal carbon budgets to identify methodological gaps in the literature.

Section 2.4 discusses the conclusions of chapters 1 and 2.

Section 2.5 sets out the rationale of the thesis.

Section 2.6 introduces the aims and objectives of the thesis,

Section 2.7 summaries the methodological approach and methods of the thesis.

2.1. Climate Behaviours

Modifying behaviour around personal carbon emissions is a topic of considerable priority and concern globally for policymakers, researchers and communities. Whilst discussions and disagreements continue about the degree of responsibility different groups may have, and the responsibility to change at an individual level against the responsibility of government and industry it is often agreed some form of individual behavioural change may be needed to reduce greenhouse gas emissions (Fawcett, 2010, Seyfang et al, 2009, Steg and Vlek, 2009, UNEP, 2020, UNEP 2023, Whitmarsh et al, 2021, Zanni et al, 2012).

As discussed in section 1.4 policy instruments can take a variety of forms depending on function, context, parties being intervened upon and purpose. Therefore, an appropriate understanding of the reasons why behaviour needs to be changed, which behaviour needs to change and the barriers to that change need to be identified to select an appropriate policy intervention.

Within the literature it is identified that habit may be a key barrier to climate related behaviour change, for many high carbon behaviours may be highly habitual, i.e. driving to work instead of taking public transport or engaging in active travel (Carrus et al 2008, Gravert et al 2021, Schwanen et al, 2021, Steg and Nordlund, 2018, Verplanken and Whitmarsh, 2021). There is considerable complexity surrounding changing habitual behaviours, and many theories of behavioural change do not necessarily address habit as a factor in behaviour change theories (Darnton, 2008a, 2008b).

Factors outside of an individual’s own behavioural intentions are identified as potential barriers to changing climate behaviour, these may include infrastructure, service provision and information availability (Steg and Vlek, 2009, Timlett and Williams, 2011). Contextual environment change may influence behaviour change, although this may vary across behaviours as the behaviours that may be required to change to reduce carbon emissions vary vastly in terms of their impact and influence on people’s lives, livelihoods and lifestyles. Additionally different demographic groups may experience different contextual barriers.

2.1.1. Theories of Behaviour Change

There are numerous theories of behaviour change, Davis et al (2014) identified eighty two distinct models, and behaviour change remains notably difficult to consistently predict or trigger. Additionally changes to behaviour relating to climate change, emissions and consumer behaviour may need to be significant and consistent to reduce emissions to an appreciable degree, therefore the difficulties in accurately predicting behavioural change are of particular concern around climate change related behaviours (Whitmarsh et al, 2021).

A comprehensive report on behavioural models and practical guide to behaviour models were developed by Darnton (2008a, 2008b) for the UK government which summarises and evaluates over sixty behavioural models and outlines the key concepts that are common across theories of behavioural change. These reports note that attitudes, norms and agency are the most common concepts arising in behaviour change models and theories, however habit and emotion feature less frequently (Darnton, 2008a, 2008b).

Darnton (2008a) states that these models and theories should be used as tools to aid the design of policy interventions as ‘aids to thinking’ but not impose them on the public without critical consideration. The highly cited review by Whitmarsh et al, (2021) posits that despite the existence of many theories of behaviour change and behavioural models their utility is limited, Whitmarsh et al, (2021) state this die due these models is due to the reductive, linear, deliberative and individualistic approaches. Whitmarsh et al, (2021) also notes that behavioural models that exist to explain and predict mitigation and adaptation policies are 'blind to environmental impact'.

2.1.1.1. Theory of Planned Behaviour

The theory of Planned Behaviour developed by Ajzen (1985) has three core concepts that interact to shape how an individual intends to behave. The theory considers self-efficacy as a conviction an individual can achieve a behaviour or outcome and influences the likelihood of an individual to act upon a behavioural intent.

The core concepts of the Theory of Planned Behaviour are:

i) Normative beliefs and subjective norms: a normative belief is an individual's belief of what behaviour may be socially expected, a subjective norm is how the individual themselves view that behaviour.

ii) Control beliefs and perceived behavioural control: control beliefs are what an individual believes in relation to factors that may support or halt a behaviour being performed. Perceived behavioural control is the perceived ease with which an individual thinks a behaviour can be completed. Perceived behavioural control is linked to self-efficacy.

iii) Behavioural intention and behaviour.

(Azjen, 1985).

This theory states that behaviour is influenced by these three concepts and how they combine in relation to a particular behaviour.

2.1.1.2. Value-Belief-Norm Model

Stern et al (1999) proposes the Value-Belief-Norm Model (VBN Model), the VBN Model states that values influence pro-environmental behaviour which is influenced by an individual's personal norms and environmental beliefs. The VBN Model indicates that pro-environmental values alone do not necessarily lead to an individual undertaking pro-environmental behaviour (Stern et al, 1999). In order for an individual to undertake a behaviour they need to hold an appropriate value, believe that their action or behaviour can protect a 'valued object' and belief that object is threatened, additionally they need to experience an obligation to restore or protect that valued object (Stern et al, 1999).

This model implies that just having awareness or placing importance on the impacts of climate change alone are not sufficient to catalyse behaviour change in an individual around their carbon emissions (Stern et al, 1999, Whitmarsh et al, 2021).

2.1.1.3. Social Cognitive Theory

The Social Cognitive Theory developed by Bandura (1989) theorises that human behaviour stems from the interactions between a person and their environment, and that behaviour is developed through an individual learning from their own past experiences alongside observations of others' behaviours and their environment. Crucial to this theory is the role of observation of the behaviour of others and the resulting consequences to inform future behaviour of the individual (Bandura, 1989). These observations may identify if another person gains a reward or punishment from acting out a certain behaviour and either avoid or replicate the behaviour (Bandura, 1989). Learning by observation is a key driver of human behaviour within the SCT.

2.1.1.4. Stages of Change Model

The Stages of Change model, also referred to as the Transtheoretical model of Behaviour Change sets out behaviour change in five sequential stages:

i) Precontemplation – there is little or no intention to enact behavioural change
ii) Contemplation – There is a consideration for changing behaviour but not a commitment to change
iii) Preparation – Intention is set to change behaviour and steps are being made towards behaviour change albeit these may be small
iv) Action – effort has been made to change behaviour, new behaviours have been enacted
v) Maintenance – The behavioural change has become the norm and is upkept

Norcross et al, (2011).

This model does not define how long an individual may stay in each stage of behaviour change, it theorises that behaviour change requires a specific sequence of states to become a maintained behavioural change (Norcross et al, 2011). Some versions of the model add a sixth step – Termination which was not an original component of the model, Termination is the lack of desire to return to the previous behaviours and relapse is not considered (Darton, 2008a, 2008b).

2.1.1.5. Infrastructure Service Behaviour Model

The Infrastructure, Service, Behaviour Model (ISB Model) was developed in the context of waste and recycling behaviour change (Timlett and Williams, 2011). The ISB model takes a holistic approach to behaviour change, considering that changes to the provision of infrastructure and services are vital to enabling changes in behaviour and that seeking to change attitudes and values alone cannot always facilitate change if an individual or group cannot action that change if their surroundings do not allow for it (Timlett and Williams, 2011). An example of this is an individual may have a positive attitude towards recycling and have the knowledge to recycle items correctly, but without recycling infrastructure and some form of management or collection they cannot act on that behaviour.

2.1.1.6. Nudge Behaviour Editing

Nudge Theory proposes that the public's behaviour can be shaped by indirect guidance and suggestions paired with positive reinforcement these 'nudges' would be used to guide the public into complying with domestic policy goals (Hansen and Jespersen, 2013; Henkel et al., 2019). Nudge theory has been employed by numerous governments globally, including Australia, the USA, and the UK.

Nudge Theory avoids creating policies and edicts that require individuals to take any action, instead attempting to influence them to demonstrate the required behaviour. This can be done via social pressure such as implying everyone is demonstrating that behaviour or via providing facilities that make the desired behaviour the easiest choice alongside other subtle methods (Hansen and Jespersen, 2013). It has also been suggested that during the COVID-19 pandemic that the UK government attempted to employ nudge theory, particularly at the outset of the pandemic where advice was given i.e. 'Hands, Face, Space' rather than legal requirements and restrictions (Sodha, 2020; Yates, 2020). This has led to criticism of nudge theory as an effective method to change behaviour in the face of a global crisis that requires the public to edit their behaviours for the benefit of others as it does not force change (Forrest, 2020; Rigby, 2020; Sibony, 2020; Sodha, 2020; Yates, 2020).

2.1.1.7. Theories of Behaviour Change and Climate Behaviours

Various theories of behaviour change have been applied to attempts to modify human behaviour in relation to their consumption and carbon emission related behaviours (Whitmarsh et al, 2021). Whitmarsh et al, (2021) identifies that the theories of change most commonly applied to environmental and climate change mitigation behaviours are the Theory of Planned

Behaviour, the Stages of Change Model and the Value – Belief – Norm Model. These theories have been criticised in relation to carbon behaviour change due to their individualistic nature and the lack of consideration for societal and cultural factors (Nielson et al, 2021, Whitmarsh et al, 2021).

Societal factors and social norms can influence an individual's behaviour, Shaw (2008) identified the nearest neighbour effect on households in terms of recycling, when someone's neighbour put out their recycling bin a household was more likely to put out their own recycling bin. Shaw (2008) also identified there may be a potential infrastructure component to this behaviour as recycling bin use was higher in cul-de-sacs than along straight terraced roads

Whilst the ISB model has been applied largely to waste related behaviour it acknowledges that there is a need to consider an individual's ability to change behaviour dependant on the infrastructure and services provided, other models applied to environmental and carbon behaviour do not unilaterally have this as a core concept (Timlett and Williams, 2011).

To design an behavioural intervention to reduce carbon emissions, understanding if the barriers experienced to participants are based on infrastructure and service, social norms or personal values is vital. If the public has high behavioural intent and motivation to for example use public transport but none is available that behaviour cannot change and a mandatory, command and control policy intervention would struggle to implement change. Additionally, an informational intervention may also have limited results as the behavioural intent and knowledge was already present. However, if the barriers experienced are rooted in habit and values but the infrastructure and service is available then a more direct behavioural change intervention may be required.

2.2 Personal Carbon Budgets

Within existing peer reviewed and grey literature numerous permutations of Personal Carbon Interventions (referred to in this thesis as PCBs) PCBs have been proposed and discussed, alongside other policy interventions that have been considered as reasonable alternatives to PCBs (DEFRA, 2008; Eyre, 2010; Fawcett, 2010; Fawcett and Parag, 2010; Haites, 2018; Lin and Li, 2011; Raux et al., 2015a; Sorrell, 2010; Upham et al., 2011). Within the literature there are three main personal carbon reduction interventions proposed:

i) Carbon Labelling: The application of a label indicating to the consumer the carbon emissions associated with the good or service to be used or purchased (Meyerding et al., 2019; Upham et al., 2011a; Jerome K et al., 2011). Consumers may be offered guidance on the amount of carbon they should be using annually.

ii) Carbon Tax: A tax applied to goods and services upstream based on the carbon emissions related to that good or service (Akkaya and Bakkal, 2020; Bristow et al., 2010; Carbone et al., 2013; Lin and Li, 2011; Sumner et al., 2011).

iii) Personal Carbon Trading (PCT): Individuals are assigned a carbon budget they can 'spend' on goods and services in relation to their carbon emissions, the budget is often proposed to be annual. Any surplus carbon can be sold to other individuals (DEFRA, 2008b; Fawcett, 2010a, 2010b; Keay-Bright et al., 2008; Lövbrand and Stripple, 2011; Parag and Fawcett, 2014; Parag and Strickland, 2011, 2009; Seyfang et al., 2009).

Chapter 3 outlines the structures of the different models of PCBs in greater detail and with diagrams.

2.2.1. Carbon Labelling

Carbon labelling has been adopted independently by businesses in the UK, particularly the food and drink sector and hospitality venues, but there is no policy guidance or mandate enforcing the behaviour or mandating carbon labels be applied to goods (Oatly, 2021, Quorn, 2020). Vanclay et al (2011) found that indicating a product's carbon intensity in relation to a comparable product had a minor impact on purchasing behaviour unless the lower carbon intensive product was cheaper than the more intensive options. This indicates that understanding the relative carbon footprint of a product alone may not induce significant behaviour change at a scale that may be required to reduce carbon emissions in line with the projected national or global targets. Additionally whilst purchasing the 'better' option will yield a carbon reduction there are concerns that this may enable high consumption to continue, or that just 'better' than a comparable item is limited in the level of reduction can be achieved (Vanclay et al, 2011). For example if an individual buys less carbon intensive beef than another beef option they are still purchasing a food with a high carbon intensity per kilogram and per nutritional value (Poore and Nemecek, 2018).

Within the literature it has been identified that carbon label design has an influence over consumer comprehension of the label, designs that use colours and letter grades have been found to communicate the carbon emission intensity of a product than a figure identifying the carbon footprint itself (Marek et al, 2018, Thøgersen and Nielson, 2016, Vanclay et al, 2011). Therefore consideration of design, and accessibility, is an important factor in the effectiveness of a carbon labelling intervention.

2.2.2. Carbon Tax

Carbon taxation structure is outlined in section 1.5.1.

Carbon taxation is an oft proposed method of reducing carbon emissions, this relies upon levying a cost that is passed on to consumers, therefore limiting their appetite for high carbon emitting goods and services. However the literature identifies this as a regressive tax, that is a tax that disproportionately impacts those on lower incomes than those on higher incomes (Carbone et al, 2013, Callan et al, 2009, Fremstad & Paul, 2019. The impact of a climate tax on those who emit most highly (those with higher incomes) is therefore likely to be less than those on lower incomes who have lower carbon footprints.

2.2.3. Personal Carbon Trading

Personal Carbon Trading models that have been proposed would theoretically function in a similar fashion to an ETS policy intervention but on an individual scale, (Fawcett, 2010). Individuals would be assigned a periodic allowance of carbon credits to use on goods and services, surplus credits could then be traded for a carbon price and additional credits purchased. This is a cap and trade policy intervention with a hard cap on the emissions credits available to be allocated and traded.

Personal Carbon Trading is a model that has been proposed in peer reviewed and grey literature and has been discussed in the policy sphere but has not been implemented on a large scale, although pilot schemes have been enacted (DEFRA 2008, Kuokkanen et al, 2020). In 2007 then Energy Secretary for the UK government David Miliband commissioned a study into personal carbon trading, this model was based on the use of ‘carbon credit cards’ that would be allocated a budget annually and scanned when a good or service was purchased (DEFRA, 2008). The proposed model allocated individuals with a carbon budget that would decrease annually to achieve the national emission reduction targets (DEFRA, 2008).

At the time the policy intervention was abandoned due to being deemed ‘ahead of its time’ and the potential resistance from the public alongside the projected implementation costs that would be associated with the infrastructure required to implement the scheme (Fawcett, 2010).

Additional discussion of the existing literature on personal carbon budget models is integrated into Chapter 3.

2.2. Personal Carbon Budget Analysis and Evaluation Methods

To explore the existing methods of PCB analysis an understanding and review of the existing literature is required, this facilitates the avoidance of repetition of methodologies and the critical analysis of the methods that have previously been employed. Additionally, studies have varied foci, studies may explore the acceptability of different models, the logistics of implementation or the potential economic impacts of a model. Understanding the areas the current literature has particularly centred on allows an understanding of the current gaps, additionally understanding the commonly employed methods aids in identifying the benefit of employing different methodologies or gathering datasets that may include different types of data to support furthering the knowledge within this field of research.

Currently there is a small pool of peer reviewed and grey literature that explores and evaluates the potential of different PCB models. Much of the literature stems from the early part of the 2010s and interest in PCBs, particularly in PCT models, has declined. With carbon emissions continuing to rise and the household/ personal emissions identified as a key contributor to carbon emissions PCBs should be re-examined as a carbon reduction method (Department for Environment Food & Rural Affairs, 2020; Dubois et al., 2019). Existing literature on PCBs is scattered across different disciplines and much only examines specific concerns such as public acceptability, economic feasibility, or logistics. A large scale holistic and systematic study has so far not taken place although several much-cited review papers tackle the topic (Fawcett, 2012, 2010b; Hyams and Fawcett, 2013). The range of methods used in studies varies (see Table 2-1. However, there is a limit on the foci of these studies as many examine social acceptability or behaviour (often using social research methods to identify stated behaviour rather than observed behaviour). Currently, the exploration of the potential of PCBs has slowed and an understanding of the existing methods used and focus of studies needs to be developed to push this important subject onwards.

2.2.1. Current Methods of Evaluating PCBs and Literature Focus

To review the literature on methods of evaluating PCBs a systematic review approach was taken to identify the current common methods of evaluating PCBs and their topic focus

(Aromataris and Pearson, 2014; Booth et al., 2011; Lam et al., 2020; Lloyd Jones MPhil et al., 2004; Pollock and Berge, 2018; Seuring et al., 2005; Wilczynski, 2017; Wright et al., 2007). Understanding the methodological approaches to exploring PCBs is of significant use as it allows the development and use of novel approaches which may provide new context and insight into this topic area.

The 'key' studies on this topic were identified using keyword searches and back and forward or 'chain' searching to identify the most cited papers through Web of Science, Google Scholar, Scopus and SciVal. Chain searching requires the exploration of a study's reference list to identify further studies, this process is repeated until new relevant studies no longer arise/ (Aromataris and Pearson, 2014; Booth et al., 2011; Horsley et al., 2011; Wright et al., 2007).

Studies were included if they had over 15 citations, flexibility was allowed for papers published recently at the time of analysis (2018 onwards). The cutoff of 15 citations reflects the average publication citations for the Topic Cluster TC.403 'Carbon Dioxide Emissions, Environmental Policy, Climate Change' as assessed by the research trends software SciVal (for the period 2019 – 2023) (SciVal, 2023, Waltman et al, 2012). The average citations per publication in this topic was 15, for the Topic CLuster T.66459 'Consumer Behavior; Carbon Footprint; Willingness-to-Pay' the average publication citations was 15.8 (for the period 2019 – 2023) as these citation averages were similar the lower figure was chosen to capture the relevant literature.

Expert reports are included despite the lack of clear citation data due to their high relevancy in the UK context due to the consideration of a PCT scheme by the UK government in 2008 being a critical piece of literature in the UK context. Whilst there are numerous highly cited review papers on this topic, they have not been included due to not involving data collection or analysis.

Keywords were identified from identifying associated keywords with relevant literature and keywords that arose in the related topic clusters (TC.403 and T.66459).

Keywords used for back and forth and chain searches were as follows:

- Personal Carbon Budget
- Personal Carbon
- Personal Carbon Allowance
- Personal Carbon Trading
- Carbon Policy

- Personal Carbon Tax
- Carbon Labelling
- Carbon Label
- Personal Carbon Emissions
- Individual Carbon Emissions
- Household Carbon Emissions
- Personal Greenhouse Gas Emissions
- Household Carbon Policy
- *Per Capita* Carbon Emissions
- Climate Change Policy
- Personal Carbon Footprint
- Carbon Behaviour
- Personal Carbon Account

2.2.1. Methods used to Analyse PCBs

Methods for analysing and exploring PCBs vary; both qualitative and quantitative methodologies are employed (see Table 2-1. Survey and interview methods are among the most common methods employed denoting a preference towards these methods of evaluation (Table 2-1.). Methods vary depending on the area being explored for example most surveys and interviews concern public acceptability or predicted behaviour, whereas the practical testing studies analyse the feasibility and effectiveness of specific facets of a potential PCB model. Different methods are engaged to evaluate different focuses.

Table 2-1.Summary of key existing PCB Studies' Methods and Broad Study

STUDY	METHODS	MODEL	FOCUS	CITATIONS
(Bristow et al., 2010)	Survey – Stated Preference	Carbon Tax and PCT	Public Preference/ Acceptability	204
(Wallace et al., 2010)	Surveys and Semi-Structured Interviews	PCT	Public Acceptability	45
(Owen et al., 2008)	Focus Groups/ Expert Report	PCT	Public Acceptability	N/A
(Satoh, 2014)	Practical Testing of RFID Tags	Carbon Labelling	Logistics and Behaviour	16
(Vanclay et al., 2011)	Practical Testing of Carbon Labels	Carbon Labelling	Behaviour – Food Purchasing	304
(Upham et al., 2011)	Focus Groups	Carbon Labelling	Potential behaviour – Carbon Labels	239
(Marek et al., 2018)	Simulation	PCT and Carbon Labelling	Potential behaviour – Decision Making	7
(Lindman et al., 2013)	Simulation	PCT	Potential behaviour – Decision Making	19
(Raux et al., 2015)	Survey – Stated Preference	Carbon Tax and PCT	Potential behaviour – Decision Making	53
(Capstick and Lewis, 2010)	Simulation	PCT	Potential behaviour – Decision Making	54
(Howell, 2012)	Interviews – Semi Structured	PCT	Potential behaviour – Case Study	56
(Li et al., 2018)	Economic Modelling	PCT	Energy Consumption Behaviour	37
(Fan et al., 2016)	Economic Modelling	PCT	Energy Consumption Behaviour	22
(Fan et al., 2015)	Economic Modelling	PCT	Energy Consumption Behaviour	35
(Lin and Li, 2016)	Economic Modelling	Carbon Tax	Impacts of Carbon Tax on Emissions	386
(Fleming and Chamberlin, 2011)	Expert Report	Tradable Quotas	Consumption and Distributional Impacts	N/A
(Guzman and Clapp, 2017)	Interviews (with experts)	PCT	PCT Design	16
(Al-Guthmy and Yan, 2020)	Survey and Modelling	PCT	Distributional Effects/ Feasibility	5
(Lane et al., 2008)	Expert Report	PCT	Feasibility	N/A
(Starkey and Anderson, 2005)	Expert Report	Tradable Quotas	Review of DEQs (inc PCT)	N/A
(DEFRA, 2008)	Expert Report	PCT	Feasibility	N/A
(Zanni et al., 2013)	Survey	PCT	Public Acceptability	23
(Wadud and Chintakayala, 2019)	Preference Survey	PCT	Public Acceptability	10
(Gao et al., 2022)	Survey	PCT	Public acceptability	2

Qualitative methods or quantitative (such as stated preference surveying) are most commonly employed, even if the methodology is quantitative the studies focus on the opinions and views of the public. Studies have various aims, such as seeking to identify the potential behavioural changes PCBs would cause in the public, the logistics of implementing a PCB and public acceptability of PCB models. However, these are based on public responses rather than measured or simulated behaviour.

The methods used generally focus heavily on human behavioural intent, preferences and acceptability around a PCB scheme. Methods focus on social science approaches, with few using practical testing or simulation methods. Practical testing of a scheme like PCT is complex and requires considerable planning, costs, and willing participants. Simulation methods can provide insights without the same resource requirements. However, these methods are utilised significantly less than social science methods such as surveys, focus groups and interviews.

2.2.2. Social Surveys, Focus Groups and Interviews

Social surveys, focus groups and interviews are often employed to gain opinions and experiences. Survey design in the analysed literature is often quantitative (i.e yes/ no questions or likert scales, rather than open questions) which allows for data that can be statistically analysed with reasonable ease and provides consistent data but may not capture nuance comprehensively or exclude socioeconomic/ cultural or personal factors that influence a participant's response (Creswell, 2010, Bryman 2006).

Howell (2012) used semi-structured interviews to gain experience related data from participants, this method is useful to gather qualitative data and allows for participants to express their opinions, attitudes and values. However, due to the intimate nature of interviews there is a risk of social-desirability bias in one-on-one interviews and participants can be influenced by their perceptions of the expertise and views of the interviewer (Krumpal, 2013, Larson, 2019).

Within the in-scope literature Owen et al, (2008) is the only paper to use focus groups, focus groups allow for numerous 'voices' to be captured in a similar timeframe to an interview, and allow for discussion and potential consensus on topics (Kitzinger, 1995).

2.2.2.1. Stated Preference Surveys

Stated preference surveys present participants with options that may be as straightforward as two options of actions, models or activities and asked to identify which if the two they would choose according to the defined criteria. For example ‘would you prefer to do…’ ‘which do you think is more important…’.

Bristow *et al.,* (2010) presents participants drawn from the public with stated preference choices between varying PCB design attributes and choices between a personal carbon trading system and a carbon tax. The study’s focus is that of the opinions of the public towards comparing personal carbon trading and the varying attributes against a carbon tax, and their stated preferences of a PCB or carbon tax in terms of their features. The study by Raux, Croissant and Pons, (2015) also uses a stated preference based methodology, this study has a narrower focus than the Bristow *et al.,* (2010) study as it examines the potential of a PCT scheme against a carbon tax on the behaviour of personal transport drivers and if carbon emissions could be reduced to a greater extent by PCT against a carbon tax through behaviour change.

Stated preference surveys present participants with predecided options, participants will be offered two different choices and they simply select their preference. This may not mean they actively approve of their chosen option, just that it is preferable to the alternative. These stated preferences are then collated and an understanding of what participants most prefer can be analysed. Participants are not given an option to express any opinions, unlike qualitative methods like focus groups or qualitative surveys.

2.2.3. Economic Modelling

The few papers that use economic modelling tend to focus on niche aspects of personal carbon trading and its impacts on energy prices. Often these focus on market behaviour and energy costs rather than environmental factors or individual consumption and explore the trade and market concepts raised in other studies and reviews. Papers that use economic modelling often use real world data within the models or map the potential of interventions already underway (Lin and Li, 2016).

2.2.4. Simulated Behaviour

A simulation methodology has been adopted by Capstick and Lewis, (2010) for a broad examination of how a personal carbon trading scheme could be implemented and engaged with by the public. A simulation puts participants in a situation where they are asked to act, and make decisions, as if they were operating in their ‘real life’ under certain parameters. Simulations for PCBs give participants choices on how to spend their carbon allowance and generate behavioural data, it is lower cost method than practical testing and requires less complex organisation. The data gained from simulations would not be as true to the general public's real-life choices under a PCB model as practical testing but allows for whole model testing.

2.2.5. Observations of Behaviour

Studies that use practical testing are usually specific to an aspect of how a PCB model may be implemented or maintained. These methods analyse at the 'day to day' reality and challenges of a PCB model or its associated features such as carbon labelling. Satoh, (2014) addresses the supply chain and realities of how carbon credits could be spent, the focus of the study is on barcodes or RFID tags on products as 'certificates' with which allowances will be claimed. This was not tested via survey for public acceptance but via low level testing in a local supermarket, allowing for a 'real world' trial of the proposed scheme and the RFID tags. Similarly, Vanclay et al., (2011) examines customer responses to carbon labels on products over a three-month period, using simple coloured labels to indicate carbon emission intensity and tracking any change in sales due to this labelling. These methods allow for unambiguous real-world data to be gathered alongside testing certain facets of a PCB for logistical feasibility, any potential flaws with rolling out PCBs on a large scale can be identified. Practical testing has considerable costs and logistical issues, for both the studies by Satoh, (2014) and. Vanclay et al., (2011) considerable effort and resources will have had to be expended to liaise with the retail outlets involved, alongside production and design, development, and production of relevant labels. Alongside any other organisational or logistical challenges such as finding willing retail outlets and ensuring their methods are not tampered with. A method like simulations requires less financial cost and less logistical effort.

Practical testing within the literature largely seems to be employed when examining carbon labelling, this may be because pragmatically it is an easier intervention to explore through this method. Explanation of the labels can be displayed publicly and explained concisely and does not necessarily require participant recruitment or sampling (Vanclay et al, 2011, Satoh, 2014)

Practical observational testing of carbon labels can be operationalised without a large burden or invasion on participants, for Vanclay et al (2011) and Satoh (2014) sales data was gathered and no data gathered on participants themselves. Whilst this limits the exploration of the impacts of an individual's personal factors (i.e. demographics, political views, cultural identity) on their behaviour it allows large amounts of easily accessible data to be gathered with reasonably low ethical concern as personal data is not involved.

2.2.6. Review Papers

A wealth of academic review articles on PCBs are available. These discuss the possibilities of PCBs and the potential barriers to such a policy. They introduce no new data to the field but signpost topics to be considered (Fawcett, 2010; Lockwood, 2010; Parag and Eyre, 2010). These papers also give considerable thought and analysis to the concept of PCBs and their appropriateness to the current time, or their viability as a policy intervention.

Those pieces of literature that are expert reports instead of peer-reviewed articles are for governmental bodies or by governmental bodies. These reports examine practicalities and feasibility, important facets when a government is considering if such a policy would be viable (DEFRA, 2008; Lane et al., 2008; Starkey and Anderson, 2005, Lane et al., 2008; Starkey and Anderson, 2005). However, they tend to work from existing secondary data or limited datasets as they are usually produced in a short amount of time and are not subject to peer review.

2.2.7. Research Focus of Current Studies

Studies vary in focus but the majority address public acceptability or the potential for public behavioural change (Table 2-1). Several studies address the distributional impacts PCB models may have, but this is a minority for a key issue surrounding the implications of any policy, and in particular a policy that could impact all facets of the life of the public. There is little in the way of literature examining the overall carbon reduction potential of PCBs or fully dimensional sustainability focused studies. Studies tend to examine acceptability of carbon budgets to the public and changes to behaviour the public may be willing to accept or prefer against other behavioural options.

As public acceptability is a focus of several studies there is often a factor in those papers examining potential behavioural change. However, there is a nuanced difference between the questions ‘would you accept this?’ to ‘would you prefer this?’ If you are given two options both of which you would not accept (for example, not flying or not driving a car) but were asked which you preferred if you had to, a different answer would be given. Preference is in some ways an indication of ‘least worst’ option, whereas acceptability means some form of approval or satisfaction with the option or subject (Adell et al., 2014; Owen et al., 2008; Schuitema et al., 2010; Wadud and Chintakayala, 2019). Whilst some papers focus solely on acceptability, others examine preferences of different PCB features or preferences across PCBs or enquire into what the public state their behaviour would be (i.e. stated preference or simulation), which involves facets of acceptability and preference (Abigail L. Bristow et al., 2010; Capstick and Lewis, 2008, 2010; Alberto M. Zanni et al., 2013). At times acceptability and preferences are used as interchangeable terms; Bristow et al, (2010) is titled as a paper concerning acceptability but employs a stated preference methodology. Therefore, there is overlap between the two, and the function of acceptability and preferences within understanding the implications of a PCB model in relation to public attitudes, opinions, and behaviour.

The potential for PCB policies to shift public behaviour is a common focus of PCB related studies. This can vary from examining how individuals may spend their carbon allowance to if energy consumption will reduce under certain PCB models to if carbon labels alone can shift behavioural patterns (Capstick and Lewis, 2010; Fan et al., 2016; Marek et al., 2018; Vanclay et al., 2011). Understanding behavioural changes brought about by PCBs can allow adjustments to potential PCB policy designs, particularly in ensuring PCB models are designed in a fair and equitable way. Understanding how different social groups 'spend' carbon can have great value in changing this behaviour; however, most studies examine this through the lens of which facets of life participants would be least flexible in changing to reduce emissions (Lindman et al., 2013; Wadud and Chintakayala, 2019). It may be that understanding what is easiest to change from a needs perspective may have value, acceptability and preferences may also differ from what the public is able to change and what they can or cannot change in relation to their needs.

Al-Guthmy and Yan, (2020) explicitly seeks to examine the distributional effects of a PCT model on the public considering if a PCT model would be regressive or progressive and the potential impacts on an individual relating to income. This topic is touched upon in other studies and reports but often in relation to acceptability (public perception of fairness) or not explored with detail. Literature which explores carbon taxation rather than PCT models tends to take distributional effects into far greater consideration, however this should be a consideration for any policy proposal (Callan et al., 2009; Fremstad and Paul, 2019; Seyfang and Paavola, 2008).

Fleming and Chamberlin, (2011) discuss the benefit of PCBs (a PCT scheme within an ETS framework model) as a tool for education and motivation of the public. This is implicit in studies that seek to analyse the influence of PCBs on behavioural change but often these studies do not evaluate changes in awareness or education around carbon emissions and the carbon costs of specific goods and services. Upham et al., (2011) analyses carbon awareness within focus groups and examine the environmental awareness individuals have and if there is a public understanding of a range of carbon emission values for goods. Results showed individuals had little comprehension of carbon emission values, they did not understand what numeric values meant in relation to carbon emissions. As a result of this the ability of PCBs to educate and raise awareness should gain further attention, PCBs may enable the public to understand and engage with what carbon emission values mean and what may constitute high or low emissions for goods and services.

Potential design features are explored within the existing literature, but these are frequently related to public acceptability of these features rather than the efficiency or effectiveness of features in comparison to each other or in general. How features may impact on carbon reduction is rarely mentioned in the literature. PCBs are often compared to simpler carbon taxation models to gauge differences in preferences, distributional differences and occasionally the potential for environmental impacts (Bristow et al., 2010; Parag et al., 2011; Raux et al., 2015; Alberto M. Zanni et al., 2013). The implications of different model design features from a socioeconomic, EDI or cultural perspective are rarely discussed, explored, or analysed.

2.2.8. Discussion of Existing Literature

Whilst there are numerous PCB related studies there is a dearth of studies that employ quantitative methods to explore the environmental impacts of PCBs or mention or discuss sustainability. Few studies on PCBs use more than one data gathering method or data source; the study by Howell (2009), which explores Carbon Rationing Action Groups (CRAGs) as a case study, uses only a single method of data gathering – interviews. Numerous methods in relation to case studies may allow for an understanding of nuances in the needs of the public in relation to carbon consumption, the barriers that may be encountered and the preferences of the public in relation to those needs and barriers. The existing literature, whilst often conducted using appropriate methods for the specific aim of the study, does not expand beyond the methods used in previous studies; new methodologies are not utilised to drive the subject area forwards. Subject areas and focus of studies tend to be clustered around several main topics that of acceptability, preferences, potential behaviour (often in relation to acceptability, preferences, or both) and/or logistics, with some other areas considered (Table 2-3).

Surveys and interviews are particularly popular methods of data gathering for PCB evaluation, these methods allow for direct data gathering from the public but focus on public attitudes and opinions only. The overwhelming focus of the existing literature on the public's acceptability and attitudes may be of less value than implied by the comparative focus on it in existing literature. Whilst much of the data gathered has significant value in understanding potential behavioural change, resistance to the policy and other social facets, it is only one small part of a PCB policy. A policy intervention of this size would have a significant impact on the lives of the public. However, it may be difficult for the public to comprehend the reality of living with a PCB until they experience it. There have been several controversial policy interventions implemented in the UK and Ireland in recent years that were met with initial public outcry but have now become an accepted part of life. In particular; the plastic bag tax, the ban on smoking indoors and the congestion charge (Convery et al., 2007; Schuitema et al., 2010; Zheng et al., 2014).

Stated preference surveys can provide clear data but the information gained from the data lacks the additional depth interviews and focus groups can provide. Anonymity in surveys may yield more 'honest' responses from participants than from face-to-face methods due to the potential for participants to feel they must answer a certain way to please their interviewer or other participants (Dijkstra, 1987; Kitzinger, 1995; Stewart and Shamdasani, 2015). However studies that utilise focus groups and interviews allow for a deeper analysis of participants responses to facets of PCB models; they allow for interrogation of a participant's reasoning rather than binary preference selection.

Studies on attitudes (including acceptability) and preferences have different purposes and outcomes although initially it may be easy to consider them the same. Acceptability allows researchers and policy makers to gauge how popular or unpopular a policy may be at the time, whereas preferences facilitate understanding of what factors or options are less desirable. Carbon emissions must be reduced in order to halt climate change; therefore, acceptability is not the only area to explore. There are times when a less acceptable policy is required to achieve the ultimate aim of a policy, such as command and control policy interventions to reduce pollution and other direct policies – for example the UK congestion charge and Ultra Low Emission Zones are largely considered reasonably unpopular, but are critical to reducing air pollution to safer levels (Levy et al, 2010, Ma et al, 2021, Zheng et al, 2003, Schuitema et al, 2010, Zhai and Wolff, 2021 , Gossling et al, 2024).

Whilst both acceptability and preferences are significant, they can be complex to measure, for both someone's stated acceptability and/or preferences may be different from their revealed. Stated preferences are based on self-reported opinions or assumptions around behaviour that may not translate into real action or behaviour. As noted in some of the presented theories of behaviour change in chapter 1 of this thesis, behavioural intent may not lead to behavioural change. Potential for desirability bias, or actions that reveal a different preference, or they may act counter to their stated preferences due to other barriers. Much of the same can be applied to acceptability although acceptability is more likely to be tied to one's overall attitudes and it may change with experience if acceptability is being evaluated on a hypothetical scenario.

The study by Schuitema et al., (2010) has participants respond to surveys before and after a congestion charge trial in Stockholm, acceptability of the congestion charge was higher after the trial took place. This demonstrates that the public may struggle to gauge their own acceptability to a policy change without experiencing it, or that only through experiencing it can they see the benefits. This change in attitude can also be seen in countries where disposable plastic bag charges have been implemented, the public initially had an adverse reaction to these charges, but now not only accept them but demonstrate pride and positivity towards the environmental benefits (Convery et al., 2007; Thomas et al., 2019). The reaction to the environmental benefits of the plastic bag charge has in some cases led to overall public support and positivity towards other 'green' taxes and policies, this indicates that public opinions change over time and initial indications of negativity may not be as large a barrier as anticipated (Thomas et al., 2019). Their stated preferences and acceptability is not the same as that revealed by their response to these 'green' taxes.

Stated preference surveys give participants the ability to compare different options and make decisions based on their own needs by prioritising some factors over others. This is a useful method for understanding how different people may prioritise different areas of carbon reduction which may be related to their individual needs. Some aspects of a carbon budget may be outside of a member of the public's understanding (i.e. what limit there needs to be on a budget for it to be effective) but they can provide information on their own needs that can help inform the development of equitable budgets. Providing participants with choices rather than ranking can yield more accurate representations of their preferences compared to a method such as ranking. This is in part due to the fact it may take less time, is closer to real world thinking a participant may have to do (rarely does anyone have to rank things) and more information can be included (Kroes and Sheldon, 1988; Ortúzar and Garrido, 1994).

The studies employing practical testing and simulation methods enable the gathering of either 'real world' data or data that may be closer to practical data than a survey (Capstick and Lewis, 2008; Lindman et al., 2013; Marek et al., 2018; Satoh, 2014; Vanclay et al., 2011). Practical testing allows a clear analysis of the public's behaviour and how they might interact with a PCB model in actuality, whilst a simulation cannot quite recreate this it engages the participants to a deeper degree in the practicalities of a PCB and how it would make them change their consumptive behaviours.

The papers that use economic modelling consider less on the process of changing behaviour or acceptability, but consider what would occur if behaviour changed.

There is little exploration of how instead of making a PCB model acceptable to the public how to make the public accept a PCB . Public opinion and acceptability, and therefore behaviour are at times treated as immutable and means that a PCB model is expected to fulfil criteria set by an uneducated (on the topic of carbon emissions) public. Whilst public acceptability does shape policy decisions, the ultimate aim of a PCB is to reduce carbon emissions, distorting a PCB model too greatly to fit public acceptability could affect the effectiveness of a PCB as a carbon reduction policy if care is not taken with implementation and design. Stated preference surveys can allow for comparisons of equally effective models (i.e. the overall cap is the same) that can gauge what model the public may find easiest to use in terms of their preferences. The inclusion of factors such as the scope of what is included in the budget should not be based on public opinion due to the need for this to be evidence based to meet the carbon budget reductions required (Bristow et al., 2010). However, acceptability remains important in those aspects that impact people in other ways, such as delivery (i.e. is internet access required to manage engagement with a policy) or if a financial penalty was to be levied due to non-compliance.

A topic that rarely appears in current PCB literature is the environmental potential of PCBs including their actual potential to reduce carbon emissions compared to other carbon reduction policies or just the general projected reductions they could cause. Whilst the actual budget a PCB may centre around may be mentioned, there has not been a clear calculation of this figure in relation to a carbon budget. What the budget would be (with the understanding it may not be applied per capita due to differing needs) is a crucial factor due to the impacts it would have on overall carbon emissions but also how severely the public would be required to change their behaviour.

The literature may propose budgets that are around the global average in their acceptability studies or modelling, but a budget would need to be below that to cause reductions, additionally this budget will have to reduce per person as the population grows but carbon emissions need to reduce. ‘Lifestyle’ carbon emissions are estimated to be between 65% and 75% of all global GHG emissions and thus need harsh cuts, lifestyle carbon emissions are those relating to the choices made by an individual on how they live their lives i.e types of consumption they undertake (Hertwich and Peters, 2009; Ivanova et al., 2016; Larsen and Hertwich, 2009). (Bristow et al., 2010) proposes a limit of 4 tons of CO_2 which was around the global average per capita at the time of publishing; however, to facilitate a reduction in emissions the limit needs to be lower than the average. For many countries, this would be a significant reduction as a global average it is still significantly too high and estimates at the time of writing of this thesis are closer to two tonnes of carbon dioxide equivalent (United Nations Environment Programme, 2023). The more recent interest in the economic realities of PCBs in terms of energy consumption, whilst highly relevant, still focuses on the human aspects of these hypothetical policies. Whilst the models may predict that the public will use 'less' in the way of energy there seems to be little in the ways that would directly impact the environment.

How PCBs could aid in sustainable development is not explored in a systematic way in any of the existing literature and very few papers or reports mention sustainability as a goal of PCB policies. Review papers discuss aspects like the potential of a PCB model to aid in fair energy distribution via emission caps and preserve natural capital but the actual value of PCBs for these goals has not been investigated. When personal carbon trading models are explored and discussed the concept of removing trading is not often raised and is often treated as an intrinsic part of a Personal Carbon Allowance model, even though this feature may impact carbon emissions. If surplus carbon credits can be traded, then they will always be used (therefore the cap will always be met) this would mean the maximum carbon emissions would always be emitted. Discussion of how each feature may change carbon emissions is a gap within the existing literature.

Sustainability across dimensions is not often discussed or included in studies evaluating PCB models, the implications of such a model on different demographics is rarely considered. Carbon taxation studies consider distributional effects, but as a PCT model includes a financial element via trading the omission of this aspect means the impacts a PCT model may have financially is rarely explored. The barriers and challenges individuals may face on a personal level when living under a PCB model is also largely absent from the literature, decision-making is explored but not the underlying context and motivators for these decisions. However, Howell (2012) uses interviews to gain experience and reflective qualitative data from those who undertook a voluntary personal carbon allowance and specifically asked questions around the difficulties they may have faced under this voluntary programme.

Data gathered is largely quantitative, even those studies exploring acceptability trend towards using closed question surveys, stated preference or the practical testing did not include follow up interviews with participants to gain their reflections or justifications for their decisions.

Surveying, simulations and other self-reporting methods can only provide us with stated preferences or answers that may be influenced by social bias. These have considerable value, but do not show us the revealed preferences of the public, how they would actually behave under a PCB. As has been discussed the public may not always quite know how they would act in a real world setting or may accept something they believed they would not. Therefore, alongside studies that examine preferences that show stated preferences, methods such as real-world testing of PCBs should be employed to gain the corresponding revealed preferences.

2.3. Literature Review Conclusions

Exploring only acceptability may be a 'red herring' because as noted the public does not always understand a policy or model until it is applied, a broader range of focus may be beneficial in when considering personal carbon reduction policies (Borland et al., 1990; Convery et al., 2007; Schuitema et al., 2010; Thomas et al., 2019). However, preferences are a slightly different type of data to gather. As preferences show what the public may tolerate or prioritise as opposed to accept there is value in understanding how the public may prioritise their carbon spending especially if this varies by demographic and attitude. The distributional impacts of a PCB could deeply impact all aspects of the life of the public and therefore needs to be carefully examined (Al-Guthmy and Yan, 2020). Understanding how diverse groups would prioritise carbon spending may indicate their specific needs. Additionally, an understanding of the environmental impacts of PCB models should be explored in greater detail, this may require more qualitative methods or environmental modelling to examine the implications on carbon emissions if the public had to follow a set carbon budget.

The key gaps in the literature are exploring the nuances of personal behaviour in relation to carbon budgeting, if a carbon budget is required or if the public can be nudged into reducing emissions, or their own personal attitudes and motivations may lead them to reduce emissions. Understanding people's behaviours and the barriers and challenges faced regarding reducing carbon emissions are vital context in relation to understanding these models. Whilst there have been proposals to consider personal carbon budget models and analysis of these models these are limited and do not consider all factors of these policies such as social justice implications. Whilst feasibility and technical aspects are explored further understanding of if such a policy is needed or if the current 'nudge' models could be further leveraged is not fully understood.

A gap exists in the exploration of PCB models compared to each other in terms of their features, implementation, and impacts. Comparisons between models are limited, whilst there are studies comparing and analysing acceptability of models it is often assumed that all models will lead to carbon emission reductions. Comparing the models through a holistic lens that incorporates all threads of sustainability is a rarely explored topic as it may be found that some models are socially unjust, regressive, or do not have the potential to reduce emissions to the degree required to combat climate change.

The current policies in the United Kingdom to reduce personal carbon emissions are largely 'top down' policies, targeting sectors or national initiatives acting on the emissions generated by industry rather than reducing demand for these services or incentivising change through customer requirements. Actions towards reducing personal emissions are often centred around nudge theory awareness raising or education rather than clear public centric policies. Therefore, there is a gap in the existing policy landscape in the UK for policies that address personal carbon emission reduction and identifying which policies may be the most effective.

The pre-feasibility report by DEFRA is currently the most comprehensive report and examination of a proposed PCT model, the report examines a specific model TEQ for the UK government rather than a comparison of potential interventions and their potential impacts and efficiency. Little of the existing literature in this area considers the potential for PCBs to reduce carbon emissions – it is assumed they would by their nature, but the potential for reduction is not explored. Some of the literature explores the social justice impacts of certain PCB models and carbon taxation, but this is often linked to public acceptability rather than equality and equity.

Exploration of the current literature does not identify a clear exploration of all dimensions of sustainability in relation to personal carbon budget models, the cultural and social aspects are neglected, as are considerations for social justice impacts and equity. Within the existing literature there is considerable focus on acceptability of models rather than effectiveness to reduce emissions and provide the required and sustained cuts to emissions needed to meet the UN targets to keep global temperature rise to below 1.5^{O}C.

Reviewing the existing literature identifies that methodological approaches to exploring PCBs are limited. PCBs are rarely compared in relation to each other, the effectiveness, feasibility, and sustainability. Additionally, when exploring the decision-making and behavioural and attitude aspects of personal carbon reduction methods used are often social surveys and simulations rather than the gathering and analysis of behavioural data. Exploration of behavioural data, and gaining insight into the motivations, barriers, challenges, and attitudes around behaviour is highly valuable for researchers and policymakers when identifying appropriate policy interventions. However, this is absent from the current literature landscape around PCBs.

Whilst acceptability is widely explored in relation to PCBs the need for a PCB model is not, if the public can modify their behaviour without an intervention there is no need to develop a specific and targeted intervention.

2.4. Rationale of this Thesis

The subject of personal carbon budgets is controversial and previous consideration given to the model in the UK have ended in it being considered, at the time, unfeasible. But as discussed in Chapter 1 all avenues of carbon emission reduction should be explored to combat the global climate crisis.

Within the field of personal carbon budgets, a sizeable portion of the peer reviewed literature are opinion pieces, reviews, and discussions, in terms of pieces of work taking a systematic, investigative approach many focus on narrow fragments of the topic, such as public acceptability. A gap in the literature is that no study explores and critically evaluates personal carbon budgets holistically, comparing different current models and formulating models based on sustainability criteria.

Fawcett, (2012) comments on the need for future work on PCBs;

“Ideally, a significant, multidisciplinary 5-year research program would commence now, which would investigate all the issues and questions about PCT (and alternative policies such as carbon taxation) ... At the end of that period, it should be clear what the design options are for a PCT policy, its costs and benefits, who would ‘lose’ and who would ‘gain,’ and how its equity, effectiveness and cost compared with alternative policies.”

A policy such as a carbon tax or mandatory policy would have considerable impact on the lives of the public, the private sector and government. To identify if such a policy is required developing an understanding of what the public is capable and motivated to change is vital in identifying if a policy intervention is required, and if so, which intervention is most suitable.

Methods used to analyse the public in relation to their personal carbon emissions and personal carbon budgets and interventions are self-reported opinion based surveys often focusing on acceptability, many of which are quantitative, qualitative data is gathered less frequently which indicates there are gaps in understanding of what barriers and challenges individuals in the UK face when attempting to reduce their personal carbon emissions. Understanding the priorities of people and why they may be unable to change their behaviour i.e. if it is an internal factor such as motivation, knowledge or attitude, or external factors such as service provision, could aid in decision making around an appropriate policy instrument to reduce personal carbon emissions.

The approach taken by this thesis is to critically evaluate and compare existing PCB models, alongside the proposal of a new PCB model, and to then explore and evaluate the preferences, barriers and challenges the public experience in relation to reducing personal carbon emissions. To identify the areas of complexity surrounding PCBs evaluation of the models was conducted as the first stage of the thesis, such as potential barriers to behaviour change or if certain models have extremely limited potential to reduce emissions. Understanding each model comprehensively informed and supported development of the following methods of data gathering and analysis. Identifying if any PCB model has the potential to reduce emissions whilst supporting all dimensions of sustainability was vital to ensuring the thesis concept of exploring PCBs as a potential policy intervention was a justifiable one.

To analyse the feasibility of a PCB policy model implementation, a policy that has such a large-scale impact on the lives of the public, the current preferences, attitudes, and behaviour of the public must be explored to ensure the policy is 'fit for purpose.' The existing literature explores technical aspects, or acceptability of PCBs, but considerations of behaviour, attitudes or if the public requires such a policy to reduce emissions are a gap in the current literature landscape.

2.5. Scope of the Thesis

This study intends to examine the potential of PCBs as a method for carbon emission reduction, considering sustainable development through four main pillars of sustainability – environment, economics, social and culture. This thesis intended to identify the challenges and barriers around reducing personal carbon emissions and discussing their implications when devising personal carbon emission reduction policies. This thesis considers these potential policy interventions from a United Kingdom perspective and policy context.

2.6. Aims and Objectives

AIM 1: Analyse and define what personal carbon budget 'acceptability' is in terms of the four dimensions of sustainability (social, cultural, economic, environmental).

OBJECTIVE 1.1. Identify and critically evaluate public values, attitudes, and behaviours in relation to personal carbon budgets with consideration of the social justice implications of these policies

OBJECTIVE 1.2. Identify and critically evaluate economic implications of personal carbon budgets

OBJECTIVE 1.3. Identify and critically evaluate positive and negative environmental impacts of personal carbon budgets in relation to the reduction of carbon emissions

AIM 2: Explore barriers and challenges the public face in reducing their personal carbon emissions

OBJECTIVE 2.1. Identify and evaluate barriers the public experience when attempting to reduce their personal carbon emissions

OBJECTIVE 2.2. Identify and critically evaluate challenges the public experience when attempting to reduce their personal carbon emissions

AIM 3: Collate findings to identify and propose appropriate PCB model to reduce carbon emissions with the consideration of environmental, cultural, economic, and social factors.

OBJECTIVE 3.1. Collate and synthesis findings to identify appropriate PCB model

OBJECTIVE 3.2. Critically evaluate the environmental, cultural, economic, and social findings to propose appropriate PCB model public face in reducing their personal emissions to support the justification or rejection of a PCB model as a potential model for personal carbon emission reduction.

2.7. Thesis Methodology

This thesis uses several different methods to fulfil the aims and objectives presented in section 2.6.

Methods utilised are as follows:

i) A PESTLE (Political, Economic, Social, Technological, Legal, Economic) Framework Analysis of existing Personal Carbon Budget models and policies and the proposal of a new PCB model following reviewing the literature which is analysed and compared to existing models. And the proposal of a new model following a review of the existing literature for testing. The model that most fulfils the five aspects of the framework to the highest degree was identified.

ii) A Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) method (multi-criteria decision making (MCDM) conjoint analysis) study of the preferences of the public surrounding their personal carbon emission reduction behaviours. Cluster analysis and analysis by demographic and attitude groups of collected preference data. Results were analysed to identify if the public are capable of changing their own behaviour to reduce emissions without requiring the policy identified in the PESTLE analysis. *ErgoII number: 67255*

iii) Development and implementation of a new carbon behaviour analysis and measurement method the CABDI (Carbon Behaviour Diary) method to gather and analyse carbon reduction behaviour data (qualitative and quantitative). Findings explored to identify barriers and challenges in changing behaviour and motivators behind the public's stated preferences to further identify if a mandatory policy intervention is required or if barriers experienced are outside the scope of what such a policy could achieve, *ErgoII number: 79504*

iv) Synthesis of findings to provided cohesive conclusions and proposals for future work.

3. CHAPTER 3: PERSONAL CARBON BUDGETS: A PESTLE REVIEW

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3.1. Abstract

Personal Carbon Budgets (PCBs) are a radical policy innovation that seek to reduce progressively individual carbon consumption. This critical review identifies three main archetypes of PCBs in current literature; Personal Carbon Trading, Carbon Tax, Carbon Labelling, and proposes a new model - Personal Carbon Allowance with no trading. We theorized that carbon trading could affect equity and allow quality of life and consumption to be driven by income rather than needs. We, therefore, developed this new model to compare to existing archetypes.

A PESTLE framework was applied to each archetype to analyse their costs and benefits in relation to each other and to critically evaluate and identify which model may be the most appropriate to reduce emissions, whilst meeting the demands of sustainability. We conclude that the only model that meets the demands of sustainability is our proposed Personal Carbon Allowance (PCA) model with no trading. PCA has a hard cap on emissions allowing controllable severe cuts to emissions, the lack of trading would prohibit those with wealth continuing high consumption lifestyles at the expense of those on lower incomes and it would be mandatory ensuring these cuts in emissions had to happen and thus carbon emissions would have to reduce.

3.2. Introduction

Carbon emissions have been identified as the key contributor to climate change (Climate Change Committee, 2020). In order to halt global temperature rises to a level at which catastrophic climate change impacts would be limited, greenhouse gases (GHGs) must be reduced (Intergovernmental Panel on Climate Change, 2018). One of the largest contributors to carbon emissions is household consumption; household energy consumption, personal transport and food consumption are key drivers of household emissions (Department for Environment Food & Rural Affairs, 2020). Whilst many seek a top-down approach to reducing carbon emissions, for example regulating industry, all sources of emissions must be addressed to slow climate change.

Due to the severity of the threat of catastrophic climate change, it is imperative that definite and effective actions take place ("actions not words"); these may be uncomfortable to many, but the scientific consensus is we are reaching 'the point of no return' in terms of anthropogenic emissions and their adverse impacts. Whilst governments, such as the United Kingdom's, have commitments to reduce GHG emissions in law the reductions needed are deep and targets seem unlikely to be met. The Climate Change Committee (CCC), the UK government's climate advisors, state within the Sixth Carbon Budget report that the UK needs to aggressively cut emissions by 78% of 1990 levels over the next fifteen years to achieve the 'Net Zero' emissions target by 2050 (Climate Change Committee, 2020). The CCC also advises that despite the UK's sizable efforts to reduce emissions the government is currently 'off track' to meet the targets of the Fourth and Fifth Carbon Budgets (Climate Change Committee, 2021). New more radical policies need to be enacted quickly to cut emissions, even in countries setting, and working towards, ambitious 'Net Zero' goals as it becomes apparent these goals may be out of reach with current strategies and policies.

Several policy interventions have been proposed in order to reduce personal carbon emissions, these range from a carbon tax, to carbon labelling and personal carbon trading. The features of these models vary, some include carbon allocations for individuals whilst others seek to nudge the public into reshaping their consumption behaviours. Four main archetypes have been defined that occur in the existing literature; however, these models are rarely compared to each other in terms of their potential efficiency, costs, and benefits to ascertain which is the most viable.

We propose a fourth personal carbon budget archetype – personal carbon allowance (no trading). Trading is almost always involved in mandatory capped carbon budgets, or if not included in a study or pilot it is the 'end goal' of such schemes and will be mentioned extensively in the discussions around the study (Fawcett, 2010; Fawcett and Parag, 2010; Kuokkanen et al., 2020; Wallace et al., 2010). The removal of trading may have a host of different impacts to how a carbon budget may work and may provide answers to issues raised by the inclusion of trading involved in proposed PCT models.

3.3. Personal Carbon Budget Models

Within the peer reviewed and grey literature, numerous permutations of PCBs have been proposed and discussed, alongside other policy interventions that have been considered as reasonable alternatives to PCBs. These models fall into three broad categories. This paper identifies three main overall archetypes; personal carbon trading (PCT), carbon labelling (CL) and carbon tax (CT). We propose personal carbon allowance with no trading (PCA) as a separate model from PCT (Table 3-1). Each model aims to reduce carbon emissions from the public.

To review and compare each model, an adapted PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis framework has been applied to each model synthesizing information from existing literature with reasonable assumptions (Perera, 2018, Buye, 2021). A set of questions were developed to facilitate a critical evaluation of each model. Not all the questions applied to all models in all cases but indicate general areas of importance (see Appendix A.1). Key features of each model were identified in relation to each PESTLE factor according to the answers to the set questions (see Appendices A.2 – A.5).

Table 3-1. Four main identified Personal Carbon Budget Models and notable features of each model.

MODEL	FEATURES	LITERATURE
CARBON TAX *(MANDATORY)*	• Either flat tax or proportional to carbon emissions by weight per good or service • Levied upstream • Could have exemptions etc. • No cap on emissions • Tax revenue could be invested in green enterprise and innovation	(Abigail L. Bristow et al., 2010; Carbone et al., 2013; Elkins and Baker, 2002; Fawcett, 2010c; Haites, 2018b; Parag et al., 2011)
PERSONAL CARBON TRADING *(MANDATORY)*	• Carbon 'credits' allocated per year each credits worth a certain amount of carbon/ value of carbon additional credits have a cost. Surplus credits can be sold. • Allocation per person or household • Scope of what is included variable but personal only • Requires goods and services carbon footprint calculated • Credits could roll over to next year • Needs government body to regulate • Hard cap on emissions	(Bristow et al., 2010; Parag and Eyre, 2010a; Roberts and Thumim, 2006; Seyfang et al., 2009)
PERSONAL CARBON ALLOWANCE WITH NO TRADING *(MANDATORY)*	• Carbon 'credits' allocated per year each credit worth a certain amount of carbon/ value of carbon • Allocation per person or household • Scope of what is included variable but personal only • Requires goods and services carbon footprint calculated • Credits could roll over to next year • Needs government body to regulate • Hard cap on emissions • No trading of credits in any way	(Fawcett, 2012, 2010; Fawcett et al., 2010; Howell, 2012; Hyams, 2009)
CARBON LABELLING *(VOLUNTARY)*	• Responsibility all on companies to provide carbon information on products and services • Regulatory body not necessary • Requires goods and services carbon footprint calculated • Public given target but no enforcement • No cap on emissions	(Marek et al., 2018; Upham et al., 2011; Jerome K. Vanclay et al., 2011)

3.3.1. Personal Carbon Trading

Personal carbon trading (PCT) is a cap-and-trade model for reducing carbon emissions (Table 3-1 highlights the key features of this model). A limit (cap) is put upon the weight of carbon (as CO_2e) that can be emitted by a country/ area/ population for a unit of time, often a year. This cap amount is then allocated amongst those regulated by the scheme (Haites, 2018; Narassimhan et al., 2018). These allocations would be in the form of carbon credits to be 'spent' on goods and services; credits can be traded to other members of the public via a credit broker for a set monetary value (Fawcett and Parag, 2010; Seyfang et al., 2007). The ability to purchase additional credits means those with higher incomes would be at an advantage to live higher consumption lifestyles; some models propose a limit to how much of a carbon allowance may be traded but there is no consensus on what this limit should be (Bristow et al., 2010; Wallace, 2009). Figure 3-1 demonstrates how a hypothetical PCT scheme may work.

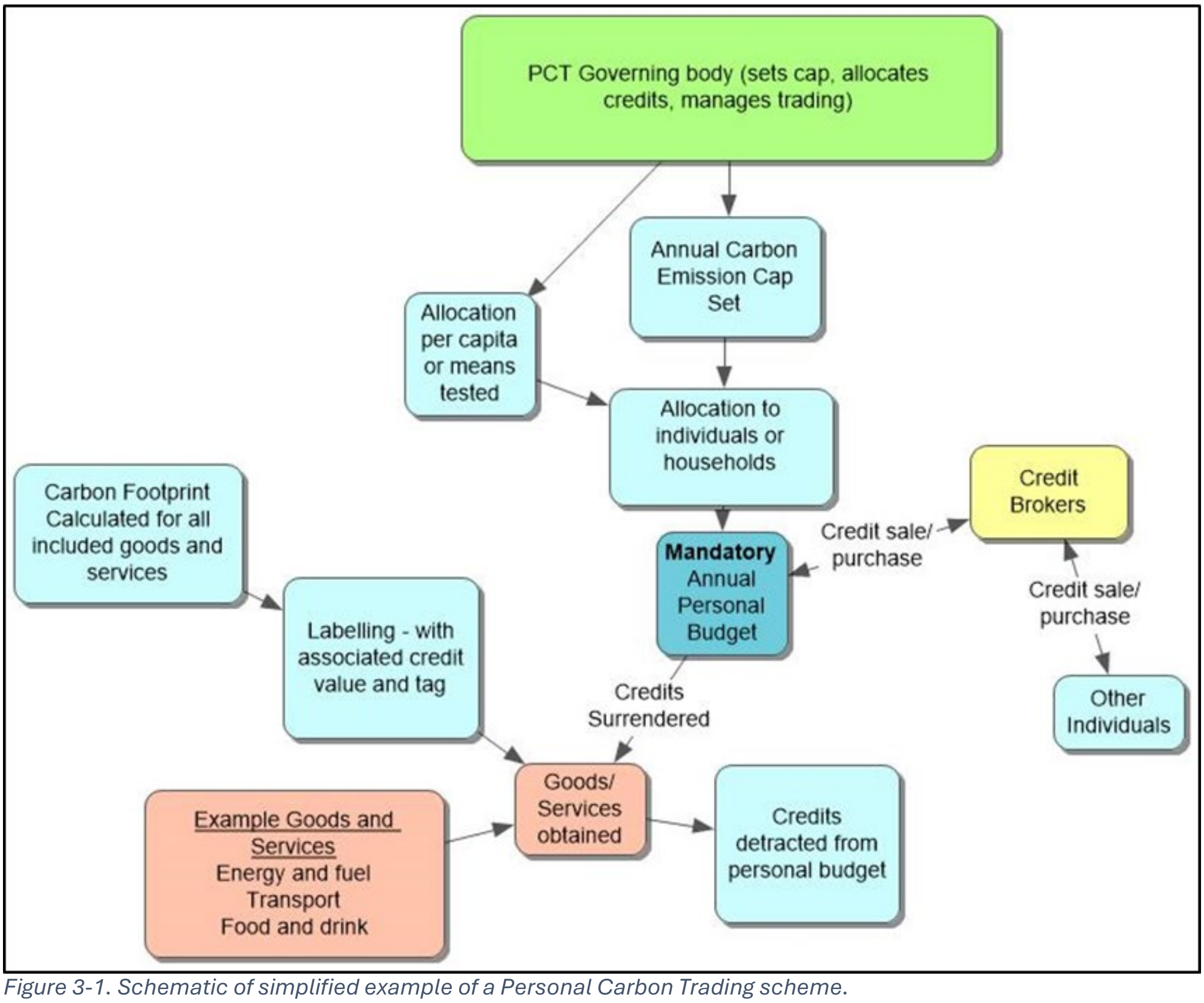

Figure 3-1. Schematic of simplified example of a Personal Carbon Trading scheme.

A personal carbon trading scheme may only involve the public, but versions of this model include industry. Tradable Energy Quota (TEQ) models allocate approximately 40% of to the public with the remaining 60% auctioned to qualifying firms (Lane et al., 2008; Narassimhan et al., 2018).

DEFRA's (2008) report, among others, proposes a system whereby the credits are monitored through existing banking systems and using contactless cards in order to spend credits (Brohé, 2010; Lane et al., 2008; Wintour, 2006). These cards would make use of existing contactless machines in shops and would have an account where the public could track their credit spending.

3.3.2. Personal Carbon Allowance (No Trading)

A PCA model without trading is mostly identical to a PCT model as the methods of distribution of carbon, the scope of emissions and various other technical aspects can be the same (see section 3.3.1.). Most literature on PCBs that cap individual carbon emissions involve carbon trading, few suggest no trading of any kind although some studies propose a limit on the percentage of the allowance that can be traded (Bristow et al., 2010; Parag and Strickland, 2011; Seyfang and Paavola, 2008). Table 4 highlights the key features of this model. PCA bypasses the social justice issues surrounding the ability of those with greater wealth to purchase carbon credits from those of lower incomes to continue their current lifestyles. Within the existing literature, most PCT/ PCA models involve trading, and no thorough examination has been given to the implications of eliminating trading. It may be that personal allowances are too low to reach the reductions needed so that trading would be redundant. Figure 3-2 demonstrates how a hypothetical PCA scheme may work.

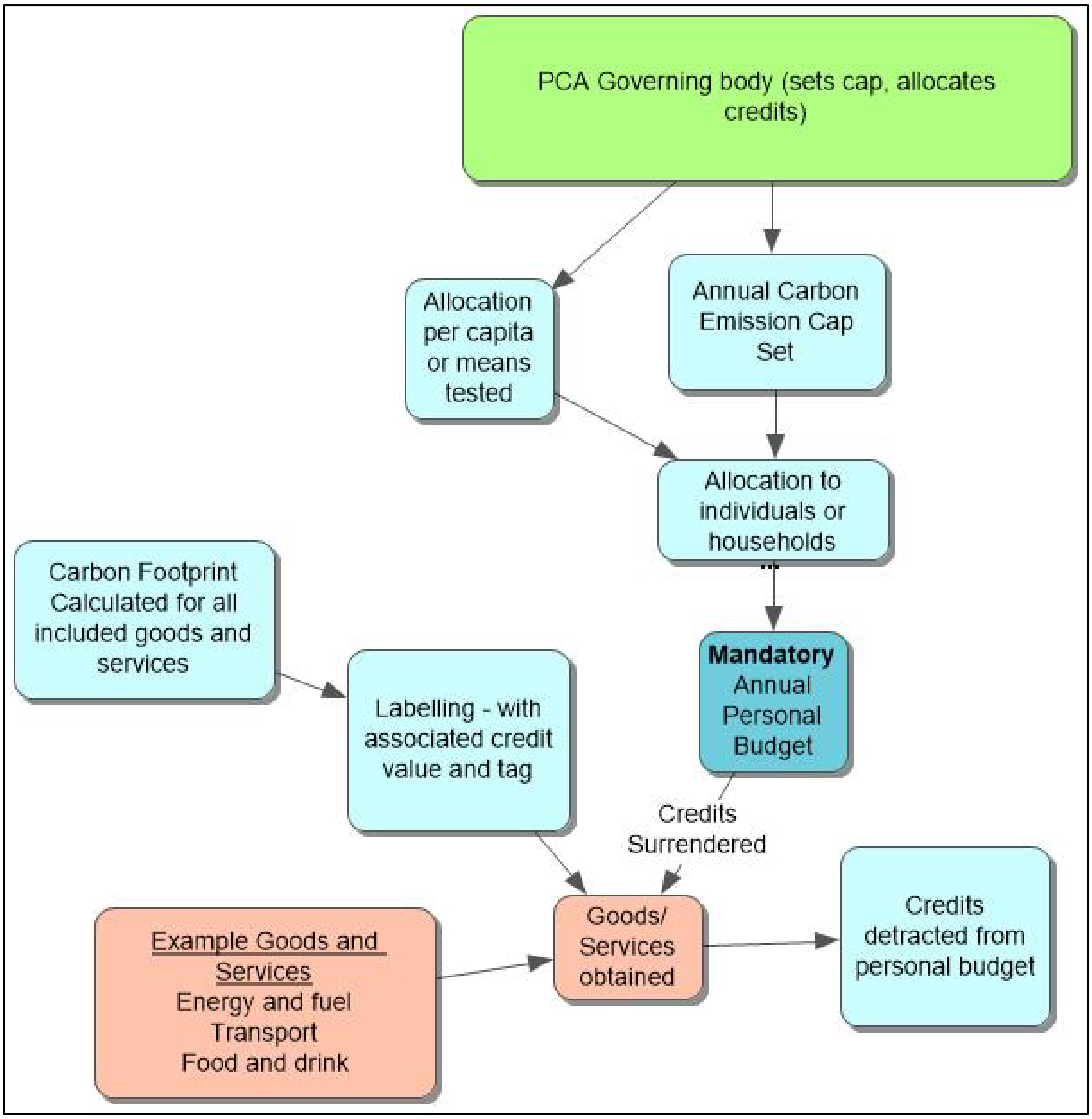

Figure 3-2. Schematic of simplified example of a Personal Carbon Allowance scheme

Allocations of carbon credits in a PCA model would be of foremost importance. The public would not be able to 'top up' their allowance by trading, even if their need is justified. The governing body would have to distribute allowances accurately and fairly with consideration for specific requirements and needs, such as mobility, housing (for example a detached house is more expensive to heat than a terraced house), disability, gender, age, and potentially even cultural impacts such as religious or cultural requirements. The governing body that would monitor and oversee a PCA scheme may need to have a reserve of carbon credits that could be applied for beyond an individual's allocation for unforeseen circumstances or need.

Public carbon allowance schemes have arisen in recent years, notably Carbon Rationing Action Groups (CRAGs). CRAGs are voluntary measures, and each participant is given a carbon allowance per year that they then manage and account for personally. If they go over this allowance, they pay a penalty for their carbon debt (Carbon Day, 2021; Howell, 2012). This is similar to the proposed idea of PCA in this paper as currently there is no trading in the CRAGs model; however, it is not mandatory and has no hard cap. At the time of writing no government has implemented a PCA (or PCT) scheme or policy.

3.3.3. Carbon Labelling

Carbon labelling (CL), unlike the other models, is a voluntary measure (Table 3-1 highlights the key features of this model). Goods and services would be required to have a label indicating the carbon emissions generated in relation to that good or service, the public would be asked to work to a voluntary carbon budget set by the government using these labels to inform their consumption, or simply asked to make 'green' choices based on labelling (see Figure 3-3) (Marek et al., 2018; Upham et al., 2011). There would be no public enforcement to follow the CL policy and no cap on emissions. A carbon labelling method would rely on nudge theory principles; the implication of the labelling and the voluntary budget would be that everyone needs to comply but would not be forced to do so and face no penalty if they did not. This type of model would rely on the principle that the public's behaviour could be shaped and drastically changed by the provision of information and education on the embodied carbon of their consumption. Figure 3-3 demonstrates how two different CL models may be implemented, one model includes a government set cap, one simply has the public encouraged to make 'green' consumption choices based on labelling.

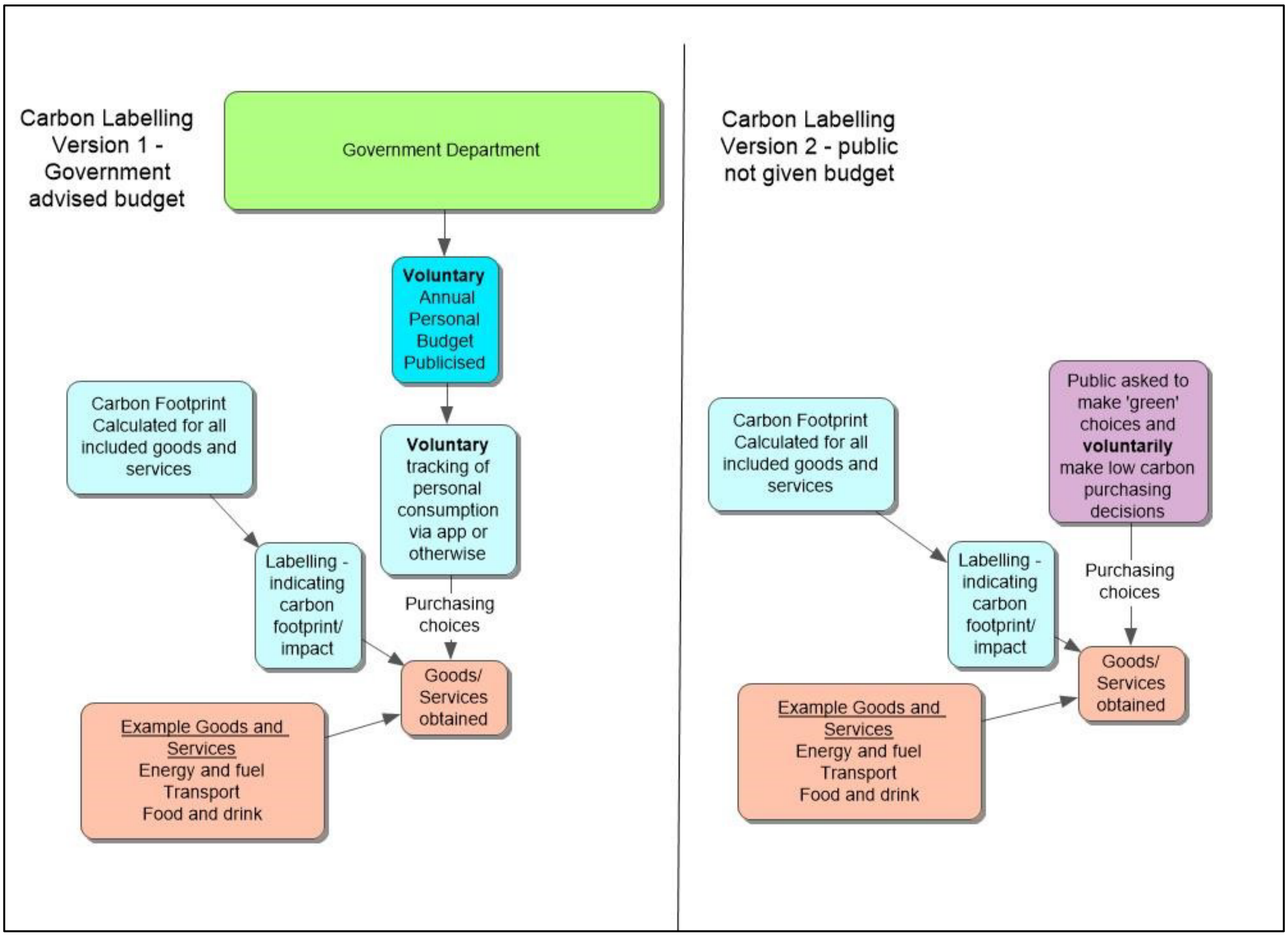

Figure 3-3. Schematic of simplified examples of two CL models, one with a government advised carbon cap, one without.

Businesses would be required to provide carbon footprints and labels for their products and hence standardization across the footprinting method used (as with all PCT/ PCA) would be necessary to ensure consistency, reliability, and accuracy.

Carbon labelling, unlike PCT and PCA has been implemented by various brands and companies on occasion, usually in the form of kg CO_2e per product. In 2007, Pepsi Co announced that Walkers Crisp packets would bear a Carbon Trust certified carbon label identifying the carbon cost of the product, there was also a commitment to lower the carbon impact of the product over two years (BBC News, 2007; Campaign Live, 2009). However, a visit to the supermarket now will show that Walkers crisps currently no longer bear a carbon label. Supermarket Tesco stated an intention to label all their products with a Carbon Trust label, however this was discontinued due to cost and time required, with estimates it would take the supermarket centuries to carbon footprint all their own brand products at the pace they were going (Smithers, 2010; Vaughan, 2012). Recently other brands have made efforts to carbon label some of their products. Both Oatly and Quorn display carbon labels on popular items, but this is not a widespread practice and still most commonly occurs on food products (Oatly, 2021; Quorn, 2020). Pilot schemes and practical testing of carbon labelling has taken place, but the nature of the labels varies, some use a 'traffic light' system that has amber as the 'average' carbon emissions for a product, black 'worse' and green 'better' (Vanclay et al, 2011). This is different from current approaches by companies like Oatly which put the kg CO_2e value on products. This relies on the public understanding what their allowance should be, and would be suitable if people had a budget (see Figure 3-3). A traffic light system could be applicable for versions of labelling with no budget.

3.3.4. Carbon Tax

A carbon tax is an often-suggested carbon pricing policy that aims to discourage the public from generating carbon emissions by taxing goods and services that generate high emissions (see Table 3-1). Several countries already have carbon taxation policies (e.g. Canada, Denmark, and Germany). A carbon tax is applied per unit on fossil fuels and similar fuels; the tax is levied in relation to the carbon content of the fuel (Lin and Li, 2011; Sumner et al., 2011). The tax is applied upstream directly to the producer of the raw product, this raises prices of any goods or services that used a carbon intensive fuel in its provision (Lin and Li, 2011; Parag et al., 2011). Figure 3-4 provides a simplified example of how a carbon tax works.

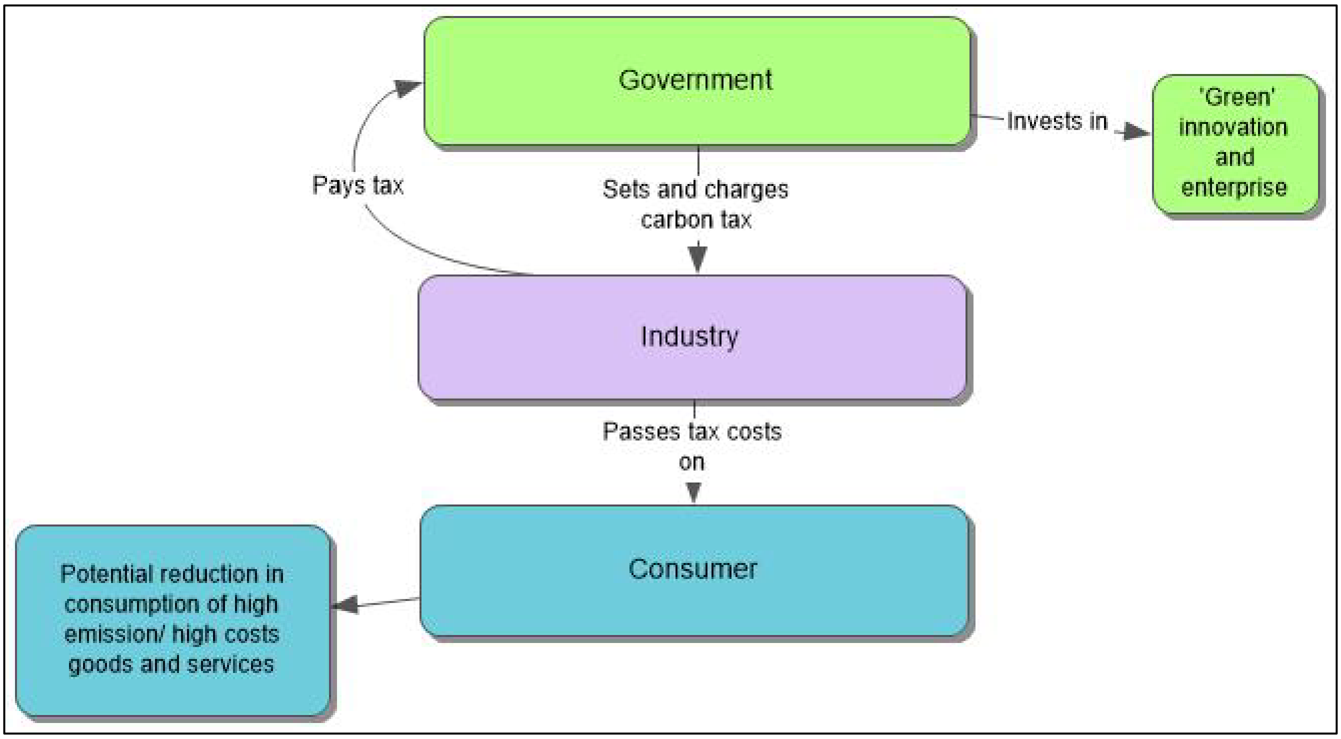

Figure 3-4. Schematic of simple example of a carbon tax.

A carbon tax does not include a cap on emissions and would not require individual goods and services to have carbon footprints calculated. The reduction in carbon emissions would not be controlled, therefore reductions in carbon emissions are expected to come from the public changing their behaviours when faced with increased costs on goods and services (Goulder and Schein, 2013; Sorrell, 2010). Many countries do not have a direct carbon tax on all fuels or one that is applied across all carbon emitting energy sources but do have fuel or energy taxes to discourage carbon emission generation. For example, India has a tax on coal both imported and nationally produced but not a carbon tax on other fuel sources (Singh, 2020).

A carbon tax would be simple to implement and would not require a new governing body or regulator to be created, depending on existing policies it could be easy to fit alongside existing climate change policies in most governments (Narassimhan et al., 2018; Sumner et al., 2011). There are a range of ways revenue raised by a carbon tax could be invested. It has been suggested that funds from carbon taxation would be reinvested into green innovation and enterprise, the revenue itself being used to combat climate change (Carattini et al., 2019; Dissanayake et al., 2020). This may not necessarily always occur; governments may use the revenue as part of the general budget, or create a revenue neutral model, as they have in Canada, where the revenue raised is returned to the public as a rebate (Nuccitelli, 2018).

3.4. PESTLE Analysis

The results of the PESTLE analysis indicate all models have complex benefits and costs (see Appendices A.2 – A.5). For example, a carbon tax may have considerable benefits from a political perspective, but its positive environmental benefits are questionable. Whilst each category of the PESTLE analysis has importance in reviewing PCBs, considerable significance must be given to the environmental factor as PCBs exist to reduce emissions. Following the environmental category considerable weight must be given to the social factor, as PCBs impact individuals and could impact all facets of a person’s life, particularly depending on their circumstances, means and needs.

3.4.1. Political

Due to the commitments by most global governmental bodies to the Paris Agreement, and many countries having targets, such as the UK's Net Zero Emissions by 2050 goal, it can be assumed that governments will have to undertake strong emission curbing policies at all levels.

From a governance perspective, the PCT and PCA require the most investment, both financially and by the nature of needing additional governing and monitoring bodies to be created. Both CT and CL place more of the burden on industry, and CT would raise revenue for the government and fit in with existing policies. PCT and PCA would be less politically popular due to their larger impact on the public and the lifestyle restrictions hard limits on emissions would bring. A carbon tax may be an unpopular policy as it could raise costs of numerous goods and services (Carattini et al., 2019). Carbon labelling, as it is voluntary, would not cost the public anything financially and would not enforce lifestyle changes, so this may be comparably more politically popular. CT may be politically unpopular; countries that have implemented any form of carbon pricing have experienced push back from the public and political opponents. Canada's federal carbon taxation policy was challenged in the Supreme Court, Australia repealed their unpopular carbon tax after two years despite the fact there was a significant drop in emissions in that time period (BBC News, 2014; Joselow, 2021; Milman, 2014; Nuccitelli, 2018b; Taylor, 2014).

Carbon labelling shares features with PCT and PCA as a budget for an individual is set and goods and services are 'bought' with this budget. However for CL this has no mandatory enforcement, instead using the currently politically popular 'nudge theory' (Allegra, 2009; Hansen and Jespersen, 2013b; Rigby, 2020). Nudge theory employs behavior-shaping to change public behaviours, using tactics such as social pressure and advertising campaigns to influence individuals (Hansen and Jespersen, 2013b). Nudge initiatives have had some modest successes; however, it is questionable how successful a policy lacking any enforcement can be at large-scale behaviour changes. For example, it has been suggested that during the COVID-19 pandemic that the UK government attempted to employ nudge theory, particularly at the outset of the pandemic where advice was given i.e. 'Hands, Face, Space' rather than legal requirements and restrictions (Sodha, 2020; Yates, 2020). As restrictions and had to then be introduced and the UK suffered in the pandemic, this has led to criticism of nudge theory as an effective method to change behaviour in the face of a global crisis (Forrest, 2020; Rigby, 2020; Sibony, 2020; Sodha, 2020; Yates, 2020). Especially one that requires the public to edit their behaviours for the benefit of others as it does not force change. Whilst CL is attractive politically as it requires little in the way of enforcement and would fit with existing nudge methods there is little proof it could achieve its goals to reduce emissions.

The ramifications related to international trade are hard to define, if all countries moved to a PCT or PCA model then they would all be working to comparable standards in terms of emissions generated by goods and services. However, if one nation had a hard cap on emissions and was engaging with trade with one without a cap, this may be complex since the nation without a cap may be doing less to reduce emissions and demand for their produce may reduce or be unsuitable for consumption by those under a cap. Any mandatory policy that reduces emissions will reduce consumption; less consumption will overall mean less trade. A labelling scheme is voluntary so if the public kept to the limits, it may impact trade but likely not to the degree mandatory policies would.

For the political factor, the CT and CL models are the most acceptable. A CT policy would raise revenue, and a CL policy has little burden on the governing body compared to PCT and PCA models.

3.4.2. Economic

PCT and PCA models would be the most financially costly models to implement, and they would require both government and industry spending (Lane et al., 2008). Governments would be required to fund new governing and monitoring bodies and infrastructure; industries would be required to have carbon footprints calculated for all included goods and services which would require considerable labour hours. A carbon tax would increase costs for industry but raise government revenue, and a carbon labelling approach would incur costs in industry (for data collection and footprint calculation). Each model has a financial burden, but a carbon tax is the only model where the public bears the brunt.

Jobs generated by any model are difficult to predict, however a carbon tax is unlikely to create jobs directly. PCT, PCA and CL all require carbon footprints developed for goods and services, the anticipated substantial requirement for this service may generate jobs in this sector as footprints would need to frequently be recalculated (Lane et al., 2008). PCT and PCA would require the development of new governing and monitoring bodies and systems that would create additional government jobs.

A carbon tax is regarded as a regressive tax since those on lower incomes pay proportionally more of their income than those with higher incomes (Callan et al., 2009; Elkins and Baker, 2002). There are social inequality concerns around carbon taxing, those with lower incomes would be paying a higher percentage of their earnings on the carbon tax than those with higher incomes on needs such as household heating (Callan et al., 2009). Those with lower incomes and less disposable income would have greater changes to their lifestyle and access to goods and services than those with higher incomes who could just pay any additional taxes without a considerable detriment to their lifestyle. PCT and PCA models have been evaluated to be progressive (those on higher incomes 'pay' proportionally more than those on lower incomes) in the case of PCT and PCA this means that those on higher incomes would have a higher proportional emissions reduction than those on lower incomes (Al-Guthmy and Yan, 2020).

Canada passed carbon pricing federal legislation in 2018 that came into effect in 2019, carbon emissions are taxed per tonne under this legislation with the cost per ton rising from 2019 to 2022, the price stating at $20 and rising to $50 in $10 increments (Nuccitelli, 2018). The model is revenue neutral with 90% of raised tax funds being returned to the public as a rebate in the province the taxes were raised. This is instead of the funds being invested in green innovation and enterprise as suggested in Figure 3-4, the only benefit of this policy is the assumption that behaviours will be changed by increased taxes and incentivized by the rebates. The use of rebates would have some impact on counteracting the regressive nature of the tax, however the lack of investment in further green innovation limits its overall environmental impact.

Any model that limits consumption would have a knock-on effect on growth and potentially GDP; if the public have a limited spending power, then growth will slow or drop. 'Green' industries and technologies, such as electric vehicles, home insulation and photovoltaic panel businesses, may see increases in revenue but there may be a period where traditional measures of economic health – growth and GDP are negatively impacted. However, the preservation of life-giving systems and natural capital has a value beyond money, and it is impossible to overstate their importance, the stalling a PCB may cause to growth is irrelevant when the cost of not acting on emissions and destroying the atmosphere and systems we need to live (Goodland, 1995; Sandberg et al., 2019).

As all models aim to reduce carbon emissions it is unlikely any model would have a negative impact on natural capital, although both the CL and CT models do not have strong protections in place for natural capital as they do not possess any hard limits. Natural capital may still be depleted and not renewed under these models.

All four models have varying economic benefits and costs, as a carbon tax is regressive this makes it a less attractive policy as it could significantly impact the wellbeing of the public. As discussed further in section 3.4.6. the importance of carbon emission reduction for the preservation of life-giving systems has far greater importance than its impact on traditional economic health measures.

3.4.3. Social

Following the PESTLE analysis, the PCT and PCA models are broadly similar. The trading model would have a greater negative impact socially due to distributional impacts as the model still allows personal finances to impact how much an individual can consume, not unlike the carbon tax. The CL model is unlikely to have a drastic overall social impact as it is voluntary and does not involve penalties or costs either financial or of other types.

An important question to consider is if carbon allowances in PCT and PCA are allocated per capita, then how do those that have high consumption requirements through no fault of their own manage on a budget designed without nuance? Per capita allowances would simply divide the carbon emissions allocated to the public by the number of members of the public. But this would mean those with additional requirements such as disability and/or mobility issues, and thus particular transport requirements, for example may be forced to go without (Li et al., 2015; Seyfang and Paavola, 2008). Careful design is required within a set carbon budgeting model to ensure allocation is fair, whilst a per capita allocation seems the most equitable it is an inflexible allocation method that cannot account for differences in life circumstances.

CL would have minor impact socially as it is not enforceable and there would be no trading, if the government publicized an 'ideal' footprint for people to follow this could be modified depending on individuals' needs. A carbon tax is a regressive tax so would have a far greater financial impact on those with lower incomes and thus have considerable social impacts (see section 3.2.2). Those with higher incomes would be able to absorb the additional tax whereas those on lower incomes would not as they spend proportionally more of their income on high carbon goods such as energy to heat the home and personal transport (Callan et al., 2009; Seyfang and Paavola, 2008).

In a PCB model that allows trading, there is significant potential for exploitation by those who have the finances to buy further carbon credits to supplement their own allowance and potentially rely on the poverty of those on low incomes being forced to sell carbon credits. Carbon trading is fundamentally unequal, whether in personal or international markets. The reason for this is simple; those with more money will always be able to purchase more carbon, those with less money will often feel the need to sell their carbon for more money in the immediate sense. If an individual who takes frequent holidays overseas can just pay for more carbon and someone who feels pressured to sell their credits for money due to food poverty, then must go with even less this would be socially unequal. Even if trading did not officially have a financial cost and only existed in theory to allow individuals to distribute any unrequired credits this could easily be exploited 'off the books.' For example, if trading had no financial cost but credits could be donated richer individuals could pay others for their carbon. A PCB scheme has the potential to drastically impact people's lives, to do so in a socially sustainable way there must be equity, everyone must have access to a fair carbon allocation that is appropriate for their needs with no one having the ability to pay more to consume more at the expense of others.

In the city of Lahti (Finland), a PCT scheme is being piloted. The CitiCAP app is funded by the EU's Urban Innovative Actions programme. This app seeks to reduce volunteers' carbon emissions from travel (Kuokkanen et al., 2020; Swain, 2020) .This model, instead of punishing going over budget incentivizes participants to go under budget, with rewards each week. As it is a voluntary pilot study there is no enforcement or hard cap. The price of carbon was increased over the course of the pilot and expressed as €/kg CO_2 rather than discrete tradable permits, and carbon was not traded between users but as mentioned, allowances could be traded in for rewards. In the reported results of the project, 21% of participants admitted to 'cheating' the system in various ways to earn more reward euros to trade for rewards (Uusitalo and Huttunen, 2021). This demonstrates that even in a voluntary and free system individual will seek to gain from it.

Only PCA and CL would not have negative impacts on those who have some form of social disadvantage, such as low income or disability, provided a fair allocation method was in place. CL would only not have a negative impact due to its voluntary nature and lack of enforcement. PCA eliminates the potential for abuse in carbon trading and the advantages wealth would bring. If responsibly managed PCA could ensure distribution of carbon allowances was equitable and all under the policy were allocated according to their needs. This makes the PCA model the only currently available socially acceptable model.

3.4.4. Technological

Technological implications of the four models vary. For the PCT and PCA models there have been various proposals to integrate carbon allowance spending with existing credit/

contactless card systems and through online banking or apps (Lane et al., 2008; Satoh, 2014; Seyfang et al., 2007). PCT, PCA and CL would all require some form of technological or software system to track and monitor carbon spending.

A carbon tax would generate revenue that theoretically could then be invested in green technology or innovation; however, in those countries where carbon taxation policies have been implemented this additional revenue has often been absorbed into the general governmental budget (Lin and Li, 2011). If a CT policy could be carefully managed and revenue ring-fenced to be invested into green technologies, this could have significant benefits on green technology development.

All models would potentially make fuel inefficient and high carbon cost technology undesirable due to either the additional tax or cost to the customer in terms of their carbon allowance. This may encourage the development of efficient technology as the public seek to lower their emissions to maximize use of their budget. There is a possibility with a strict PCA or PCT policy that public spending on complex technology would drastically reduce if carbon budgets meant they took a considerable proportion of their allowance to buy. Some technological sectors may be hampered by this.

3.4.5. Legal

The key legal factor comparison to be made is the importance of a mandatory policy versus a voluntary policy. CL is a voluntary model, there would be no legal implications for the public if they did not abide by the policy. There could be legal implications if businesses did not provide carbon information for their products that may require enforcement, but this would not affect the public's behaviours. Mandatory policies would require enforcement, the type of enforcement would be important to the efficiency of the policy and the social justice aspect. If a violation of a PCT method was a £500 flat fine someone on a higher income would be able to simply pay the fine and carry on as they have, someone on a lower income would not be able to. The enforcement would need to be equitable and have the same impact regardless of personal privilege.

A discussion can be had on the concept of carbon credits themselves in terms of PCT and PCA schemes, within the literature the amount of carbon an individual is allocated is often not given as a weight but as several credits. This implies the allowance in the form of these credits is a currency the individual owns, rather than a limit they cannot overstep. If credits are owned by an individual this implies they have some rights over whether they can be traded or not – it is theirs to use as they see fit. However, if the allowance is expressed as a weight this implication is lessened (California Environmental Protection Agency, 2015).

3.4.6. Environmental

PCB models are designed with the intention to reduce GHG emissions and so the environmental component of the PESTLE analysis is vital. Two models are mandatory and have a fixed cap on emissions (PCT and PCA), whilst the allocations of emissions within the cap may vary, the cap itself is unchangeable. The reduction these models could bring about is simple to understand, if an ambitious enough cap was implemented, the required GHG reductions could be achieved. However, the CL and CT models have no cap, no overall control over GHG emissions although CT is mandatory so would certainly have some impact. The CL model may have a theoretical cap to aim for using labelling and diligence from the public but without this being mandatory it is unlikely it would be reached. The reductions a CT model could bring is similarly nebulous, taxes and charges have changed behaviours at small scales, such as congestion charges and plastic bag charges but GHG emissions are at a far larger scale and are far more central to people's overall consumption (Thomas et al., 2019; Zheng et al., 2014). A carbon tax is regressive, so may force lower income households to change their behaviour due to cost. However, higher income houses can emit three times as many emissions as lower income, and these households would be less impacted by the tax and less likely to change consumption (Fremstad and Paul, 2019; Hargreaves et al., 2013; Preston et al., 2013).

Whilst PCT has a cap there are still environmental concerns with this model; if trading is allowed then there will never be a surplus, the cap would always be met, extra credits would always be bought up. It would be environmentally beneficial to not always hit the emissions cap as this would mean even greater emissions reductions. If carbon trading is disallowed then those who are thrifty with their allowance may have a surplus, which could then roll over for a certain number of years then be surrendered back to the government, or be surrendered at the end of the year, potentially for some kind of benefit. Even if everyone only had a small surplus this could create significant emissions savings.

Three models, PCT, PCA and CL all would require carbon footprinting (or some other form of carbon accounting) to calculate the carbon emissions associated with included goods and services. A method and definition of a carbon footprint would need to be adopted and standardized with all goods and services being footprinted to the same standard. The nature of this footprint, the scope of what emissions are included and cut-offs within processes would require standardization.

What is included in the carbon budget is critically important for a PCT, PCA or CL method. If for example only hairstyling and bed linen were included most emissions would not be accounted for and emissions would not be impacted. A PCT, PCA or CL model is only as effective as its scope. For example, the PCT model proposed by DEFRA included the carbon content of energy for use in the home and personal transport purchases, aviation covered through fuel purchase by airline (DEFRA, 2008). This model does not include food, textiles and other goods created by agricultural processes that are responsible for around 18% of global emissions (CAIT, 2021). By excluding all goods and services from this sector, a considerable quantity of carbon emissions are unregulated by the policy and can continue to contribute to global climate change.

Carbon labelling would require a considerable amount of education surrounding carbon costs, alongside clear and informative labelling to ensure the public made informed choices. Without any kind of enforcement, they would have no legal reason to spend time understanding any carbon labelling system. Carbon labelling was trailed in Vanclay et al., (2011), coloured labels were attached to products indicating if a product was 'below average emissions' (green), 'around average' (yellow) or 'above average emissions' (black) in a grocery store over three months. Sales of black labelled products reduced by 6%, sales of green labelled products increased by 4%, so only slight changes in sales over the time period. There was an increase in green-labelled products when they were comparatively lower priced than products with other coloured labels to a 20% switch from black labelled products to green (Vanclay et al., 2011). However, as this study used the average emissions that could still be a high value it may not be the most appropriate scheme as it does not provide the public with detailed information surrounding carbon emissions.

The DEFRA synthesis report states: *'…the key benefit of personal carbon trading is the increase in the visibility of personal carbon emissions that it creates.'*

This statement is the key justification of the report for the implementation of a PCT method rather than other policies such as carbon taxation or upstream trading. The public developing a clear understanding of their carbon emissions, and responsibility for them, is put forward repeatedly as a vital component of PCT and a consideration outside of straightforward feasibility. This assertion is also put forward in other literature that TEQ/ PCT models allow participants to understand their role in emissions, how they can limit them and their personal responsibilities (Fleming, 1997; Starkey and Anderson, 2005; Fleming and Chamberlin, 2011). These reports acknowledge other policies may be easier to implement but would have less benefits in terms of public education around carbon emissions and public responsibility.

PCA may be the most environmentally acceptable model although PCT would have a similar impact, the difference may be the potential impact trading would have on 'using up' the cap limit which may be negligible. As carbon taxes and carbon labelling have no way to enforce a limit on emissions, they are unlikely to enable the deep cuts to carbon emissions required to limit global temperature rises.

The most effective environmental feature is a hard cap on carbon emissions; with a controlled cap emissions can be reduced as stringently as they need to be, there are no grey areas. CL and CT models have no enforcement to limit overall emissions and therefore could not be relied upon to make cuts deep enough to halt climate change, and therefore cannot be the sole policies to reduce carbon emissions. Both the PCT and PCA models provide hard caps on emissions and as both function in similar ways would mostly have the same ability to cut emissions. However, as trading would mean all surplus carbon credits would always be purchased and spent PCT may be less environmentally effective than PCA. To limit the catastrophic impacts of climate change every advantage must be taken and the lowest amount of carbon emitted.

Whilst PCT is a popular policy model, it would create considerable disparity between those who can afford to purchase more carbon credits via trading and those who either could not purchase more or had financial pressures that led them to sell credits. A PCT scheme cannot be socially equitable and on these grounds is unsuitable as a method to limit personal carbon emissions. PCA eliminates the trading element, all the public is treated equally in terms of income, and no one has an advantage due to their personal wealth. Each individual can be allocated a carbon budget in relation to their needs rather than their wealth. A PCA scheme with no trading is an opportunity to reduce inequalities those with lower incomes suffer from, with all individuals treated as equals with their specific needs respected and accounted for.

Carbon taxation suffers from the same concerns as PCT as those with greater financial means would simply pay more to continue their lifestyles, and as there is no cap on emissions there is no certainty CT would create the carbon reduction needed. Carbon labelling is voluntary, whilst this may be attractive politically, require less financial investment form the government and not disadvantage individuals socially, like CT without enforcement it is likely people would carry on as usual. Political attractiveness will make both CL and CT tempting to governments; however, governments should not take the 'easier' path and instead must focus on the environmental effectiveness and social equality of policy models.

Considering the social and environmental factors as having the highest weight in terms of importance the PCA model would be the recommended model to reduce emissions without disadvantaging those with lower incomes. Whilst this model may be less popular politically than a voluntary model like carbon labelling it would have greater effectiveness at implementing the reductions all governments have pledged to make. Severe cuts in carbon emissions must be made to have any hope in limiting global temperature rise to 1.5°C, to do so radical mandatory measures must be taken.

3.5. Conclusions

We identified three main archetypes of PCBs; Personal Carbon Trading, Carbon Tax and Carbon Labelling, and proposed a new policy model: Personal Carbon Allowance (no trading). Each policy model has an array of costs and benefits across the PESTLE factors. Some impacts are difficult to quantify as many PCB models are currently largely theoretical and their impacts when applied at a national or global scale can only be assumed. Because PCBs are an environmental policy measure, greatest weight must be given to this factor, but as PCBs would directly impact individuals' lives in every area consideration of social factors must be as important. Individuals must not be disadvantaged due to carbon budgets and those on higher incomes should not be able to benefit from a trading based system where they can exploit their greater wealth at the detriment of those that must sell their carbon to survive. As this policy seeks to reduce carbon emissions. it must be an effective measure, regardless of popularity with the public or the discomfort it may cause those currently living lavish lifestyles.

Whilst PCT is a popular policy model, it could create considerable disparity between those who can afford to purchase more carbon credits via trading and those who either could not purchase more or had financial pressures that led them to sell credits. Individuals then may find that having sold credits for immediate financial relief no longer have enough carbon credits to then spend that income on goods and services they need later in the budget period. A PCT scheme cannot be socially equitable and on these grounds is unsuitable as a method to limit personal carbon emissions. PCA eliminates the trading element, all the public are treated equally in terms of income, and no one has an advantage due to their personal wealth. Everyone can be allocated a carbon budget in relation to their needs rather than their wealth. A PCA scheme with no trading is an opportunity to reduce inequalities those with lower incomes suffer from, with all individuals treated as equals with their specific needs respected and accounted for.

Carbon taxation suffers from the same concerns as PCT as those with greater financial means would simply pay more to continue their lifestyles, and as there is no cap on emissions there is no certainty CT would create the carbon reduction needed. Carbon labelling is voluntary, whilst this may be attractive politically, require less financial investment form the government and not disadvantage individuals socially, like CT without enforcement it is likely people would carry on as usual. Political attractiveness will make both CL and CT tempting to governments; however, governments should not take the ‘easier’ path and instead must focus on balancing the environmental effectiveness and social equality of policy models.

Considering the social and environmental factors as having the highest weight in terms of importance the PCA model would be the recommended model to reduce emissions without disadvantaging those with lower incomes and providing aggressive emissions cuts. Whilst this model may be less popular politically than a voluntary model like carbon labelling it would have greater effectiveness at implementing the reductions all governments have pledged to make. Severe cuts in carbon emissions must be made to have any hope in limiting global temperature rise to 1.5°C, to do so radical mandatory measures must be taken.

4. CHAPTER 4: "I'LL TAKE THE EASIEST OPTION PLEASE' CARBON BEHAVIOUR PREFERENCES OF THE PUBLIC

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Alice Brock: Conceptualization, Methodology, Software, data collection, Data curation, Formal analysis, Writing – original draft. **Ian Williams:** Conceptualization, Methodology, Writing – review & editing. **Simon Kemp:** Conceptualization, Methodology, Writing – review & editing.

4.1. Abstract

The depth and breadth of the climate crisis is well known, all sectors, industry, government, and the individual have the potential to reduce emissions to slow or stop catastrophic climate change. To determine and evaluate the (revealed) preferences of the public in reducing their personal carbon emissions, a conjoint analysis survey, using the PAPRIKA (Potentially All Pairwise RanKings of all possible Alternatives) method, was distributed to the public in a city in the south of England (Southampton). Knowledge of the deep-seated preferences of the public makes a fundamental contribution to future climate actions because it enables publicly acceptable system change to be developed.

Results showed the public were unwilling to make large-scale lifestyle changes, even if they would cause large emission reductions. There was a clear preference for making easy, convenient changes to behaviour rather than making more difficult personal lifestyle changes involving diet and transportation. A significant value-action gap is evident, with the public showing high awareness of the seriousness of climate change but showing an unwillingness to make deep cuts to their personal emissions. Demography and personal factors had a low

influence over preferences with trends staying the same across demographic groups, aside from income brackets. Participants believed that reductions in emissions should come from a ‘group effort’ from all levels of government, business, environmental groups, and individuals. Few participants placed themselves as individual drivers of carbon emission reduction. In order to reduce emissions some form of intervention needs to be made, as the public are not personally willing to make large-scale reductions in carbon emissions, regardless of their environmental awareness or demography.

4.2. Introduction

The climate crisis is the biggest challenge of the modern age; our changing climate impacts all facets of human life, and our behaviour directly influences the severity of the issues at hand (Intergovernmental Panel on Climate Change (IPCC), 2018; United Nations Environment Programme, 2020). Since we have caused global climate change, human behaviour has a fundamental role in countering it. A sizeable percentage of emissions are generated by households in developed countries through their consumption of goods and services (Department for Environment Food & Rural Affairs, 2020; Druckman and Jackson, 2010; Dubois et al., 2019; Hargreaves et al., 2013; Hertwich and Peters, 2009). The United Kingdom (alongside America, Europe, and other nations) far exceeds the limit of greenhouse gas emissions that would facilitate keeping the global temperature rise to 1.5^{O}C (Tukker et al., 2016).

The scope of individual behaviours that need to change to limit global temperature rise to the 1.5^{O}C value recommended by the Intergovernmental Panel on Climate Change is vast (Climate Change Committee, 2020a; Committee on Climate Change, 2019; Höhne et al., 2017; Intergovernmental Panel on Climate Change (IPCC), 2018; Robinson and Shine, 2018). Whilst many policy interventions must target industrial polluters directly, the demand of individuals must also be addressed (Hertwich and Wood, 2018; Intergovernmental Panel on Climate Change, 2018; Sanderson et al., 2016; United Nations Environment Programme, 2020d). Identifying and ranking which behaviours the public are willing to change in terms of their emission generation can aid in prioritising which carbon emission generation areas to target, and if the actions the public would prefer could yield significant reductions in carbon emissions. There may be variations in behaviour demonstrated by a specific demographic category; this may be down to their needs, for example, those with mobility issues may need to use personal transport. Policies that seek to reduce personal carbon emissions must consider all aspects of the public's needs in order to make equitable but effective reductions in emissions (Brock et al., 2022; Lockwood, 2010; Seyfang and Paavola, 2008).

Identifying how and why individuals may prefer to prioritise their carbon reductions can aid in developing personal carbon reduction policies and strategies (Brock et al., 2022). The most potent behavioural changes would be to areas such as personal transportation and diet that typically contribute a high percentage of an individual's carbon emissions (Ivanova et al., 2020a; Neves and Brand, 2019). However, policies that require large scale lifestyle choices may spark considerable resistance when the public are expected to change in order to reduce emissions (Hagmann et al., 2019; House of Lords Environment and Change Committee, 2022; Perry and Williams, 2007; Whitmarsh et al., 2021). There is currently no overarching policy in the UK that tackles personal carbon emissions. Such a policy would require an understanding of how great a reduction different demographic groups may be able to make according to their needs and if they would be willing without intervention to make cuts to the most carbon emitting factors of their lives (Brock et al., 2022).

Households are the largest direct contributor to carbon emissions (and overall greenhouse gas emissions) in the United Kingdom due to household heating and travelling. However, individuals also drive emissions through consumption in other sectors such as manufacturing according to the Office of National Statistics (Office for National Statistics, 2022). This indicates there is some responsibility at an individual level for a portion of emissions in the UK. Whilst there will be some aspects of these emissions that are unchangeable – for example heating type provision in a rented home - an individual is able to make choices for the duration this heating is used therefore having a direct influence on the amount of emissions generated (Schwenkenbecher, 2012).

Studies have found an environmental value-action gap; the public state strong environmental views, such as considering climate change highly serious but show an unwillingness to change their behaviour and take actions to mitigate climate change (Barr, 2006; Chaplin and Wyton, 2014; Chung and Leung, 2007; ElHaffar et al., 2020; Panda et al., 2020; Whitmarsh et al., 2011). Many resources go into raising the awareness of the public of 'green' issues. Evidence suggests that although the public may have a reasonable awareness of current global environmental challenges that are being faced globally, their behaviour is not necessarily being influenced by this awareness (Islam et al., 2016; Whitmarsh et al., 2011). Awareness is not always a valid measure of the public's willingness to make changes to their behaviour.

Steg, (2018) highlights that climate change denial is not widespread and emphasises the cruciality of comprehending why people do not act in line with their firm belief in the negative consequences of climate change. Steg, (2023) review of the psychology of climate change concluded that further research is needed to account for its human dimensions. Human behaviour is not easy to predict, and understanding what people might do in different circumstances is difficult when only using self-reported information due to the various biases that may influence results (Carlsson et al., 2018; Choi and Pak, 2005; Ronald B. Larson, 2019; Anton J. Nederhof, 1985). It is important to use methods that either provide real world data or use a 'revealed preference' rather than a stated preference approach, since responses from the latter may not predict actual behaviour well (Kroes and Sheldon, 1988; Thoma, 2021; Kevin C. Urama and Hodge, 2006).

A preference is the action an individual would take if they had to. Preferences are likely to be influenced by a range of personal factors, including an individual's attitude, affect, agency, behavioural intention, cognition, habit and routine, personal norms, self-identity, situational factors, social norms, and values (Williams, 2015). An individual may be presented with a choice where no option aligns perfectly with their personal factors, but they must make a choice, and must therefore make the 'least-worst' choice; in this situation, this would be their preference.

A stated preference is one the participant puts forward themselves. It is how they *believe* they would feel or act, and thus it is not a representation of their *actual behaviour* if the situation they were presented happened (Artabe and Gardeazabal, 2017; Ortúzar and Garrido, 1994; Phillips et al., 2002). Revealed preferences tend to hold greater validity than self-reported stated preferences; for example, an individual may state that they *always* use a reusable coffee cup as it is the socially desirable answer, but in the real-world they may only do this *occasionally*. This is a limitation of a stated preference methodology that can be mitigated by moving away from traditional social surveying methods (where participants may be under desirability bias) to analytical hierarchy process methods or multiple-criteria decision making (Forman and Gass, 2001; Hansen and Ombler, 2008; Vaidya and Kumar, 2006). These methods give participants preference-based choices. Different criteria are presented to the public and they must choose which options are preferable. Participants are not presented with the entire range of criteria or attributes of the criteria to be able to choose the one that they may evaluate is the 'correct' answer, instead having to make quick, instinctive decisions (Hansen and Ombler, 2008).

Whilst it is well established that system changes are necessary to stimulate society-wide climate action, these will only be realized if they are acceptable to the public. Therefore, this study's goals were to identify and critically evaluate: i) public preferences for carbon reduction behaviours ii) potential differences in these preferences iii) any potential 'value-action gap' in relation to carbon reduction behaviours.

The study makes a fundamental contribution to the literature by clearly identifying what personal actions the public are currently prepared to take to tackle climate change. Pairwise ranked multiple criteria decision-making software was used to minimise social desirability bias and gain insight into the deep-seated preferences of the public rather than their superficial opinions. Analysing preferences in relation to demographic group and stated environmental opinions and attitudes has allowed for analysis on whether awareness and perceived importance of climate change had an impact on the preferences of the public, i.e. would a more aware member of the public who considered climate change a serious problem prioritise carbon reduction behaviours that would have higher carbon emission reductions than someone with lower awareness or consideration of climate change. Knowledge of the deep-seated preferences of the public will make a substantial contribution to future climate actions because it will enable publicly acceptable system change to be developed.

4.3. Methodology

This study was implemented through several stages:

i) Development of social survey questions to identify demographic groups and carbon attitudes and opinions of the public with support from Southampton City Council

ii) Development of multi-criteria decision making conjoint analysis survey to identify preferences of the public in relation to carbon emission reduction behaviours with support from Southampton City Council

iii) Distribution of survey to public in Southampton online through the Southampton People's Panel and through the university's social media channels

iv) Identification of trends in results

v) K-Means cluster analysis to identify any clustering of preferences, with particular consideration of demographics, attitudes, and opinions

4.3.1. Social Survey

A mix of survey methods was utilised. Traditional survey questions were developed in conjunction with a conjoint analysis survey using the 1000Minds software that incorporates the PAPRIKA method (see section 4.3.2.). Demographic data were gathered to allow for clustering and analysis of preferences. Following this section, participants responded to a conjoint analysis survey before a concluding section asked Likert scale and multiple-choice questions on carbon emission attitudes and behaviours. Likert scales were selected to identify attitudes as they allow participants the ability to rank their attitude or behaviour in relation to a question (Rebecca F. Guy and Norvell, 2010; Andrew T. Jebb et al., 2021; Youn et al., 2017). Multiple choice questions allow participants to make clear attitude statements.

Selected questions previously used by Eurobarometer polls were referred to in development of multiple choice questions on attitudes (European Commission, 2022). All questions were presented in a straightforward fashion and reviewed by professionals from Southampton City Council to ensure comprehension by members of the public.

The sample was taken from a special panel of residents of the city of Southampton using purposive sampling, enabling individuals with a spectrum of beliefs and experiences to be reached (Bellhouse, 1984; Campbell et al., 2020; Etikan, 2016; Klar and Leeper, 2019; Neves and Brand, 2019). Surveys were distributed online via email to the Southampton City Council (SCC) People's Panel and across the University of Southampton's social media platforms to Southampton residents. This panel consists of ~3,500 Southampton residents who respond to surveys that have relevance to Southampton. Established by SCC in 2015, participants must be over 18 years of age and the panel is used to inform decisions, service changes and gain information from a representative section of the public on a range of topics (Southampton City Council, 2021). Panel participants are not obligated to respond to surveys distributed to them.

4.3.2. PAPRIKA Method

The PAPRIKA is a new method for scoring additive multi-attribute value models. Participants are presented with two alternatives, each has a pair of options, both alternatives' options relate to the same two criteria (see Figure 4-1) (Hansen and Ombler, 2008). Participants must then select which of the two alternatives they prefer. Each criterion is given rank levels from most desirable or 'best' to least desirable or 'worst.' For this study, the 'best' values were assigned to those levels of a criterion that would create the greatest reductions in carbon emissions. Each alternative had options that opposed the other. Alternative one had an option that was of an elevated level and another of a low level. Alternative two had the same criteria but with the levels reversed, the high-level criteria option on alternative one would be of a low level on alternative two (see Figure 4-1). Thus, participants would have to make trade-offs, compromising on some criteria to prioritise those they would prefer to undertake.

The PAPRIKA method and 1000Minds software is adaptive, as each decision is made by a participant superfluous decisions are eliminated by the algorithm as the participant continues to make decisions.

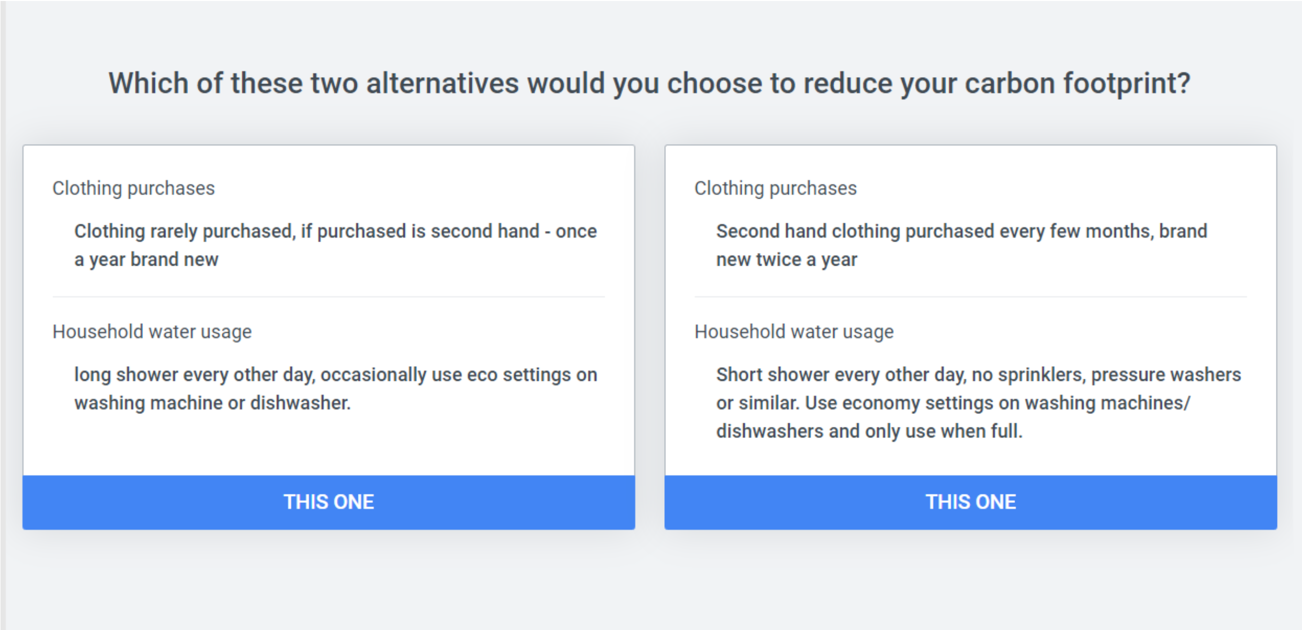

Figure 4-4-1. Example of pairwise choices presented to participants in 1000Minds software survey.

In Figure 4.1, the 'clothing rarely purchased' and 'short showers' levels are the most significant carbon reduction options but are paired with 'worse' options on each side, which options are 'worse' are defined by their levels within the criteria. Therefore, participants must decide which of the two they prefer. The method is simple for the participant to use as they are not presented with every single combination of pairs to rank; it identifies the implicit rank of unseen pairings from those pairings that have been explicitly ranked (Hansen and Ombler, 2008). PAPRIKA is adaptive; one choice leads to a new choice being offered based on the previous choice, which limits how many choices a participant is presented (Hansen and Ombler, 2008).

Once the participant has selected their choice, they will continue to make choices between a series of these paired options. This demonstrates which criteria are prioritised by the participant as they make trade-offs. PAPRIKA allows the generation of 'weights' of importance of criteria to the participant, so not just which is preferred by the participant but by how much and how much in relation to the other criteria. PAPRIKA generates individual participant weights and preferences rather than aggregates, which allows for cluster analysis related to preferences using weight values as cluster parameters.

The PAPRIKA method and 1000Minds software were selected for this study due to their intention to discern preferences rather than opinions or attitudes. The 1000Minds software provides clear instruction and guidance to participants on how to undertake a survey to ensure there is no confusion. As participants cannot see the full lists of criteria or criterion levels, this means they should have to answer honestly instead of influenced by what they think they 'should' answer. Trade-offs assist in gaining honest responses from the public as each pairwise choice will have levels on each side that are less preferable, forcing participants to prioritise their preferences.

4.3.3. Criteria Development

The nine criteria for the PAPRIKA survey section were developed from an initial list of proposed criteria of carbon generating or reducing behaviours that the public had some direct control over and had associated carbon emissions (see Appendix B.1). These criteria were identified by examining UK governmental emissions datasets, literature reviewed, expert knowledge and advice and consultation with Southampton City Council officials (Carter, 2008; Darby and Obara, 2005; Department for Business Energy and Industrial Stratergy, 2020; Department for Environment Food & Rural Affairs, 2020; Druckman and Jackson, 2010; Gill and Moeller, 2018; Hargreaves et al., 2013; National Atmospheric and Inventory, 2019; National Statistics, 2020; Preston et al., 2013)

Some initial criteria were combined in the final list; for example personal transport methods and active transport were combined into 'Domestic Personal Transport' to improve clarity and avoid the inclusion of an excess of variables. The 1000minds software is not limited by how many variables can be included; however, a higher number of variables leads to more time being taken by participants to complete the survey.

Potential criteria were evaluated on:

i) Their overall share of global carbon emissions generated

ii) Ubiquity of behaviour or activity

iii) How much control the public has over the criteria for example is it a behaviour they can change

iv) Potential carbon impacts of the behaviour (a range was selected to identify if the public would choose higher reduction behaviours)

v) Potential impact of behaviour change on individuals i.e. would it be daily, monthly, only done once

Justifications for criteria selection are shown in Table 4-1. Consideration for the ease the public might have in enacting these behaviours, difficulty and 'life impact' were included as considerations for criterion selection, some such as changing diet or personal transport would require daily behaviour modification, others such as overseas travel and clothing purchasing would not require daily behavioural change. Criteria were also selected on their variation of potential carbon emission reductions, behaviours such as 'changing lighting' by switching to LED bulbs was included alongside more impactful behaviours such as changing diet or transport. This allowed insight into willingness to make behavioural changes with higher compromises to current lifestyles or preferred lower compromises that may have less impact in terms of reducing carbon emissions (Hargreaves et al., 2013).

Table 4-1. Table showing the nine selected criteria, description of criteria and justification for selection. Each criterion was had four 'levels' - from most to least impactful in terms of carbon emissions (see Appendix 1D).

CRITERION	DESCRIPTION	JUSTIFICATION
DOMESTIC PERSONAL TRANSPORT	Transport choices, such as; public transport use, walking or cycling, personal car or taxi use or the use of electric vehicles.	- Personal transport via car or taxi can have considerable carbon emissions, especially in cities (Brand et al., 2021; Hargreaves et al., 2013a; Neves and Brand, 2019). - 43% of UK household emissions come from transport [44] - High impact carbon behaviour when using personal cars or taxis
OVERSEAS TRAVEL	Overseas travel by air, rail, or boat particularly frequency of trips.	- Flights per person can contribute incredibly high emissions into the atmosphere (Kommenda, 2019). Are also often 'non-essential' (i.e. holiday) so are an area that could be reduced. - Aviation contributes 7% UK emissions, 91% of this is international travel [46]
FOOD – DIET COMPOSITION	Behaviours around food consumption, food choices; meat consumption, plant based food choices	- Meat, fish, and dairy have high contributions to global carbon emissions (Carlsson-Kanyama and González, 2009; John J. Hyland et al., 2017; Ivanova et al., 2016b; Sabaté and Soret, 2014a; Scarborough et al., 2014b) - Plant based diets have significantly lower emissions than high meat or 'average' diets (Chai et al., 2019a; Scarborough et al., 2014b) - Food accounts for approximately 35% of UK greenhouse gas emissions (including methane and

		carbon dioxide) and has considerable global emissions (Clune et al., 2017; Crippa et al., 2021; Poore and Nemecek, 2018a; Ritchie, 2019; Scarborough et al., 2014b; WRAP, 2016b) - High impact carbon behaviour considering the high emissions of red meat
HOUSEHOLD HEATING	Heating of the home via radiator	- Heating decarbonisation common topic when carbon emission reduction discussed (Committee on Climate Change, 2018b; Confederation of British Industry, 2020; Department of Energy and Climate Change, 2012; Dubois et al., 2019; Schmidt et al., 2007) - UK has higher than European Union emissions from heating the home and household heating accounts for 14% of emissions (Department for Business Energy and Industrial Strategy, 2020a; McDowall and Britchfield, 2021a).
HOUSEHOLD ENERGY – APPLIANCES	Energy used by gadgets and personal electronics	- Largely under the control of those living in households (although they are not in control of the grid's energy mix) - Estimated to contribute to 6% of UK household electricity usage (Department for Business, 2022; Energy Saving Trust, 2022; Preston et al., 2013b)
HOUSEHOLD WATER	Water usage by the household	- Water requires energy to transport it, energy to heat it, and energy for waste water to be treated/ transported. - Water contributed 0.8% UK emissions (in 2008) but 5.5% if water heating included (Reffold et al., 2008)
WASTE	Amount of waste generated, reused, or recycled by the participant including food waste	- Waste accounts for 6% of UK GHG emissions, emissions have reduced below 1990 levels due to less landfilling but have currently plateaued due to UK recycling not increasing and emissions from energy from waste plants (Climate Change Committee, 2020a).
CLOTHING	Frequency of purchasing of clothing both new and second hand	- Production and transport of clothing have high energy and water cost (Hibberd, 2019; Karthik and Murugan, 2017; Muthu, 2015; Niinimäki et al., 2020). 'Fast fashion' leads to frequent purchasing of clothing to remain on trend/ fashionable. - Fashion contributes between 2% - 10% of global emissions, estimates vary considerably but anticipated to grow (Ivanova et al., 2016b; Niinimäki et al., 2020; Sadowski et al., 2021; United Nations Economic Commission for Europe, 2018) - Low impact on lifestyle as clothing purchases are largely less frequent than consumption of other goods such as food
HOUSEHOLD ENERGY – LIGHTING	Lighting of home	- Under the control of household on type of lightbulbs used and when lights are turned on or off

		- Lighting contributes around 11% of household energy usage in the UK, household energy usage contributes to 21% of household emissions - (Climate Change Committee, 2020a; Energy Saving Trust, 2022; Huang et al., 2018) - Low impact on lifestyle to make relevant changes such as changing to LED lightbulbs

4.3.4. Demographic Questions

Demographic questions were developed with consideration of differing needs in terms of carbon consumption. A broad range of demographic questions were asked to identify any trends or differences in preferences related to demographics to identify potential differing needs or barriers for diverse groups. A broad approach of demographic inclusion was taken as a key objective of this study was to explore and identify any demographic related differences in preferences, therefore a narrow range of demographic questions may exclude previously unconsidered demographic factors.

Several questions were required to identify social class, as self-identification may not demonstrate a clear socioeconomic class due to differing attitudes towards class identity . (See Appendix B.2) (Krieger et al., 1997; Savage et al., 2013). Questions were adapted from the UK Census and Office for National Statistics guidance, in terms of appropriate wording, sensitivity to protected characteristics and to ensure consistency across data gathered (Office for National Statistics, 2012; Office for National Statistics ; National Records of Scotland ; Northern Ireland Statistics and Research Agency, 2016). Not all UK Census and ONS demographic questions were included for brevity, justifications for demographics chosen can be found in Appendix B.2 Demographic data were obtained on:

- Age
- Gender
- Ethnicity
- Religion
- Mental disability
- Physical disability
- Self-identified socioeconomic class
- Marital or civil partnership status
- Home location – rural/ urban/ suburban
- Household income

- Level of education
- Level of education of parents
- Home ownership
- House size
- Household heating method
- Car ownership
- Employment status

4.3.5. K-Means Cluster Analysis

The 1000minds software generates individual weighted data for each participant so cluster analysis can be performed on the data to identify clusters and trends in preferences. These clusters can then be examined in relation to the demographics and attitudes. K-Means cluster analysis is the standard method of cluster analysis for 1000Minds data in the existing literature and is recommended by the software developers (Feeny et al., 2019; Hansen and Ombler, 2008; Hansen and Jespersen, 2013; Martelli et al., 2016; Steinley, 2004). K-Means clustering is a centroid model of clustering, each case of weighted preference data for each criterion is assigned to the cluster with the nearest means to their values (Steinley, 2004; Yuan and Yang, 2019).

Following data gathering and simple analysis of preferences and needs by demographics, k-means clustering was performed on the data in MATLAB R2020a (manufactured by MathWorks) software. K-means clustering is a clustering method that allows data to be partitioned into a predetermined number of clusters that must be defined before clustering. The number of clusters was defined using the Calinski Harabasz index, silhouette coefficient and hierarchical clustering (Yuan and Yang, 2019).

The demographics and attitudes of each cluster were evaluated to identify trends in demographics across clusters. Due to the high number of part -worth utilities from the criteria, k-means analysis clustering provide insight and significant clusters value with multiple part-worth utilities (Djokic et al., 2013; Yuan and Yang, 2019).

K-means clusters were checked for significance between clusters using independent t-tests performed in MATLAB.

4.4. Results

The number of respondents to this survey was 381, a response rate of 10.9%. The constitution of the SCC People's Panel led to an older age demographic but importantly provided a broad distribution of different socio-economic backgrounds.

4.4.1. Preferences Trends

Trends of preferences were identified. In Table 2 the criteria are ranked (at the top is the most preferred carbon reducing method, at the bottom the least preferred) according to their mean preference value. Table 2 also displays the relative importance of each criterion i.e. how many 'times more preferred' a criterion is compared to another.

The 'Household electricity – lighting' criterion was the most preferred method of carbon reduction by the public from the results of the conjoint analysis; 'Diet Composition' was the least preferred method of carbon reduction as seen in Table 4-2 and Figure 4-2.

As the data was not normally distributed, a Kruskal-Wallis test was performed to test for statistical differences between criteria; results showed statistically significant differences (df = 8, p = 0.000 (p = 2.2e-16)).

Table 4-2. Table displaying criterion preference in comparison to other criteria. Numbers denote how many times more important participants ranked a criterion against another. Example 1.2 indicates participants prefer a criterion 1.2 times more than another

		Household electricity - lighting 16.4%	Overseas Travel Per Year 13.3%	Clothing purchasing 12.7%	Waste generation and management 12.2%	Household Heating 11.7%	Household water usage 10.4%	Domestic personal transport 9.6%	Household electricity - Appliances 7.4%	Diet composition 6.3%
Household electricity - lighting	16.4%		**1.2**	**1.3**	**1.3**	**1.4**	**1.6**	**1.7**	**2.2**	**2.6**
Overseas Travel Per Year	13.3%	0.8		**1.0**	**1.1**	**1.1**	**1.3**	**1.4**	**1.8**	**2.1**
Clothing purchasing	12.7%	0.8	1.0		**1.0**	**1.1**	**1.2**	**1.3**	**1.7**	**2.0**
Waste generation and management	12.2%	0.7	0.9	1.0		**1.0**	**1.2**	**1.3**	**1.6**	**1.9**
Household Heating	11.7%	0.7	0.9	0.9	1.0		**1.1**	**1.2**	**1.6**	**1.9**
Household water usage	10.4%	0.6	0.8	0.8	0.8	0.9		**1.1**	**1.4**	**1.6**
Domestic personal transport	9.6%	0.6	0.7	0.8	0.8	0.8	0.9		**1.3**	**1.5**
Household electricity - Appliances	7.4%	0.5	0.6	0.6	0.6	0.6	0.7	0.8		**1.2**
Diet composition	6.3%	0.4	0.5	0.5	0.5	0.5	0.6	0.7	0.9	

All other criteria were considered at least 1.2 times more preferred than the lowest ranked ("Diet Composition"). "Household electricity – Lighting" was preferred at least 1.2 times more than all other criteria.

Figure 4-2 displays the criteria on axes with the mean weight reported alongside each criterion to give a visual demonstration of the comparative preferences of the public. The most preferred criterion is at the top, the second most preferred is then next in a clockwise direction, with criterion following on in order of preference to the least preferred criterion.

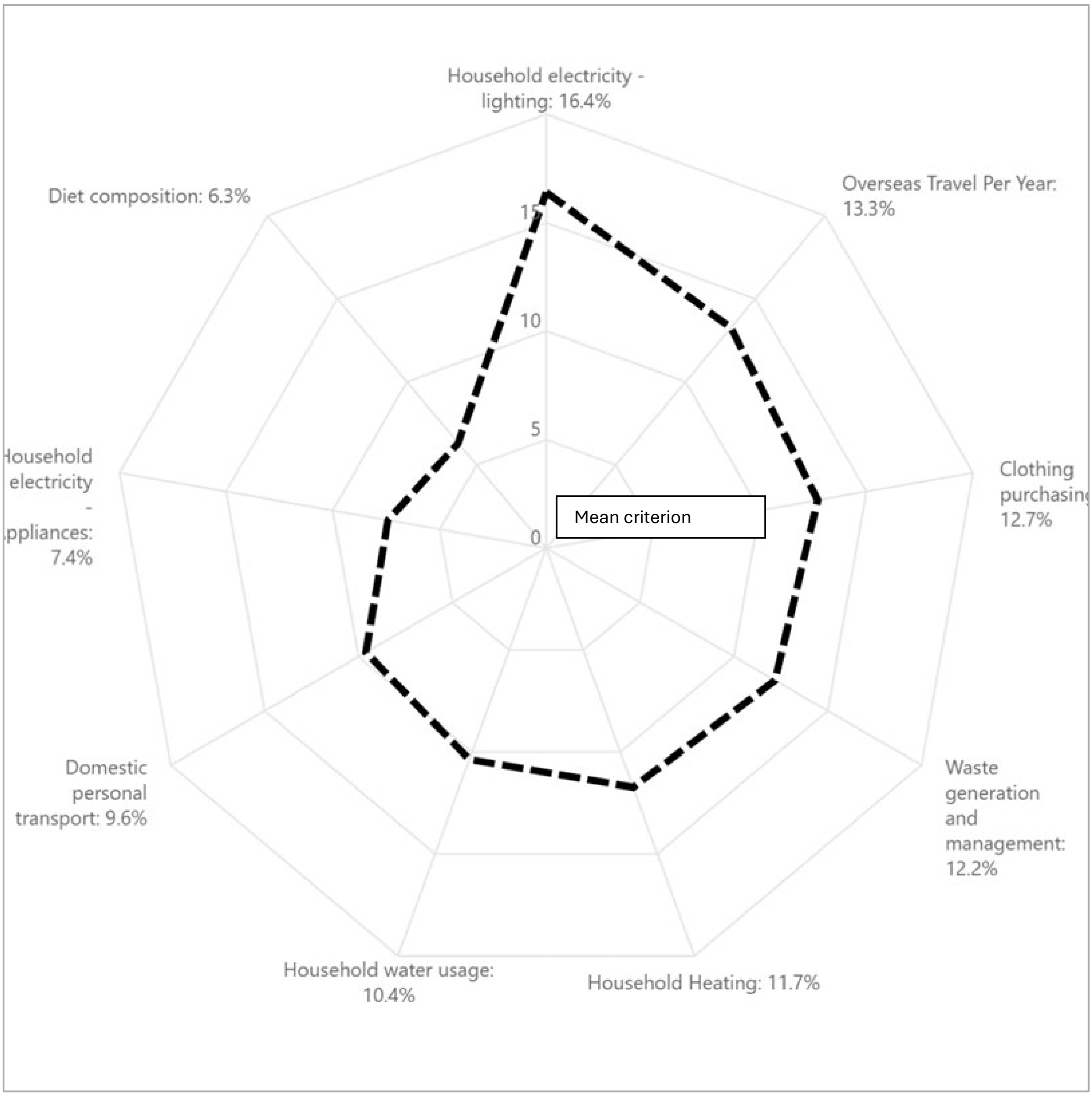

Figure 4-4-2. Spider chart of criterion weights, each axis represents a carbon emission reduction criterion with the mean weight of the criterion reported alongside it.

Figure 4-3 shows the density of weights by the public for each criterion ordered in preference rank via violin plots with overlaid box plots. Lighting shows the highest median weight with the widest point of the distribution on the violin plot near the average. Diet Composition shows the lowest median weight with a considerable distribution of weights low in the violin plot but a broad range of weights. Overseas travel shows a tapered distribution with a median with marginal differences from clothing purchasing.

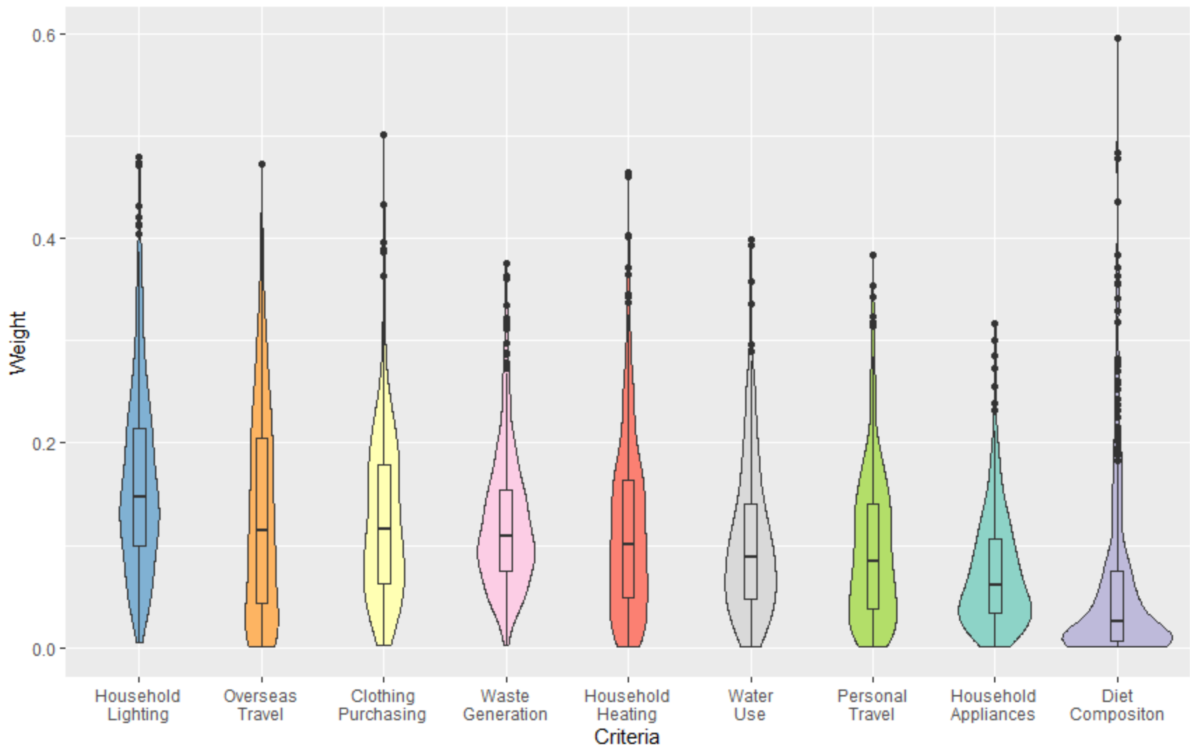

Figure 4-4-3. . Violin plots with overlaid box plots for weight of each criterion by the public identifying distribution of weights across participants, boxplot shows median.

4.4.2. Self-Reported Personal Factors

As demonstrated in participant responses to questions in Appendix 2A, participants displayed ‘green’ personal factors, ranking climate change as a highly important issue and recognising its “heavy” weight compared to other global issues.

The most frequent responses on the Likert scale questions were those with the highest agreement with environmental statements or attitudes such as ‘agree’ or ‘strongly agree’ as seen in Table 4-3. With participants most frequently considering climate change a ‘very’ or ‘extremely’ serious problem. Participants stated willingness to make changes such as using air source heat pumps as opposed to other options (see Appendix B.6).

Table 4-3. Frequency of results of survey question "How serious a problem do you think climate change is at this moment?"

SERIOUSNESS OF PROBLEM	RESPONSE FREQUENCY (N=381)
0. NOT A PROBLEM AT ALL	4 1%
1. NOT A SERIOUS PROBLEM	8 2.1%
2. A FAIRLY SERIOUS PROBLEM	56 14.6%
3. A VERY SERIOUS PROBLEM	117 30.5%
4. AN EXTREMELY SERIOUS PROBLEM	198 51.7%

Table 4-4 shows participants' responses to a question on responsibility for tacking climate change in the UK. The most frequent answer is that all suggested groups are the most responsible, with National Government the second most frequent response. The response that the participant alone was the most responsible for tackling climate change had only 2.9% support (11).

Table 4-4. Frequency of results of survey question "in your opinion who within the UK is most responsible for tackling climate change?"

RESPONSIBILITY FOR CLIMATE CHANGE	RESPONSE FREQUENCY (N=381)
NATIONAL GOVERNMENT	117 30.5%
BUSINESS AND INDUSTRY	33 8.6%
REGIONAL AND LOCAL AUTHORITIES	2 0.5%
YOU PERSONALLY	11 2.9%
ENVIRONMENTAL GROUPS	4 1%
OTHER	0 0%
ALL OF THEM	213 55.6%
NONE OF THEM	3 0.8%

Most participants stated they had personally taken action to address climate change in the six months preceding the survey, with 76% (291) of respondents stating they had, and 24% (92) stating they had not. This indicates a high level of self-reported environmentally conscious behaviour. Although what respondents consider action to tackle climate change varies, it demonstrates they *believe* they are acting. Most commonly individuals stated they would occasionally use carbon offsetting as a reduction method, but it did not seem to be widely rejected or endorsed.

Carbon labelling had high endorsement, with 94.5% (n = 361) of participants stating products should have carbon footprint labels. Fifty-four percent (n = 207) responded they would be more likely to purchase a product based on its carbon footprint, and an additional 38.1% (n =146) of participants say would be likely to purchase a product based on its carbon footprint. Fifty-four percent (n = 207) responded that Climate Change was the single most serious problem facing the world as a whole out of ten total options; this was the option with the majority of responses.

4.4.3. Preferences in Relation to Demographics and Personal Factors

Due to the random sampling method and the existing demographics within Southampton, not all demographics were proportionally represented, particularly age demographics. Preferences were ranked for different demographic groups (see Appendix 3); whilst there were some variations, the preferences across demographics followed similar trends.

There were a few notable variations, such as those lower incomes ranking overseas travel reduction as their most preferred behaviour change over lighting changes and ranking use of appliances as marginally less preferable to changing their diet. Individuals in the highest income bracket were more resistant to changing their overseas travel behaviour ranking this 7th instead of 2nd as the overall sample population does, a Kruskal-Wallis test of significance was conducted between income groups in terms of their overseas travel preference weight, identifying if different income groups preferences in relation to overseas travel carbon reductions the test determined there was statistically significant differences between income groups ($df = 9$, $p = 0.0005$). Those who selected 'prefer not to say' in relation to their gender identity preferred overseas travel, heating, and waste generation, ranked lighting (the most preferred for most demographics) 5th. This group would least prefer to change their diet behaviour. In relation to age, the youngest age bracket (18-24) ranked diet 3rd most preferable, a departure from the normal trends, however there were only $n = 5$ respondents in this demographic. The next demographic in age (25-44) ranked diet composition as 7th, marginally more preferable to the general consensus The two younger age ranges ranked overseas travel as a far less preferable carbon reducing behaviour to older demographics, with the 18-24 group ranking it 7th and the 25-44 age bracket ranking it 6th. Figure 4-4 shows violin plots with overlaid box plots to illustrate the distributions of weights for age in terms of overseas travel preference. The median weight for overseas travel preference decreases with age, although the youngest age bracket had a low response rate. A Kruskal-Wallis test between age groups for diet weights determined they were significantly different ($df = 3$, $p = 0.007$). Therefore, there were some statistically significant differences in preferences, but this was an uncommon finding.

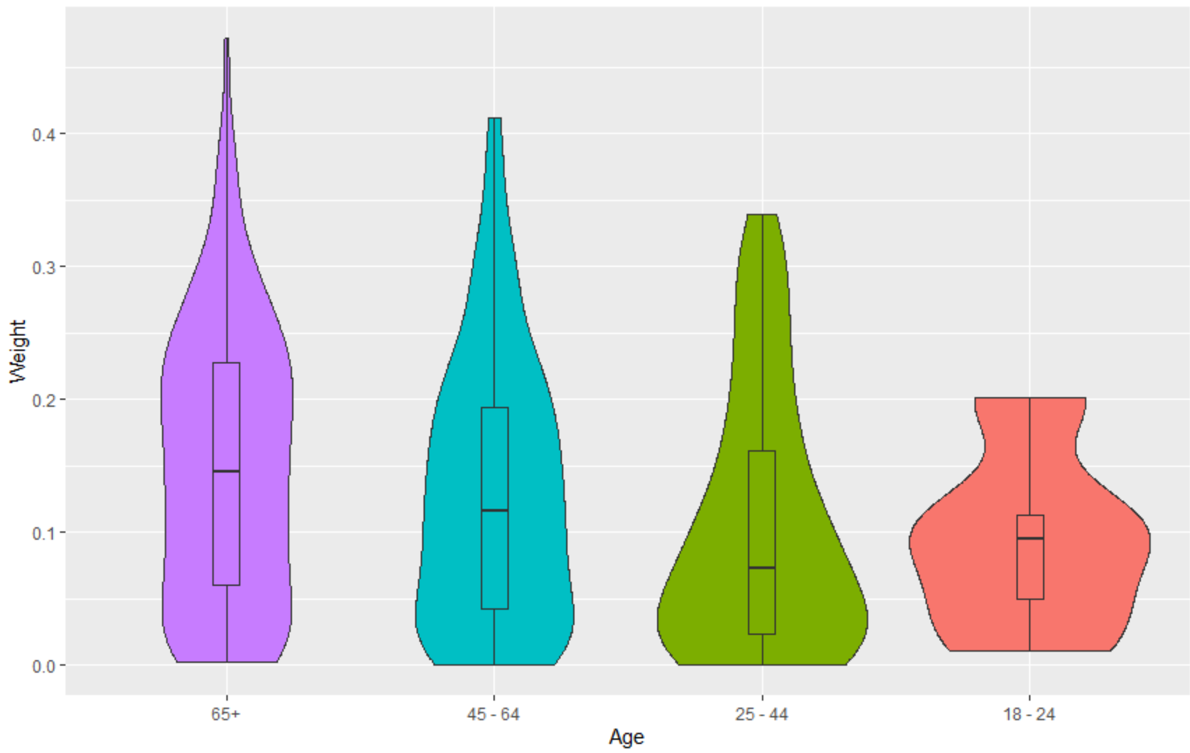

Figure 4-4-4. Violin plots with overlaid box plots for weight of overseas travel by the public by age identifying distribution of weights across participants, boxplot shows median.

Preferences were ranked for different attitude response groups (see Appendix 4 for examples). Whilst there were some variations, the attitude-related preferences followed similar trends, even where rankings might imply larger variations in preferences. Straightforward actions such as changing lightbulbs were considered preferable to significant lifestyle changes such as changing diet even for those participants whose attitude results demonstrated engagement with climate change and carbon emissions. Those who stated they had taken action to prevent climate change ranked preference criteria in the same way as those who stated they had not (see Appendix B.7). Preferences ranked by responses showed those who considered climate change to be 'an extremely serious problem' had the closest ranking pattern to the overall sample. All respondents regardless of response to the question on climate change seriousness ranked lighting as most preferable and diet change as least preferable change to make.

3.4.4. K-Means Cluster Analysis

A K-Means Cluster Analysis was applied to the part worth utility data (which was recorded for each participant and supplies individual weighting for each participant on their preferences) to identify any common demographics or attitudes between participants with similar preferences.

To evaluate how many clusters were needed for the k-means analysis a Calinski Harabasz criterion test was applied to the data (see Appendix B.8); this is defined as ratio between the within-cluster dispersion and the between-cluster dispersion. This identified that the optimum number of clusters was two. Hierarchal clustering was performed to corroborate the Calinski Harabasz index results (see dendrogram in Appendix B.8); this does not yield a clear result with the height of clusters and clusters not having clear groupings. Additional hierarchical clustering using Eulicidian distances gave similar outcomes, therefore the result of the Calinski Harabasz index was used.

K-means clustering analysis was performed on the data to generate two clusters (mean part worth of clusters can be found in Appendix B.8). To analyse the separation of these clusters, Euclidean and Cosine distance silhouette plots were generated (see Appendix B.8). The average silhouette values were not high indicating the clusters might not be particularly distinct (Yuan and Yang, 2019). This is due, in part, to the high number of part worth utility variables.

Tests on pairwise comparisons of means between the two clusters and an independent t-test between the clusters mean part utilities showed statistically significant differences between the two clusters. Preferences of the two clusters were ranked alongside the preferences of the sample overall in order to identify patterns and compare results from the clusters to each other and the overall sample in Table 4-5.

Table 4-5. Table displaying overall preference ranks of the public for carbon reduction behaviours in comparison to the two identified clusters.

CARBON REDUCTION BEHAVIOUR	OVERALL RANK	CLUSTER 1 RANK	CLUSTER 2 RANK
LIGHTING - ELECTRICITY	1	1	3
OVERSEAS TRAVEL	2	8	1
CLOTHES	3	4	2
WASTE	4	2	5
HEATING	5	3	6
WATER	6	5	7
DOMESTIC TRAVEL	7	7	4
APPLIANCES - ELECTRICITY	8	6	9
DIET	9	9	8

Cluster 1 prioritises lighting, waste, and heating; these are all household-focused changes to make and are behaviours that would be undertaken each day i.e. lower heating, less waste generation. Cluster 2 prioritises overseas travel, clothing purchasing and lighting. Overseas travel, changing lightbulbs and clothing purchasing are not daily behaviours to change like waste and heating. Both clusters rank diet as one of the least preferred behaviours to change. Part worth utility values of the clusters can be seen in appendix B.8. The k-means cluster analysis did not demonstrate that preferences reported by those of similar demographics showed trends or identifiable patterns by demographic and environmental personal factors.

4.5. Discussion

Overall, a majority of respondents recognise climate change as an extremely serious problem that requires action and is a global priority. A majority of participants self-report they have taken action and state they would take further actions to tackle climate change. A preference for carbon reduction behaviours that would have a low impact on their day-to-day lives regardless of demography or personal factors is evident. The priority seems to involve making relatively effortless changes to behaviour rather than any that involve more significant personal sacrifices. Changing lightbulbs, less overseas travel and changes to clothing purchasing have less influence over daily life than making changes to diet (i.e. reducing or eliminating meat), using fewer electrical appliances daily or changes in domestic travel such as getting rid of a car and using public transport or active transport (Climate Change Committee, 2020; Hibberd, 2019; Ivanova et al., 2016; Scarborough et al., 2014). For example, living car free is estimated to save on median average 2 tons of CO_2e per capita annually and a partial car reduction or shifting to public transport could save 0.6 to 1 ton of CO_2e per capita annually, but this is perceived as a high cost in terms of changing behaviour (Hagmann et al., 2019; Persson et al., 2021; Rondoni and Grasso, 2021).

The least popular behaviour change, diet, contributes 35% to UK carbon emissions; whilst this will not all be from meat production changes to a plant based diet could make far deeper cuts to emissions overall than reductions in air travel for example (Carlsson-Kanyama and González, 2009; Garnett, 2011; Ivanova et al., 2020; Neves and Brand, 2019; Poore and Nemecek, 2018). A change in diet is frequently put forward as one of the most effective methods of reducing a personal carbon footprint, and yet this was the least preferred reduction method, although the public may not have been educated on this fact (Lozano, 2008; Robinson et al., 2015; Sharp and Wheeler, 2013; Wibeck, 2014). Changing to a vegan diet is estimated to save 0.8 – 0.9 tons of CO_{2e} per capita annually (L. Baroni et al., 2007; Carlsson-Kanyama and González, 2009; Scarborough et al., 2014). However, this, like changes to domestic transport is a large-scale lifestyle change in behaviour rather than the more preferred easier low impact options.

Household energy is one of the highest contributors to greenhouse gas emissions globally (Department for Environment Food & Rural Affairs, 2020; Our World in Data, 2020; Preston et al., 2013). However, lighting is not as big a contributor to household energy as large appliances and heating (Department for Business, 2022; Department for Environment Food & Rural Affairs, 2020; Department for Environment Food and Rural Affairs, 2013; Druckman and Jackson, 2010; Switch Plan, 2022). This behaviour is for the public to simply change their bulbs to energy saving or LED bulbs, whilst there would be an initial small financial cost this behaviour change would have little day to day impact on a household or individual. In fact it is predicted that a household with entirely LED lights could pay two thirds less annually in their lighting bills than a household using entirely halogen lightbulbs (Temple, 2017). With the 2022/23 global energy crisis and energy becoming increasingly expensive, the public are likely to find themselves more motivated to change their energy consumption behaviour based on financial constraints (Ambrose et al., 2021; BBC, 2022; Mcfeatters, 2006). Therefore, this preference could be financially motivated instead of being related to the public's willingness to undertake actions and behaviours for carbon emission reductions. Lighting emission reduction predictions due to switching to LEDs vary depending on uptake, type of LED and on the lighting households are already using, the prediction of emission reductions by switching to LEDs vary between 40% - 80% (Switch Plan, 2022; Temple, 2017). The reduction of emissions from lighting would be significant; however, lighting contributes less overall to greenhouse gas emissions than diet and domestic transport (Bradley, 2012; Ivanova et al., 2020; Our World in Data, 2020)

The result that overseas travel was the second ranked behaviour change may seem significant as air travel is a considerable contributor to carbon emissions contributing 3.5% of emissions globally and 7% of UK emissions (Kommenda, 2019; Office of National Statistics, 2019). However, most households only make very infrequent trips overseas with the majority of the public traveling overseas between 0–2 times a year (Büchs and Mattioli, 2021; Office of National Statistics, 2019). Travel frequency varies across demographics, for example, first generation migrants return home more frequently to visit family and friends [101]. Similarly, to changing lighting in the home less overseas travel may have a financial benefit or be financially motivated. However, there is evidence that some domestic holidays may be more expensive than a holiday overseas, this of course depends on the type of holiday individuals expect to have and there may be differing opinions on what constitutes essentials when it comes to a holiday. Younger demographics were more resistant overall, to changing their overseas travel; this could be due to the cost of domestic holidays, which may be relevant to young families (Gibbons, 2022; Jones, 2022). However, in the UK those in the older demographic groups on average took more overseas holidays than those in the younger age demographics (Office of National Statistics, 2019)

Across most demographics and environmental attitudes, diet was the lowest ranked preference. In the k-means cluster analysis, diet was ranked 8th out of the nine criteria. No demographic or group examined prioritised changes in diet, 56% of participants ranked changes in diet as their 8th or 9th (out of nine criteria) preferred behaviour change. Only 11% of participants ranked it as their 1st or 2nd most preferred behaviour option and it is possible these participants already followed a plant based or lower carbon diet. A YouGov poll reported 2% of respondents were vegan, 5% were vegetarian and 16% were flexitarian (mainly vegetarian but occasionally eat meat or fish according to the YouGov criteria) (YouGov, 2022). Therefore, in the sample there would be individuals who had already amended their diet. Figure 4-3 highlights the high levels of unwillingness to change diet, with the distribution of results showing a considerable spread at the lowest preference values.

Within the cluster analysis, both clusters ranked diet as a lower preferred behavioural change. Participants did not seem to consider carbon offsetting an appropriate method of reducing their carbon emissions instead of their preferred behaviours, with the most frequent answer being that participants would only occasionally use it (54% n = 207). As the sample had more participants aged 45+, there may be some influence from this variation in terms of preferences related to age. No demographic or attitude patterns could be identified between the two clusters generated by the k-means cluster analysis. This indicates that there may be some other factor that drives the similarities in preferences that has not been identified in the cluster analysis. If preferences tightly aligned with demographics, it could be expected that demographic trends would occur across clusters.

Demography has less impact on preferences than may have been anticipated with most demographics demonstrating similar overall trends in preference ranking. Those engaging with the People's Panel may be more socially engaged than the public which may have had some influence over their responses in the attitude questions. It was anticipated that different demographics might demonstrate different preferences, potentially related to their needs, lifestyles, or environmental attitudes. For example, potentially due to those with higher incomes having far higher carbon footprints they may have demonstrated different preferences from those with lower incomes for example (Bruckner et al., 2022). A general consensus in the literature is that women are more environmentally concerned and aware than men, which could indicate they may have had differing preferences, due to different life experiences and needs in relation to men (Carrier, 2007; Denton, 2002; Goldsmith et al., 2013; Hunter et al., 2004; MacGregor, 2010; McCright, 2010). However, the only variation in the results between genders was that women were marginally more resistant to changing their clothing purchasing behaviours, ranking it lower than men did. There are some variations in preferences that align with a demographic groups' means; in the case of income, those with lower income have a higher preference to reduce overseas travel than those with high incomes. This may be less a preference and more a practicality that those on lower incomes cannot afford frequent overseas travels (Büchs and Mattioli, 2021). However, general trends across demographics and personal factors show preferences for 'easier' or more infrequent behavioural changes. This unwillingness to voluntarily change larger aspects of their lives by the public is not without precedent; previous UK policies such as the introduction of congestion charges, a plastic bag tax and an indoor smoking ban were all resisted despite being policies aimed at improving air quality, health or reducing waste (Borland et al., 1990; Convery et al., 2007; Schmöcker et al., 2006; Schuitema et al., 2010; Thomas et al., 2019; Townsend, 1987; Zheng et al., 2014).

Preferences of participants varied little across self-reported personal factors. Participants ranking climate change as a high risk or stating they have acted against climate change recently had similar preferences to those who stated less concern about climate change and no personal actions taken (76% (n = 291) said they had taken personal action, 24% (n = 92) said they had not). Both those who stated they took personal action and those who stated they had not ranked lighting their most preferred and diet their least preferred, following the general trends across the sample. A total of 82% of participants considered climate change a 'very' or 'extremely serious problem, but those with high concern for the environment still preferred the lower impact and effort behavioural changes, and resisted more difficult changes. There are several possibilities for why this may occur, there may be a degree of social desirability bias where participants feel because the survey concerns environmental issues and climate change, they should show higher 'green' preferences (Nederhof, 1985). But it is also possible that despite genuinely held personal factors on the importance and severity of climate change individuals do not really wish to make impactful life changes; their attitudes do not influence their preferences and therefore voluntary behaviour.

The results in Table 3 in response to the survey question "In your opinion who within the UK is most responsible for tackling climate change?" show the public consider national government and businesses to have greater responsibility for tackling climate change than themselves. Whilst the majority of respondents' opinion was that all groups were responsible, the results indicate an unwillingness from the public to take personal responsibility for climate action they regard as necessary. The public do not believe they need to be the ones undertaking stringent lifestyle changes to tackle climate change; this may be unwillingness to make sacrifices and/or because they do not believe their personal actions can make a considerable difference compared to the top-down approaches governments could take (Persson et al., 2021). There is a clear value-action gap between the green values stated in the survey compared to the public's willingness to take actions and personal responsibility; the stated values do not result in correlating 'environmentally-friendly' preferences (Barr, 2006). Despite the perception that the public has less or equal responsibility as government bodies and businesses, approximately 40% of greenhouse gas emissions in the UK come from households (Climate Change Committee, 2020a; Department for Business Energy and Industrial Stratergy, 2020; Hargreaves et al., 2013; Scarborough et al., 2014). In contrast 18% of UK emissions are estimated to come from businesses (Department for Business Energy and Industrial Strategy, 2020).

The value-action gap demonstrated in the results is not an outlier. There are numerous studies where participants state strong environmental or sustainability-related values and attitudes and yet their measured or self-reported behaviour does not correlate with them (Babutsidze and Chai, 2018; Barr, 2006; Chai et al., 2015; Chaplin and Wyton, 2014; Chung and Leung, 2007; Whitmarsh et al., 2011). The reasons for this gap are complex, and in many cases specific to the challenges of each action. There are external influences on the value-action gap, such as the behaviour of an individual's peers - for example, if everyone around an individual puts their recycling out, or it is considered a social norm to undertake a certain pattern of environmentally friendly actions (Babutsidze and Chai, 2018a; Shaw, 2008). However, relying on the actions of others to influence behaviour means there must be some individuals perpetuating those behaviours, and that is out of the control of governmental bodies or policymakers who may be targeting personal carbon emission reduction.

The public has ample information through media outlets on carbon emissions. Attributing their preferences to education alone is incorrect, as the majority of respondents considered environmental and climate change issues as highly important (Eghbalnia et al., 2013; Lawrence C. Hamilton, 2016; Knight, 2016; Whitmarsh et al., 2011). However, the public get their information from a range of sources, including unregulated and unchecked social media sources such as Facebook where there are pre-existing biases that contradict evidence-based information sources generated by professional scientists and journalists (Devonshire and Hathway, 2014; Moser, 2010; Sterman, 2011). There may be variation in what the public understand and what their own impact on climate change may be. Resistance to recommendations that the public needs to take voluntary action to change their behaviour, regardless of source was found by Palm et al (Palm et al., 2020). So even with a considerable understanding of climate change the public may still resist change due to their perceptions of the impacts on their own lifestyles.

Being fully aware of and comprehending the issues relating to the impacts of carbon emissions and climate change does not mean the public will be inclined to act, especially if they consider other aspects of their lives more important, such as their free time, finances, or lifestyle (Chai et al., 2015; Whitmarsh et al., 2011). Personal factor data indicated that the majority of participants stated they had taken action to reduce their own carbon footprint and reduce emissions, however extrapolating from their preferences these may only be moderate efforts and not the substantive behavioural changes needed to reduce emissions in order to halt or even slightly mitigate the current and anticipated future impacts from climate change. From our study, it seems unlikely the public will change their behaviour relating to the most carbon intensive activities and goods without mandatory policy interventions (Brock et al., 2022). These are unlikely to be politically popular due to the demonstrated resistance by the public to undertaking the types and scale of changes necessary to reduce emissions.

4.6. Conclusions

A sound understanding of why people do not act in line with their firm belief in the negative consequences of climate change is central to the development of realistic future climate actions. For the first time, this study identifies the deep-seated preferences of the public in terms of personal climate actions. To address the grand challenge of carbon reduction, the majority of the public report a preference for low intensity and 'easy' reduction behaviours rather than larger-scale, more challenging lifestyle changes. The actions participants preferred would have weaker carbon emission reductions than those they least preferred. There is minor variation in preferences in relation to demographics and attitudes. The findings highlight the importance of fully appreciating the human dimensions of climate change and not simply relying on public education and awareness-raising to stimulate behavioural changes. The study has clearly identified what personal actions the public are currently prepared to take to tackle climate change, enabling publicly acceptable system change to be developed.

Demographic and personal factors have a low influence on the public's carbon reduction preferences. General trends were observed across demographics, high preference for changing their lighting use and low preference for changing diet. There are some moderate variations that may be unrelated to climate change attitudes and behaviours, such as participants in lower income brackets showed preferences in line with their financial means such as a lower preference for overseas travel. It may have been expected demographics such as age bracket would have had a bigger influence on attitude, younger generations are believed to be more well informed on the breadth of the crisis, but their preferences mirror those from older age groups. It may have been expected that there would be variations in preferences in relation to demographics such as age i.e. due to differing education on climate change or differences in awareness whilst growing up as the climate crisis has become a more pressing global issue.

In general, the public undoubtedly now acknowledge that they are well informed on the climate crisis; high public awareness of the severity of climate change, its impacts and priority as a global concern is evident in responses to the questions asked on their attitudes towards carbon and climate change. There are elevated levels of concern and anxiety surrounding climate change as a global issue. However, this awareness does not translate into action, the preferences demonstrated across demographics and attitudes clearly show the public are unwilling to make the more difficult changes to their lifestyles, such as changing their diet – a daily challenge but one with a considerable potential for carbon reduction. The desire to consume, to carry on life as normal with its excess of carbon emissions and their detrimental effects outweighs the public's self-reported concerns and attitudes towards climate change.

Whilst carbon emissions and climate change must be tackled at an industrial and governmental level individual choices and behaviours have a considerable impact on carbon emissions. Public demand drives industry, public opinion influences government decisions, the actions of the public have great power to reduce emissions in many facets of society. If the public were willing to act on their attitudes towards climate change and overcome their desire to consume to make the more challenging changes to their lives carbon emissions would reduce. This however relies on the individual taking responsibility for their own emissions, actions, and impact on the rest of the world.

The public believe the main responsibility for taking action should either be a 'group effort' between all forms of governments, businesses and individuals, or just national government the public do not believe themselves responsible for action. Without some form of intervention, the public will not make the necessary changes to consumption behaviour and lifestyle choices to drive down emissions in order to tackle climate change in a meaningful fashion; using encouragement and hoping individuals are going to change their behaviours is currently failing to deliver. A policy such as personal carbon budgets, the allocation of an annual carbon allowance to individuals who then must make lifestyle choices to drive down emissions, may be a viable policy in this case, despite its controversial nature. However, we have seen that politicians suggesting such a policy are unlikely to be elected. This is a colossal and complex "wicked problem" for scientists, governments and politicians tasked with changing the world for the better – how do we enable society to alter its self-destructive behaviours if it does not feel able or willing to do so?

5. CHAPTER 5: BARRIERS AND CHALLENGES TO REDUCING PERSONAL CARBON EMISSIONS

ALICE BROCK, IAN WILLIAMS, AND SIMON KEMP

Concept for this chapter was developed by Alice Brock and supervisors (co-authors). Methodological development and refinement, research of literature, data gathering, management and cleaning, statistical analysis and writing was undertaken by Alice Brock

This chapter is currently undergoing the journal submission process.

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Alice Brock: Conceptualization, Methodology, Software, data collection, Data curation, Formal analysis, Writing – original draft. **Ian Williams:** Conceptualization, Methodology, Writing – review & editing. **Simon Kemp:** Conceptualization, Methodology, Writing – review & editing.

5.1. Abstract

Anthropogenic climate change is an urgent global crisis. Carbon emissions from all sources must be reduced including personal carbon emissions. To develop robust policies to reduce personal emissions the barriers and challenges people experience in reducing their emissions must be explored. A multi-stage diary study was undertaken to explore these barriers and challenges. A new method of analysing carbon behaviours, barriers, challenges, and motivators was developed, the CArbon Behaviour DIary Method (the CABDI Method). This method integrates quantitative and qualitative data to explore and analyse carbon reduction behaviours and motivators to provide a multifaceted analysis of behaviours, motivators, and barriers. The most commonly arising barriers were participants' own attitudes. Participants expressed a preference to take the most convenient action, despite high awareness of climate change and the impact their behaviours had. Education was found to only have a short-term effect, implying awareness raising and education alone cannot change behaviour. Although the post-diary carbon footprint showed an average reduction per participant of 0.9 tons CO_2e, contemporary evidence suggests this is unlikely to be sustained. The public cannot be 'nudged' into reducing their carbon emissions appreciably and a top-down policy intervention is required.

5.2. Introduction

The extreme changes in climate caused by anthropogenic greenhouse gas emissions and the resultant dramatic and often devastating impacts are rapidly escalating (Henley, 2023). We might expect an urgent response from governments and the public, but this is not happening fast enough. The 28 annual Conferences of the Parties since 1995 have not stemmed the rising tide of carbon emissions, with 2023 showing a record high of 37.55 Gt CO_2, Brock et al (2023) highlighted that although public awareness of climate change is widespread, even the most informed people are not prepared to alter their lifestyles aside from easy, convenient, and low impact changes. This is an immense and complex problem for scientists, governments, and politicians.

Understanding the barriers and challenges the public experience when attempting to reduce their carbon emissions are vital to developing policy interventions and methods to reduce personal emissions as part of a broader global strategy to drive down emissions. However, there are limitations on the carbon emissions an individual can achieve. These will vary by demographic group, location, and factors such as local infrastructure and services and financial constraints, regardless of their environmental attitudes (Tabi, 2013; Timlett and Williams, 2011). However, individuals have influence over aspects of their carbon emission generation, such as their household heating, transport, and diet. Thus whilst tackling the climate crisis requires large-scale structural changes, the severity of the crisis requires all avenues of reduction are explored (Chai et al., 2019; Hou et al., 2022; McDowall and Britchfield, 2021; Walsh et al., 2008). Despite these limitations, changes in individual behaviour reduce households' energy usage and personal emissions (Ivanova et al., 2020; Jakučionytė-Skodienė et al., 2022; Tabi, 2013).

A variety of factors contribute to an individual taking part in carbon reduction behaviour. Attempts at modelling these factors have been stymied due to the sheer complexity of the circumstances (Kollmuss and Agyeman, 2002). Approaches to encouraging the reduction of personal carbon emissions requires varied interventions and methodologies underpinned by an understanding of the contributing factors and their individual significance.

Currently a considerable proportion of resources go into 'awareness raising' and education to reduce personal carbon emissions. However, due to growing global awareness of the climate crisis, it is vital to explore other barriers that may be present (Hamilton, 2016; Knight, 2016; Sommer and Klöckner, 2019).The behaviours demonstrated by some of the UK public during the COVID-19 pandemic could indicate that despite awareness campaigns and scientifically valid advice, individuals may act against in ways against that advice (Sibony, 2020). This affirms the need to understand the complexity of the factors that influence behaviours, particularly those that contribute 'to the greater good' rather than those with immediate personal rewards.

A practical and tangible ability to track progress may give the public an incentive to change their behaviour (Lin, 2016). This is an underlying principle of policy interventions such as carbon labelling where the public is expected to make choices based on the associated carbon emissions of goods. Some models propose that the *per capita* 'carbon budget' is disseminated to the public who are expected to keep to it to reduce personal carbon emissions (Lemken et al., 2021; Panzone et al., 2020; Rondoni and Grasso, 2021; Taufique et al., 2022; Zhao et al., 2020). This relies upon the public having the awareness and motivation to stick to a budget and to prioritise carbon emission reduction over other aspects of their lives.

Existing literature explores stated preferences about carbon behaviours and how people may be persuaded to attempt to reduce their emissions, alongside rising interest in 'eco anxiety' (Barr, Stewart. Gilg, 2003; Bourque and Cunsolo Willox, 2014; Carrus et al., 2008; Coffey et al., 2021; Cunsolo et al., 2020; Doherty and Clayton, 2011; Henkel et al., 2019; House of Lords Environment and Change Committee, 2022; Pihkala, 2020; Steg and Nordlund, 2018; Zanni et al., 2013). Eco-anxiety arises more frequently as environmental awareness and evidence of the impacts of climate change increase, implying that the public is becoming far more educated and aware of the climate crisis and emotionally affected by it.

There is a considerable body of work exploring how personal behaviour around consumption and generation of carbon emissions may be changed, and the methods that may be used. These methods include nudge theory, awareness raising and various political interventions such as carbon taxation or carbon labelling (Armstrong et al., 2004; Carbone et al., 2013; Lawrence C Hamilton, 2016; Kollmuss and Agyeman, 2002; Sommer and Klöckner, 2019; Sumner et al., 2011; Taufique et al., 2022; Upham et al., 2011; Vanclay et al., 2011). There are gaps on the barriers the public may experience when trying to undertake carbon reductions, particularly without external support. Motivations behind environmental behaviours have been explored, particularly motivations driven by emotion, attitudes, and values. Environmental self-identity may be an important motivator in the promotion of pro-environmental behaviour (Van der Werff et al., 2013). But it is a complex and multi-faceted challenge to understand why the public do not wish to engage with the most carbon reducing behaviours (Brock et al., 2023).

Young people are increasingly considered to be more ‘eco-aware’ and suffering from high levels of eco-anxiety, and are a group whose attitudes and awareness of climate change is increasingly examined (Coffey et al., 2021; Kuthe et al., 2020; Ramadan et al., 2023; Rousell and Cutter-Mackenzie-Knowles, 2020). Younger generations will be most impacted by the impacts of climate change, and hence are often more climate change aware and concerned (Coffey et al., 2021; Ramadan et al., 2023; Rousell and Cutter-Mackenzie-Knowles, 2020). Young people such as Greta Thunberg are at the forefront of climate campaigning and activism, demonstrating the conviction and concern of this generation (Haugestad et al., 2021; Murphy, 2021; Nässén and Rambaree, 2021; Neas et al., 2022; Sabherwal et al., 2021). However, it is suggested that even young people have difficulty in transforming these environmental attitudes, and their increasing eco-anxiety into significant carbon reduction behaviour and action(Dimitrova et al., 2021; Haug and Hassinggaard, 2023; Hume, 2010; Piscitelli and D’Uggento, 2022).

It is evident the public resist making deep cuts to their personal carbon emissions through behavioural change. Investigating why the public is not enacting changes is vital to develop policy interventions. Therefore, this study aimed to identify, explore, and analyse the barriers and challenges faced by people in reducing their personal carbon emissions. Young people were chosen as participants to explore if those with high levels of motivation and awareness were able to change their behaviour in order to reduce their emissions. This allowed for exploration and investigation of barriers and challenges by the most engaged and motivated societal group.

5.3. Methodology

There is currently no consistent method in the literature to gather, integrate and interpret people's carbon behaviours, barriers, and challenges. This is partially due to the resource heaviness of gathering behavioural data and the difficulty around recruiting large sample sizes. A new method of assessing carbon reduction behaviour and motivators was therefore developed, The CArbon Behaviour DIary method, (CABDI).

Due to the complex nature of the research question, a Mixed Methods Explanatory Sequential Design methodology was used as the basis for this new model (Esterberg, 2011; Ivankova et al., 2006; Schoonenboom and Johnson, 2017; Tashakkori and Creswell, 2007). Trends in behaviour can be observed through quantitative data and explanations and reflections on these trends from participants can explain the cause for quantitative findings, allowing for deeper interrogation of behavioural causes and motivators (Esterberg, 2011; Schoonenboom and Johnson, 2017; Tashakkori and Creswell, 2007). To be applicable and repeatable across a range of circumstances, data gathering methods were chosen that could be conducted online and, in the participants, 'own time.'

The sequential explanatory design involved two data collection phases; an initial quantitative data gathering and analysis phase and a subsequent qualitative data gathering and analysis phase to explain the findings of the quantitative data. The quantitative data provides an overview of the behavioural trends and barriers to the public in this study. The qualitative analysis allows participants to explain their behavioural results and give in-depth analysis of their views (Ivankova et al., 2006).

A mixed methods approach allowed complexities to be addressed. The public's behaviours relating to carbon emission reductions are influenced by factors such as their personal beliefs, demographics, cultural identity and location. For each individual there may be myriad reasons, values, and internal justifications for behavioural choices that cannot be identified by quantitative data alone. The use of a reflective piece of writing, written alone and with anonymity, provided participants with an opportunity to provide answers that are honest rather than influenced by social desirability bias.

The CABDI model includes an identical survey and carbon footprint taken before and after the quantitative and qualitative data gathering activities. This allows for a baseline to be developed on the participants' self-reported attitudes, knowledge, and self-reported carbon footprint, giving comparison metrics to support analysis.

Diary studies can suffer from participant fatigue and inconsistent response rates and so the diary stage of the CABDI model was designed to be quick and quantitative, with participants recording behaviours on an online form (Gochmann et al., 2022; Goossens et al., 2000; Horstmann, 2021). The form was tested to ensure the time taken to complete the form would be under five minutes. Participants were provided with the option to include qualitative notes for each day if they so desired which would subsequently be coded thematically into quantitative data; this was also for their own records to support their qualitative reflections. This provides a diary that is a low burden to complete but flexible if participants choose to express themselves further. A diary study includes self-reported behavioural data rather than observed behavioural data. However, personal life observations would be time-consuming, logistically complex, and highly invasive.

The CABDI model was designed with the flexibility to allow for varying methods of data collection. The final reflective piece in this study has taken the form of a written piece, although other qualitative methods such as interviews could collect the required data for this stage (Knox and Burkard, 2009). Whilst the quantitative data has been gathered online these types of quantitative data could be gathered via paper-based methods for those researchers or participants who do not have consistent internet access.

Figure 5-1 shows the CABDI model and Figure 5-2 shows the structure of the study using the CABDI model mapped onto the explanatory sequential mixed methods design. In summary, there are four key data gathering steps in the CABDI model:

i) Determining a baseline of attitudes, opinions, and a carbon footprint (quantitative)
ii) Gathering behavioural data (quantitative)
iii) Repeating the baseline data gathering for comparison (quantitative)
iv) Data collection to gather experiences, explanations, and reflections (qualitative).

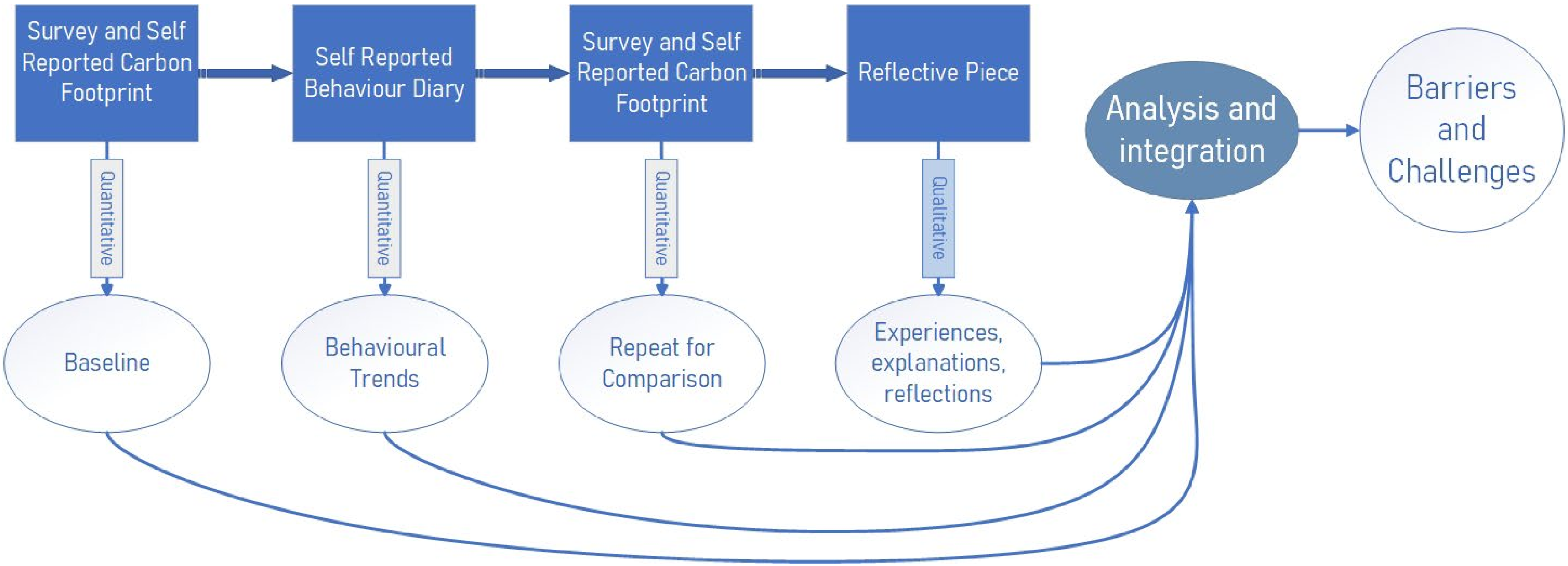


Figure 5-5-1. CABDI Model Schematic (CArbon Behaviour DIary Model), blue boxes show data gathering methods used in this study, downwards arrows and boxes indicate if the data gathered is qualitative or quantitative. Gradient ovals show data outputs.

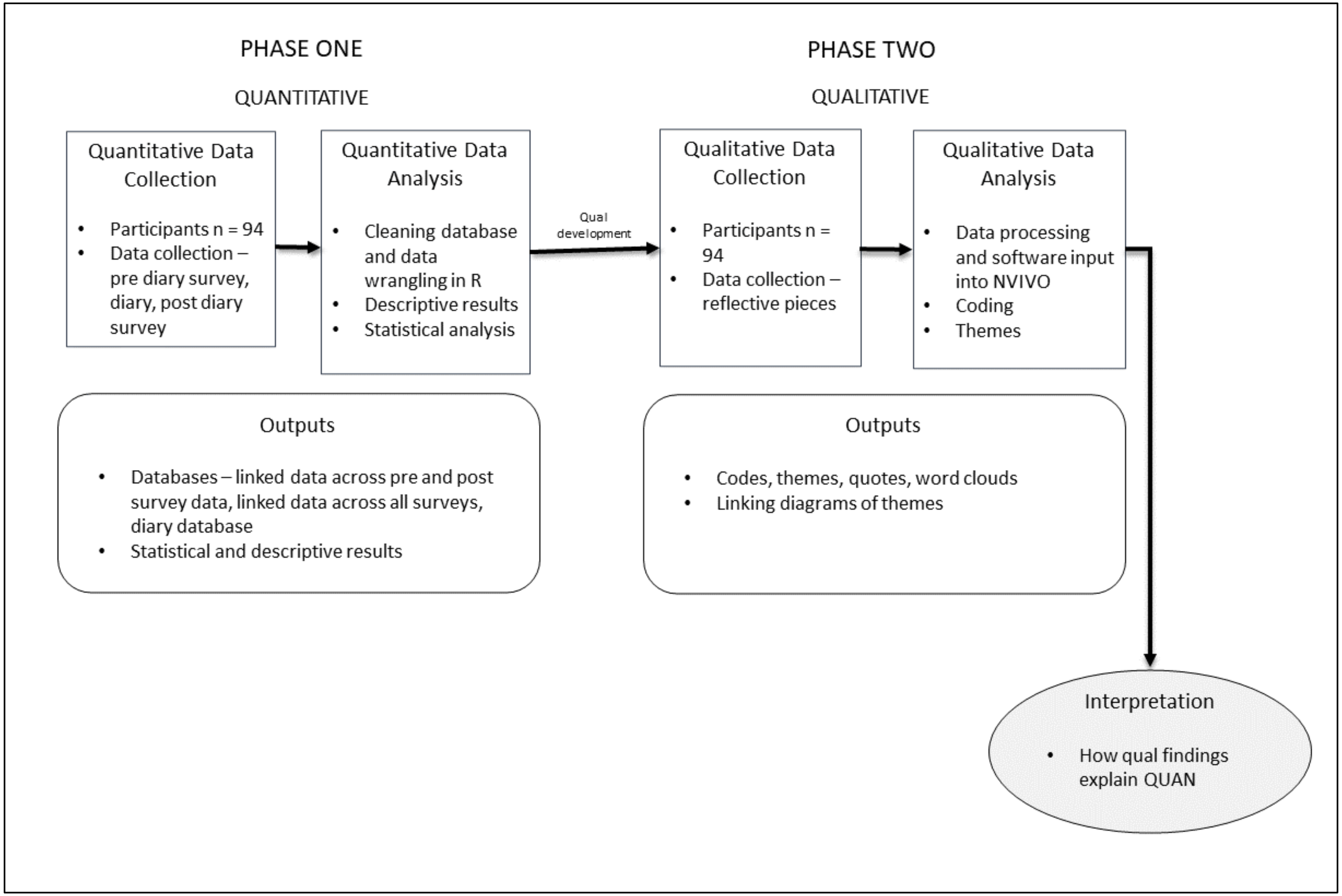


Figure 5-5-2. Schematic of study design and relationships between datasets with outputs and methods according to explanatory sequential desi

5.3.1. Quantitative and Qualitative Data Gathering and Analysis

Participants were drawn from the student body of an English university (the University of Southampton). Participants were undertaking an optional 'Global Sustainability Challenges' module, indicating a degree of awareness or interest in sustainability and climate change.

Ethical approval was gained through the institution's Research and Ethics and Governance Team, participants were distributed participant information sheets and attended a session on the ethical framework of the research and invited to ask questions. Grades related to the module were in no way linked to participation in the study and participants could withdraw until the data analysis stage. Participants were not expected to complete any aspect of the study in the presence of the researchers to minimise social desirability biases.

As this study involved a considerable time commitment, the use of participants' work that also formed part of an assignment meant there was a high return of completed diaries and surveys. Participants were of a similar age and life-stage, and all lived in a similar area with similar lifestyles (i.e. academic commitments, financial circumstances). Alongside this study students were undertaking a sustainability based module on a broad range of topics, some topics included subject matter related to carbon emissions and behaviour as a facet of the lecture or workshop.

All surveys were distributed online through Microsoft Forms. All data was anonymous but linked via numeric codes.

The quantitative data gathering consisted of three activities:

i) A pre-diary survey conducted on the day before the first diary entry. The survey gathered information on the participants' attitudes on carbon emission reduction behaviours, responsibilities and knowledge and included the completion of a carbon footprint.

ii) A carbon diary over a period of 28 days, the behaviours selected to be recorded were developed building on previous work (Brock et al., 2023, 2022).

iii) A post-diary study with identical questions to the pre-diary survey to identify any changes in responses following the carbon diary experience.

Analysis (using R software and the Tidyverse package, (R Core Team, 2024; Wickham et al., 2019)) was conducted on the quantitative data prior to the generation and gathering of the qualitative data. Quantitative analysis was as follows:

i) Statistical and descriptive analysis of pre- and post- diary study results and carbon footprint comparison between the two time periods.
ii) Coding of qualitative data within quantitative dataset to themes – coded if theme was present or absent for each diary entry, multiple themes coded if present.
iii) Statistical and descriptive analysis of carbon diary entries.
iv) Analysis of behavioural trends across carbon diary time period.

Following quantitative analysis four questions were developed based on the findings of the quantitative results (see section 5.4.). To gather qualitative data, a written piece was created by participants to record their own reflections on their experiences, identify the barriers, challenges and benefits they experienced and any other unstructured thoughts they may wish to record. This method was selected for several key reasons:

i) Practicality – participants were all students with differing and complex timetables therefore a piece they could do to their own time requirements increased the likelihood of completion.
ii) Potential for social desirability bias and researcher influence – as the researchers for this study are known to the students it would have been impossible to eliminate bias and students may find themselves answering questions in the way they considered the 'right' way for an academic audience or their peers (Gittelman et al., 2015; Krumpal, 2013; Larson, 2019; Nederhof, 1985).
iii) Anonymity – all submissions were anonymous to those conducting data analysis and from other participants.
iv) Feasibility – due to the high number of participants, methods such as interviewing would be logistically complex in the timeframe available.

Qualitative analysis was coded in NVivo 14 (2023), A theme codebook was developed alongside additional codes developed following thematic analysis of the qualitative data to explore the breadth of nuance within the qualitative data (Reyes et al., 2021). The codebook was developed from introductory deductive codes and themes based on the questions raised by the quantitative analysis, additional inductive codes were developed following a preliminary analysis of the data (Belotto, 2018; Boyatzis, 1998; Elliott, 2018; Saldana, 2016; Stuckey, 2015). The thematic coding was iterative. throughout the thematic analysis and coding of data any additional reoccurring themes were analysed and included in further iterations of coding.

5.3.1.1. Pre and Post Diary Surveys

The pre- and post-diary surveys were developed to provide indications of participants' attitudes towards personal carbon emissions reduction behaviours and gain insight into their overall opinions on carbon emission reduction and climate change.

Indicative carbon footprints were generated using the World Wildlife Federation carbon footprint calculator (WWF, 2021). This calculator was selected due to its ease of use on web browsers and mobile phones, the simplicity of its methodology, and appropriateness for the participants due to many not owning their own homes and therefore not having access to certain pieces of information (WWF, 2021). The carbon footprint was intended as an indicator of change during the study period. See Appendix C.1 for the survey.

5.3.1.2. Carbon Diary

Participants recorded their behaviours across a selection of criteria each day. The criteria were developed from previous work with some criteria in previous works combined to reduce the time burden to participants (Brock et al., 2023). Participants completed a daily Likert scale indicating how difficult they had found making sustainable choices that day (Guy and Norvell, 2010; Andrew T Jebb et al., 2021; Youn et al., 2017). Space was given for participants to give context for their behaviours and to aid their personal reflections. See Appendix C.2 for Carbon Diary.

The areas of behaviour included were:

i) Clothing Purchasing
ii) Food Consumption
iii) Water Usage
iv) Electrical Appliance Usage
v) Transport Usage
vi) Waste Generation

5.4. Results

A total of 112 participants of 115 students undertaking the module (response rate 97.4%) contributed to the study; of these 94 completed all aspects of the study, including the pre- and post-diary study, at least 26 carbon diary entries and the reflective piece. Any participant that did not reach this threshold was eliminated to ensure the data was robust.

5.4.1. Quantitative Results

5.4.1.1. Carbon Footprints

Figure 5-3 shows that there was a reduction in participants' average carbon footprint and a reduction in the range of footprints submitted.

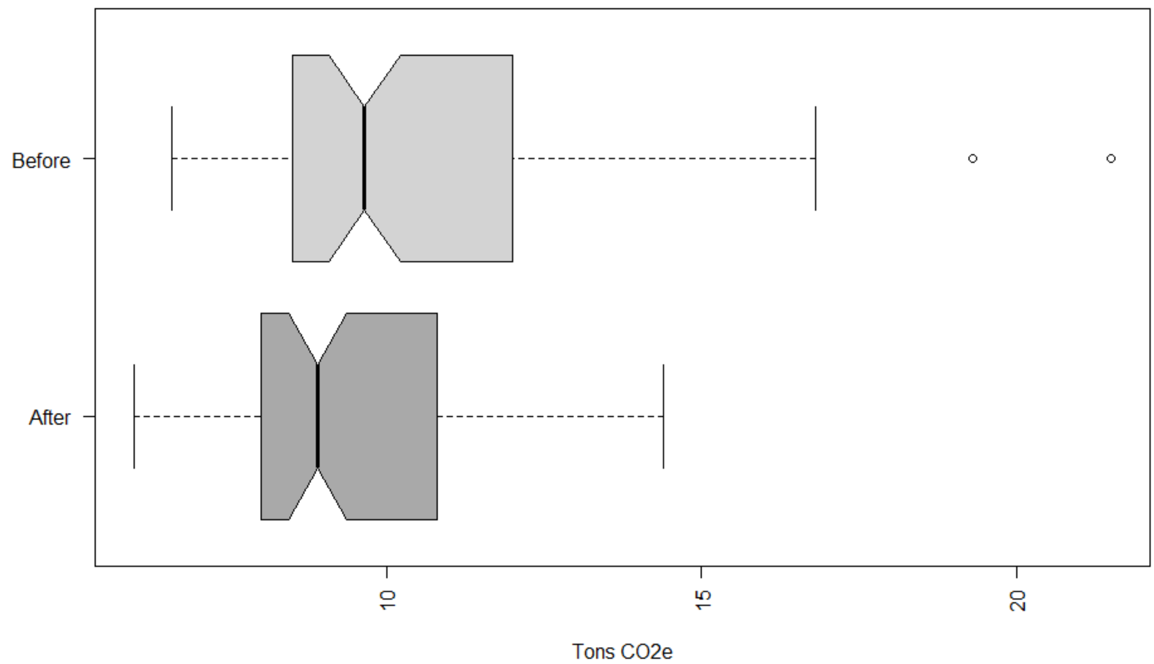


Figure 5-5-3. Notched boxplots showing self-reported carbon footprints of participants before and after the diary period.

Data was tested for normality (Before p = <0.5, After p = 0.07). As the paired datasets varied in normalcy it was subject to a Wilcox paired signed rank test and an additional paired t-test. There was a statistically significant difference between the two time periods in the Wilcox paired signed rank test ($p = 4.347^{e-08}$) and the paired t test ($t = 5.0631$, $df = 93$, p-value = 2.077^{e-06}); the mean difference was 0.98 tonsCO_2e. The post-diary carbon footprint showed an average reduction per participant of 0.9 tons CO_2e.

Not all participants reported a decrease in their carbon emissions:

i) 67 participants self-reported a decrease in carbon footprint

ii) 18 participants self-reported an increase in carbon footprint

iii) 9 participants self-reported no change in carbon footprint.

In the subset of participants who reported a increase in their carbon footprint the mean footprint before the diary period was 8.97 and after was 9,93 . The mean difference in footprint was 0.96 tons CO_2e (Appendix C.1). Data was tested for normalcy (Before p = <0.33, After p = 0.73). As the data was normally distributed a paired t-test was used. The paired t test (t = 3.7224 , df = 17, p = 0.002).

In the subset of participants who reported a decrease in their carbon footprint the mean footprint before the diary period was 11 tons CO_2e. reducing to 9.36 tons CO_2e after the diary period, a difference of 1.64 tons CO_2e. Data was tested for normality (Before p = <0.5, After p = 0.08). As the paired datasets varied in normalcy it was subject to a Wilcox paired signed rank test and an additional paired t-test. There was a statistically significant difference between the two time periods for the decreased footprint subset in the Wilcox paired signed rank test (p = 0.3) and the paired t test (t = -7.596, df = 66, p = 1.399^{e-10}).

As the footprints of the increase subset and decrease subset seemed similar following the diary period the two subsets were tested for significant difference. As the datasets varied in normalcy it was subject to a Mann Whitney U test and an additional t-test. There was no statistically significant difference between the two subsets following the carbon diary in the Mann Whitney U test (p = 1.134^{e-12}) and the p t test (t = 1.038, df = 26, p = 0.4).

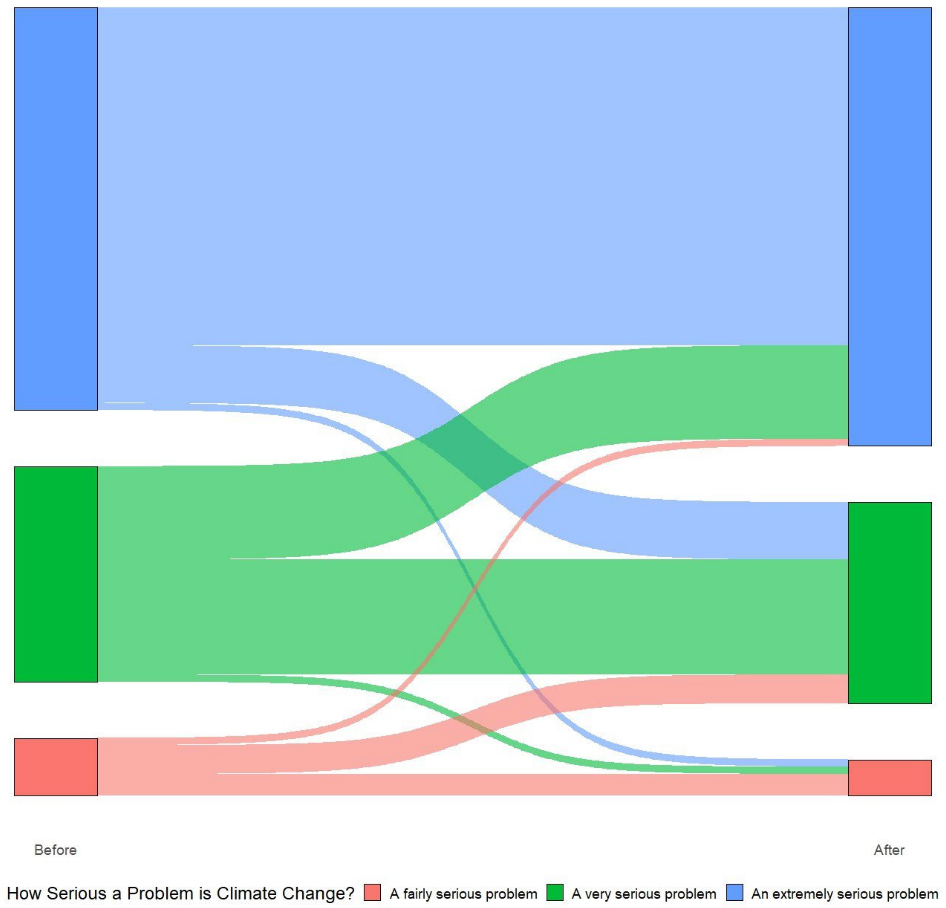
The median before study carbon footprint for the entire sample was 9.65 tons CO_2e, the median for the entire sample after the study was 8.9 tons CO_2e showing a decrease in the median of 0.85 tons CO_2e. The median before study carbon footprint for the decrease subset was 10.6 tons CO_2e the median for the decrease subset after the study was 8.9 tons CO_2e showing a decrease in the median of 1.7 tons CO_2e. The median before study carbon footprint for the increase subset was 8.75 tons CO_2e the median for the increase subset after the study was 9.8 tons CO_2e showing an increase in the median of 0.95 tons CO_2e.

55.6% of participants who reported an increase in their carbon footprint (n = 18) stated – Yes to the question: “Have you undertaken carbon reduction behaviour in the last 12 months?” 22.2% answered ‘Maybe’. 35% of participants who reported a decrease in their carbon footprint (n = 67) stated Yes to this question, 35.8% responded Maybe.

5.4.1.2. Pre and Post Diary General Results

Figure 5-4 summarises participants' views on how serious a global problem they considered climate change.

Figure 5-5-4. Diagram showing change in stated opinion before and after diary period



PRE-DIARY OPINION TO POST DIARY OPINION	FREQUENCY	CHANGE
A FAIRLY SERIOUS PROBLEM > A FAIRLY SERIOUS PROBLEM	3	None
A VERY SERIOUS PROBLEM > A VERY SERIOUS PROBLEM	16	None
AN EXTREMELY SERIOUS PROBLEM > AN EXTREMELY SERIOUS PROBLEM	47	None

A VERY SERIOUS PROBLEM > A FAIRLY SERIOUS PROBLEM	1	Downgrade one level
AN EXTREMELY SERIOUS PROBLEM > A FAIRLY SERIOUS PROBLEM	1	Downgrade two levels
A VERY SERIOUS PROBLEM > AN EXTREMELY SERIOUS PROBLEM	13	Upgrade one level
A VERY SERIOUS PROBLEM > AN EXTREMELY SERIOUS PROBLEM	8	Upgrade one level
A FAIRLY SERIOUS PROBLEM > A VERY SERIOUS PROBLEM	4	Upgrade one level
A FAIRLY SERIOUS PROBLEM > AN EXTREMELY SERIOUS PROBLEM	1	Upgrade two levels

The majority of participants did not change their view on the seriousness of climate change, with most considering climate change 'An Extremely Serious Problem.' Only two participants downgraded the level of seriousness they considered climate change and 26 upgraded. Changes in responses to the knowledge-based questions across the pre- and post-survey were negligible.

In the pre-survey, the 38 participants stated they had taken action to reduce their carbon emissions in the past month, this rose to 68 in the post-diary survey implying that throughout the diary completion period, most were attempting to change their behaviours or believed themselves to be (see Appendix C.3).

Figure 5-4 shows who participants believed to be most responsible for reducing the public's carbon emissions. Moderate shifts are evident, with a reduction in participants stating those responsible are business and industry, and a minor increase in participants stating themselves as individuals are the most responsible. Changes in opinion can be seen across the data between the before and after data.

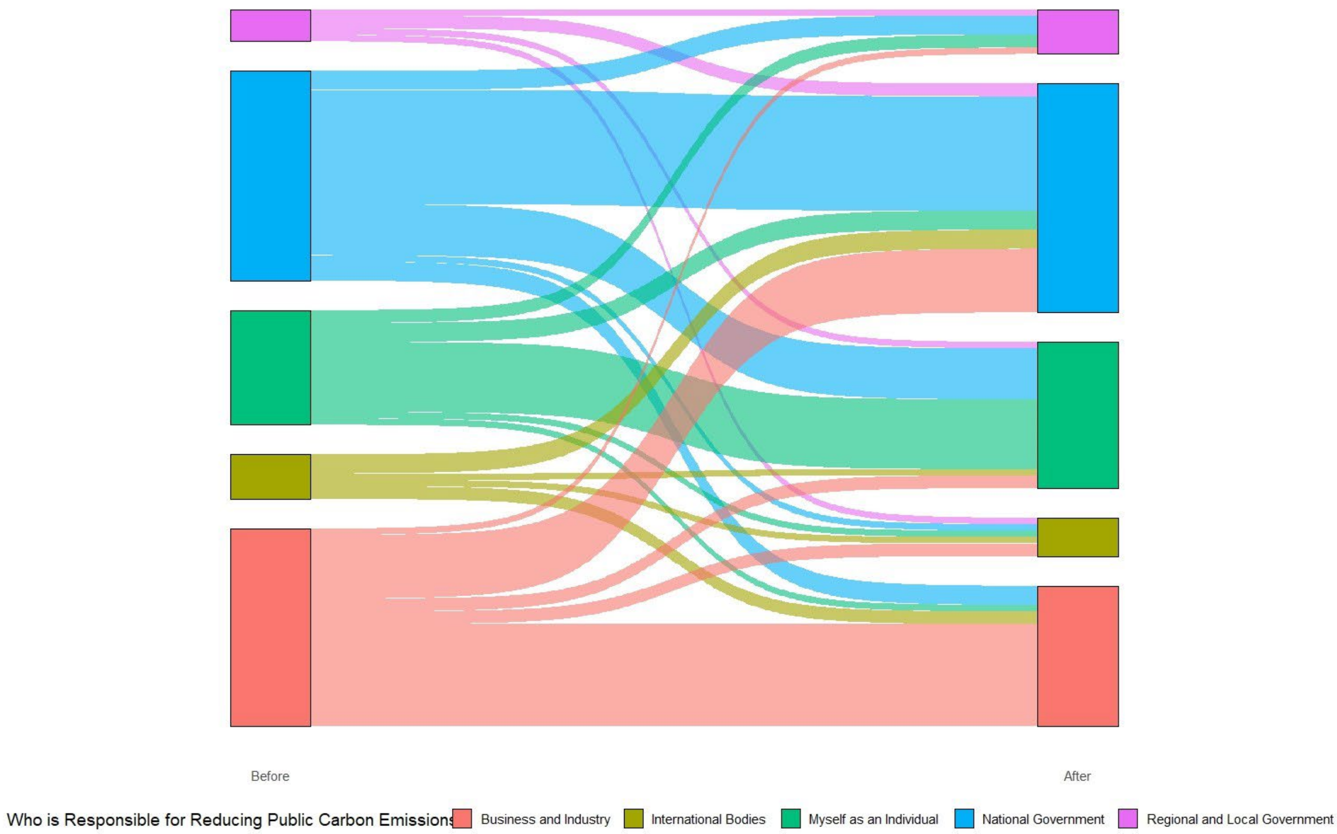


Figure 5-5-5. Participant responses from pre- and post-surveys on who is responsible for reducing public carbon emissions.

Participants were asked to rank which behaviour changes they believed would be the most and least difficult behaviours to change. Figures 5-5 and 5-6 shows that there were shifts in opinion following the carbon diary on which would be the most difficult behaviour to change, with participants identifying Household Electrical Appliance Usage as the most difficult by a greater degree than it was in the pre-survey, there was considerable movement of participants' opinion of the most difficult behaviour to change following the diary period with participant opinions . However, in both surveys participants identified household electrical usage as the most difficult behaviour to change. Participants stated clothing purchasing would be the least difficult behaviour to change and participants selecting this opinion increased in the post-survey, implying this was not a behaviour participants struggled with in terms of consumption.

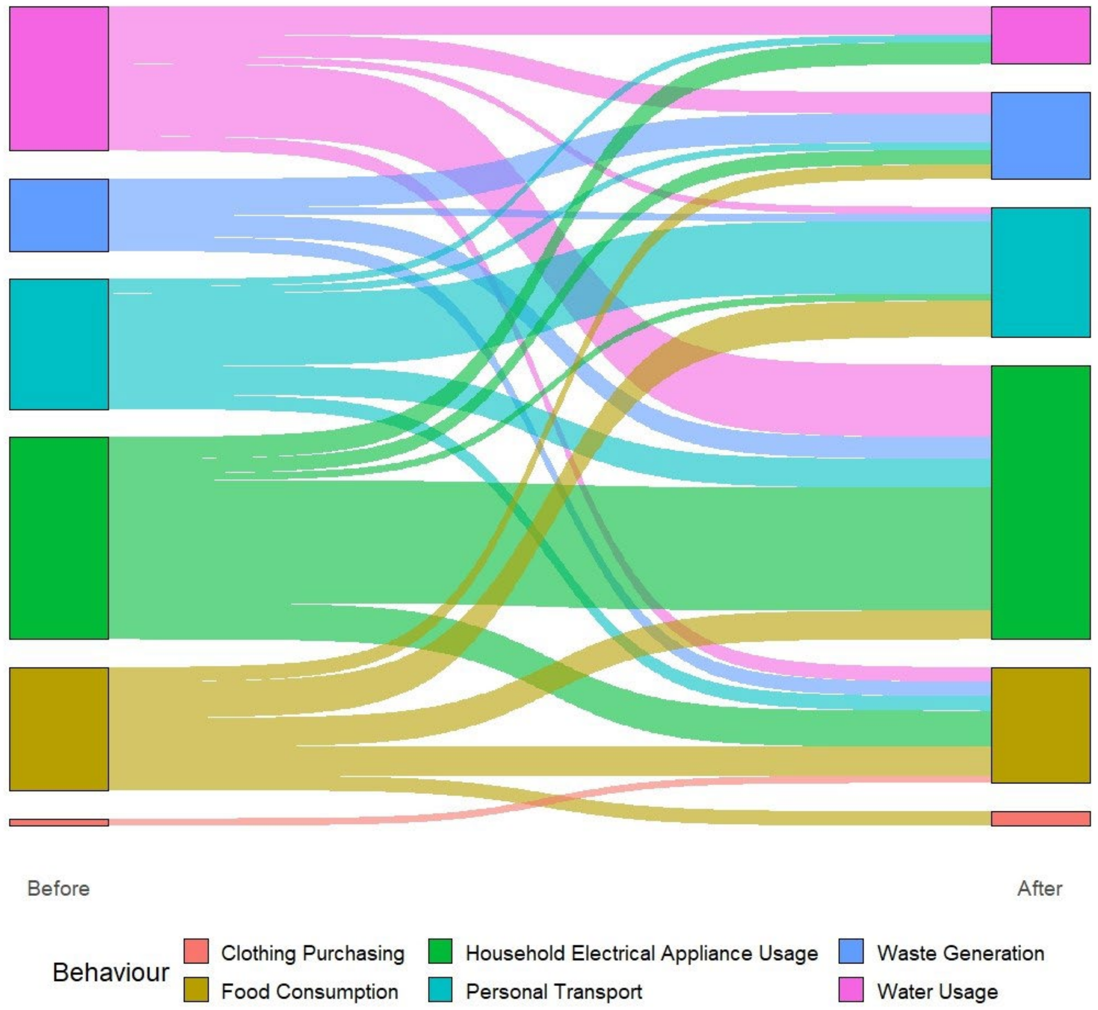


Figure 5-5-6. Participant results of most difficult behaviour to before and after the diary period.

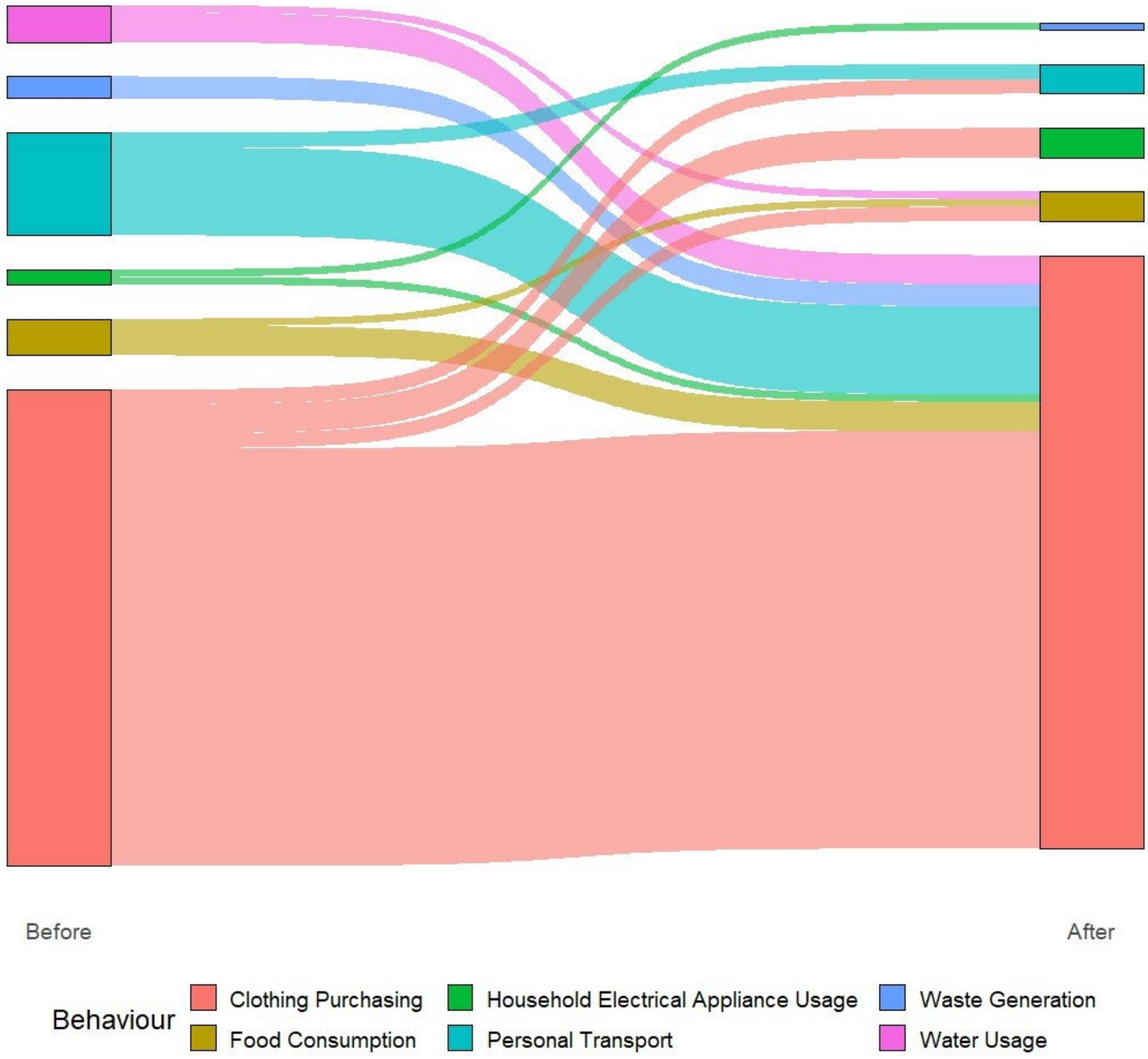


Figure 5-0-1. Participant results of least difficult behaviour to change before and after the diary period.

Participants stated their opinion on how they rated the sustainability of their current lifestyle on a Likert Scale before and after the carbon diary (Appendix C.1). Participants considered themselves to be of an average level of sustainability with a trend towards the lower scores following the diary. Similar trends can be identified when participants were asked to identify how achievable a sustainable lifestyle was on a Likert scale (Appendix C3).

5.4.1.3. Carbon Diary Results

Across the six behaviour categories, behaviour remained consistent across the time period. Clothing purchasing was infrequent. Behavioural trends such as waste generation and water usage remained consistent (Appendix C.4). There was a slight increase in frequency of recycling recyclable waste and single use items, however this did not correlate with a reduction in recyclable and single use waste not being recycled (the diary only records activity, therefore if a participant both recycled and threw away a recyclable item on the same day both would be recorded).

Car usage declined until approximately the mid-point of the study period when it then rose and became variable (Figure 5-7). Walking frequency initially rose but then dropped over the diary period with a moderate increase towards the end (Figure 5-8). Data are presented with locally estimated scatterplot smoothing (LOESS) curves to identify trends due to the high number of responses and long time period.

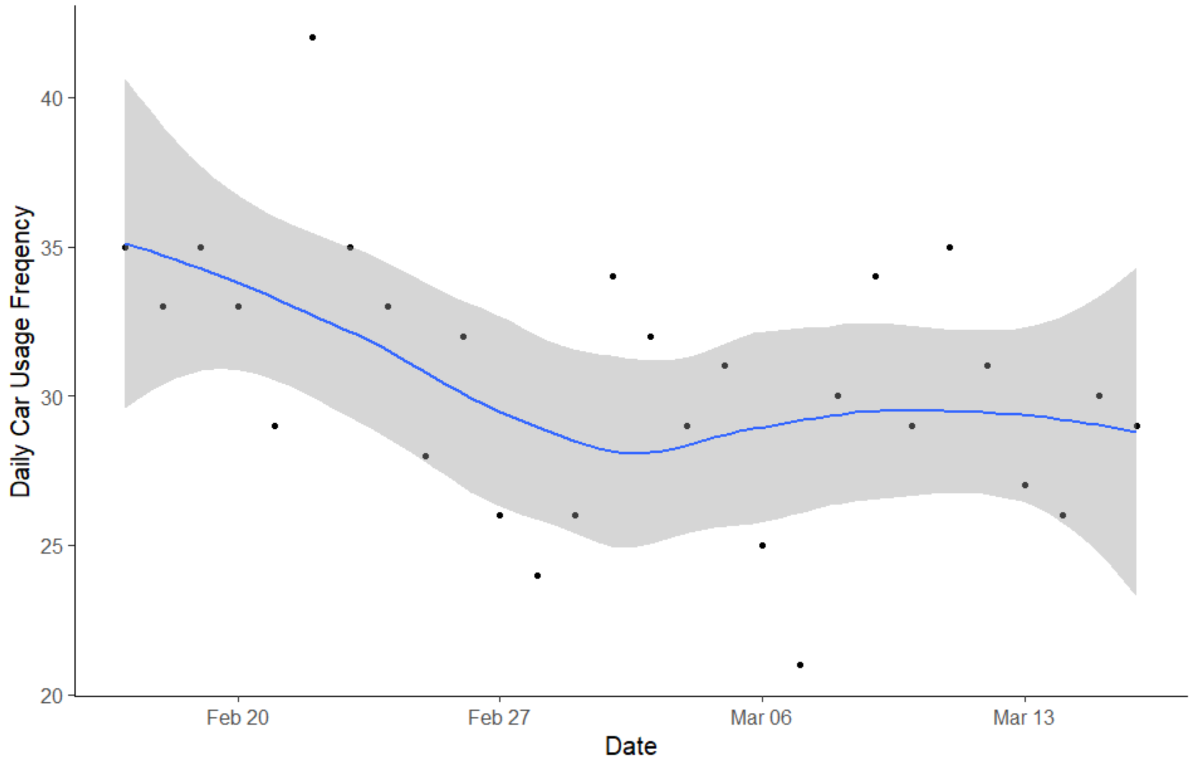


Figure 5-0-2. Loess curve showing car usage frequency and trend across the diary period

Initially there was an increase in walking across the study period, and although this declined, it did not reach the same frequency as at the beginning.

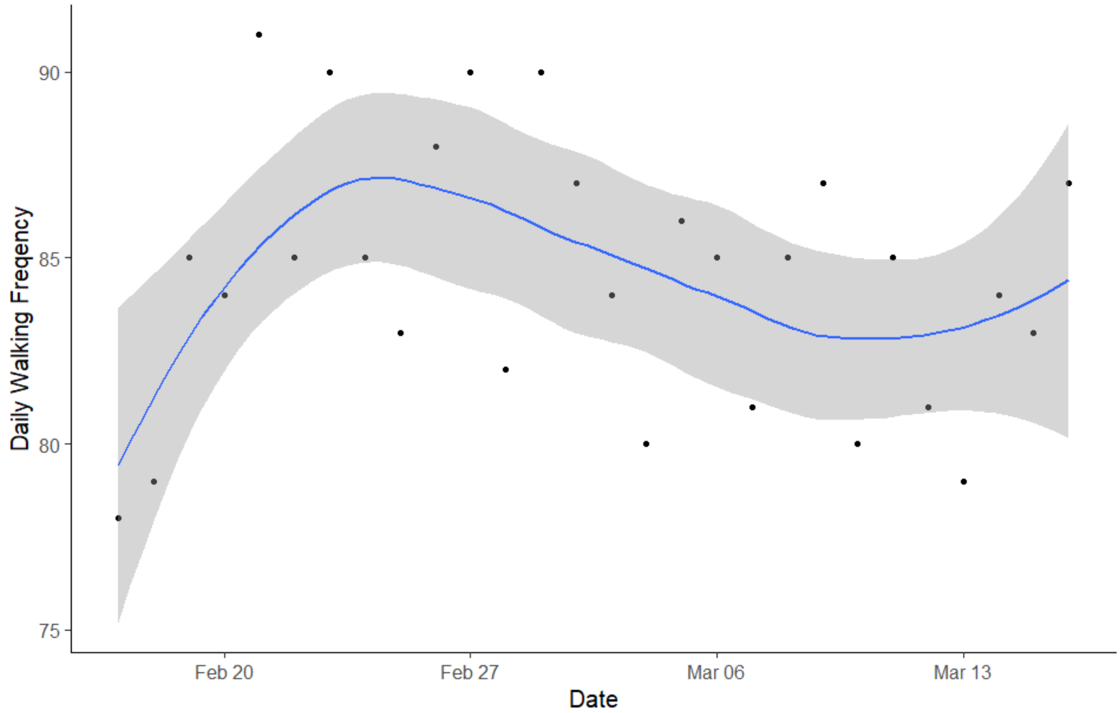


Figure 5-0-3. Loess curve showing walking frequency and trend across the diary period.

Participants identified household electrical appliance use (including personal electrical and electronic items) as the most difficult behaviour to change. There was a high frequency of use of electrical and electronic items by all participants, frequencies of use are shown in Table 11. Participants frequently made use of the 'other' option to include additional electrical and electrical items.

Table 0-1. Table showing frequency of household electrical and electronic appliances by participants across the diary period (due to the high number of items used those included are those with only over 100 uses.

EQUIPMENT	COUNT
MOBILE PHONE	2620
LIGHTING	2601
LAPTOP/ TABLET	2474
LARGE APPLIANCES	2331
TELEVISION	830
ELECTRICAL HEATING	807
PERSONAL GROOMING ITEMS	450
ELECTRICAL SHOWER	440
AIR FRYER/ SLOW COOKER	259
GAME CONSOLE	235
PC AND MONITOR	182

There were 2,642 cases of household appliance usage, with Mobile Phones and Lighting and Laptops/ tablets self-reported to be used by all participants every day. As the diary itself had to be entered online it is reasonable to assume that all participants made use of one of these items every single day even if it was not reported.

The majority of participants' daily diets included some form of meat or fish (Figure 5-9). However, there was a slight increase in vegetarian and vegan daily diet behaviour over the time period although meat and fish diets remained predominant. There was an increase in vegetarian and vegan diet behaviours from 06/03/2023; however, this slowly declined.

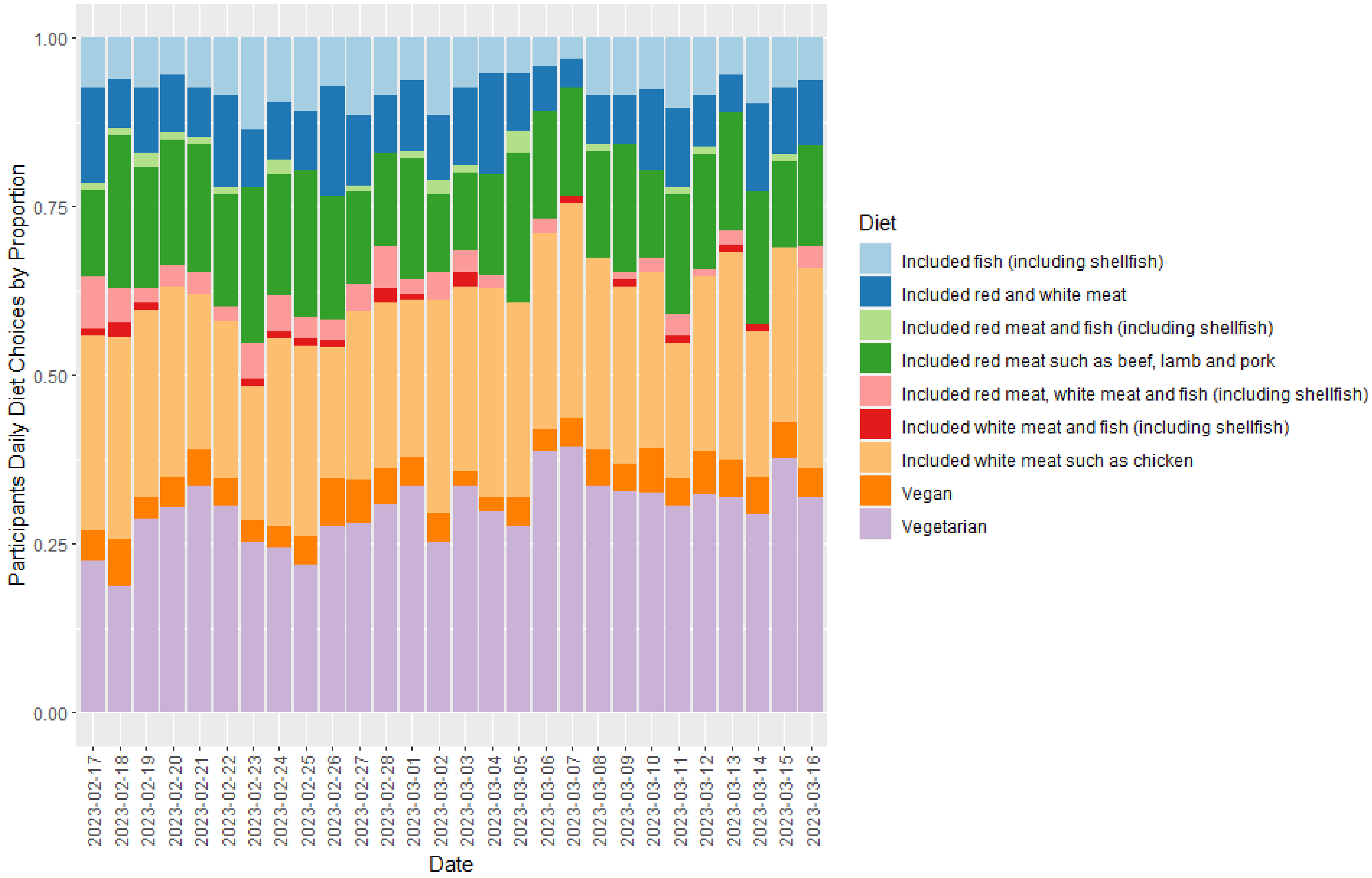


Figure 5-0-4. Daily behaviour trends in relation to diet across the diary period.

Participants scored their perception of how difficult it had been to behave sustainably each day (Figure 5-10). Difficulty scores were between 2-3 with no discernible changes in trends or patterns in daily difficulty perception.

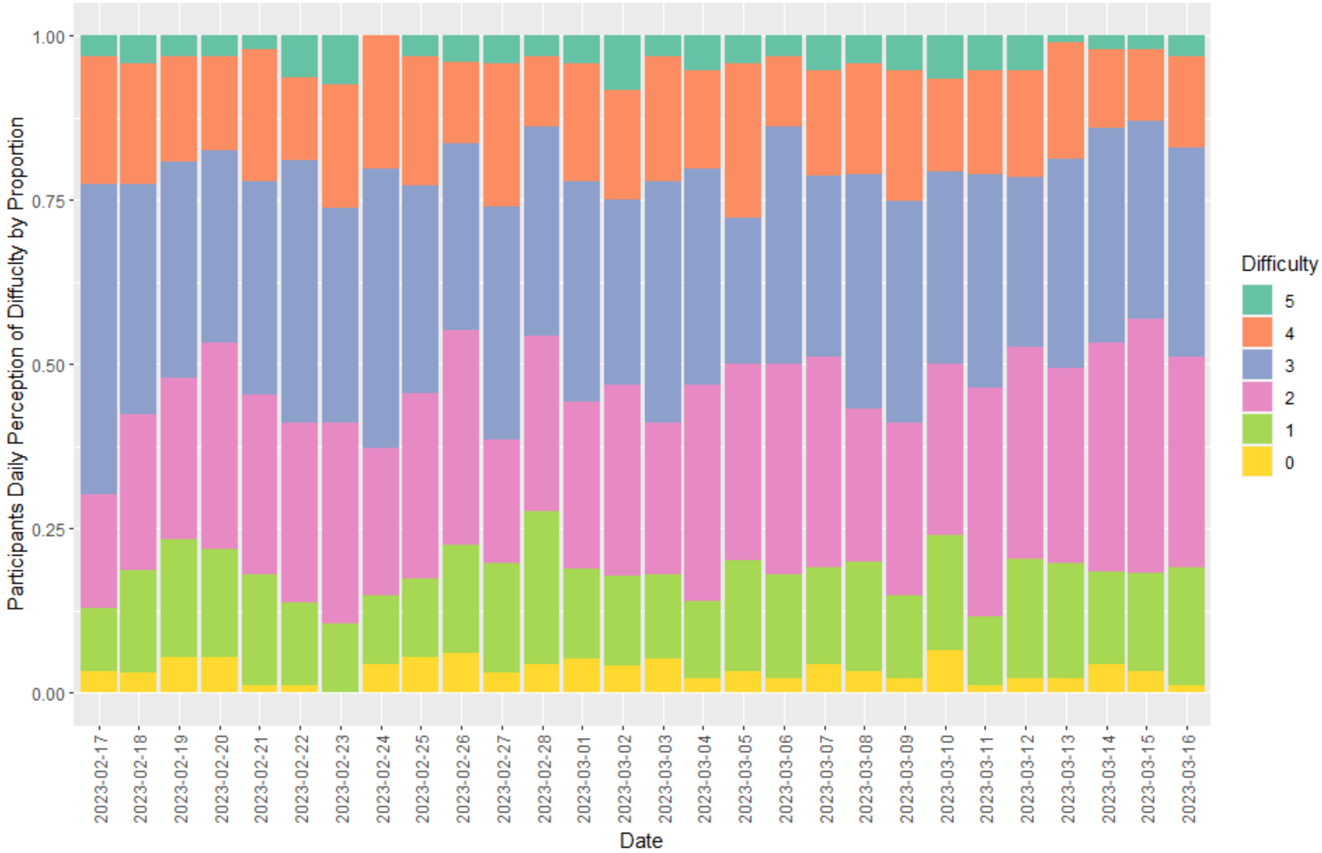


Figure 5-0-5. Daily self-reported difficulty score by participants across the diary period.

Analysis of the data led to the development of eight simple codes based on commonly reoccurring themes. Cases were coded as either the theme being present or not to identify trends over the period and if participants' reflections and comments showed change over time. Examples from each theme that was coded into quantitative data can be found in Appendix C.5. The themes developed for coding were as follows:

i) Need for protein in diet
ii) Convenience of choices
iii) Making conscious changes and adaptations to reduce emissions
iv) Financial concerns
v) Consumption for mental and physical health
vi) Guilt related to behavioural choices

vii) Awareness and knowledge of sustainability and climate change

viii) Pride in choices made.

Across seven of the themes and codes frequency remained consistent across the time period. However, for the 'Convenience of choices' theme a downward trend was observed (Figure 5-11).

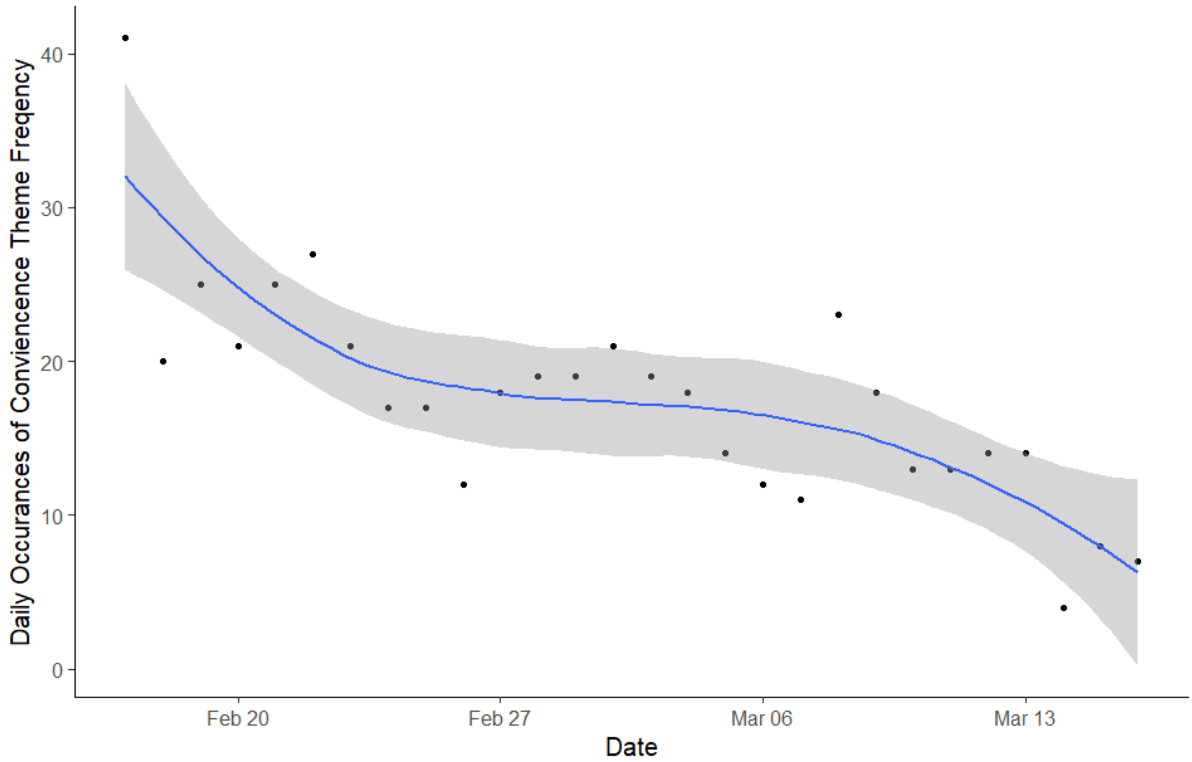


Figure 5-0-6. Loess curve showing frequency and trend of occurrence of convenience theme across the diary results.

5.4.2. Quantitative Questions Raised for Qualitative Data Analysis

Questions were developed following quantitative analysis to be explored through qualitative data analysis to provide deeper context and understanding following the methodology laid out by Ivankova et al, 2006 and Creswell and Creswell, 2023,

i) For what reason did 27 participants report no change in their carbon footprint or an increase in their carbon footprint?
ii) What barriers and challenges were experienced around the following behaviours: food, transport, electrical appliances?
iii) What general barriers and challenges led to unchanging patterns of behaviour across the diary period?
iv) For what reason did participants' perception of difficulty remain unchanged across the diary period?

To answer the first question raised participants who did not record a change in their carbon footprint or recorded an increase in their carbon footprint were subsetted and their reflections on their carbon footprint analysed and compared to the reflections of those who recorded an increase in their carbon footprint,

5.3.3. Qualitative Results

5.3.3.1. Carbon Footprints

Those who reported no change or an increase in their carbon footprint or carbon behaviours before and after the diary were coded in Nvivo. Participants from this subset tended to state they believed their increase in carbon footprint was related to gaining a better understanding of the carbon footprinting process and their own carbon consumption. Participants believed they filled in the carbon calculator more accurately following the study and attributed the change accordingly. Those whose score stayed the same claimed their behaviour had not changed. Two participants identified flights they had taken in the study period as the causes for their changes in footprint.

Those who saw an increase in their carbon footprint referred to this more frequently than those who recorded no change or a decrease in their carbon footprint. The subset who recorded an increase in carbon footprint did not express particularly higher existing environmental than those that decreased in the qualitative reflective piece through thematic analysis, despite having a higher rate of stating they had undertaken carbon reduction behaviour in the past 12 months compared to the subset where carbon footprints decreased.

The participants who reported no change in their carbon footprint expressed either ambivalence towards the study or noted a change in opinion towards carbon reduction but stated they were not currently attempting to change any of their behaviours.

Participants who self-reported a decrease in carbon footprint following the carbon diary occasionally commented with pride that they had noted the reduction, comments on reporting accuracy were less frequency, but there was a notable increase in stated confidence surrounding completing a carbon footprint.

5.3.3.2. Qualitative Codebook Development

Ten overarching themes (Table 5-3) were defined with some notable subthemes developing. Subthemes were only developed and included where they occurred frequently and with notable impact on the larger theme that was distinct from other subthemes.

Table 0-2. Thematic codes for qualitative analysis.

THEME	DEDUCTIVE/ INDUCTIVE	SUBTHEMES IF PRESENT	DESCRIPTION
BARRIERS AND CHALLENGES	Deductive	Convenience, financial, habit, consumerism	This theme concerns the overarching barriers and challenges faced by participants in reducing their emissions, the drivers behind their behaviour rather than the specifics of actions taken
DIET	Deductive	Protein, sport	This theme concerns the dietary choices of participants and their reasoning behind the overall trends of unchanging diet
TRANSPORT	Deductive	Weather	This theme concerns the transport choices of participants in relation to why transport changes did not tend to persist
APPLIANCES	Deductive	Reliance	This theme concerns the appliance usage of participants and their interactions with appliances and why usage remained consistently high across the time period
BENEFITS	Inductive	Wellbeing	This theme was developed as participants highlighted the benefits of reducing their carbon emissions
BEHAVIOUR CHANGE	Inductive		This theme was developed as participants noted their perceptions of their behaviour changing, not always aligned with the behaviour recorded but general 'sustainability' behaviour
OPINION CHANGE	Inductive		This theme was developed as participants noted changing the opinions on carbon emissions, sustainability ,or other environmental concerns
KNOWLEDGE GAIN	Inductive		This theme was developed coding only when participants noted learning an entirely new piece of knowledge (not a change of opinion)
RESPONSIBILITY	Inductive	Self, government	This theme was developed as participants stated who they believed was responsible for reducing carbon emissions

SELF-JUSTIFICATION	Inductive	Blame, comparison	This theme was developed as participants either directly claimed their emissions were caused by others or engaged in comparisons or ‘whataboutism.’

5.3.3.3. Thematic Coding And Analysis

Figure 5-12 presents a tree map of the frequency of themes and subthemes coded across the dataset. Not all codes identify barriers and challenges to participants, as noted in table 5-3.

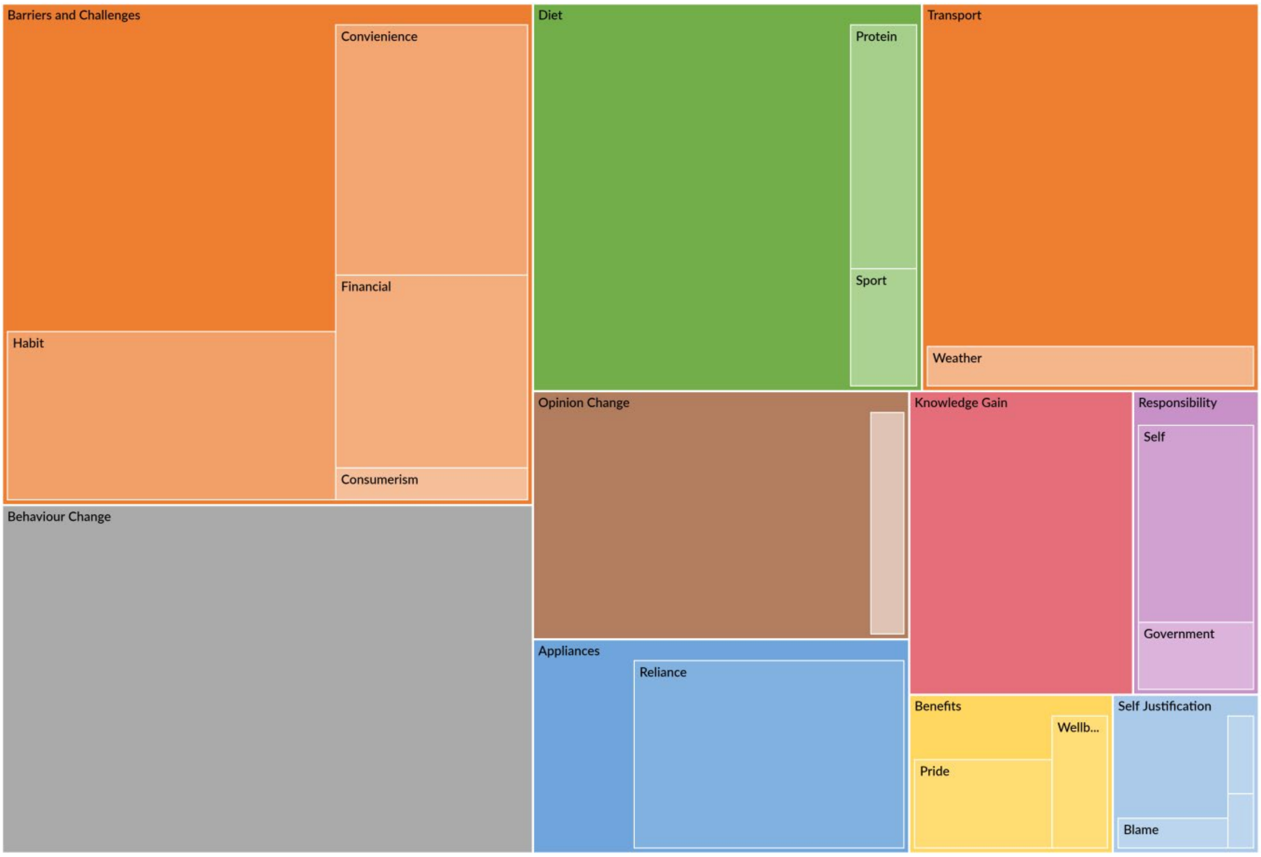


Figure 5-0-7. Tree map of qualitative thematic code frequency across dataset.

The most frequent theme was “general barriers and challenges.” This encapsulated any barriers and challenges specifically identified by participants that did not align with a particular other theme (i.e. diet) and concerned overarching barriers such as personal beliefs, convenience, and systematic concerns. The Behaviour Change theme was the second most frequent thematic code where participants reflected upon active behavioural changes, they undertook to reduce their carbon emissions.

Examples of participants' reflections for each theme can be found in Appendix C.6 An exploration of each theme is undertaken below.

5.3.3.4. Barriers And Challenges

Barriers identified varied by personal circumstances. Many respondents felt there were systematic barriers relating to the provision of infrastructure and this was particularly notable in those that showed frequent waste generation and high car usage. Convenience was highly prevalent as a challenge experienced by participants, with numerous participants noting they often did things because it was easier and didn't require thought. This was heavily tied with the Habit theme, participants undertaking behaviours because it was what they had always done so felt it was not something they could challenge. Others mentioned that they felt they should be able to 'treat themselves' and that it was convenient to do so using food ordering applications or online shopping. Several participants discussed shopping for new items as a form of self-care, particularly in relation to stress.

Some habitual behaviours related to the identity and culture of the participant. Several participants remarked upon homesickness and behaving as they would at home, which was often carbon intensive behaviours, particularly those who self-identified themselves as international students. Participants identified this as a cause for concern and were aware they were acting in this way. Numerous participants stated an ambition to work against this impulse in the future, although others stated they believed they had the right to do what they found easiest.

Participants believed that there was a high financial cost to reducing their carbon emissions, that lower carbon options cost more, particularly vegetables or local food, 'Eco' clothing brands and rail travel.

5.3.3.4.1. Diet

Participants who mentioned their need for protein in their diet and their perceived lack of protein availability in plant-based diets often stated they were heavily involved in sports and therefore had higher than the usual requirements for protein. Participants noted concerns about how they may get protein into their diet without meat and several stated that the cost of plant-based proteins was excessively more expensive than animal-based sources. There was considerable concern around the cost of plant-based proteins compared to their protein content and the complexity of cooking unknown plant-based foods.

There is a shift in diet (Figure 5-19) from 6/3/2023 over a period of three days where participants increased their vegetarian and vegan behaviours, it then returns to a pattern comparable with previous consumption. Several participants mentioned they had a contemporaneous lecture on the sustainability of diets and carbon emissions and had responded with surprise and statements they wished to reduce their meat consumption.

5.3.3.4.2. Transport

Many participants cited convenience as a cause of car use, or using public transport over walkable distances because they were not motivated to walk. The weather (cold or rain) was often noted as a reason for certain travel behaviours. Transport issues most commonly arose in combination with statements coded to convenience; often if a participant found there was an option to take an ‘easier’ form of transport they stated they would, rather than taking a lower emission option. Participants who stated they lived near to their intended destinations, such as work, the supermarket or University campus, stated they walked to these locations. Participants who said they did not have cars seemed the most inclined to walk, commenting on it being free compared to the bus. Those with cars often mentioned using their car was cheaper than using the bus so was the preferred option.

Women commented that they felt unsafe walking in certain areas or at certain times, particularly at night and therefore chose to use a car. Similar concerns applied to use of public transport late at night, as well as lower provision of public transport at night making it more difficult to travel.

5.3.3.4.3. Appliances

Examples in Appendix 2 demonstrate the commonly expressed justifications about electrical appliance usage. Participants stated that the use of these items is integral to their lives, and many expressed surprise at how many of these appliances they use every day and the importance of their usage. A common sentiment was that this usage is impossible to reduce, despite some expressions of desire to change their energy consumption in this area. Some expressed attempts at reducing the usage of personal electronics such as hairdryers but items like laptops, mobile phones and domestic appliances were all considered vital.

5.3.3.4.4. Benefits

Participants identified the key benefit of attempting to reduce their carbon emissions was an increase in their perceived well-being. Several participants linked this to being more active, and some participants felt empowered to be taking action to reduce climate change and therefore felt their mental well-being was improving. Other benefits noted were saving money on bus fares or fuel when walking and the pride participants felt when achieving something they considered sustainable. Some participants mentioned pride in learning new skills or information that aided them in making more sustainable behavioural choices that they hoped would reduce their carbon emissions.

5.3.3.4.5. Behaviour Change

Many participants commented they felt their awareness of carbon emissions and the impacts of their consumption was spreading to areas of behaviour outside of the recorded behaviours. Many stated that the action of keeping a diary influenced their behaviour and they found themselves making behaviour choices they felt were more sustainable so they could report the ’better’ behaviour in their diary and felt disappointment when they had to enter a behaviour they felt was ‘bad.’ Several participants reported changing the behaviour of their household, using the diary to drive change among those they lived with, particularly activities that impacted the whole house such as energy usage and waste disposal.

Participants still perceived behavioural changes as difficult or not difficult as they had previously but stated they felt more motivated to change their behaviour due to being able to hold themselves accountable. Many participants knew previously of the impacts of climate change and were of the opinion it was important, but with the motivation of the diary they found it easier to attempt to change their behaviours.

5.3.3.4.6. Opinion Change

Participants opinions changed through their experiences. Some changed their opinions on behaviours they had previously found unpalatable, and whilst they did not make commitments to change their behaviour overall some participants expressed surprise that something was not as difficult as they had perceived. Often these were actions such as using public transport being easier than expected and giving them additional time to use their phone or read, some changed their opinion on if plant-based food could taste acceptable. Others found walking was not as onerous as they had expected. Participants responded positively to these changes in opinion but did not all link them to long term changes in those behaviours.

5.3.3.4.7. Knowledge Gain

Many participants sought their own information about carbon emissions and climate change during this period. Numerous sources were used including academic and course materials, social media and news outlets. Participants that gained knowledge often repeated the fact or facts within the reflective piece and were often proud they had learned a new piece of information.

5.3.3.4.8. Responsibility

Participants did not have a set consensus on who they believed was responsible for climate change. Many believed the systematic and infrastructure barriers to changing their behaviour were considerable, that governmental bodies were responsible and needed to make changes, and that individuals were powerless to make changes. Others felt they had a greater level of responsibility than they initially thought and reflected that they felt they understood what actions they could take and therefore should be responsible for taking them. By keeping the diary, many participants noted they became more aware of how ‘costly’ their behaviours were regarding carbon emissions. They held themselves accountable for their emissions due to having to record their actions in the diary, with some stating they avoided certain behaviours because they did not wish to record a carbon emitting behaviour such as using their car.

5.3.3.4.9. Self Justification

Often participants placed blame on others, including those they lived with or industry. There was an element of comparison to those wealthier than themselves who generate more carbon emissions via use of private swimming pools and private jets, and opulent lifestyles. Some justified behaviour as detrimental to their current lifestyle or that their situation was exceptional and despite having awareness of lower carbon options, they made choices based on other factors, such as alcohol consumption and safety. Participants who self-identified as from a non-United Kingdom background particularly raised the issue of their emotional attachment to the preparation of particular foods, often meat and fish and reflected on the importance of these foods to keep them connected to their home culture and stated this was a behaviour they did not want to change as it kept them connected to their home and alleviated homesickness.

5.5. Anecdotal Qualitative Evidence

Following the implementation of the CABDI model intervention individuals who had shared accommodation with those undertaking the diary shared anecdotal evidence with the researchers involved in the project that they had found the behaviour of participants a positive influence on their own carbon reduction behaviour and noted that participants had been significantly engaged with the diary, particularly around waste and recycling, water usage in areas such as shower length, and gave greater thought and deliberation to car usage. It was noted that changes to usual routines and household behaviours instigated by participants were often involved direct reference to participation in the CABDI study. Those participants who shared their experiences with the researchers for this project also noted a reluctance to commit a behaviour if it would be the only instance of that behaviour in a day (i.e. one car journey) that would require them to record they had done the behaviour and generated additional carbon emissions. They referred to days where they felt they had done 'too many' actions such as using personal transport or eating red meat as a 'bad day' and expressed pride in 'good days' where they felt they had undertaken positive climate behaviours.

Several participants anecdotally identified themselves as parents, and noted that they noticed how much they consumed in care of their children, such as food packaging and water for washing clothing and their children. Additionally, they noted that they felt often they had to use personal transport rather than active transport to transport their children for safety or time reasons.

5.1. Discussion

A reluctance to change behaviour has been identified, justified by 'convenience.' Quantitative data shows that despite a reduction in self-reported carbon footprints, behaviour remained unchanged across the diary period. There were initial changes in transport with car use reducing and walking increasing. However, this slowed over time ,and car use increased, and walking decreased, although neither returned to the initial levels. Similar trends were observed across diet behaviours, with shifts occurring but with trends showing a return to the norm. Perception of difficulty remained consistent across the diary period, although which behaviours participants believed the most difficult to change before and after the survey showed some changes. Whilst electrical appliances were considered the most difficult to change before and after the survey, a higher number of participants chose this behaviour following the survey.

Use of the CABDI model allowed for a high quantity of data to be gathered to explore the complexity and nuance of this topic. The ability to compare before and after opinions and self-reported carbon footprints allowed for a perspective of the impact of the diary itself. Additionally, the use of the mixed methods approach in this model allowed participants to give insight into their perceived barriers and challenges, and to examine if their statements correlate with the reported behavioural data. It must be noted that the success of the model is likely to be related to the situation in which it was applied, as participants were motivated to complete the diary as part of their studies.

The findings support the authors' previous work Brock et al., (2023)., with participants justifying carbon intensive behaviour as more convenient and 'easy' or so habitual they are difficult to change in a large-scale way. It is agreed by the scientific community that deep cuts to carbon emissions are required in order to combat climate change (United Nations Environment Programme, 2023). Participants were aware of climate change issues and had ongoing sustainability education throughout the diary period, but this did not seem to provide the impetus to enact considerable behavioural shifts. Those behaviours that showed little change, such as change in diet and reduction of household energy use, are associated with considerable emission reductions implying that the emission reductions the public will achieve without intervention will be low compared to the cuts required (Baroni et al., 2007; Chai et al., 2019; Dunne, 2017; Hargreaves et al., 2013; Ivanova et al., 2016; Poore and Nemecek, 2018; Preston et al., 2013; Sabaté and Soret, 2014).

Attempts were made by participants to reduce their personal transport emissions. However, opinions on the difficulty of changing this behaviour did not change following the survey. Participants showed a clear awareness for which travel options emitted the lowest carbon, but often cited convenience, the weather and cost as their main motivators for their travel choices rather than emission reductions. This aligns with the existing literature; participants are reluctant to change their transport behaviour often due to how central it is in their lives and the associated perceived costs such as time, money, and discomfort (Brock et al., 2023; Carrus et al., 2008; Gardner and Abraham, 2010; Hou et al., 2022; Schwanen et al., 2012). Convenience as a factor in transport choices is often reported, with the public preferring modes of transport that take less time and are punctual and reliable even when participants have a degree of environmental awareness (Hergesell and Dickinger, 2013). This again, implies that knowledge, awareness, and education about carbon emissions has limited effects; participants prioritised their own perception of their needs and justified their behaviour based on their own individual requirements, rather than considering the broader impacts of their behaviour.

There may be some areas where additional education is required. Understanding of diet, dietary needs and sources of macronutrients were inconsistent across the dataset and many participants believed meat was the ‘best’ protein although plant-based proteins containing all essential amino acids are available (Gorissen et al., 2018; Herreman et al., 2020; Millward, 1999). This is supported by the finding that following a lecture on sustainable diets (that all students attended on their course) there was a change in behaviour on the following weekend and the lecture was frequently mentioned in the qualitative data. However, there was a reversion to previous diet trends following the initial increase in plant based diets; habits are hard to change. Participants described a lack of understanding on how to prepare plant-based meals and numerous concerns were raised about sources of protein. This indicates there may be a lack of relevant skills to transition to lower carbon lifestyles, alongside fears of the unfamiliar and that the food will not taste to the participant’s liking (Fehér et al., 2020; Niimi et al., 2022; Pohjolainen et al., 2015; Taufik et al., 2019). There was hesitancy to buy new ingredients and attempt to learn new skills with a degree of concern that this effort would be wasted as they would not enjoy what they made, or they just stated they did not want to try new things.

There were several opinion changes before and after the diary study. Participants either continued to think Climate Change was a problem or upgraded the degree of seriousness they attributed to climate change as a problem. The process of conducting the carbon diary seems to have impacted on the opinions of participants, this is reflected in the reflective pieces where participants noted their opinions on climate change, with increases in participants reflecting on their own responsibility to reduce their carbon emissions. Others expressed greater enthusiasm for keeping a carbon diary than they anticipated, finding it a useful tool to monitor their behaviour and that it made them feel more responsible and accountable for their carbon emitting behaviours.

The majority of participants self-reported carbon footprints reduced from the baseline to the post-diary survey. Those who saw an increase in footprint stated they believed this was due to having a greater understanding of how to input their information rather than a particular response to the diary itself. This may indicate that participants are attempting to make some behavioural changes not captured by the diary, for example whilst they may eat red meat each day it may be for one meal rather than all three. For the majority of participants there was an average reduction of a ton of carbon across the majority of participants' self-reported annual carbon footprints. If this is an accurate indication of the level of reduction that could be achieved annually through keeping a mandatory carbon diary and monitoring and reporting personal emissions is significant. The adult population of England and Wales in the 2021 census was approximately 47 million, indicating this method has a potential to reduce the carbon emissions of England and Wales by approximately 47 million tons (Office for National Statistics, 2024b) .

There is an implication that even mandatory reporting has an impact on behaviour and personal scrutiny of carbon related behaviours. Participants reported they felt keeping the diary helped them attempt to reduce their behaviours, whilst significant behaviour change didn't occur this is a finding that supports existing work on the lack of effectiveness of relying on nudge theory policies only. Nudge policies have limited effectiveness, Gravert and Olsson Collentine, (2021) found that norm nudges had negligible impact, instead a tangible economic incentive policy had far greater impact on participants' travel choices. It has been found that 'nudges' alone are not enough to change behaviour, these interventions can complement other policies but do not enact significant long lasting behavioural change alone (Böhm et al., 2020; Gravert and Olsson Collentine, 2021; Lehner et al., 2016). There is potential for awareness raising and education to support those under a mandatory policy, for example if monitoring and reporting carbon emissions through a diary was mandatory additional 'nudges' could assist the public in making lower carbon choices where they felt inspired to do so.

Convenience is a reoccurring theme. It was a common theme in the reflective pieces and participants often stated they acted on what was easiest rather than what they knew to be the lowest carbon option. Awareness, knowledge, and eco-anxiety could not overcome participants' desire to undertake the behaviours they considered convenient. Convenience is a noted motivator, from 'convenience stores' to fast food, to online shopping, convenience is much-used to entice customers (Berry et al., 2002; Jiang et al., 2013; Sabine et al., 2009). The ingrained value of convenience to the public cannot be ignored. Participants did not commonly discuss a decline in their experience of making choices based on convenience in the reflective pieces, despite the theme declining in frequency in the quantitative diary. But there was an increased desire to change behaviour and many participants listed the behaviours they wanted to change. This does not confirm they will change their behaviour; statement of intent is not the same as observable behavioural change. It may be that despite the intention to change the importance of convenience as a motivator is a difficult priority to shift.

The growth of consumerism is a defining feature of this modern age. Social media and the internet provide a never-ending opportunity for advertisements and the exacerbation of marketing strategies such as 'fear of missing out' (FOMO) (Argan and Tokay-Argan, 2018; Hussain et al., 2023). Participants used their mobile phones and laptops daily and many mentioned elevated levels of social media usage, exposing them to the numerous marketing strategies and consumerist ideologies daily. Consumerism is entwined with convenience. An B ability to purchase the latest fashionable item of clothing or summon a ride hailing service at the touch of a button makes it (increasingly) difficult for young people to resist engaging in high consumption and thus carbon intensive behaviour. The omnipresent theme of convenience and its relationship with consumerism is unsurprising. Moving away from consumerism can be difficult, and would require large-scale shifts personally, socially, and politically (Brown and Vergragt, 2016).

Participants did not highlight or discuss their concerns about the global impacts of climate change on others. Compassion can be a powerful motivator in developing pro-environmental opinions (Lu and Schuldt, 2016; Pfattheicher et al., 2015). However, individuals experience 'compassion fade' when the number of individuals being impacted and needing aid increases, especially if the identifiability of victims is low (Markowitz et al., 2013). The World Health Organisation states that 3.6 billion people live in areas highly susceptible to climate change, a number of people that it may be difficult to feel empathy for due to compassion fade (Butts et al., 2019; Cameron and Payne, 2011; Friedrich et al., 1999; Markowitz et al., 2013; World Health Organisation, 2023). Awareness campaigns often cite numbers of those impacted to raise awareness and effect behavioural change through compassion, however participants did not identify compassion as a motivator. This may contribute to the lack of motivation to enact change, as within the United Kingdom the impacts of climate change currently are moderate and not markedly changing the day-to-day life of participants or those around them.

Despite the participants' assertions they were attempting to make changes to their lifestyles to reduce their carbon emissions this is unsupported by the behavioural trends reported. Where there are variations or reductions in carbon intensive behaviours the behaviour tends to begin to return to the initial levels of frequency. Electrical appliances were used with particularly high frequency, and individuals used personal electronics such as laptops and mobile phones daily, in part this could be influenced by the method of diary completion being online. However, the qualitative data shows that participants confirmed their reliance on personal electronics, not just for university work but for social communication and 'scrolling' through social media. Habitual behaviour, such as daily electrical equipment use and diet changed less than behaviours that would be more varied, such as transport, due to varying distances and travel requirements, and waste generation, which varied depending on personal consumption of goods and services throughout the day.

Tackling the challenge of reducing personal carbon emissions is complex and multifaceted. The public shows reluctance to make the more difficult choices of their own volition, and the results of this study indicate their reasoning for this tends to be issues such as convenience and habit rather than a lack of awareness or care (Brock et al., 2023). Awareness raising and education are important 'parts of the puzzle;' there are areas the public lack nuanced understandings of or lack the skills to act upon, such as changing to a plant-based diet and the impacts of diet on climate change.

A lack of knowledge does not seem to be a key barrier to changing carbon emitting personal behaviour. The key barriers are "internal," such as opinions and attitudes held by participants and their lack of motivation to undertake behaviours they consider inconvenient. There are additional barriers, such as a systemic barrier around public transport provision, safety of vulnerable groups when travelling, lack of skills, financial concerns around the cost of more carbon reducing options and the perception that those outside of the individual have all the power to reduce carbon emissions.

The results demonstrate the 'mountain' that policymakers and researchers have to climb to drive behavioural change in the public to reduce emissions.

5.7. Conclusions

Using the CABDI model key barriers and challenges facing people in the United Kingdom in reducing their carbon emissions have been uncovered. The participants that engaged with this study were all younger people who were actively engaging in sustainability education, even individuals that show a drive to gain further education on sustainability struggle to change their behaviour.

Use of the CABDI model allowed for analysis of behavioural trends and exploration of the trend causes through the qualitative reflective piece. The baseline and repeated survey for comparison gave insight into if participants had a change in their opinions and self-reported carbon footprint. The majority of participants reported a decrease in their carbon footprint and some shifts in opinions were reported, although contemporary evidence suggests this is unlikely to be sustained longer-term . Using these various stages of the model provided a robust dataset that could be easily integrated and provided a vast array of findings. For a complex area of study such an approach is highly beneficial as it allows exploration of the many facets of the challenge of reducing personal carbon emissions.

Eco-anxiety and climate change awareness are increasing; whilst the public clearly considers climate change a serious problem, there are still barriers preventing them from changing their personal behaviour. The largest barriers to change are personal, the public still would rather do what is convenient and habitual than change their behaviour enough to appreciably reduce personal carbon emissions. This implies that hoping the public can just be ‘nudged’ into changing through awareness raising is a forlorn hope. More effective methods are likely to include enacting top down policies that mandate changes, alongside improvements to infrastructure/services and further enabling of behavioural change

Young people are highly aware of climate change and experiencing considerable eco-anxiety, but there is little urgency or motivation to make changes. In the United Kingdom there are still limited impacts from climate change and thus despite awareness and anxiety the public may feel a certain distance from impacts personally. No themes arose that identified any form of stated compassion for those who currently are being impacted by climate change; the participants in this study focused entirely on themselves, their own feelings and convenience. This is a generation inundated with consumeristic messaging and many avenues to conveniently engage in consumerism that can be difficult to escape.

Whilst there is some evidence that awareness-raising and education had temporary influences on behaviour there was also a clear reversion to original behaviours and trends. The influence of education and awareness raising alone is limited and only provides short term changes rather than deeper attitude and behavioural changes. Due to the pressing nature of the climate change crisis we cannot rely on short term changes to behaviour or any slow progress that might be made. The public cannot be 'nudged' into reducing their carbon emissions appreciably and a top-down policy intervention is required.

6. CHAPTER 6. GENERAL DISCUSSION

6.1. Introduction

The severity of the climate crisis and its impacts cannot be overstated. As global temperatures rise all options must be considered and all sources of carbon emissions addressed and reduced. The area of study for this thesis is the collection of policy models referred to in this thesis as 'Personal Carbon Budgets.' Personal Carbon Budgets have been proposed in a range of forms: carbon labelling, carbon tax and personal carbon trading, and this thesis proposes a fourth model, personal carbon allowance. All these models seek to reduce the emissions generated directly or indirectly by individuals. However, they vary in their delivery and method.

Carbon labelling is a voluntary intervention with labels applied to goods and services identifying the associated carbon footprint with the intention this will encourage lower carbon choices (Marek et al., 2018; Panzone et al., 2020). A carbon tax is a mandatory upstream tax applied to goods and services in relation to their associated carbon emissions, this tax is then passed on to consumers (Elkins and Baker, 2002; Sumner et al., 2011). Personal carbon trading is a mandatory policy where individuals are assigned a carbon budget for a set period to 'spend' on goods and services, the credits that form this budget can be sold and purchased to other individuals (DEFRA, 2008; Eyre, 2010; Fawcett, 2012; Fawcett et al., 2010; Fawcett and Parag, 2010). The model this thesis proposes is akin to the personal carbon trading model but eliminates the trading function.

Personal Carbon Budgets are a controversial policy proposal and evidence suggests they may be politically and publicly unpopular, as other interventions such as the plastic bag tax initially have been despite Personal Carbon Budgets' potential for reducing emissions (Bristow et al., 2010; Convery et al., 2007; DEFRA, 2008; Fawcett, 2012, 2010; Parag and Eyre, 2010; Seyfang et al., 2009; Thomas et al., 2019). However, all options should be explored, and whilst the responsibility of reducing carbon emissions may not be solely on the individual and the public, reductions in emissions can be generated from individual behaviour and consumption change.

The aims and objectives of this thesis can be found in Chapter 1.

This study has demonstrated its originality via publication of papers in international peer-reviewed journals. A new personal carbon budget (personal carbon allowance) and new methodological model (the CABDI model) have been published or are undergoing review for publishing. They provide additional context and understanding to the complexities of the challenge of reducing personal carbon emissions. This thesis analyses and compares PCB models to identify the most sustainably acceptable, with consideration of numerous factors. The focus of the literature as identified in Chapter 2 is on public acceptability and technical aspects, rather than the emission reduction potential of the models. Studies exploring the socioeconomic impacts of PCBs are present in the literature, but often these studies only focus on one model rather than comparison between models to identify which model can reduce emissions whilst avoiding unintended consequences socio-economically or otherwise on individuals. Chapter 3 fills a gap in the literature by conducting an analytical comparison of all proposed models in the literature comparing their features through a PESTLE framework. Additionally a new model is proposed that seeks to mitigate the identified concerns around other PCB models, both carbon taxation and Personal Carbon Trading have been identified in the literature as regressive policies that have higher financial costs to those with lower incomes (Al-Guthmy and Yan, 2020; Callan et al., 2009; Carbone et al., 2013; Fremstad and Paul, 2019; Harrison, 2013; Li et al., 2015; Thumim, 2008; White and Thumim, 2009).

Exploring the preferences of the public shows that the public may not be inclined to change their behaviour to create significant emission reductions, regardless of their environmental awareness or demographic groups. Through analysing the barriers and challenges the public face, potential causes for these preferences can be identified and evaluated. Personal convenience and habit are found by this thesis to be barriers to the pubic when attempting to reduce their personal carbon emissions and change their behaviour despite the majority of participants showing awareness of climate change and demonstrating concern around climate change.

The methodological approach taken to this thesis implements recently developed methods such as the PAPRIKA method (multiple-criteria decision analysis and discrete choice experiment method) and conducts model analysis and development using a PESTLE framework to explore the viability of different PCB models. At the time of writing this thesis these methods had not been applied to the topic of personal carbon behaviours and preferences.

This thesis develops a new method of analysing the public's carbon reduction behaviours and the barriers and challenges they experience and perceive; The CArbon Behaviour Diary Model (CABDI Model). This model uses the exploratory sequential mixed methods approach as a basis. The CABDI model allows for large amounts of varied data to be gathered and integrated into a complex composite dataset. Outputs from the use of the CABDI model can reveal overall behaviour trends, the effect of using a diary itself on public carbon reduction behaviour and their own experiences and reflections. As the diary uses a mixed methods approach both quantitative and qualitative analysis can be implemented on the data. Diary studies can be complex to undertake and therefore gaining the most complete dataset possible in relation to the time commitment and demands on participants is vital. The CABDI model is flexible and repeatable and can be applied to different sets of behaviour other areas of sustainability where behaviour needs exploration. Different methods of data gathering can be used in the model's framework to suit the needs of participants and researchers.

6.2. Summary of Thesis Findings and Discussion

To understand if a PCB policy, and which policy, would be necessary to reduce personal carbon emissions an understanding of the public in relation to their personal carbon behaviours had to be developed. Any proposed model should align with sustainability principles as outlined in Chapter 2.

The studies that form this thesis show that the public, despite high awareness, anxiety and acceptance of the science are often unwilling to change their behaviour in relation to carbon consumption to the degree required to reduce their carbon emissions to the levels required to achieve the 1.5^{O}C warming limit. Participants showed potential preferences for low impact 'easy' behavioural changes and justifications for reluctance to change were attitudinal, with participants citing convenience and habit as key drivers of their decision-making processes. Therefore, a policy intervention may be required to reduce personal carbon emissions.

In Chapter 3 the PESTLE (Political, Economic, Social, Technological, Legal, Environmental) model of analysis was selected to identify which of the proposed models may be the most suitable from a sustainability perspective. Sustainable development and sustainability require a holistic definition, which satisfies environmental, socio-economic, and cultural needs as laid out by the United Nations Sustainable Development Goals (United Nation, 2021). However, as the aim of a PCB model is to reduce personal carbon emissions considerable consideration was given to the potential of different models to reduce emissions.

Three main personal carbon budget models that pre-existed in the literature are carbon labelling, carbon taxation and personal carbon trading (Elkins and Baker, 2002; Fawcett et al., 2010; Fawcett and Parag, 2010; Fuso Nerini et al., 2021; Sumner et al., 2011; Taufique et al., 2022). This study proposes a novel PCB model to mitigate the potential environmental, social, cultural and economic impacts other PCB models have been identified to possess (DEFRA, 2008; Eyre, 2010; Fremstad and Paul, 2019; Lockwood, 2010; Rondoni and Grasso, 2021; Seyfang et al., 2009.) These potential impacts stem from carbon tax and personal carbon trading being potentially regressive policies, carbon labelling being a voluntary measure and carbon taxation and carbon labelling having no controls or caps on emissions.

The personal carbon allowance model uses personal carbon trading as a framework but removes the trading aspect and therefore may avoid the economic impacts it may have on those with lower incomes. As the personal carbon allowance model is mandatory it would allow a hard cap on emissions that could be set in line with current reduction requirements. The PESTLE model applied to the models demonstrates the PCA model's potential to reduce emissions due to the cap on emissions and by being mandatory, be socially just with considered application. Social justice can be a neglected factor when it comes to carbon emission reduction, this analysis considers the depth of reductions required whilst analysing the potential impacts policies could have beyond those reductions. Individuals still can prioritise their carbon consumption according to their needs and cultural differences, but there is no advantage to those with higher incomes to benefit through financial means to the detriment of those on lower incomes. A policy that considers an individual's needs and allocates consumption of carbon on that basis rather than purely on what an individual can afford financially cannot be sustainable as this means that individuals with greater needs but no ability to financially purchase more carbon cannot meet their own needs or may find themselves in complex financial situations if they sell credits they need or need to purchase more. A widely accepted definition of sustainability is that by Brundtland, (1987) in the UN report 'Report of the World Commission on Environment and Development: Our Common Future.'

"…meeting the needs of the present without compromising the ability of future generations to meet their own needs."

Hence the ability to meet 'needs' is the central concern of this definition and thus vital to any implementation of a policy that seeks to limit individuals' consumption if this has the potential to reduce their ability to meet their needs. However, this would require considerable investment to assess needs and regulate assigned budgets, previously the feasibility of personal carbon trading was assessed in a UK context and investment and complexity were considered a considerable barrier to implementation (DEFRA, 2008b; Lane et al., 2008.).

Whilst the PESTLE analysis in Chapter 3 identified the PCA model, in the context of the analysis as the most socially just model and the model with the greatest potential to reduce carbon emissions it is a policy intervention with a high economic cost compared to other models. Additionally it could be politically unpopular due to the high impact on the public's daily lives. Therefore, the preferences and behaviours of the public were evaluated to identify if such a stringent policy was required, or if the public were willing or able to change their behaviour without a mandatory policy intervention. Mandatory policies can be initially unpopular, such as the congestion charge and smoking ban (Borland et al., 1990; Zheng et al., 2014). Unpopular policies have been found to become more acceptable to the public over time, but the initial unpopularity may make them politically undesirable leading to hesitancy by policymakers in enacting such policies (Borland et al., 1990; Convery et al., 2007; Schuitema et al., 2010). The plastic bag charge when introduced was publicly unpopular and triggered outcry within the UK from the public, however over a more prolonged time period public acceptability has risen considerably and behaviours have changed (Convery et al., 2007; Thomas et al., 2019). Similarly, the indoor smoking ban saw a mixed public response, but acceptance of the policy has grown over time and the positive health benefits widely publicly appreciated (Allwright, 2008; Borland et al., 1990). If a more politically and publicly popular intervention that is not regressive or mandatory such as carbon labelling, or no intervention at all is a viable option this must be explored.

To understand if a policy intervention is required, and if so, which model would be acceptable and effective it is critical to understand the public's behaviour, awareness, attitudes, and barriers they may experience when reducing their emissions. Understanding what the public can change without a mandatory and invasive policy is vital as it may transpire all that is required is a targeted awareness raising campaign, new educational resources, training or the public may be fully willing to change their behaviour but are limited by other factors. Understanding the barriers experienced is key, if the barriers experienced are based on factors outside of people's control such as infrastructure and people are taking all feasible actions then a policy targeting personal emissions may be of low priority.

The preferences of the public in Chapter 4 demonstrate the public may only be willing to reduce their emissions in the areas that are 'easiest' and have the lowest burden on their day to day lives. There is considerable reluctance to change behaviours such as personal transport and diet, both of which have high emission costs (Dunne, 2017; Hatzopoulou et al., 2011; Hou et al., 2022; John J Hyland et al., 2017; Jakučionytė-Skodienė et al., 2022; Scarborough et al., 2014; Walsh et al., 2008). The behaviour change participants showed the highest preference for was changing their household lightbulbs, something with minimal cost and change to lifestyle and with a low potential for reducing emissions. Participants showed considerable reluctance to change their diet, even though a reduction in meat consumption can cause a significant reduction in personal carbon emissions (Hyland et al., 2017; Poore and Nemecek, 2018; Scarborough et al., 2014).

It may have been anticipated that participants' demographics groups would have influence over the carbon reduction preferences and willingness of the public due to the variety in needs, means and cultural factors (i.e different norms across groups). The findings of this thesis do not demonstrate the anticipated influence of these demographics on these preferences. The demographic groups of participants in Chapter 4 showed minor variation in their preferences in relation to carbon emission reduction behaviours. It may have been anticipated that there would be variance based on either differing beliefs or needs. However, the only notable difference was that those on lower incomes were less likely to be concerned about overseas travel, this could be explained by the fact that those on lower incomes travel less overseas than those with higher incomes (Büchs and Mattioli, 2021; Pappas, 2019). There are variations in climate change and environmental attitudes across demographic groups as seen in Chapter 4 and the wider literature, however there can be a value-action gap between climate change attitude and behaviour (Babutsidze and Chai, 2018; Chaplin and Wyton, 2014; Chung and Leung, 2007). Therefore, whilst there may be variations in attitudes and beliefs, even those from demographics that may consider climate change a serious issue and accept the scientific evidence on climate change, this does not appear to translate into taking the most carbon reducing actions from the findings of this study.

Understanding the value-action gap between the stated beliefs and preferences identified in Chapter 4 can give policymakers and researchers understanding of how to design policy interventions to reduce personal carbon emissions. These findings show that the public are unlikely to make the required decisions around their personal behaviour to reduce their emissions alone. To understand if there were barriers and challenges to the public that could be mitigated or eliminated to aid personal carbon reduction the behavioural diary study in Chapter 5 was developed.

In Chapter 5, through implementation of the CABDI Model and exploration of a detailed diary dataset, the causes for demonstrated preferences to take the easier options were analysed. Behavioural trends across the study showed that participants struggled to make significant changes to behaviours and behavioural trends showed only little variation across the time period despite ongoing education on climate change and emission reduction behaviours. Participants stated some attitudinal changes and Gralton et al., (2004) found in their review of the literature at the time that environmental education initiatives had minor impact on environmental behaviour, particularly long term, Knapp and Poff, (2001) found that short term environmental education could provide stated attitudinal change but limited behavioural change. The findings of this thesis show that a sole focus on awareness raising is a limited approach to changing behaviour, and that interventions that rely on the knowledge of the public will be limited as knowledge alone may not influence large scale behavioural change.

Participants of the CABDI study had ongoing sustainability education from scientifically valid sources, some behaviours had slight change across the period and did not seem to change in relation to this ongoing education. Others, such as diet choices did show a brief change in relation to participants attending a lecture on sustainable diets, however before the end of the study behaviours were returning to previous trends. Nudge theory methods may be of considerable value when requiring very short-term change in particular scenarios but in this instance the impact of this awareness raising did not sustain itself past two weeks. Participants across both studies were highly aware of climate change and the majority considered it a serious global problem even without ongoing education or before experiencing it. However, the preferences demonstrated, the behavioural trends recorded, and the reflections of participants did not show that this awareness was leading participants towards the most carbon reducing behaviours.

An unintended finding of the CABDI study was the impact of the diary itself on participants, reflective qualitative data and anecdotal evidence passed to the researcher informally indicate that the diary and act of monitoring motivated participants in attempting to reduce their personal carbon emissions. The mean change in self-reported carbon footprint among participants following the diary period was a reduction of 0.9 tonnes $CO_{2e.}$ In the subset that reported a decrease in their carbon footprint as opposed to no change or an increase the mean reported reduction was 1.64 tons CO_2e.whilst there was likely an improvement in reporting and carbon accounting due to having used the carbon footprinting tool previously this is a considerable potential decrease in carbon emissions if any changes in behaviour were sustained.

The UK working age adult population in mid-2023 was approximately 42 million people (Office for National Statistics, 2024c). Theoretically if the CABDI model was applied to all working age adults in the UK there could be a potential decrease of 37.8 million tons (37.8Mt) of CO_2e using the 0.9 CO_2e mean figure. This figure has only been calculated as a potential approximate and working adults used as children and those who have retired may have widely differing needs and an inability to undertake the diary. Actual reductions would vary across groups and differ from the sample due to the limitations of the demographics of the sample being largely similar in age, living situation and carbon education. Homeowners may have more scope to reduce their household emissions for example as participants being students noted their inability to make substantial changes to their home to reduce energy consumption. However, as an indicator of the scale of reduction the CABDI model alone could have in the UK. UK households were reported to be responsible for 125Mt CO_2e by the Office of National Statistics (2024d) in 2021 based on consumer expenditure, a possible reduction of 37.8Mt CO_2e would be a 30% decrease in household emissions.

Those who reported an increase in their carbon footprint after the diary study had a lower mean (and median) carbon footprint than those who reported a decrease in their carbon footprint. Following the diary study the carbon footprints from the increase and decrease subsets were statistically not significantly different. Participants who reported an increase or in carbon footprint particularly noted an improvement in their ability to use the provided carbon calculator, they also showed responses 'yes' or 'maybe' at a higher percentage than the decrease subset on the pre-diary survey question 'Have you undertaken carbon reduction behaviour in the last 12 months?'. This implies this subset may include those who were already taking action but improved their ability to use the carbon calculator or made errors in completing the calculator.

Anecdotal evidence passed on informally from participants and those around them showed that participants had become very engaged in completing the diary and the behaviour had influenced those living with them or around them. Largely by participants encouraging those in their household to adopt behaviours that aligned with the behaviours recorded in the carbon diary. Additionally, participants discussed the barriers they encountered through the overall student culture they were surrounded by, with others often encouraging or endorsing behaviours that were carbon intensive, such as overseas holidays, new clothes purchasing and meat consumption. Participants who discussed this were particularly proud when they resisted the overall culture around them that encouraged behaviours they identified as 'bad'. This shows that there may be potential influences on social norms and change of others, but the existing social norms may be difficult to go against and this may require emotional effort for people to go against the norm. However, this information was gained through informal discussions and was not gained through rigorous questioning so may only indicate the potential for further influence and future study would be required.

Participants noted a desire to avoid certain behaviours because they did not want to record it in the diary both anecdotally and within the study, instead actively choosing to walk rather than using a car to avoid recording a behaviour they considered 'negative'. They also noted pride for 'good days' where they felt they recorded only positive climate behaviours. Public commitments to changing behaviour such as a pledge or being involved in an activity like the carbon diary aspect of the CABDI study can be effective in changing climate behaviour, although these impacts may be temporary (Matties etc al, 2006, Steg, 2018, Whiteman et al, 2021). As participants had shared with others they were taking the study, and despite data being anonymous were aware their data would be viewed they may have been influenced by this to change behaviours over the course of the study.

Understanding the causes of the value-action gap between stated environmental and sustainability values and behaviours is vital for policymakers and researchers when developing interventions to change behaviour to reduce emissions. Understanding the drivers of decision-making and the barriers people may face allow interventions to be selected and developed to mitigate barriers and support decision-making. Through analysis of the data in Chapter 5 people's key barriers and challenges were identified as attitudinal. Convenience and habit were key barriers put forward by participants in terms of changing their behaviours, this was identified across all the measured behaviours. Participants stated particularly high reluctance to change their transport methods, diet, and personal electronic use. Attitudes are difficult to change, and changing an attitude to stimulate behaviour change poses a considerable challenge to researchers and policymakers (Barr, 2007; Jain, 2014; Perrin and Barton, 2001).Even if an attitude change can be instigated there remains a gap between attitudes (or values) and behaviour (Chai et al., 2015; Chaplin and Wyton, 2014; ElHaffar et al., 2020; Lane and Potter, 2007).

Participants for the studies in Chapters 4 and 5 did not see themselves as the most responsible for reducing carbon emissions. Participants tended towards viewing national government, business, and industry as the most responsible for reducing global emissions. This implies that personal responsibility is not a motivator to reduce personal carbon emissions or factors into their decision-making process. In Chapter 3 participants stated their opinion that bodies such as government and industry were responsible in the pre and post diary surveys, and within the reflective piece some participants justified their behaviour by putting the 'blame' on others. Some participants stated that others were emitting more than they were and therefore were more responsible for reducing carbon emissions.

Chapters 4 and 5 show a high level of concern around climate change, with them expressing worry and concern about climate change in their reflective pieces of work. The majority of participants showing high awareness of climate change and acceptance of the underpinning science and the qualitative data shows considerable emotional distress is felt by participants alongside feelings of hopelessness. Despite this participants did undertake carbon intensive behaviours even when they identified in the diary they were aware of the carbon intensity and the alternatives they could take. These findings may highlight that people's emotional responses to climate change are not necessarily identical, and that relying upon an emotional response to awareness raising or knowledge may not guarantee the response that is being sought to motivate people to change behaviour.

This thesis develops a new methodological model and finds that the use of a multi-stage mixed method based behavioural diary model (the CABDI model) allows for collection of a high quantity of interconnected quality data. The use of baseline and repeat comparison measures allows an analysis of if the diary itself had an impact on participants' behaviour and opinions and if the efforts of participants over the time period has had a short-term effect. The quantitative diary circumvents some of the challenges found in diary studies in terms of the time burden it puts on participants (Gochmann et al., 2022; Horstmann, 2021; Ohly et al., 2010; Singh and Malhotra, 2013). The use of quantitative data allows for clear time series behaviour analysis and the exploration of trends over the study period. The qualitative stage of the model for reflections by participants allows for nuance, explanation and reflection by participants which otherwise would be unrepresented with only a quantitative diary. The CABDI model had high engagement and consistent reporting by participants, each stage was designed to have a minimal burden on participants' lives as all data gathering could be completed around participants' daily lives. Whilst there are existing models to explain behaviour and numerous studies on environmental behaviour, there are no standardised and commonly used methods of gathering climate change and sustainability related behaviour. Creating a flexible model of data gathering in this area would allow for comparisons between studies and support the collection of rich interconnected datasets.

As discussed in Chapter 5, understanding people's carbon emission related behaviour and decision-making is complex due to the numerous factors that may have influence. Data gathered on carbon related behaviour needs to be able to not only identify behavioural trends but causes and the decision-making process to provide widely usable findings.

6.3. Synthesis

The findings of this thesis demonstrate that the public may not change their behaviour due to their potential prioritisation of convenience and habit despite high awareness of climate change and rising eco-anxiety. Researchers and policymakers cannot assume the public will prioritise carbon emission reductions for 'the good of the planet' or by being informed of which behaviour leads to climate reductions. This is supported by Whitemarsh et al (2021) which found that there is a focus on 'suboptimal intervention strategies' particularly those that are based purely on relaying information which are 'relatively ineffective' at changing impactful climate change behaviours.

Additionally due to factors such as compassion fade and the limited climate change impacts currently in the United Kingdom the public in the UK are not necessarily motivated to change behaviour by climate change considering it something that impacts others and not themselves (Butts et al., 2019; Grodeck et al., 2022; Markowitz et al., 2013). Possible key barriers and challenges people experience are found by this thesis to be internal and based on their own attitudes and motivations, these are not barriers that can be easily removed by external bodies unlike systemic barriers that may be around infrastructure or education. Additionally, people did not generally report considering themselves as personally responsible for reducing carbon emissions so do not have personal responsibility as a motivator.

Therefore, to reduce personal carbon emissions and curb emission generating behaviour a top-down mandatory policy may need to be enacted if the intention of policymakers is to reduce global emissions. As it is demonstrated by this thesis that the public may not be motivated to act on their own and require regulation to ensure the appropriate reductions in emissions are met. Education and awareness alone may not have the ability nudge their behaviour into changing, nor will their concern about climate change at this current point in time.

Any policy, regulation or limit on the public will have social, cultural, and economic impacts, on individuals, the private sector and government. To ensure that there are not unintended socioeconomic impacts on the public the proposed Personal Carbon Allowances policy model could be adopted. As stated, the removal of trading from the existing personal carbon trading model should ensure equity and removes the potential for this to be a regressive policy. In assigning carbon budgets to individuals, consideration of individual needs must be considered, those with health or mobility needs may have higher carbon requirements than those without.

Any application of a PCB policy model requires careful evaluation and strategy to ensure all can meet their own needs whilst reducing global emissions.

PCA is similar to the existing PCT model but removes the trading aspect, this is a critical factor in increasing the social equity aspect of a PCB. This is not only because those on higher incomes could purchase additional credits and potentially carry on 'business as usual' depending on credit purchasing limits, but those on lower incomes may be incentivised to sell credits in times of short-term financial risk, therefore reducing their overall annual credits. This concern already exists in relation to the disproportionate number of people from low socioeconomic backgrounds, and vulnerable people who take out payday loans and are victims to predatory lending practices (Crossney, 2017, Saunders, 2021). Those who have uncertain financial situations can find themselves taking on additional debt to defer short term pressing concerns, however this may create greater debt and financial concerns in the future (Anderson *et al,* 2020). If carbon credits can be sold it may be that behaviour follows this trend, with people selling credits to defer their financial concerns, however the outcome of this would be lower access to goods and services throughout the rest of the year, there is also a potential risk that in this situation they would then be required to repurchase credits which either would limit their income or raise a risk of them taking on financial debt. The issues around short-term debt and vulnerability to predatory lending are disparate across ethnic groups and gender, those from minority ethnic groups have been found more vulnerable than the general population to these practices and women are more likely to have debts relating to payday loans, however men are more likely to have higher levels of short term debt (Anderson *et al,* 2020, Saunders, 2021). Therefore, it could be anticipated that personal carbon trading has the potential to cause considerable social and economic imbalances within society and have regressive impacts on the population. As no large scale PCT trial has taken place over a significant period behaviour can only be anticipated from existing behavioural trends.

As analysed in Chapter 3 a personal carbon budget has the potential to impact all aspects of an individual's life, both financially and in terms of behavioural change and place restrictions on lifestyle. Mandatory models have the highest potential restriction impact, and the proposed personal carbon allowance model is the most restrictive of the evaluated models. The exclusion of carbon trading in the model means that individuals can only use their designated budget, therefore as individual needs differ budgets would need to differ to be equitable. When this model is stated to be the most socially-just it is with the caveat that it would require appropriate design and implementation as a uniform per capita budget could negatively impact those with additional needs or vulnerabilities.

Such a model may be highly unpopular with the public initially, especially with the resistance of the public to changing the behaviours that could provide the biggest reductions in their emissions, such as diet and personal travel (Dunne, 2017; Hatzopoulou et al., 2011; Hou et al., 2022; Scarborough et al., 2014). Such a policy would require large lifestyle shifts for many individuals Aas identified in Chapter 5 whilst overall awareness of climate change is high there are gaps in people's understanding of how to make carbon reducing changes. This was notable when participants were unsure how to prepare plant-based meals due to lack of skills, there would need to be support across sectors for a transition to a PCA policy, including practical education, reskilling, and changes to infrastructure. This is a policy proposition that would require support from all levels of government and the private sector, and the development of considerable infrastructure to facilitate its provision. However, the scale of the climate crisis is such that there needs to be considerable mobilisation to enact deep emission cuts at all levels (United Nations Environment Programme, 2023). There is limited time in which to reduce global emissions to combat the catastrophic impacts of climate change and therefore policies which are guaranteed to reduce emissions require consideration and development. The PESTLE analysis in chapter 3 explores the political practicalities of implementing PCB policies. For a policy such as personal carbon allowance there would need to be large scale infrastructure changes, methods of implementation discussed for similar policies have included using a 'carbon credit card' linked to a bank account which would require considerable collaboration with the private sector (DEFRA, 2008b; Lane et al., 2008). There are other implementation methods suggested across the literature, using methods such as scannable codes and phone applications (Kuokkanen et al., 2020; Lane et al., 2008; Satoh, 2014). This is an area that would require further study and consideration to ensure any form of carbon budget system was accessible and equitable.

To consider the cultural dimension of the overall findings of this thesis it is beneficial to refer back to the UNESCO (2014) cultural thematic indicators of culture and their relationship to sustainability. As these indicators span a wide range of different aspects of a person's life, from their relationship with the environment to their livelihoods and education demonstrating the highly integrated nature of culture in people's behavioural choices and interactions with their environment. Participants in Chapter 5 noted that when the moved to active travel they enjoyed experiencing the green spaces in the city and reflected they perceived it improved their wellbeing with some reflecting that they had not previously appreciated the space. Others expressed pride in learning new information, but also identified skills gaps that they believed caused their inability to undertake less carbon intensive behaviours. This skills gap particularly arose around food, cultural attachment to food was also cited as an barrier to carbon reduction, it is possible that depending on how an individual was taught to cook they do not have experience in alternative cooking skills and are unmotivated to change from what they find familiar and comforting.

Capturing the impact of people's cultural heritage and place-space association on their carbon reduction behaviour is complex. Participants in chapter 4 showed little differentiation in preferences across demographics. Whilst demographic data alone may not give a clear indication of individuals' cultural background it implies that there may be similar preferences across different groups. In Chapter 5 participants reflected on aspects of their cultural background that impacted their choices around reducing their carbon behaviour, often this was by participants who self-identified as not being from the UK. Their reflections were often around feeling a strong emotional attachment to the food they prepared and ate as a connection to their countries of origin. In chapter 4 across groups diet was the behaviour people would least prefer to change, which supports the findings from chapter 5 that diet is a complex behaviour to change, and this may be in relation to the particular cultural space it holds for people. Additionally, several participants noted the need to fly overseas to 'return home' due to their family and feeling a need to return to the country they felt most emotionally and culturally connected to.

It was an unexpected finding that demographic groups did not identify wide ranging changes in preferences in relation to the cultural groups individuals may belong to as indicated by their religious or ethnic background or gender identity and other groups. It has been theorised that different groups may display different preferences based on different social norms in each group that reflected their cultural practices and beliefs.

PCA implementation would have a considerable cost in establishment, monitoring, and administration, due to the lack of a financial component such as the revenue generated by carbon taxation. This may reduce the political appetite for such a scheme, as identified in previous feasibility reports PCT (DEFRA, 2008b; Lane et al., 2008).

As discussed, a policy with such an impact on the public's lives and lifestyles would certainly be unpopular considering how previous environmental policies such as the smoking ban and congestion charge have been received publicly (BBC News, 2014; Schuitema et al., 2010; Taylor, 2014; Zheng et al., 2014). However, despite the initial unpopularity of the policies listed, as they continued to be implemented they became part of the public's 'life as usual' acceptance of these policies increased and the benefits, be they environmental or health, were positively received (Brown et al., 2009; Convery et al., 2007; Schuitema et al., 2010; Seter et al., 2023; Thomas et al., 2019). This implies that whilst a PCB policy may initially be unpopular if the public can perceive the benefits and it becomes integrated into their 'life as usual' it could become more acceptable to the public (Brown et al., 2009; Seter et al., 2023; Thomas et al., 2019).

6.4. Limitations

Due to the scope of this study the focus was on personal carbon emissions with little consideration of the wider scope of carbon emission reductions across the United Kingdom and the world. Whilst behavioural change would lead to emission reduction there are limitations on what an individual would be able to change or reduce without infrastructural change.

The sample for the PAPRIKA study in chapter 4 was taken from a special panel of residents of the city of Southampton using purposive sampling, enabling individuals with a spectrum of beliefs and experiences to be reached (Bellhouse, 1984; Campbell et al., 2020; Etikan, 2016; Klar and Leeper, 2019; Neves and Brand, 2019). The sample for the diary study in chapter 5 was a convenience sample due to access to participants and was a group that was likely of a similar age range and all university students, and therefore further testing on other groups may be required to confirm findings and affirm validity (Etkins, 2016).

This thesis relies largely on self-reported data by participants, whilst methods were selected with the intent to reduce influences such as social desirability bias self-reported data of stated preferences cannot be taken as an absolute in terms of how the public are behaving or will behave (Craig et al., 2016; de Corte et al., 2021; Ortúzar and Garrido, 1994; Urama and Hodge, 2006). The same issue arises with stated attitudes, opinions, and self-reported behaviour. As behaviour was self-reported and not observed it is possible that behavioural trends were under or over reported by participants. As participants were asked to write a reflective piece, they knew would be read by researchers in sustainability social desirability bias may have been a factor in responses given. Mitigation such as participants being aware their responses were anonymous was undertaken due to awareness of this limitation. Additionally, as the study in chapter 5 used an identical survey before and after the diary study participants would be able to anticipate the questions and their replies, as noted some expressed an improvement in their ability to understand how to complete the carbon foot printing tool which may have had an influence on overall results to some degree.

This study was conducted using participants from a similar geographical area, therefore the experiences of participants, including barriers experienced or preferences may differ from those in other locales. Demographic groups vary across separate locations in the United Kingdom so findings may differ in different areas and may differ depending on different provisions of services in that area (i.e. public transport). In Chapter 5 no demographic data is gathered on participants due to the nature of their selection as students who may be recognisable through sharing their demographic characteristics therefore, except where participants volunteer demographic information (such as their gender identity), this means differences between demographic groups cannot be assessed and findings applicability across demographic groups cannot be assumed.

Additionally, all participants are likely of a similar age group due to being University students, however this could not be confirmed without gathering demographic data and can only be an assumption. Therefore, these participants may have similar types of environmental and sustainability education, or similar attitudes, values and opinions arising from their age group.

There is the possibility of selection bias in the study in Chapter 5, the sample was a convenience sample and students who chose to attend a sustainability-based module. However, this module is open to all students and not only attended by those on sustainability-based courses. However, due to the integration of the study into the curriculum there was a low dropout rate, no participants dropped out or asked to be removed from the study but instead were removed from the study due to not meeting the cut off point of diary entries. Whilst the use of a convenience sample of potentially already engaged individuals may indicate some biases the benefit of a consistent and large dataset for a mixed methods study was considered an acceptable trade off.

As this study was part of a teaching assessment participants may have been more motivated and enthused to engage in carbon reducing behaviour. It was made clear to all participants that their consent for their data from the assessment being used in a study would have no impact on their grades. Students did not gain higher grades for being less carbon intensive in their behaviours there was no material or academic benefit from changing their behaviour and this was made clear to participants. No data was assessed for the study until pieces were marked and returned to students, the academic responsible for the module was not involved in raw data cleaning, preparation or analysis and this was made clear to participants that this academic would only see the results that would be publicly shared and have no influence over the reporting or analysis. Participants were able to withdraw at any time and get in contact at any time to query any part of their participation in the study. However, it is accepted that there may have been an influence on results from the integration with a teaching assessment.

The studies in this thesis relied on participants owning devices with access to the internet, whilst this may exclude those without internet access this decision was made to ensure anonymity and ease of data collection. Additionally, the study in Chapter 4 was conducted during the height of the COVID-19 pandemic where the ability to gather data in person was highly limited. No participants in the studies in chapter 4 or chapter 5 had to undertake any part of the studies in an unfamiliar environment, all parts of the studies can be conducted from home on their own devices and without the presence of any researcher involved in the studies. All data is anonymous, and it made clear to participants that no data that would allow them to be identified would be gathered. So, whilst the use of online forms may have excluded potential participants it allowed for the assurance that participants could undertake the studies without potential environmental impacts from a laboratory or formal setting or proximity to researchers.

The focus of this thesis is on personal barriers, challenges, and reductions therefore this thesis does not consider the full scope of carbon emission reductions across the UK or globally. It is understood that not only changing personal behaviour and emissions is what is needed to reduce global emissions to combat climate change. There will be interactions between ‘top down’ methods and ‘bottom up’ methods, such as personal carbon budgets, which may cause unexpected outcomes that need to be identified and potentially mitigated or eliminated if there is a negative outcome in terms of emission reductions or socioeconomically. These interactions will be complex and discerning the potential influences there may be on personal emission reduction policies by policies that apply nationally to industry and the third sector. An integrated approach is required, ensuring all policies complement each other, do not have negative social or cultural impacts, and most vitally lead to the severe carbon emission cuts required. The findings of this thesis should be considered in the broader context of carbon emission reduction literature and policy considerations.

7. CHAPTER 7. CONCLUSIONS AND FUTURE WORK

7.1. Conclusions

The global climate change crisis continues to drastically worsen. All potential policies and interventions need consideration to slow or halt climate change and its devastating global impacts. Currently in the United Kingdom policies to reduce carbon emissions are 'top down', with a focus on industry. Whilst the reduction of industry emissions is critical, the behaviour of, and demand for goods/services by, the public drives industry emissions and must also contribute to carbon emissions reductions. This study has identified the unwillingness of people to change their consumption-related behaviours despite their high awareness of and concern about climate change. The behaviours the public reported they would prefer to change are minimal impact both on their lives and on potential emission reductions and the key barriers they experience are attitudinal. Hence a Personal Carbon Budget model may be the most appropriate policy to facilitate carbon emissions reductions from the public.

Within the scope of this thesis the Personal Carbon Allowance Model was identified as a possible policy intervention to reduce personal carbon emissions with consideration of the barriers and challenges faced by the public. As the public are unwilling to change the behaviours that are most carbon intensive and indicate that a factor in these preferences is their internal attitudes, motivations and habit. Therefore purely informational, market based or nudge policy interventions may not entirely achieve the depths of cuts required to reach the targeted emission reductions in the UK.

An additional finding is that keeping a carbon diary and having a sense of accountability may have the potential to aid in personal carbon reductions, participants qualitative remarks that they did not want to have to record 'bad' (carbon intensive) behaviours appears to have had an impact on their self-reported carbon footprints, with the average footprint lowering by approximately 0.9 tons CO_{2e} per year.

The methodological approach taken in this thesis uses methods not previously used in the field of study, making use of PESTLE analysis, the PAPRIKA method and the development of the new CABDI Model. This allows for original and novel findings, the gathering of qualitative information in Chapter 5 provides additional nuance and context for other findings within the thesis.

This thesis identifies the general unwillingness of the public to make large behavioural changes without an external impetus, such as a policy intervention. Trends are consistent regardless of stated attitudes around carbon or demographics. If even those who are willingly involving themselves in further sustainability education do not demonstrate the ability or desire to change their behaviour significantly to reduce emissions, it paints a dire picture of the overall willingness of the public to change.

This finding supports the existing literature which finds that informational approaches to changing climate behaviour can be ineffective depending on design (Kenis and Mathijs, 2012, Steg, 2018, Whitmarsh 2009, Whitmarsh et al, 2021, Wu & Otsuka, 2021). However, this is an active topic of study and depending on the type of informative or educational intervention awareness raising may aid attitudinal or behaviour change (Wu & Otsuka, 2021). This thesis finds that awareness alone may not be a viable metric to assume an individual will be undertaking climate reduction behaviours or be willing to change them. Implying interventions beyond only information and awareness raising are necessary to generate impactful reductions in personal carbon emissions.

People, regardless of their 'green' attitudes or demographics may be unwilling to make the considerable behavioural changes needed to cut personal carbon emissions. Therefore, a mandatory policy intervention is required to make the significant cuts to emissions required. Habit and convenience are the key barriers to the reduction of personal carbon emissions alongside the inability to convert climate concern and anxiety into motivation to change. Whilst there are external barriers to behavioural change, such as lack of or poor infrastructure and service provision, the evidence in this thesis shows that people's refusal to change their habits and desire to take the easiest options in daily life are critical barriers to behavioural change. Whilst people demonstrate high awareness and concern about climate change, they show preferences only to change the behaviours that they find easiest, and their concerns do not convert into behavioural change or willingness to change. Therefore consideration of a stringent policy directly limiting personal emissions to change behaviour may be required.

7.2. Originality and Contributions to the Field

This thesis makes numerous contributions to the field of study. As discussed by Fawcett (2012) and the literature review within this thesis the topic of personal carbon budgets is currently largely unexplored and often within specific niche areas using similar methodologies. This thesis expands the field of study and provides vital context on the preferences, behaviours, and attitudes of the public in relation to reducing their personal carbon emissions.

This thesis contributes to filling the identified gaps in the literature through using a varied methodological approach, within the existing literature studies tend to employ a singular method of analysis with a narrow research focus on a specified aspect of a PCB model. An analytic comparison using the PESTLE framework of existing PCB models is conducted alongside the proposal of a new PCB model previously not proposed in the existing literature. This thesis provides an identification of the PCB model that would be most effective in reducing emissions with consideration for the other dimensions of sustainability and feasibility.

This thesis examines the preferences of the public in relation to changing their behaviours in reducing their personal emissions, considering their demographics and attitudes. Which is not currently present in the literature. This study uses the PAPRIKA method (Potentially All Pairwise RanKings of all possible Alternatives) a Multi-Criteria Decision-Making (MCDM) conjoint analysis method that provides weighted preference results. Additionally demographic and attitude data was gathered for all participants to conduct cluster analysis and explore the differences in preferences across demographic groups and stated attitudes. This allows identification of demographic or attitudinal influences over stated preferences and the type of PCB that may be suited to reducing personal emissions considering public preference. Findings show that regardless of attitudes and demographics the public show preferences for easier carbon reduction behaviours despite the low associated carbon reduction potential. This challenges some existing theories that education and awareness raising are the most vital aspect of environmental behaviour change. Despite high concern over climate change and high knowledge the public were unwilling to change their behaviour accordingly.

This thesis explores and identifies the barriers and challenges people experience in reducing their carbon emissions through behavioural trends using a mixed method carbon diary, survey, and reflective study, recording of ‘real life’ behaviour over a twenty-eight-day period. This allows the identification of which aspects of attitudes and behaviour are hindered by external factors and which aspects are entirely attitude based. Motivations, attitudes, and experiences are explored and analysed using qualitative methods This study is conducted with a large sample size (n= 94) for a mixed methods behavioural study of this length of time. Using both quantitative and qualitative data allows for in depth and nuanced exploration of behaviour and behavioural causes. Findings show that convenience is a considerable barrier encountered by participants and that education and awareness had limited short term impacts on behavioural change.

This thesis develops a new model for gathering and analysing carbon behaviour data and identifying the causes and motivations for this behaviour. Utilising both quantitative time series data, before and after attitude data and carbon footprints alongside qualitative reflective data this generates a comprehensive dataset that can be interrogated and analysed using a wide variety of quantitative and qualitative methods.

The key contributions to the field of study from this thesis are:

i) The analytic critical comparison of multiple PCB models through a PESTLE framework providing additional knowledge to the body of literature by providing a direct comparison between models through a recognised framework.

ii) The proposal of a new PCB model – Personal Carbon Allowance not currently identified in the literature, proving a new ‘option’ to policymakers and researchers working in this field.

iii) Identification of the PCB model that would be most effective in reducing emissions with consideration for the other dimensions of sustainability and feasibility within the scope of this thesis.

iv) The use of Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) multi-criteria decision making (MCDM) conjoint analysis to identify the carbon reductions of the public and exploring and analysis demographic and attitude differences and cluster analysis. This methodology has not previously been applied to personal carbon policy interventions and has a difference from existing literature due to the focus on preferences rather than acceptability. Additionally it identifies that demographic groups within this study do not show considerable differences in preferences.

v) Identification of carbon reduction behaviour preferences of the public in relation to demographics and attitudes.

vi) Large scale carbon behavioural diary study investigating the barriers and challenges experienced by people when attempting to reduce their personal carbon emission. Providing new knowledge and contributing via the provision of further understanding of the barriers and challenges experienced by people when attempting to reduce their personal carbon emissions.

vii) Development of a new flexible mixed methods carbon behaviour analysis method the CABDI method that can be used and applied to a variety of sustainability behaviours and can be implemented in a variety of formats. This is a bespoke tool for sustainability behaviour integrating quantitative and qualitative methods which are rarely used in this topic area.

viii) Identification of possible barriers and challenges experienced when attempting to change behaviour to reduce carbon emissions.

ix) Finding that a diary/ behaviour monitoring based intervention may have the potential to moderately reduce people's (self-reported) carbon footprints.

x) Recommendation of a PCB intervention with consideration for all four dimensions of sustainability and identification of if such a policy is required based on the preferences and barriers experienced by people in relation to personal carbon emission reduction.

This thesis fulfilled its aims and objectives as signposted in table 7.1.

Table 7-1 Table showing fulfilment of aims and objectives by this thesis

Aim or Objective	Associated Findings
AIM 1: Analyse and define what personal carbon budget 'acceptability' is in terms of the four dimensions of sustainability (social, cultural, economic, environmental).	Fulfilled through Chapter 3, Chapter 4 and Chapter 5, through PESTLE analysis.
OBJECTIVE 1.1. Identify and critically evaluate public values, attitudes, and behaviours in relation to personal carbon budgets with consideration the social justice implications of these policies	Fulfilled through Chapter 4 and Chapter 5. Chapter 4 identifies which behaviours the public would be willing to change, Chapter 5 gains quantitative and qualitative findings on public values, attitudes and behaviours.
OBJECTIVE 1.2. Identify and critically evaluate economic implications of personal carbon budgets	Fulfilled through Chapter 3 PESTLE analysis.
OBJECTIVE 1.3. Identify and critically evaluate positive and negative environmental impacts of personal carbon budgets in relation to the reduction of carbon emissions	Fulfilled through Chapter 3 PESTLE analysis..
AIM 2: Explore barriers and challenges the public face in reducing their personal carbon emissions	Fulfilled through Chapter 4 and Chapter 5 opinion, behaviour value and attitude findings and analysis.
OBJECTIVE 2.1. Identify and evaluate barriers the public experience when attempting to reduce their personal carbon emissions	Fulfilled through Chapter 5 with findings potentially showing attitudinal barriers.
OBJECTIVE 2.2. Identify and critically evaluate challenges the public experience when attempting to reduce their personal carbon emissions	Fulfilled through chapter 5 through mixed methods analysis of data identifying behavioural trends and qualitative feedback and experience building on findings from Chapter 4.
AIM 3: Collate findings to identify and propose appropriate PCB model to reduce carbon emissions with the consideration of environmental, cultural, economic, and social factors.	Fulfilled through Chapter 6. Synthesis of findings led to proposal of Personal Carbon Allowance model as the most appropriate model within the scope of this thesis.
OBJECTIVE 3.1. Collate and synthesise indings to identify appropriate PCB model	Fulfilled through Chapter 6. Personal Carbon Allowance Model identified as most appropriate following synthesis of findings
OBJECTIVE 3.2. Critically evaluate the environmental, cultural, economic, and social findings to propose appropriate PCB model public face in reducing their personal emissions to support the justification or rejection of a PCB model as a potential model for personal carbon emission reduction.	Evaluation showed the public may often have internal barriers to changing their carbon reduction behaviours. These may be due to convenience or difficulties in changing habits. Chapter 4 found that the public may be unwilling to change the most impactful behaviours (i.e. transport, diet) which are the behaviours they would most commonly undertake.

7.3. Future Work

Following from this thesis there are many avenues of future work to be developed and explored.

Further development and a feasibility study of the Personal Carbon Allowance model leading to low level testing would provide a robust understanding of the practicalities of implementing this model and the potential emission reductions it could return. As discussed, any Personal Carbon Budget policy intervention would require careful design to ensure people can meet their own needs and assigned carbon budgets do not impede an individual's personal well-being. Identifying the different carbon requirements of individuals across demographic groups would provide valuable insight into how complex this aspect of a Personal Carbon Allowance may be and the degrees of difference in carbon requirements between individual needs would support a clearer estimation of how carbon emission credits could be assigned.

Methods of implementation require analysis and assessment through several lenses. Economic, technical feasibility and socio-economic factors, such as accessibility of bank accounts, mobile phones, or other methods of delivery of tracking and spending carbon credits.

Further exploration a policy intervention may have on the cultural aspect of sustainability and how those with different cultural aspects may respond or use a carbon budget is needed to fully capture this complex aspect of sustainability.

Data gathered for the CABDI model study has other applications, for example, greater mapping of behaviours to the education and awareness sessions provided over the period could allow for a deeper exploration of the role of education on carbon behaviour. Analysis of the format of the education provided (i.e. lectures, workshops, delivery) could provide insight into the complexities of how education may have short term impacts on carbon reduction behaviours. Future iterations of the CABDI Model study should be conducted to gain a larger sample size to monitor potential changes over time in people's behaviour as the climate change crisis worsens, and to continue to analyse the causes of low behavioural change despite high climate change awareness. A further carbon behaviour dataset using the CABDI model has been gathered with the intention to repeat the study to develop a study across multiple cohorts.

Further exploration of the potential of the CABDI model as an intervention itself should be undertaken using future cohort data to identify the role self-monitoring and reporting may have on people's carbon reduction behaviour.

APPENDIX A: CHAPTER 3 SUPPLEMENTARY MATERIAL

Appendix A.1 PESTLE FRAMEWORK

FACTOR QUESTIONS

POLITICAL CRITERIA

i) How does it fit with existing policy?

ii) Feasibility of implementation

iii) Burden on government – would it require new governing bodies established

iv) Popularity with public – would political parties be hesitant to enact policy due to implications for electability

v) Would it require government funding?

ECONOMIC CRITERIA

i) Is the model regressive or progressive (if applicable)?

ii) Would it incur costs on industry or public?

iii) Would it impact natural capital?

iv) Would it impact growth/ GDP?

v) Would it generate jobs?

SOCIAL CRITERIA

i) Social justice implications

ii) Potential changes to lifestyle

TECHNOLOGICAL CRITERIA

i) Would new technology/ software need to be developed to facilitate this policy?

ii) Would this policy encourage the development of 'green' technology?

iii) Would this policy hinder technological development?

LEGAL CRITERIA

i) How would this policy be enforced?

ii) Mandatory or voluntary

iii) Potential penalties

iv) Implications for changes to law

ENVIRONMENTAL CRITERIA

I) Emissions cap or no cap?

II) Carbon footprinting requirement/ scope

III) Would this policy encourage environmental awareness?

Appendix A.2 PESTLE analysis of a PCT model according to criteria defined in Appendix A.1.

Political	- Could fit in with existing ets schemes - Would require significant money and manpower to implement - Would require governing body to oversee - May be unpopular due to limitations on public - Funded by government, projected to potentially cost between £700 million - £2 billion to set up (according to 2008 projection) and require running costs from government (lane et al., 2008)
Economic	- Incurs costs on businesses etc to have carbon footprints for goods/ services conducted and maintained - Job generation – within government body and carbon footprinting organisations - Limits amount of goods and services public will purchase due to limits on carbon they can 'spend' - Progressive policy - [1]
Social	- Trading allows wealthy individuals to pay to keep their current lifestyle, poorer individuals may feel pressure to sell credits to gain additional income - Trading would allow for flexibility of lifestyle - Educates the public on their carbon spending and carbon cost of lifestyle - Individuals may try to 'cheat' the system to gain more credits/ incentives [2]
Technological	- Could require adaptation of existing banking systems or require new systems to be created to track carbon credits [3] - Would need the creation of online credit marketplace or brokers - Carbon credit cards would require contactless machines to spend credits - Items may need barcodes or tags that have carbon credit cost - May encourage development of 'greener' technology - Unlikely to hinder technological development
Legal	- Mandatory - New regulations on carbon emitting and carbon spending - Regulation and definition of carbon footprint must be set and adhered to for parity across all goods and services - Some form of penalty for non-compliance

Enviro nmen tal	- Hard cap on emissions possible so emission reduction can be controlled - Requires carbon footprinting (or similar) for goods and services, method of CF will impact reductions - Scope of included goods and services flexible – some models only include household heating/ energy and transport [4] - Trading would allow all yearly surplus to be used – therefore cap would always be met rather than aiming to not meet the cap

Appendix A.3 PESTLE analysis of PCA model according to criteria defined in Appendix A.1.

POLITICAL	- Could fit in with existing ETS schemes - Government funded - Would require governing body to oversee - May be unpopular due to limitations on public – even more limitations than PCT - Funded by government, projected to potentially cost similar to predicted PCT models between £700 million - £2 billion to set up (according to 2008 projection) and require running costs from government
ECONOMIC	- Incurs costs on businesses etc to have carbon footprints for goods/ services conducted and maintained - Job generation – within governmental body and carbon footprinting organisations - Limits amount of goods and services public will purchase due to limits on carbon they can 'spend' - Limits amount of goods and services public will purchase due to limits on carbon they can 'spend' this could have some impact on GDP
SOCIAL	- Public's activity heavily limited by carbon budget, cannot buy credits to continue existing lifestyle if carbon intensive. - People with higher income cannot buy further credits to maintain current lifestyle - No trading means lower income/ vulnerable peoples cannot be exploited by those with greater wealth to gain carbon credits. - Progressive policy - [1]

TECHNOLOGICAL	-	Could require adaptation of existing banking systems or require new systems to be created to track carbon credits [3]
	-	Carbon credit cards would require contactless machines to spend credits
	-	Items may need barcodes or tags that have carbon credit cost
	-	May encourage development of ‘greener’ technology
	-	Unlikely to hinder technological development
LEGAL	-	Mandatory
	-	New regulations on carbon emitting and carbon spending
	-	Regulation and definition of carbon footprint must be set and adhered to for parity across all goods and services
	-	Some form of penalty for non-compliance
ENVIRONMENTAL	-	Hard cap on emissions possible so emission reduction can be controlled
	-	Requires carbon footprinting (or similar) for goods and services, method of CF will impact reductions
	-	Scope of included goods and services flexible – some models only include household heating/ energy and transport [4]
	-	Surplus not used each year – could roll over but more likely any surplus would be unused and therefore possibility emissions could stay below cap

Appendix A.4 PESTLE analysis of carbon labelling model according to criteria defined in Appendix A.1

POLITICAL	- Does not require a new government body in order to regulate it - Burden to carbon footprint can be on producers rather than government - 'Nudge' rather than policy
ECONOMIC	- Low cost to government - Incurs costs on businesses etc to have carbon footprints for goods/ services conducted and maintained - Job generation –within carbon footprinting organisations
SOCIAL	- Reliant on public changing own behaviour due to raised awareness - Nudge principles - Allows people to make their own choices - Raises awareness of carbon emission costs of products and services
TECHNOLOGICAL	- Carbon labelling would not require additional technology in terms of additional barcodes/ accounts for goods and services - Unlikely to hinder technological development
LEGAL	- Voluntary for the public not for businesses – still enforcement needed - Regulation and definition of carbon footprint must be set and adhered to for parity across all goods and services
ENVIRONMENTAL	- Does not have hard cap, only can encourage public to be more environmentally aware rather than clear cuts in emissions - Minimal changes in behaviour so likely minimal changes in emissions [5] - Requires carbon footprinting (or similar) for goods and services, method of CF will impact reductions

Appendix A.5 PESTLE analysis of carbon tax model according to criteria defined in Appendix A.1

POLITICAL	- Fits in with existing policies – due to being tax - Technically easy to implement - Has direct impact on public which may be unpopular - Would not require a specific new governing body to oversee it - Would generate revenue may be some implementation and monitoring costs
ECONOMIC	- Regressive tax – lower income households would spend proportionally more of their income on tax than higher income households - Costs on industry and public - Unlikely to significantly impact growth as no cap - Unlikely to generate jobs
SOCIAL	- Consumers would likely carry on 'as usual' and absorb the cost to an extent as they have with heavily taxed products like alcohol [7] - May widen social income divide due to nature of regressive taxes - Often an upstream tax so public would have little awareness of carbon weight per good or service
TECHNOLOGICAL	- Does not require massive technological changes to current systems or ways of life - May encourage businesses to use more efficient technology that does not incur carbon taxation - May inspire technological development of less polluting technology
LEGAL	- Mandatory - Could incur legal penalties if avoided - Could be vulnerable to fraud and therefore legal pursuit - Change in taxation policy
ENVIRONMENTAL	- Could encourage reduction of carbon emissions - No hard cap on emissions so level of emissions reduced cannot be controlled - Often upstream so would be applied on fuels for goods and services - May not raise environmental awareness – people may just carry on as usual

APPENDIX B: CHAPTER 3 SUPPLEMENTARY MATERIAL

Appendix B.1 Original Criteria List

- Car use – trip frequency and distance
- Overseas travel
- Car ownership
- Public transport use
- Active transport
- Meat or plant-based diet
- Takeaway consumption
- Local food
- Seasonal food
- Food waste
- Household heating
- Household cooling
- Household lighting
- Household appliances
- Renewable energy tariff
- Clothing
- Electronic/ electrical goods purchases
- Internet
- Social media use
- Solar panels
- Insulation
- Other adaptations i.e. heat pumps
- Waste
- Recycling
- Reuse
- Children
- Pets
- Water use
- Shower frequency

Appendix B.2 Demographic Justifications

DEMOGRAPHIC	JUSTIFICATION
AGE	Those of differing ages may have different needs, i.e transport, diet (Blumberg et al., 1997; Marx et al., 2010; Rosenbloom, 1993; Shrestha et al., 2016) . Different age groups have also been reported to have differing attitudes towards climate change and
GENDER	Gender gap in environmental attitudes identified (BUSH and CLAYTON, 2022; Goldsmith et al., 2013). Also potential different needs in terms of lifestyle or needs (Denton et al., 2021)
ETHNICITY	May be differences in priorities related to carbon consumption (Arshed et al., 2022; Maciej Serda et al., 2013; Song et al., 2020; Yasin et al., 2022)
NATIONAL IDENTITY	May be differences in priorities in relation to climate consumption or upbringing, included in census
RELIGION	May be differences in priorities related to carbon consumption
MENTAL DISABILITY	May have differing carbon consumption needs from those without disability due to needs/ medical equipment
PHYSICAL DISABILITY	May have differing carbon consumption needs from those without disability – i.e mobility or due to needs/ medical equipment
SELF-IDENTIFIED SOCIOECONOMIC CLASS	May have differing needs based on financial constraints, upbringing, or priorities. Those in more affluent socioeconomic classes often have higher carbon emissions (California Environmental Protection Agency, 2015; Coskuner et al., 2020; Liu et al., 2019; Wei et al., 2020)
HOUSEHOLD INCOME **LEVEL OF EDUCATION** **LEVEL OF EDUCATION OF PARENTS** **HOME OWNERSHIP** **HOUSE SIZE**	Indicators of socioeconomic class – taken from census
MARITAL OR CIVIL PARTNERSHIP STATUS	May have differing priorities due to different needs and lifestyles of those in a partnership or single (Fan et al., 2019)
HOME LOCATION – RURAL/ URBAN/ SUBURBAN	Transport or heating may be prioritised differently due to location, housing type, population density or public transport provision/ proximity to goods, services, and employment (Gill and Moeller, 2018; Heinonen and Junnila, 2011)

HOUSEHOLD HEATING METHOD	May have differences in heating priority depending on heating method (Ivanova et al., 2016b; Kenny and Gray, 2009; McDowall and Britchfield, 2021a)
CAR OWNERSHIP	May have differences in transport priority if they have personal transport, cars have considerable contribution to transport carbon emissions (Department for Business Energy and Industrial Stratergy, 2020a; Hou et al., 2022b; Laakso, 2017; Long et al., 2020; Vasic and Weilenmann, 2006; Walsh et al., 2008b)
EMPLOYMENT STATUS	May have different priorities i.e daily transport if employed (Yang et al., 2018)

Appendix B.3 Demographics Survey

DEMOGRAPHICS

What is your age?

1. 18 – 24
2. 25 – 44
3. 45 – 64
4. 65+

What is your ethnic group?

Choose one option that best describes your ethnic group or background

- White - English/Welsh/Scottish/Northern Irish/British
- White - Irish
- White - Gypsy or Irish Traveller
- Roma
- Any other White background, please describe
- White and Black Caribbean
- White and Black African
- White and Asian
- Any other Mixed/Multiple ethnic background, please describe
- Indian
- Pakistani
- Bangladeshi
- Chinese
- Any other Asian background, please describe
- African
- Caribbean
- Any other Black/African/Caribbean background, please describe
- Arab
- Any other ethnic group, please describe

In the text box below please describe ethnicity if necessary from above question

How would you describe your National Identity?

- English
- Welsh
- Scottish
- Northern Irish
- British
- Other please describe

In the text box below please describe National identity if necessary from above question

What is your religion? No religion

- Christian (including Church of England, Catholic, Protestant and all other Christian denominations)
- Buddhist
- Hindu
- Jewish
- Muslim
  Sikh
- Any other religion, please describe

In the text box below please describe religion if necessary from above question

What is your gender?

A question about gender identity will follow later on in the questionnaire

- Female
- Male
- Other, please describe

In the text box below please describe gender identity if necessary from above question

Is the gender you identify with the same as your sex registered at birth? Yes

- No
- Prefer not to say

What is your legal marital or civil partnership status?

- Married
- In a registered civil partnership
- Separated, but still legally married
- Separated, but still legally in a civil partnership
- Divorced
- Formerly in a civil partnership which is now legally dissolved
- Widowed
- Surviving partner from a civil partnership
- Never married and never registered a civil partnership
- In a long-term relationship

What best describes your household's location?

- Rural
- Urban
- Suburban

What type of accommodation do you live in?

- Whole house or bungalow – detached
- Whole house or bungalow – semi-detached
- Whole house or bungalow – terrace (including end terrace)
- A flat, maisonette or apartment that is – In a purpose-built block of flats
- A flat, maisonette or apartment that is – part of a converted or shared house (inc bedsits)
- A flat, maisonette or apartment that is – part of another converted building (i.e school)
- A flat, maisonette or apartment that is – in a commercial building (i.e over a shop)
- A caravan or other mobile or temporary structure

How many occupants resided in this household?

(input number)

Does your household own or rent the accommodation you live in?

- Own outright
- Own with mortgage or loan
- Part owns and part rents
- Rents (with or without housing benefit)
- Lives there rent free

What type of central heating does this accommodation have?

- **(tick all that apply)**
- No central heating
- Mains gas
- Tank or bottled gas
- Electric (including storage heaters)
- Oil
- Wood (i.e logs, waste wood, pellets)
- Solid fuel (i.e coal)
- Renewable energy (i.e solar or heat pumps)
- District or communal heat network
- Other

In total how many cars or vans are owned, or available for use by members of this household?

- 1
- 2
- 3
- 4
- 5
- 6+

Which best describes your employment status?

- Employed – full time
- Employed – part time
- Volunteering
- Self employed
- Retired
- Unemployed
- Full time student

Please select the highest level of education you completed or are undertaking currently.

- GCSEs
- A-Levels/ International Baccalaureate
- B-Tec
- Degree
- Masters Degree
- Doctorate/ other equivalent qualification
- Not applicable
- Other

Please select the highest level of education at least one of your parents or caregivers completed.

- GCSEs
- A-Levels/ International Baccalaureate
- B-Tec
- Degree
- Master’s Degree
- Doctorate/ other equivalent qualification
- Not applicable
- Other

Which category best describes your yearly household income before taxes?

- Not applicable due to retirement/ pension
- £5000 or under

- £5001 - £10000
- £10000 - £17000
- £17001 - £25000
- £25001 - £35000
- £35001 - £45000
- £45001 - £60000
- £60000 - £100000
- £100001+

Do you consider yourself to have a physical disability?

- Yes
- No

Do you consider yourself to have a mental disability?

- Yes
- No

If yes to either of the two above questions, does your disability mean you have additional mobility requirements i.e. a mobility vehicle?

- Yes
- No
- Other, please describe

Appendix B.4 Criteria Levels Descriptions

HOUSEHOLD HEATING ENERGY USE

LEVEL RANK (WORST TO BEST)	LEVEL DESCRIPTION
1	Household thermostat set over 21°C
2	Household thermostat set between 18 & 21°C
3	Household thermostat set at 18°C
4	Household thermostat set below 18°C

Table 1. Level descriptors of Household Heating Energy Use criterion

HOUSEHOLD ELECTRICITY - APPLIANCES (NON-ESSENTIAL REFERS TO ITEMS SUCH AS TABLETS, HAIRDRYERS, ELECTRICAL TOYS, AND GADGETS ETC)

LEVEL RANK (WORST TO BEST)	LEVEL DESCRIPTION
1	Continual use of electronic gadgets, left to charge overnight
2	Regular use of electronic gadgets, sometimes left to charge overnight
3	Occasional use of electronic gadgets, only charged when necessary
4	Minimal use of electronic gadgets, only charged once battery empty

Table 2. Level descriptors Of Household Electricity – Appliances criterion

HOUSEHOLD WATER USE

LEVEL RANK (WORST TO BEST)	**LEVEL DESCRIPTION**
1	Daily long shower (10 minutes or longer) or daily bath
2	Daily shower (up to 10 minutes) or Frequent bath
3	Daily shower (up to 5 minutes) or Infrequent bath
4	Shower every other day (or less) never bath or only when absolutely necessary

Table 3. Level descriptors of Household Water Use criterion

DOMESTIC PERSONAL TRANSPORT USE

LEVEL RANK (WORST TO BEST)	**LEVEL DESCRIPTION**
1	Use personal petrol or diesel vehicle or taxis
2	Public transport (bus or train)
3	Use electric- car, bike, or scooter
4	Active transport (walk or cycle)

Table 4. Level descriptors of Domestic Personal Transport Use criterion

OVERSEAS TRAVEL FREQUENCY PER YEAR

LEVEL RANK (WORST TO BEST)	**LEVEL DESCRIPTION**
1	Frequent long haul or short haul flights
2	One return short haul flight or equivalent
3	One or two trips via method other than plane
4	No overseas travel of any kind

Table 5. Level descriptors of Overseas Travel Frequency Per Year criterion

DIET COMPOSITION

LEVEL RANK (WORST TO BEST)	LEVEL DESCRIPTION
1	No limitations on diet - meat, dairy and other animal products all consumed daily if wished
2	Half plant-based ingredients, half animal product-based ingredients
3	Vegetarian - no meat or fish but dairy, eggs
4	Vegan - no meat, dairy or other animal products

Table 6. Level descriptors of Diet Composition criterion

CLOTHING PURCHASES PER YEAR (BRAND NEW REFERS TO BRAND NEW AND UNWORN, NOT NEW TO YOU)

LEVEL RANK (WORST TO BEST)	LEVEL DESCRIPTION
1	Brand new clothing purchased every few weeks or more frequent
2	Brand new clothes purchased every few months
3	Second-hand clothing purchased every few months, brand new infrequently
4	Clothing rarely purchased, if purchased is second hand - brand new very infrequently if at all

Table 7. Level descriptors of Clothing Purchases Per Year criterion

WASTE GENERATION AND MANAGEMENT

LEVEL RANK (WORST TO BEST)	LEVEL DESCRIPTION
1	Purchases made with no consideration of packaging and waste generated
2	Significant waste generated from purchases – i.e. Amazon delivery packaging
3	Medium waste generated from purchases
4	Minimal/ no waste generated from purchases – i.e. cardboard packaging

Table 8. Level descriptors of Waste Generation and Management criterion

HOUSEHOLD ELECTRICITY - LIGHTING

LEVEL RANK (WORST TO BEST)	LEVEL DESCRIPTION
1	No bulbs changed for energy saving bulbs or LEDs– lights left on in numerous rooms frequently
2	Some bulbs swapped for energy efficient bulbs/ LEDs lights – lights often left on in multiple unused rooms
3	Some bulbs swapped for energy efficient bulbs/ LEDs lights sometimes left on in unused rooms
4	Bulbs swapped for energy efficient bulbs/ LEDs, lights on only on in rooms used

Table 9. Level descriptors of Household Electricity - Lighting criterion

Appendix B.5 Attitude and Behaviour Survey Section

Which of the following statements do you most agree with? Pick one.

(Carbon offsetting is the practice of exchanging money for trees planted or other carbon sinks that may capture carbon emissions)

- I would never use carbon offsetting as a method to reduce my carbon footprint as I disagree with the practice
- I would occasionally use carbon offsetting as a method to reduce my carbon footprint
- I would frequently use carbon offsetting as a method to reduce my carbon footprint
- I would use carbon offsetting as my only method to reduce my carbon footprint

Which of the following do you consider to be the single most serious problem facing the world as a whole? Please pick one.

- The increasing global population
- Spread of infectious diseases
- Climate change
- Poverty, hunger and lack of drinking water
- The economic situation
- Deterioration of democracy and rule of law
- International terrorism
- Health problems due to pollution
- Armed conflicts
- Proliferation of nuclear weapons

How serious do a problem do you think climate change is at this moment?

- 0. Not a problem at all
- 1. Not a serious problem
- 2. A fairly serious problem
- 3. A very serious problem
- 4. An extremely serious problem

In your opinion who within the UK is most responsible for tackling climate change? **Pick one**

- National government
- Business and industry
- Regional and local authorities
- You personally
- Environmental groups
- Other
- All of them
- None of them

Have you personally taken any action to fight climate change over the past six months?

- Yes
- No

To what extent do you agree or disagree with the following statements?

Tackling climate change and environmental issues should be a priority to improve public health

- 0. Totally disagree
- 1. Tend to disagree
- 2. Neither agree nor disagree
- 3. Tend to agree
- 4. Totally agree

The costs of the damages due to climate change are much higher than he costs of the investments needed for a green transition

- 0. Totally disagree
- 1. Tend to disagree
- 2. Neither agree nor disagree
- 3. Tend to agree
- 4. Totally agree

Adapting to the adverse impacts of climate change can have positive impacts for citizens in the UK

- 0. Totally disagree
- 1. Tend to disagree
- 2. Neither agree nor disagree
- 3. Tend to agree
- 4. Totally agree

Appendix B.6 Attitude and Behaviour Results

WHICH OF THE FOLLOWING STATEMENTS DO YOU MOST AGREE WITH? PICK ONE.

I WOULD NEVER USE CARBON OFFSETTING AS A METHOD TO REDUCE MY CARBON FOOTPRINT AS I DISAGREE WITH THE PRACTICE	95 24.9%
I WOULD OCCASIONALLY USE CARBON OFFSETTING AS A METHOD TO REDUCE MY CARBON FOOTPRINT	206 54.1%
I WOULD FREQUENTLY USE CARBON OFFSETTING AS A METHOD TO REDUCE MY CARBON FOOTPRINT	70 18.4%
I WOULD USE CARBON OFFSETTING AS MY ONLY METHOD TO REDUCE MY CARBON FOOTPRINT	10 2.6%

Table 1. Responses to question, “Which of the following statements do you most agree with?”

WHEN MAKING PURCHASING DECISIONS WOULD YOU BE MORE LIKELY OR MORE UNLIKELY TO CHOOSE A PRODUCT BASED ON ITS CARBON FOOTPRINT? (I.E. IF PRODUCTS HAD A LABEL INDICATING THE ENVIRONMENTAL IMPACT OF THE PRODUCT)

MORE LIKELY	205 53.8%
SOMEWHAT LIKELY	146 38.3%
SOMEWHAT UNLIKELY	23 6.0%
MORE UNLIKELY	7 1.8%

Table 2. Responses to question “when making purchasing decisions would you be more likely or more unlikely to choose a product based on its carbon footprint? (i.e. if products had a label indicating the environmental impact of the product)”

DO YOU THINK PRODUCTS SHOULD HAVE LABELS INDICATING THEIR CARBON FOOTPRINT?	
YES	359 94.5%
NO	21 5.5%

Table 2. Responses to question “Do you think products should have labels indicating their carbon footprint?”

WOULD YOU BE WILLING TO SWITCH FROM YOUR CURRENT ENERGY PROVISION TO INSULATING YOUR HOME OR HAVING AN ALTERNATIVE ENERGY SOURCE SUCH AS A HEAT SOURCE PUMP?	
YES – BOTH INSULATION AND ALTERNATIVE ENERGY SOURCE SUCH AS HEAT PUMP	206 53.9%
YES – JUST INSULATION	62 16.2%
YES - JUST ALTERNATIVE ENERGY SOURCE SUCH AS HEAT PUMP	38 9.9%
NO	76 19.9%

Table 3. Responses to question "would you be willing to switch from your current energy provision to insulating your home or having an alternative energy source such as a heat source pump?"

WOULD YOU RATHER PRIORITISE SPENDING INCOME ON YOUR CURRENT ENERGY PROVISION OR SPEND THE EQUIVALENT MONEY ON IMPROVING ENERGY EFFICIENCY IN YOUR HOME?

RATHER PRIORITISE SPENDING MONEY ON CURRENT ENERGY PROVISION	35 9.2%
WOULD SPEND SOME MONEY ON EACH	169 44.4%
RATHER SPEND MONEY ON IMPROVING ENERGY EFFICIENCY	177 46.5%

Table 4. Responses to question “would you rather prioritise spending income on your current energy provision or spend the equivalent money on improving energy efficiency in your home?”

WHICH OF THE FOLLOWING DO YOU CONSIDER TO BE THE SINGLE MOST SERIOUS PROBLEM FACING THE WORLD AS A WHOLE? PLEASE PICK ONE.

THE INCREASING GLOBAL POPULATION	77 20.1%
SPREAD OF INFECTIOUS DISEASES	4 1%
CLIMATE CHANGE	207 54.0%
POVERTY, HUNGER AND LACK OF DRINKING WATER	29 7.6%
THE ECONOMIC SITUATION	6 1.6%
DETERIORATION OF DEMOCRACY AND RULE OF LAW	23 6%
INTERNATIONAL TERRORISM	2 0.5%
HEALTH PROBLEMS DUE TO POLLUTION	3 0.8%
ARMED CONFLICTS	27 7%
PROLIFERATION OF NUCLEAR WEAPONS	5 1.3%

Table 5. Responses to question "which of the following do you consider to be the single most serious problem facing the world as a whole? Please pick one."

HOW SERIOUS A PROBLEM DO YOU THINK CLIMATE CHANGE IS AT THIS MOMENT?	
0. NOT A PROBLEM AT ALL	4 1%
1. NOT A SERIOUS PROBLEM	8 2.1%
2. A FAIRLY SERIOUS PROBLEM	56 14.6%
3. A VERY SERIOUS PROBLEM	117 30.5%
4. AN EXTREMELY SERIOUS PROBLEM	198 51.7%

Table 6. Responses to question "How serious a problem do you think climate change is at this moment?"

HAVE YOU PERSONALLY TAKEN ANY ACTION TO FIGHT CLIMATE CHANGE OVER THE PAST SIX MONTHS?	
YES	291 76%
NO	92 24%

Table 7. Responses to question "Have you personally taken any action to fight climate change over the past six months?"

TO WHAT EXTENT DO YOU AGREE: TACKLING CLIMATE CHANGE AND ENVIRONMENTAL ISSUES SHOULD BE A PRIORITY TO IMPROVE PUBLIC HEALTH	
0. TOTALLY DISAGREE	10 2.6%
1. TEND TO DISAGREE	12 3.1%
2. NEITHER AGREE NOR DISAGREE	48 12.5%
3. TEND TO AGREE	128 33.4%
4. TOTALLY AGREE	185 48.3%

Table 8. Responses to question “to what extent do you agree: tackling climate change and environmental issues should be a priority to improve public health”

TO WHAT EXTENT DO YOU AGREE: THE COSTS OF THE DAMAGES DUE TO CLIMATE CHANGE ARE MUCH HIGHER THAN HE COSTS OF THE INVESTMENTS NEEDED TO MOVE TO A GREENER AND MORE SUSTAINABLE SOCIETY	
0. TOTALLY DISAGREE	9 2.3%
1. TEND TO DISAGREE	15 3.9%
2. NEITHER AGREE NOR DISAGREE	65 17%
3. TEND TO AGREE	109 28.5%
4. TOTALLY AGREE	185 48.3%

Table 9. Responses to question “to what extent do you agree: the costs of the damages due to climate change are much higher than he costs of the investments needed to move to a greener and more sustainable society”

TO WHAT EXTENT DO YOU AGREE: ADAPTING TO THE ADVERSE IMPACTS OF CLIMATE CHANGE CAN HAVE POSITIVE IMPACTS FOR CITIZENS IN THE UK	
0. TOTALLY DISAGREE	13 3.4%
1. TEND TO DISAGREE	22 5.7%
2. NEITHER AGREE NOR DISAGREE	80 20.9%
3. TEND TO AGREE	143 37.3%
4. TOTALLY AGREE	125 32.6%

Table 10. Responses to question “To what extent do you agree: Adapting to the adverse impacts of climate change can have positive impacts for citizens in the UK”

APPENDIX B.7 Results by Demographic

Table 1. Ranked criterion preferences by gender identity

CRITERION	MALE (N = 153)	FEMALE (N= 224)	PREFER NOT TO SAY (N = 6)
LIGHTING	1	1	5
OVERSEAS	2	2	1
CLOTHING	3	4	6
WASTE	5	3	3
HEAT	4	5	2
WATER	6	6	8
DOMESTIC TRANSPORT	7	7	4
APPLIANCES	8	8	7
DIET	9	9	9

CRITERION	RETIRED (N=49)	£5000 AND UNDER (N=5)	£5001 - £10000 (N=9)	£10001 - £17000 (N=27)	£17001 - £25000 (N=47)	£25001 - £35000 (N=59)	£35001 - £45000 (N=55)	£45001 - £60000 (N=58)	£60001 - £100000 (N=17)	£100001+ (N=17)
LIGHTING	1	2	2	3	2	1	1	1	1	1
OVERSEAS	4	1	1	1	1	2	3	4	6	7
CLOTHING	6	3	3	2	3	3	2	3	3	5
WASTE	3	6	7	4	5	5	4	2	4	2
HEAT	2	7	4	5	6	4	5	7	2	3
WATER	5	8	6	7	4	7	6	5	7	6
DOMESTIC TRANSPORT	7	5	5	6	7	6	7	6	5	4
APPLIANCES	8	4	9	8	9	9	8	8	8	9
DIET	9	9	8	9	8	8	9	9	9	8

Table 2. Ranked criterion preferences by income

Table 3. Ranked criterion preferences by household location

CRITERION	RURAL (N = 16)	URBAN (N = 191)	SUBURBAN (N = 176)
LIGHTING	1	1	1
OVERSEAS	3	2	2
CLOTHING	2	3	5
WASTE	4	4	3
HEAT	5	5	4
WATER	7	7	6
DOMESTIC TRANSPORT	6	6	7
APPLIANCES	8	8	8
DIET	9	9	9

Table 4. Ranked criterion preferences by disability status

CRITERION	**DISABILITY – YES (N = 130)**	**DISABILITY – NO (N = 253)**
LIGHTING	1	1
OVERSEAS	2	3
CLOTHING	3	2
WASTE	4	4
HEAT	5	5
WATER	6	6
DOMESTIC TRANSPORT	7	7
APPLIANCES	8	8
DIET	9	9

Table 5. Ranked criterion preferences by employment

CRITERION	EMPLOYED – FULL TIME (N = 123)	EMPLOYED – PART TIME (N = 46)	VOLUNTEERING (N = 5)	SELF EMPLOYED (N = 28)	RETIRED (N = 156)	UNEMPLOYED (N = 15)	FULL TIME STUDENT (N = 10)
LIGHTING	1	1	3	1	1	2	1
OVERSEAS	5	4	4	2	2	1	7
CLOTHING	2	3	6	3	4	3	4
WASTE	3	2	1	4	5	6	2
HEAT	4	6	2	5	6	5	3
WATER	7	7	5	7	3	8	6
DOMESTIC TRANSPORT	6	5	7	6	7	7	5
APPLIANCES	8	8	8	8	8	6	9
DIET	9	9	9	9	9	9	8

Table 6. Ranked criterion preferences by age category

CRITERION	18 – 24 (N = 5)	25 – 44 (N = 81)	45 – 64 (N = 158)	65+ (N = 139)
LIGHTING	1	1	1	2
OVERSEAS	7	6	2	1
CLOTHING	3	2	3	4
WASTE	2	3	5	5
HEAT	5	4	4	6
WATER	8	8	6	3
DOMESTIC TRANSPORT	4	5	7	7
APPLIANCES	9	9	8	8
DIET	3	7	9	9

Table 7. Ranked criterion preferences by response to question "Have you personally taken any action to fight climate change over the past six months?"

CRITERION	PERSONAL ACTION – YES (N = 291)	PERSONAL ACTION – N0 (N = 92)
LIGHTING	1	1
OVERSEAS	2	2
CLOTHING	3	4
WASTE	4	5
HEAT	5	3
WATER	6	6
DOMESTIC TRANSPORT	7	7
APPLIANCES	8	8
DIET	9	9

Table 8. Ranked criterion preferences by response to question “How serious a problem do you think climate change is at this moment?”

CRITERION	NOT A PROBLEM AT ALL (N = 4)	NOT A SERIOUS PROBLEM (N = 8)	A FAIRLY SERIOUS PROBLEM (N = 56)	A VERY SERIOUS PROBLEM (N = 117)	AN EXTREMELY SERIOUS PROBLEM (N= 198)
LIGHTING	1	3	1	1	1
OVERSEAS	3	7	5	2	2
CLOTHING	6	1	4	3	4
WASTE	2	2	3	4	3
HEAT	8	9	2	6	5
WATER	4	5	6	5	6
DOMESTIC TRANSPORT	5	8	7	7	7
APPLIANCES	7	4	8	8	8
DIET	9	9	9	9	9

Appendix B.8 K-Means Cluster Analysis

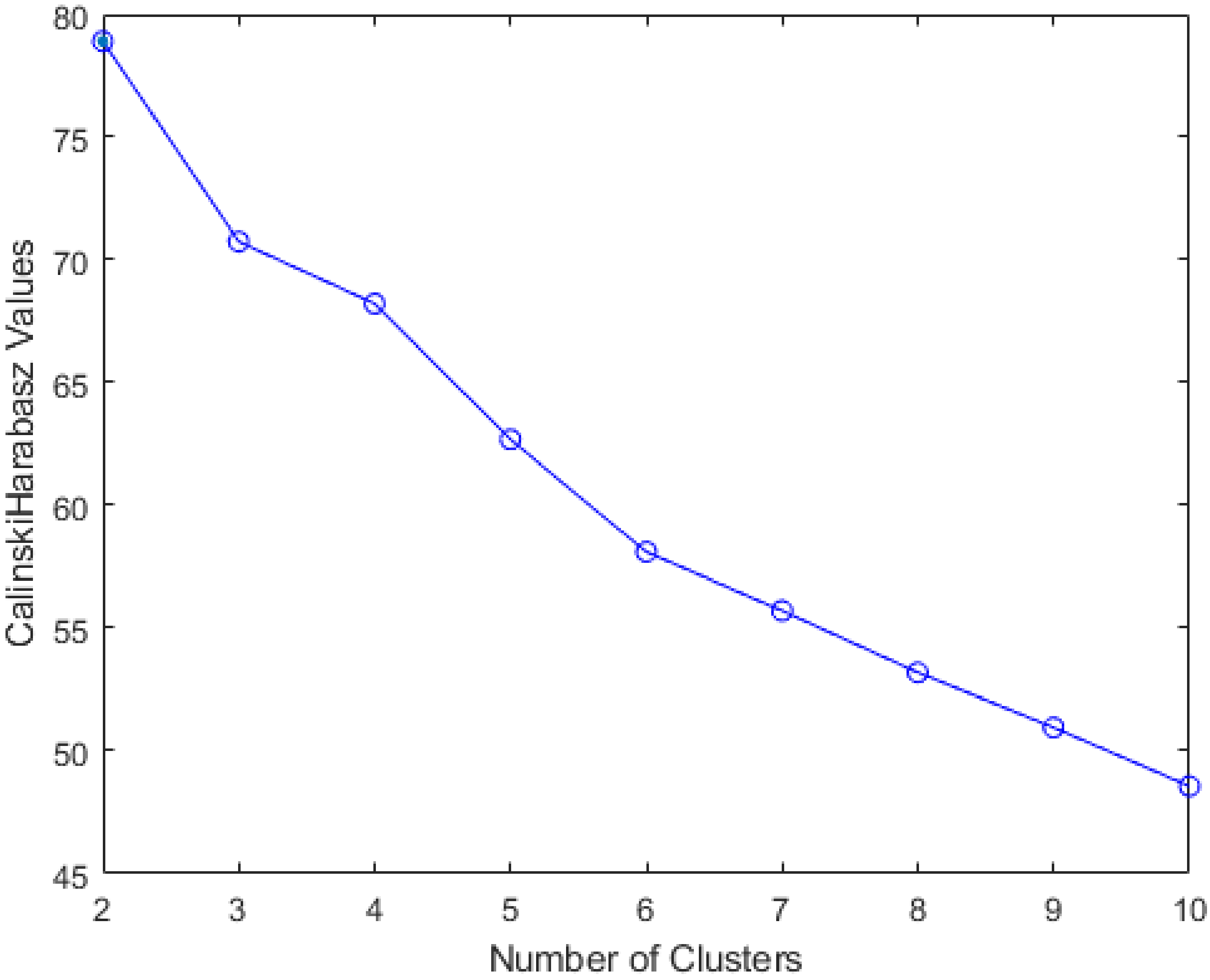


Figure 1. Calinski Harabasz Criterion Evaluation Values for clustering of preference data

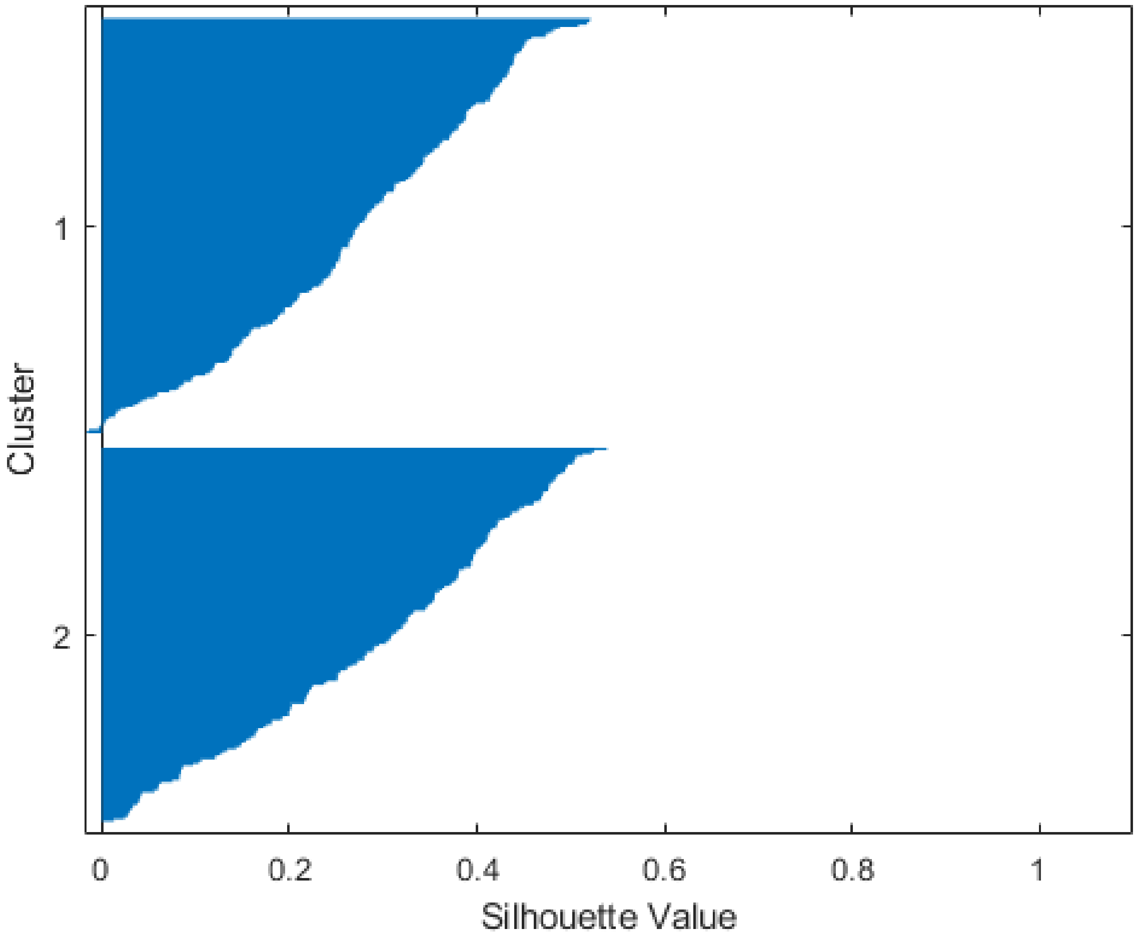


Figure 2. Eulucidian silhouette cluster graph for preference data

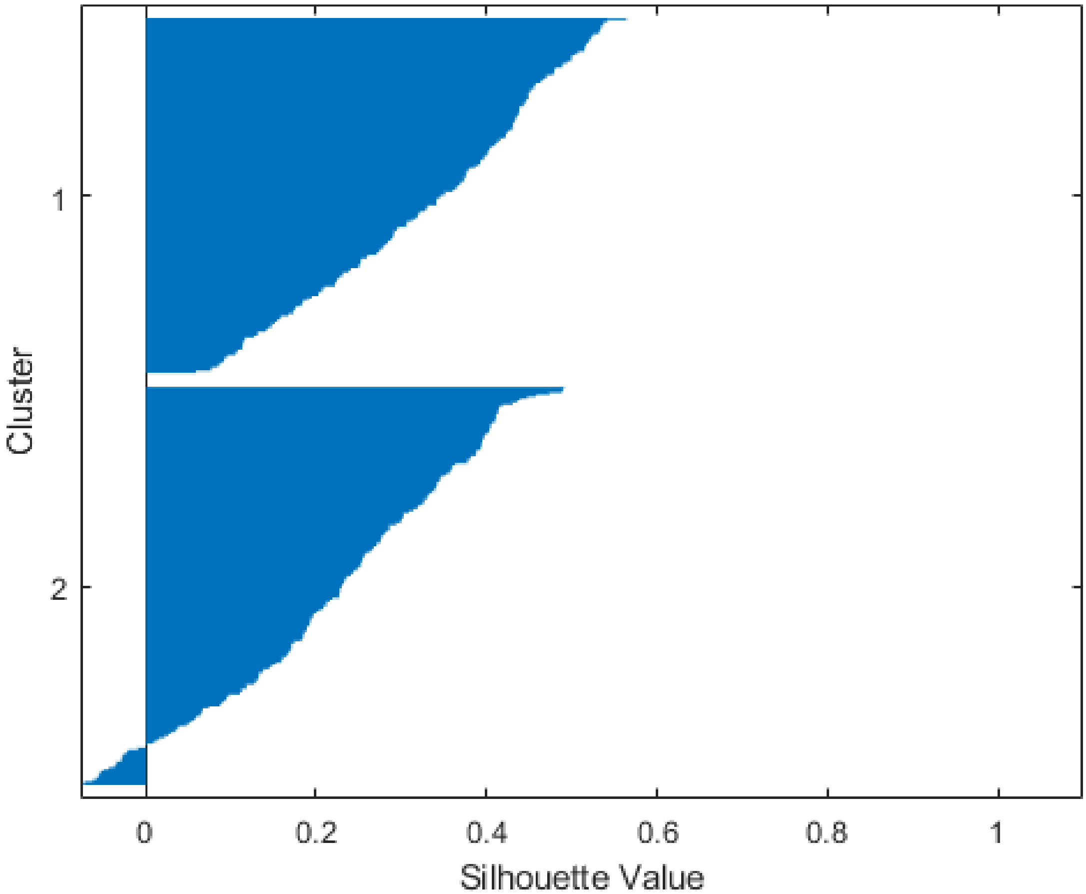


Figure 3. Cosine silhouette cluster graph for preference data

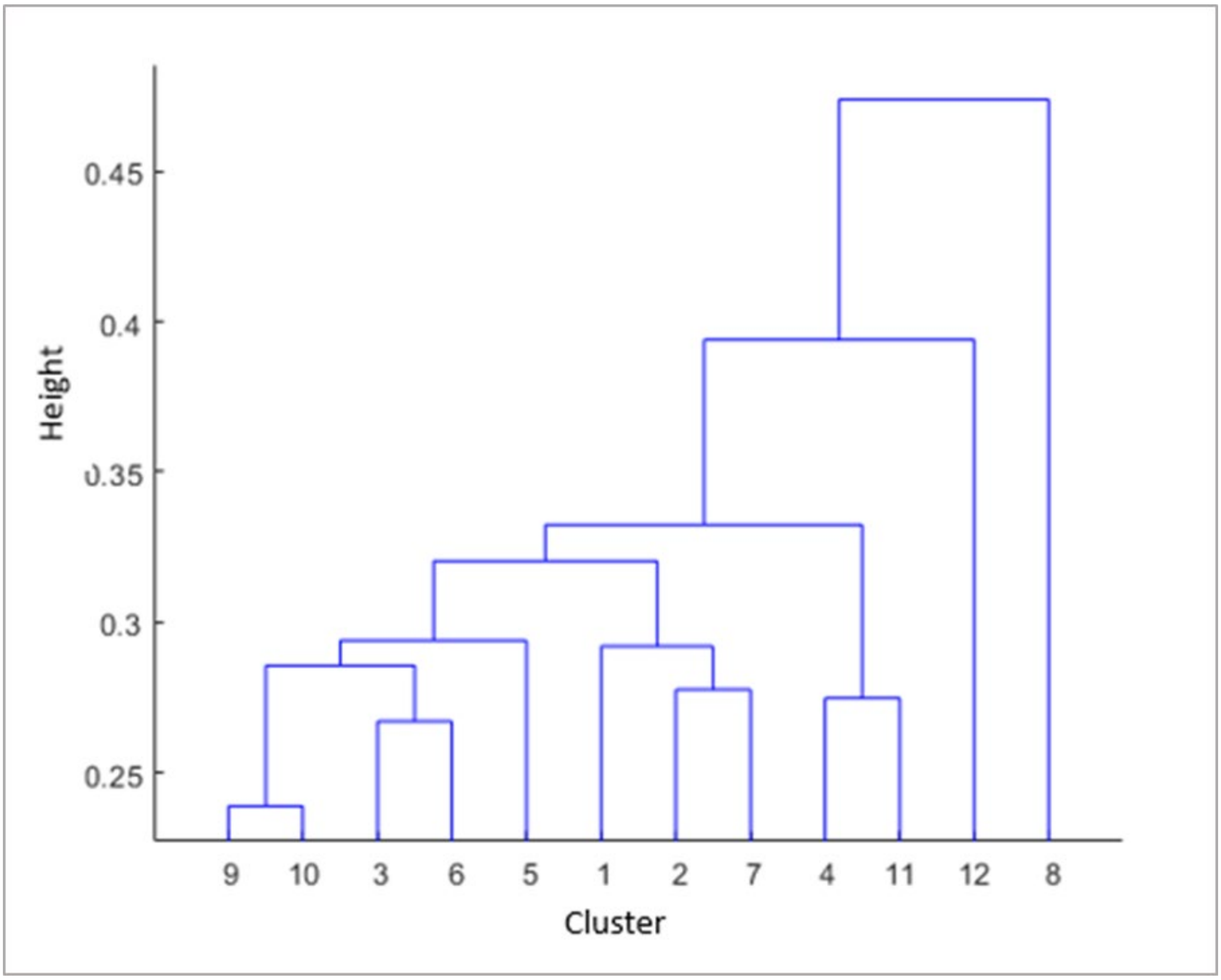


Figure 4. Hierarchical clustering dendrogram using cosine distance for public's part worth utilities, dendrogram truncated at 12 branches

Table 1. Clusters values for part worth utilities for two generated clusters

CLUSTER	LIGHT	OVERSEAS	CLOTHES	WASTE	HEAT	WATER	TRANSPORT	APPLIANCES	DIET
1	0.212785021	0.057098201	0.12653687	0.148224704	0.137597617	0.112363834	0.079385643	0.082869747	0.043138363
2	0.11417603	0.209023354	0.129195506	0.100504288	0.095799794	0.090724418	0.113621211	0.063974337	0.082981062

APPENDIX C: CHAPTER 5 SUPPLEMENTARY MATERIAL

Appendix C.1. Pre and Post Diary Study Survey

1. Student ID:

2. Degree Programme:

3. Rank these areas of daily life in order of which you believe are the most difficult for you to reduce related carbon emissions. 1 is the most difficult 6 the least difficult.

Personal Transport

Food Consumption

Waste Generation

Water Usage

Household Electrical Appliance Usage

Clothing Purchasing

4. Have you undertaken carbon reduction behaviour in the last 12 months?

Yes

No

Maybe

5. Who is most responsible for reducing carbon emissions?

Myself as an Individual

National Government

International Bodies

Regional and Local Government

Environmental Groups

Business and Industry

6. How serious a problem do you think climate change is at this moment?

Not a problem at all

Not a serious problem

A fairly serious problem

A very serious problem

An extremely serious problem

7. Complete this carbon calculator: https://footprint.wwf.org.uk/#/questionnaire record your footprint in the box below

8. Which of the following foods has the lowest carbon footprint?

Chicken

Beef

Pork

Tofu

Potatoes

9. Which of the following are impacts of climate change? Select all that apply.

Increased extreme weather

Rising sea levels

Increased global health risks

Loss of species diversity

10. How do you rate yourself in relation to the carbon emitted because of your current lifestyle? 0 is a low carbon lifestyle 5 is a high carbon lifestyle.

Carbon lifestyle 0 1 2 3 4 5

11. How do you rate yourself in terms of being able to reduce the carbon emitted as a result of your anticipated future lifestyle 0 is not being able to achieve a low carbon lifestyle, 5 is a high chance of achieving a low carbon lifestyle.

Achievement of low carbon lifestyle 0 1 2 3 4 5

Appendix C.2 Carbon Diary

Please fill this in daily for the allotted time period.

1. Student ID

2. What form/s of personal transport have you used today? Select all that apply

Train

Bus

Bicycle

Taxi

Walk

E-scooter

Car

Electrical bike

Aeroplane

Ship/ boat/ ferry

Other [participant can enter other option]

3. What has your diet been today?

Vegan

Vegetarian

Included fish (including shellfish)

Included red meat such as beef, lamb, and pork

Included white meat such as chicken

Included red and white meat

Included red meat, white meat, and fish (including shellfish)

4. What clothing have you purchased today?

No clothing purchases today

Second hand clothing purchased today (i.e charity shop, Depop)

Online clothing purchase

Instore clothing purchase

Other [participant can enter other option]

5. What has your water usage been today? Select all that apply

No shower or bath

Shower

Bath

Hose use

Dishwasher

Washing machine

Car wash

Water used for cooking/ food preparation

Washing up (by hand)

Other [participant can enter other option]

6. What waste have you generated today? Select all that apply

Single use plastic (i.e plastic bottles, crisp packets) – recycled

Single use plastic (i.e plastic bottles, crisp packets) - not recycled

Paper/ card/ glass/ metal such as drinks cans and food tins – recycled

Paper/ card/ glass/ metal such as drinks cans and food tins - not recycled

Electrical and electronic waste (i.e batteries, vapes, headphones) - disposed of to general waste

Electrical and electronic waste (i.e batteries, vapes, headphones) - disposed of to battery recycle point/ take back scheme or household waste centre

Food waste

Textiles

Garden waste

Waste from DIY

Other [participant can enter other option]

7. What household electrical appliances have you used today? Select all that apply

Lighting

Laptop/ tablet

Mobile phone

Large appliances (i.e fridge, freezer, electrical cooker)

Electrical heating

Television

Air fryer/ slow cooker

Electrical shower

Game console (i.e PlayStation or Switch)

Personal grooming items (i.e hairdryer)

PC and monitor

Other [participant can enter other option]

8. How difficult did you find making sustainable choices today? Rate difficulty, 0 is easy 5 is difficult

Difficulty 0 1 2 3 4 5

9. What barriers, challenges or positive experiences have you encountered today when attempting to make sustainable choices today?

[Short answer]

Appendix C.3 Pre and Post Survey Results

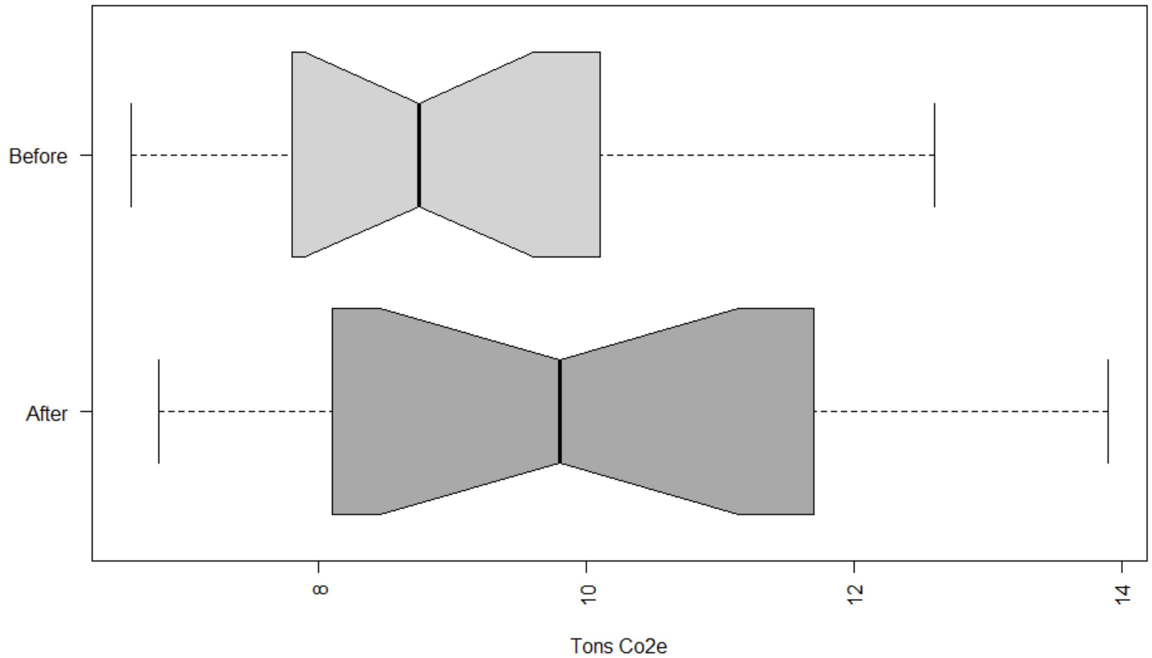


Figure 1a. Boxplot of participants carbon footprints for participants whose carbon footprint was self-reported to have increased from the pre- survey to the post-survey.

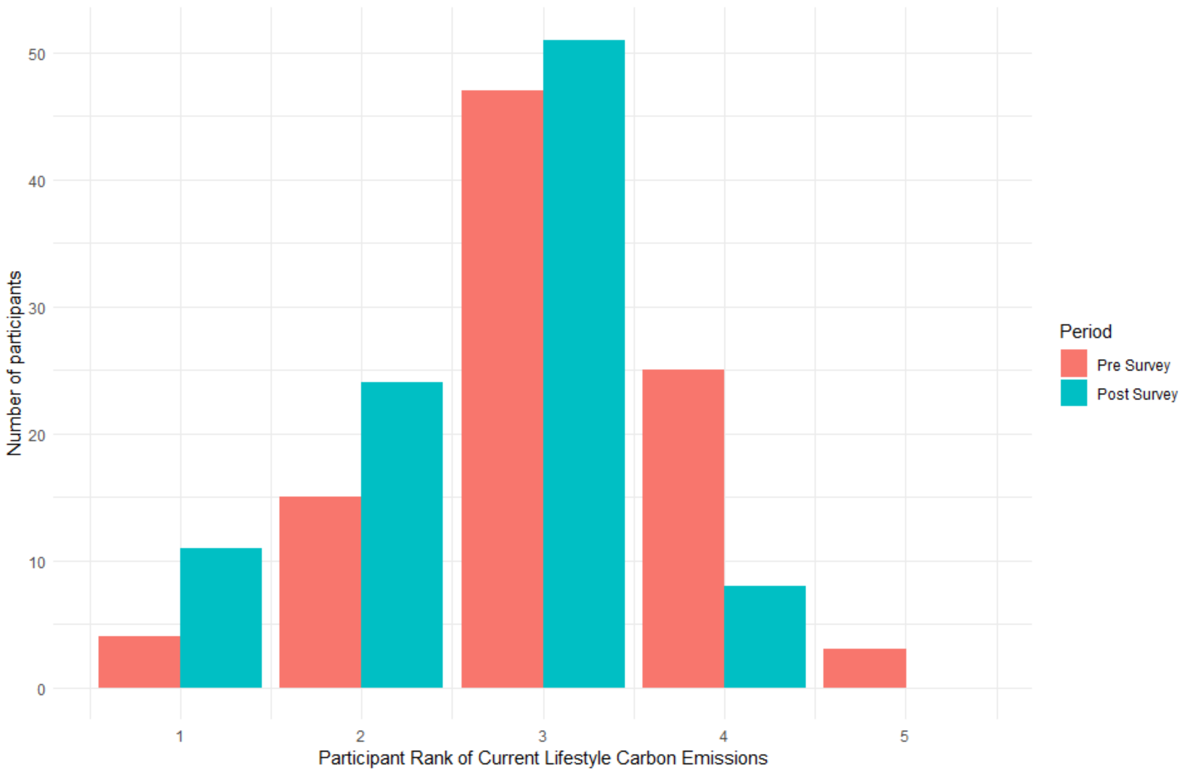


Figure 1b. Bar chart of participants self-reported rank of the carbon emissions and intensity of their current lifestyle before and after the study. 1 is lowest impact 5 is highest.

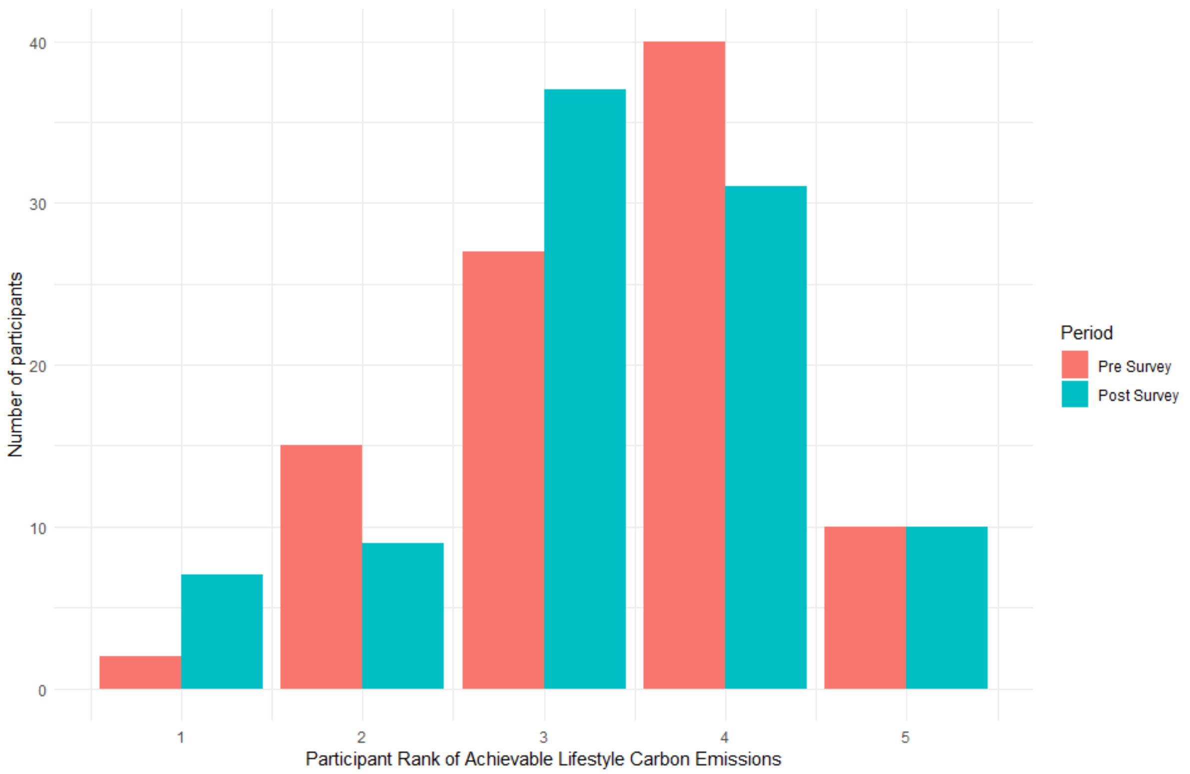


Figure 1c. Bar chart of participants self-reported rank of how achievable a low carbon lifestyle before and after the study. 1 is lowest impact 5 is highest.

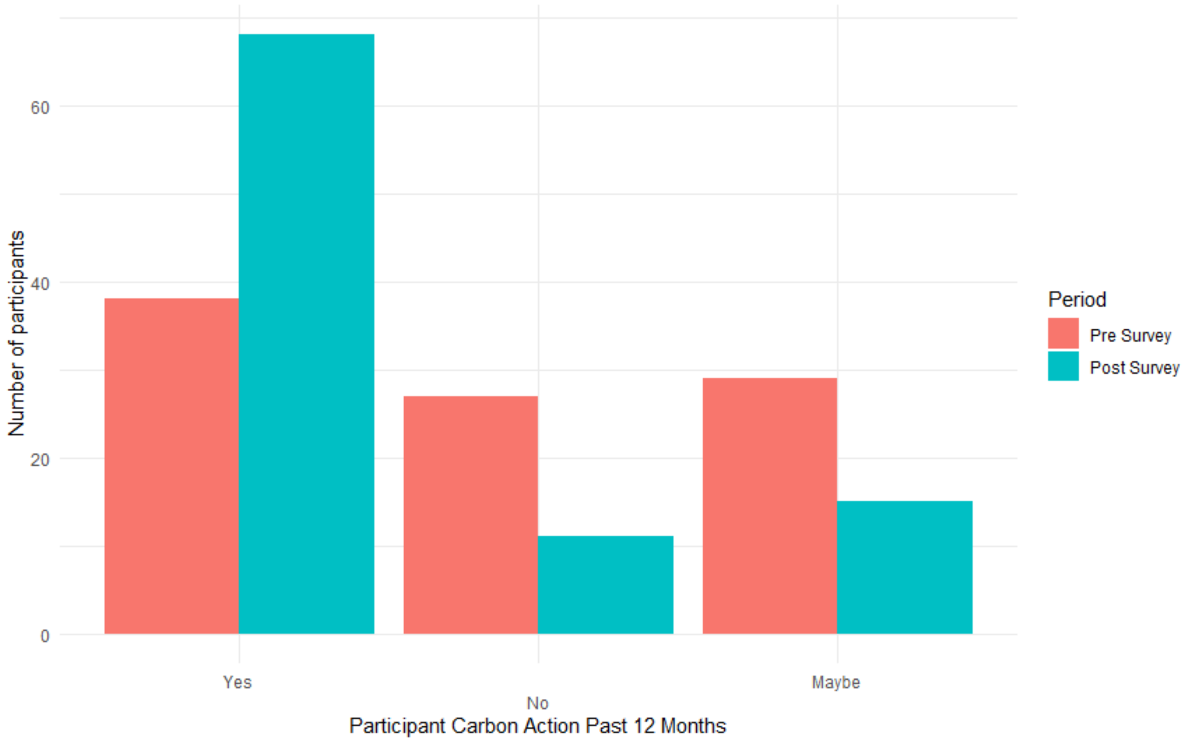


Figure 1d. Bar chart showing participant's responses to if they had taken action to reduce their carbon emissions in the past 12 months.

Appendix C.4 Quantitative Carbon Diary Results

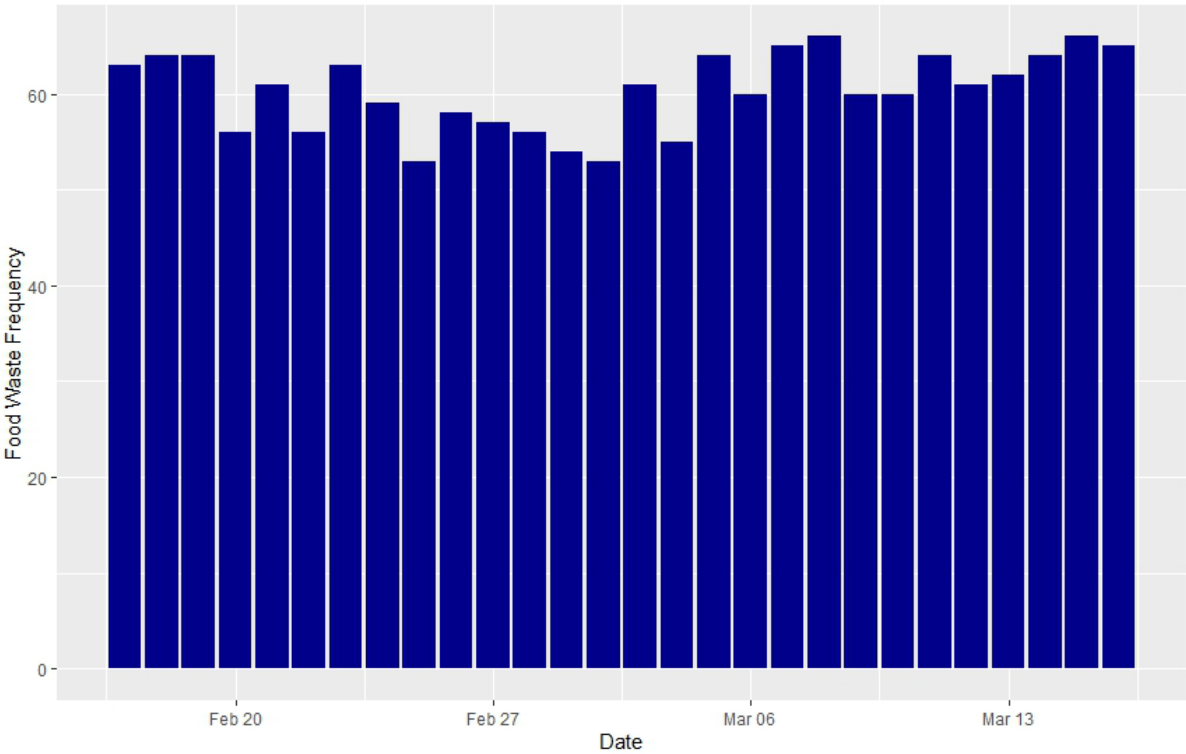


Figure 2a. Bar chart of number of participants throwing away food waste across diary period.

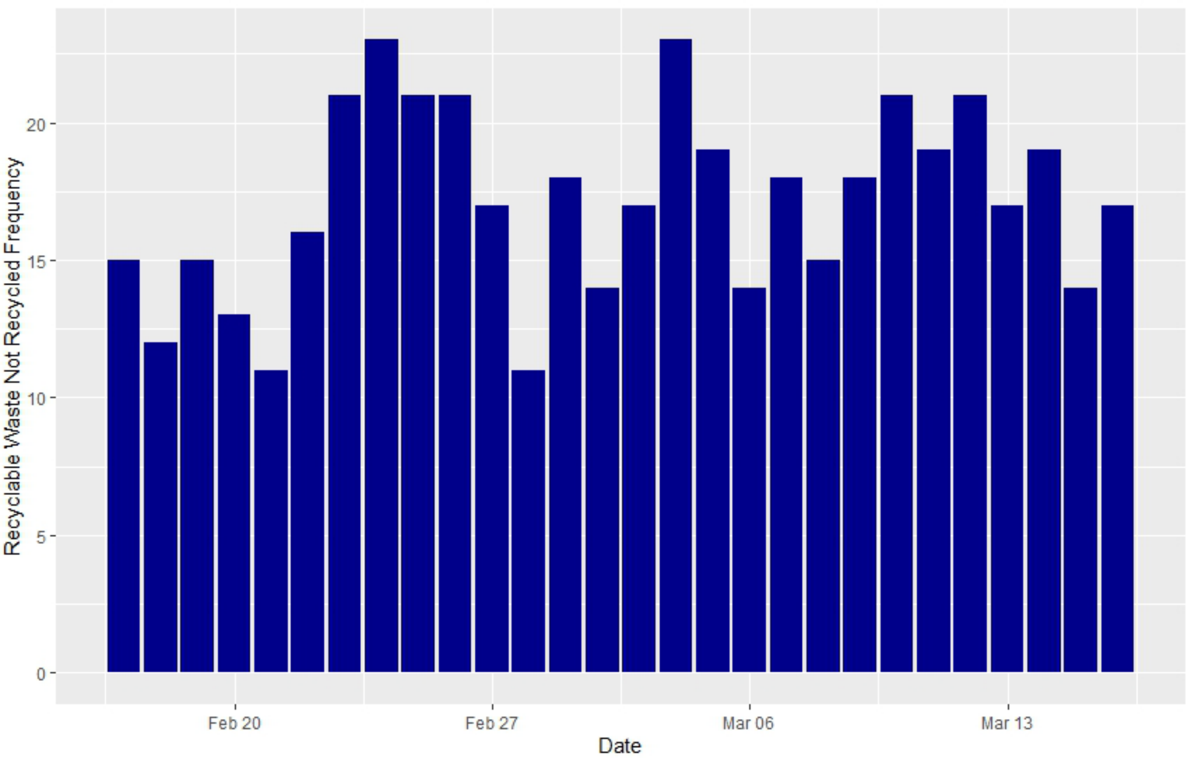


Figure 2b. Bar chart of number of participants throwing away non-recyclable waste across diary period.

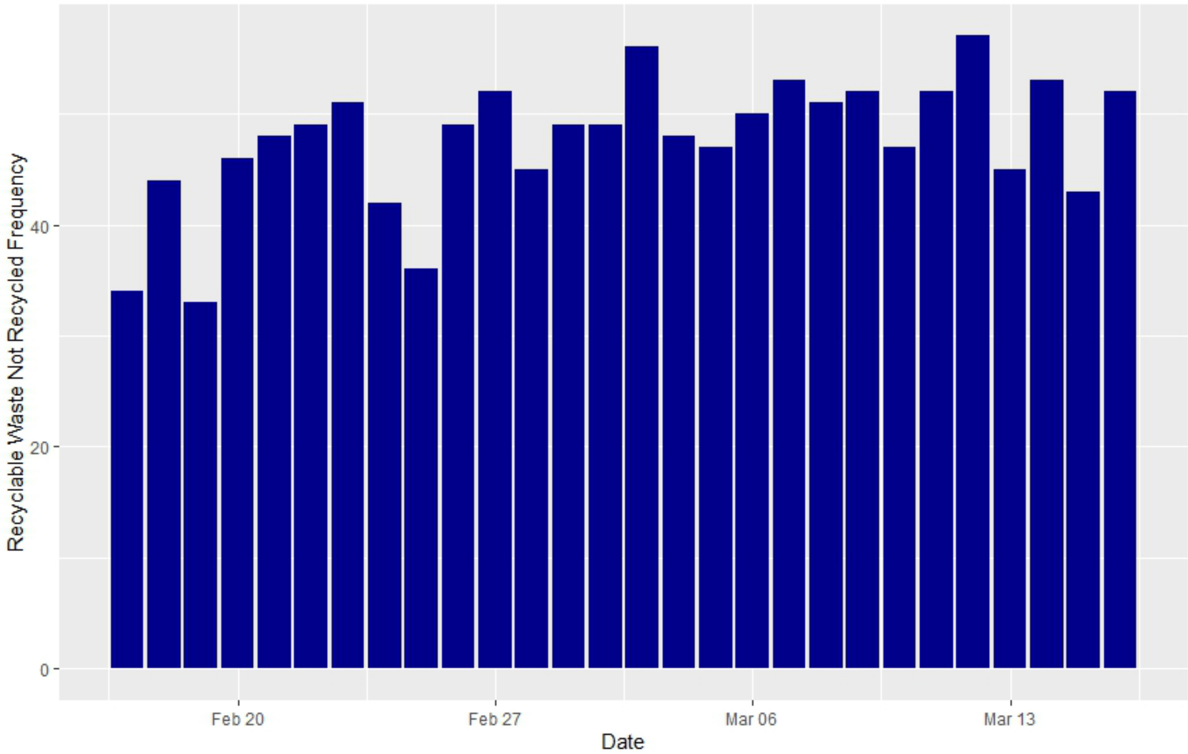


Figure 2b. Bar chart of number of participants throwing away recyclable waste across diary period.

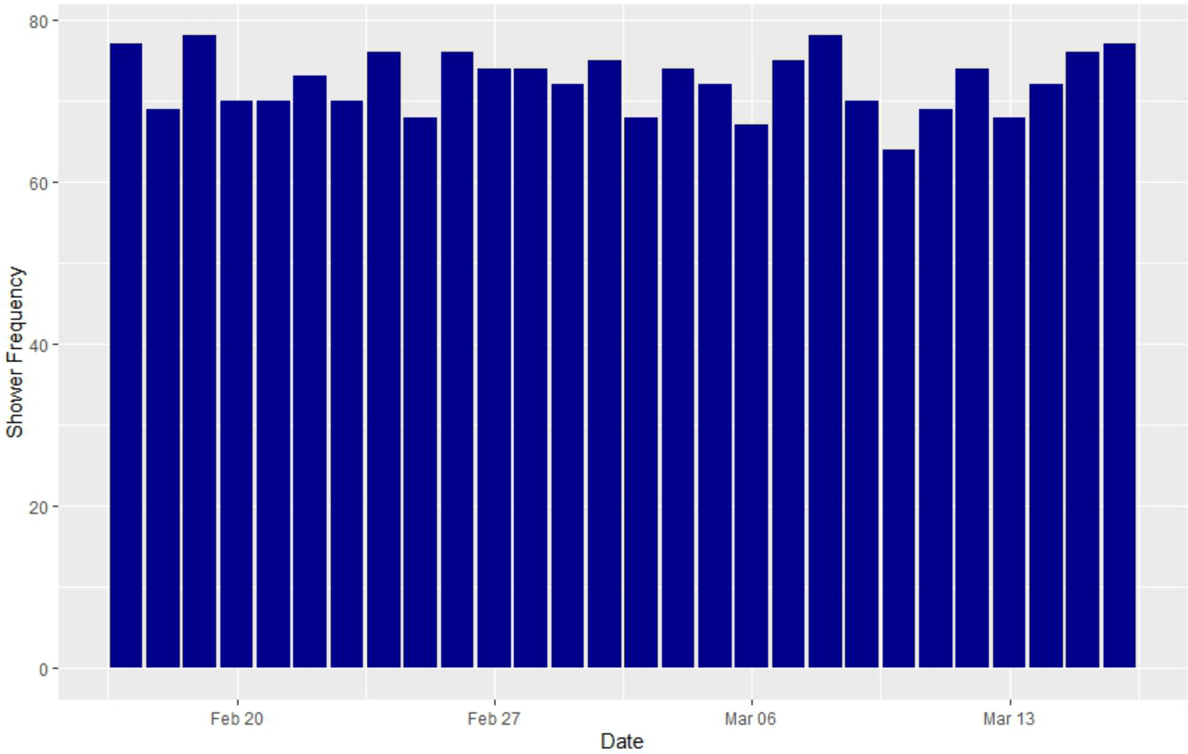


Figure 2c. Number of participants showering daily across diary period.

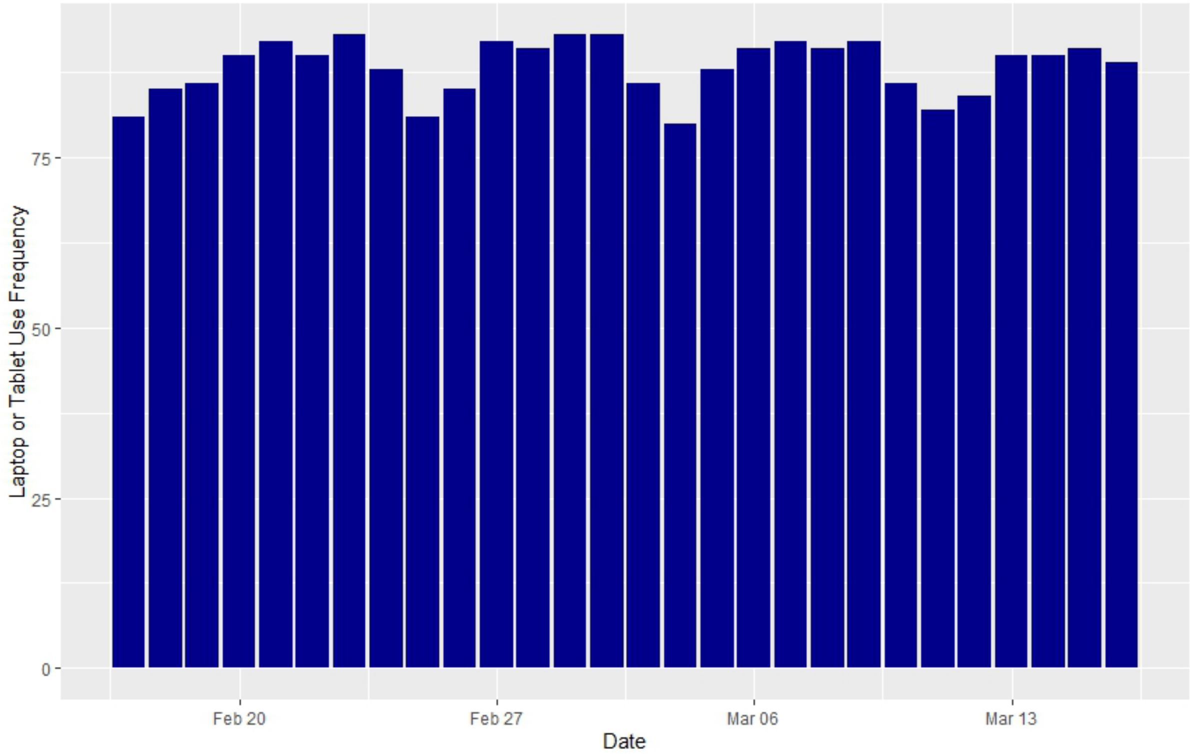


Figure 2d. Bar chart showing laptop or tablet daily use across diary period.

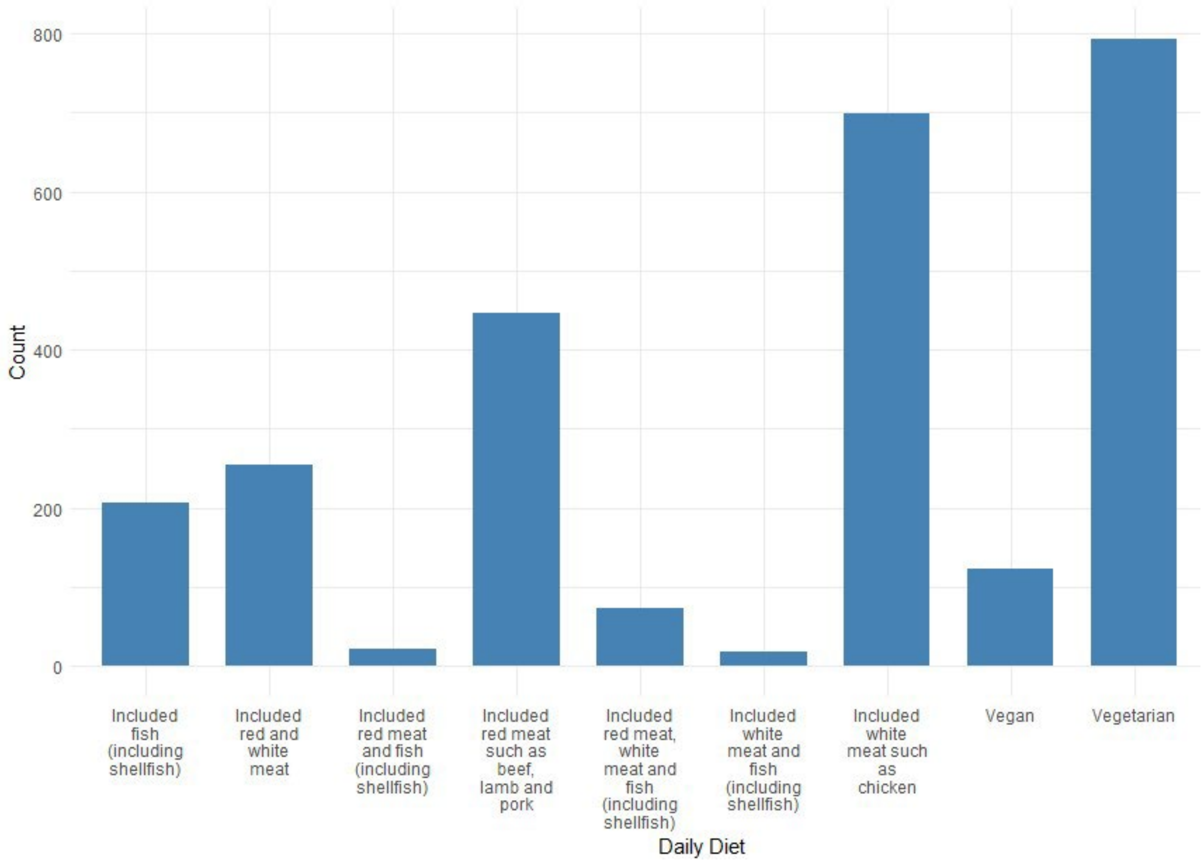


Figure 2e. Bar chart showing frequency of diet types during diary period.

Appendix C.5 Qualitative Carbon Diary Coded to Quantitative Data Examples

Table 3a. Examples from 'Need for protein in diet' theme

Theme	Examples
Need for protein in diet	"... it's important for me to get protein into my diet hence why I ate both fish and red meat" " My diet which requires protein" " I find it hard to get protein sources that are not meat as I don't particularly enjoy vegetarian meals/haven't come across vegetarian meals that make me want to have them. I'm also considered somewhat of a fussy eater so that doesn't help when trying to find protein packed vegetarian meal" " When working out, it becomes harder to limit consumption of meat and fish as they are such convenient protein sources" " I could eat food that aren't meat but still has protein, but I don't want to change"

Table 3b. Examples from 'Convenience of choices theme

Theme	Examples
Convenience of choices	" Not having time to cook so having to grab lunch with single use plastic." " My main barrier from today was I was in a for labs, so I didn't get the usual time to meal prep and had to buy packaged food instead." " it is hard to make sustainable choices in a group situation/when with friends" " my lifestyle doesn't allow me to be sustainable currently." " Poor weather meant it was most convenient to drive" " I took a car to campus as I didn't want to walk, it isn't sustainable, but it was convenient at the time"

Table 3c. Examples from ‘Making conscious changes and adaptations to reduce emissions theme

Theme	Examples
Making conscious changes and adaptations to reduce emissions	“ I have found it very easy to cut beef out of my diet over the last year in an attempt to reduce my environmental impact” “ I was quite conscious of how long I was spending in the shower and tried to shorten the length of time I spent.” “ I decided to wash up rather than using the dishwasher and I decided to walk home after night out rather than getting an uber (taxi).” “ I walked to the shops instead of getting the bus and used bags for life I brought from home instead of buying bags at the shop.” “ Went to a party and got a bus instead of car lift both ways - less emissions”

Table 3d. Examples from ‘Financial concerns ‘theme

Theme	Examples
Financial Concerns	“ Using my car to get into town was the cheaper and faster option” “I bought a pair of gym leggings from Amazon as I don’t have the money to buy them from a ‘sustainable’ clothing shop.” “I had to travel in the car today (carshare) because I had no money for the train.” “Chose to travel by car instead of bus to save money” “I got a pizza from the supermarket for dinner - only the pepperoni option was reduced, and although I do always try to choose the vegetarian option, it is difficult when the decision is influenced by money”

Table 3e. Examples from ‘Consumption for mental and physical health’ theme

Theme	Examples
Consumption for mental and physical health	“ Was feeling stressed with uni work so went shopping. It was challenging to be sustainable as unfortunately buying new items can help lift my mood sometimes” “What i did learn was that if not in the right mental state sustainable choices become increasingly harder, therefore moving forward i believe mental health should be taken into account with sustainable living”

Table 3f. Examples from ‘Guilt related to behavioural choices’ theme

Theme	Examples
Guilt related to behavioural choices	“The main challenge I face is the guilt of eating meat (even though I need to eat meat due to health requirements), to combat this I often buy meats that are going off (on offer in shops and would be thrown away if not bought).” “Ate red meat and felt guilty about it, becoming a lot more accountable for my actions and thinking more about sustainable choices” “took 2 Ubers today to city centre as it was way too cold to wait for the bus. felt a bit guilty but i was freezing” “Understood the impacts of my choices, chose to eat meat, guilt” “...felt guilty for continue to drive a lot of places” “The gym tired me out a bit too much so I chose to get the bus to and from Sainsburys. This is only a 5-10minute ride, but my legs really hurt. I felt guilty as I knew I was being lazy”

Table 3f. Examples from 'Awareness and knowledge of sustainability and climate change' theme

Theme	Examples
Awareness and knowledge of sustainability and climate change	" Charity shopping allowed me to give a second home to clothes and contribute less to the fast fashion industry" "… better to travel by public transport than by car" ". I have actively tried not to be buying clothes this past month for this carbon diary, having been revealed the environmental negative impacts it has in my lectures."

Table 3g. Examples from 'Pride in choices made' theme

Theme	Examples
Pride in choices made	" When I went out to get coffee, I bought my re-usable cup!" "I've been making efforts to use things, such as eggshells for soil and making freezer bags of vegetable scraps for stocky, which I am proud of." "Besides the takeout, I ate 100% vegan the rest of the day, which I am very pleased and proud about." "I was able to eat a fully vegetarian diet today, for the first time, which I was proud of." "I am happy that I have yet to purchase any clothing since starting this carbon footprint diary."

Appendix C.6 Qualitative Data Theme Examples

Table 4a. Examples from 'Barriers and Challenges – expressions of general barriers and challenges experienced' theme

Theme	Examples
Barriers and Challenges – expressions of general barriers and challenges experienced	"However, a lot of Aldi-packaged products are still unable to be recycled, hence my high level of non-recycled plastic waste. Although my waste generation has led to high carbon emissions, I believe this is primarily as a result of systemic barriers as opposed to my attitude." "...on a few of the days I found my mental drive to make positive change was reduced, leading to quite negative thoughts about my ability to make a difference. I believe this was because when considering climate change, it is a vast challenge that I have limited control over." "...Southampton City Council does not offer a food compost service, so all food goes in the general waste." "...my behaviours have demonstrated reluctance to change. Often this is due to a lack of money or knowledge, or a requirement to fulfil my own needs." "...I found that it became increasingly difficult to make sustainable choices.... I believe I started strong and tried my best, but slowly the motivation wore off."

Table 4b. Examples from 'Electrical Appliance Use – reasoning for usage trends' theme

Theme	Examples
Electrical Appliance Use – reasoning for usage trends	"These appliances are a fundamental part of most people's daily lives..." "Appliance and Energy use was another aspect of my carbon behaviours that I found surprising and the most challenging to make changes to." "Realistically however in this Fourth Industrial Revolution, the use and demand of electrical appliances will only increase as time goes on and people won't be able to cut down its use of their own volition, as soon everything will include tech." "As a university student electrical appliances are used daily. I am using a laptop to write this reflection article"

Table 4c. Examples from 'Transport – choices around transport provision and transport decisions' theme

Theme	Examples
Transport – choices around transport provision and transport decisions	"...often used the car to drive to the gym and for food shopping, preferring the convenience of the car over other options. I made little effort to change this behaviour..." "...the health and well-being benefit of walking encouraged this behaviour." "On reflection, there is still a large amount that could be done with regards to personal travel to improve carbon impact, especially looking at overseas travel." "Expense of transport has also been a challenge that I have experienced; getting the train home from university costs approximately double the price of a flight that I recently booked to France." "Although the more sustainable option would be to walk or get the bus, neither are feasible. For a matter of safety, I will not walk back home from town as Southampton can be unsafe for women at night."

Table 4d. Examples from 'Benefits – any benefits identified by the participant based on their own perception of a benefit' theme

Theme	Examples
Benefits – any benefits identified by the participant based on their own perception of a benefit	" I believe that overall, I had a positive experience as I was able to visualise my progress and make changes in my routine even if they were small" " Positives of this assignment were spreading awareness on sustainability with friends who do not take this module." " In conclusion, this personal carbon emissions diary has been a valuable exercise in raising awareness about my daily habits and their impact on the environment."

Table 4e. Examples from 'Behaviour Change – statements about actively changing a behaviour and their experience of doing so' theme

Theme	Examples
Behaviour Change – statements about actively changing a behaviour and their experience of doing so	" However, I consciously limited shower times both in consideration of the environment..." " Furthermore, I found that when the weather improved, I did not consider other transport to walking. Whereas, deciding to walk in the rain was because I was determined to use the most sustainable method available for the survey." " I also adopted new positive behaviours, for the first time I took recycling to in-store dropoffs and held onto waste to dispose of it correctly. I always use a reusable water bottle and make sure to consume leftover food." " Throughout this 28 day period my behaviours towards carbon emissions have changed. The key reason for behavioural change has been due to being able to reflect and record my carbon behaviours in real time." " During the day I made changes solely because I didn't want to put it in my diary, making me question why I was making these changes and why I hadn't made them before."

Table 4f. Examples from 'Opinion Change – stated changes in opinion on aspects of reducing their own carbon emissions' theme

Theme	Examples
Opinion Change – stated changes in opinion on aspects of reducing their own carbon emissions	"Despite meat consumption being an issue I was aware of as someone interested in the climate crisis, it took this reflection on myself to spark change." "To conclude, this survey improved my understanding of sustainability and how I can live an improved lifestyle. I also believe it has changed my mindset and made me more determined to make positive changes" "After completing this diary, my views towards areas to change for sustainable living has pivoted to a broader view of how to improve."

Table 4g. Examples from 'Knowledge Gain – identification of knowledge gained through the diary period' theme

Theme	Examples
Knowledge Gain – identification of knowledge gained through the diary period	"However, my action was amplified after the lecture on diets, my qualitative recording on that day was; "I am let down by meat consumption which was further enforced through the lecture" " I read an article on water and energy consumption in washing up and was quite shocked to realise that hand washing items can use greater than 10 times the water, and twice the energy of a dishwasher" "The train was used for traveling longer distances, as train approximately uses 60% less carbon emissions per km than a bus"

Table 4h. Examples from 'Responsibility – statements or feelings on who is responsible for reducing carbon emissions' theme

Theme	Examples
Responsibility – statements or feelings on who is responsible for reducing carbon emissions	"In conclusion, this personal carbon emissions diary has been a valuable exercise in raising awareness about my daily habits and their impact on the environment." "Some factors listed in the survey are out of the control of the participant as they rent the property in which they reside." "

Table 4i. Examples from Self-Justification – the reasoning given for their behaviours particularly those self-identified as 'bad' in terms of carbon emissions' theme

Theme	Examples
Self-Justification – the reasoning given for their behaviours particularly those self-identified as 'bad' in terms of carbon emissions	"In addition to this, nights out also lead me to take buses or Ubers, as compromising my health and safety to be more sustainable seemed ill-advised, as alcohol reduces a person's ability to make correct judgements and act fast, causing numerous road risks if walking." "Reducing the use of transport further would be immensely difficult and would require sacrificing either large amounts of time or activities I undertake, many of which I cannot avoid doing."

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