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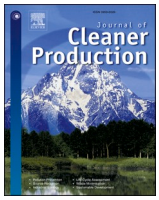

"I'll take the easiest option please". Carbon reduction preferences of the public

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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 relatively 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 relatively low influence over preferences with trends generally 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.

1. 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, 2018; United Nations Environment Programme, 2020). Since we have caused global climate change, human behaviour has a fundamental role in countering it. A large 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 Committee on Climate Change, 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 (IPCC), 2018; Sanderson et al., 2016; United Nations Environment Programme, 2020). 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

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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., 2020; 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; 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 largely due to household heating and traveling. 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; Larson, 2019; 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; 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 relatively 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.

2. Methods

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 universities 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 and attitudes and opinions

2.1. 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 2.2.). Demographic data were gathered to allow for clustering and analysis of preferences. Following this section, participants responded to a conjoint analysis survey before a final 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 (Guy and Norvell, 2010; 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 Comission, 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 ~3500 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. PAPRIKA METHOD.

The PAPRIKA is a relatively 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 Fig. 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 a high 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 Fig. 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.

In Fig. 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 as seen in appendix 1C. 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.

2.2. 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 1A). 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

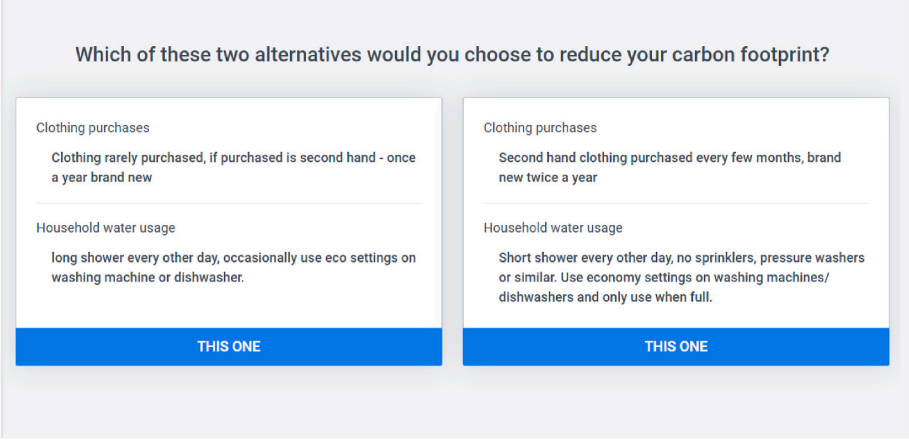

Fig. 1. Example of pairwise choices presented to participants in 1000Minds software survey.

'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 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).

2.3. 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 different 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 1C) (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; National Records of Scotland; Northern Ireland Statistics and Research Agency, 2016; Office for National Statistics, 2012). Not all UK Census and ONS demographic questions were included for brevity, justifications for demographics chosen can be found in Appendix 1B.

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

Table 1
Table showing the nine selected criteria, description of criteria and justification for selection. Each criteria 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., 2013; 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; Hyland et al., 2017; Ivanova et al., 2016; Sabaté and Soret, 2014; Scarborough et al., 2014) - Plant based diets have significantly lower emissions than high meat or 'average' diets (Chai et al., 2019; Scarborough et al., 2014) - 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, 2018; Ritchie, 2019; Scarborough et al., 2014; WRAP, 2016) - 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, 2018; 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 Stratergy, 2020; McDowall and Britchfield, 2021).
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)

(*continued on next page*)

Table 1 (*continued*)

CRITERION	DESCRIPTION	JUSTIFICATION
		- Estimated to contribute to 6% of UK household electricity usage (Department for Business, 2022; Energy Saving Trust, 2022; Preston et al., 2013)
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% and 10% of global emissions, estimates vary considerably but anticipated to grow (Ivanova et al., 2016; 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

- Home ownership
- House size
- Household heating method
- Car ownership
- Employment status

2.4. 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; Martelli et al., 2016; Steinley, 2004). K-Means clustering is a centroid model of clustering, each case of weighted preference data for each criteria 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.

3. 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.

3.1. Preference 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 2 and Fig. 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 ($df = 8$, $p = 0.000$ ($p = 2.2e\text{-}16$)).

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.

Fig. 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.

Fig. 3 shows the density of weights by the public for each criteria 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.

Table 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 criterion.

	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 Use ! 0.4%	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 Use 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	0.6	

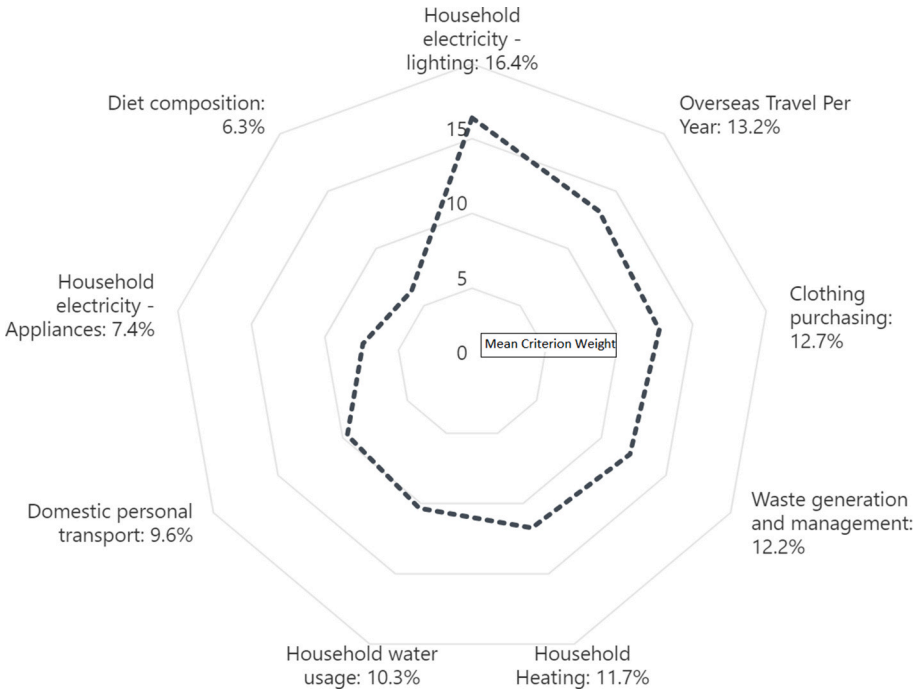

Fig. 2. Spider chart of criterion weights, each axis represents a carbon emission reduction criterion with the mean weight of the criterion reported alongside it.

3.2. Self reported personal factors

As demonstrated in participant responses to questions in Appendix 2A, participants generally 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

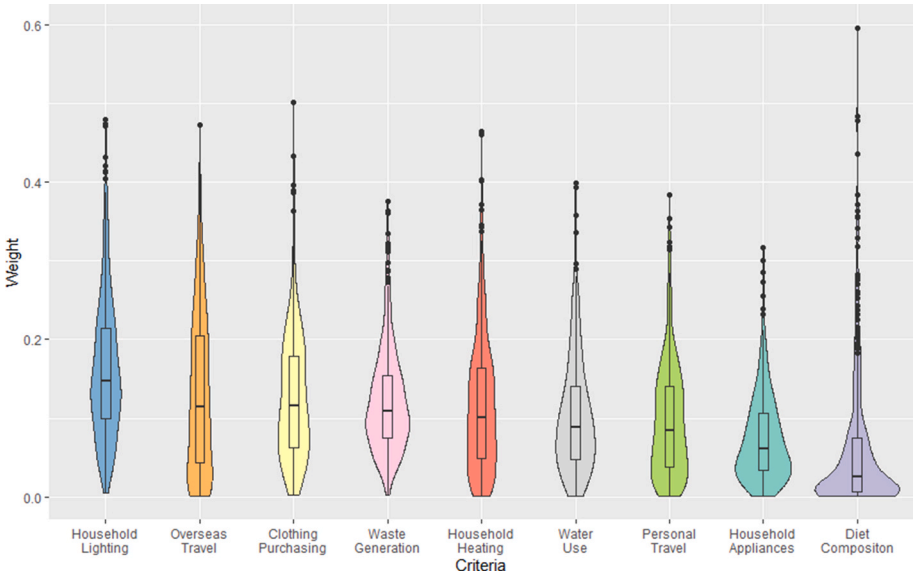

Fig. 3. Violin plots with overlaid box plots for weight of each criteria by the public identifying distribution of weights across participants, boxplot shows median.

such as 'agree' or 'strongly agree' as seen in Table 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 2A).

Table 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).

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 taking action. 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. 54% (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 somewhat 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.

Table 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
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%

3.3. *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. Fig. 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.

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. Relatively 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 4B). 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. 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 4A); 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 4A); 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 4B). To analyse the separation of these clusters, Euclidean and Cosine distance silhouette plots were generated (see Appendix 4A). The average silhouette values were not high indicating the clusters might not be particularly distinct (Yuan and Yang, 2019). This is likely 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 5.

Cluster 1 prioritises lighting, waste, and heating; these are all largely household-focused changes to make and are behaviours that would be undertaken each day i.e. lower heating, less waste generation. Cluster 2

Table 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

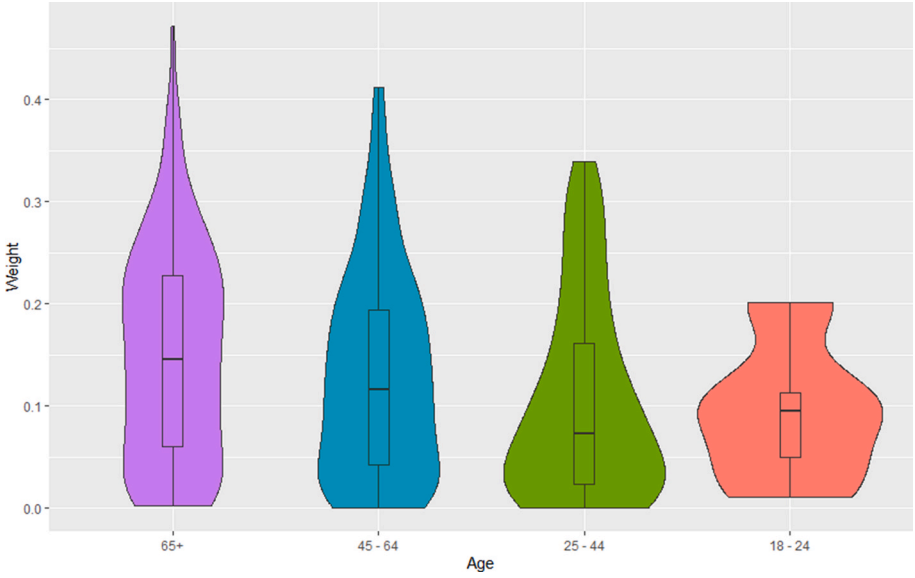

Fig. 4. Violin plots with overlaid box plots for weight of overseas travel by the public by age identifying distribution of weights across participants, boxplot shows median.

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 4 B. 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. 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, 2020b; 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 0.6–1 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 (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% and 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 and 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 most likely be individuals who had already made changes to their diet. Fig. 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, probably 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 largely 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 taken action 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 Stratergy, 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, 2018; Shaw, 2008). However, relying on the actions of others to influence behaviour means there must be some individuals perpetuating those behaviours, and that is largely 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; 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. (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.

5. 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 little 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 relatively 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 generally believed to be more well informed on the breadth of the crisis, but their preferences largely 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 high 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?

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CRediT authorship contribution statement

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.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix 1

Appendix 1A. 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 1B. 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	Indicators of socioeconomic class – taken from census
Level of education	
Level of education of parents	
Home ownership	
House size	
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., 2016; Kenny and Gray, 2009; McDowall and Britchfield, 2021)
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, 2020; Hou et al., 2022; Laakso, 2017; Long et al., 2020; Vasic and Weilenmann, 2006; Walsh et al., 2008)
Employment status	May have different priorities i.e daily transport if employed (Yang et al., 2018)

Appendix 1C. 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 - £10,000
- £10,000 - £17,000
- £17,001 - £25,000
- £25,001 - £35,000
- £35,001 - £45,000
- £45,001 - £60,000
- £60,000 - £100,000
- £100,001+

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 1D. Criteria Levels Descriptions

Table 1
Level descriptors of Household Heating Energy Use criterion

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 2
Level descriptors Of Household Electricity – Appliances 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 3
Level descriptors of Household Water Use criterion

HOUSEHOLD WATER USE	
level rank (worst to best)	LEVEL DESCRIPTION
1	Daily long shower (10 min or longer) or daily bath
2	Daily shower (up to 10 min) or Frequent bath
3	Daily shower (up to 5 min) or Infrequent bath
4	Shower every other day (or less) never bath or only when absolutely necessary

Table 4
Level descriptors of Domestic Personal Transport 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 5
Level descriptors of Overseas Travel Frequency Per Year 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 6
Level descriptors of Diet Composition 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 7
Level descriptors of Clothing Purchases Per Year 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 8
Level descriptors of Waste Generation and Management 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 9
Level descriptors of Household Electricity - Lighting 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

Appendix 1E. 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 2

Appendix 2A. Attitude and Behaviour Results

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

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 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)"

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 2a
Responses to question "Do you think products should have labels indicating their carbon footprint?"

Do you think products should have labels indicating their carbon footprint?	
yes	359 94.5%
no	21 5.5%

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 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 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?"

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 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."

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

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

Have you personally taken any action to fight climate change over the past six months?	
yes	291
	76%
no	92
	24%

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: 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 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: 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 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"

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%

Appendix 3

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

Table 2
Ranked criterion preferences by income

Criterion	Retired (n = 49)	£5000 and under (n = 5)	£5001-£10,000 (n = 9)	£10,001 - £17,000 (n = 27)	£17,001 - £25,000 (n = 47)	£25,001 - £35,000 (n = 59)	£35,001 - £45,000 (n = 55)	£45,001 - £60,000 (n = 58)	£60,001 - £100,000 (n = 17)	£100,001+ (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 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 4

Appendix 4A

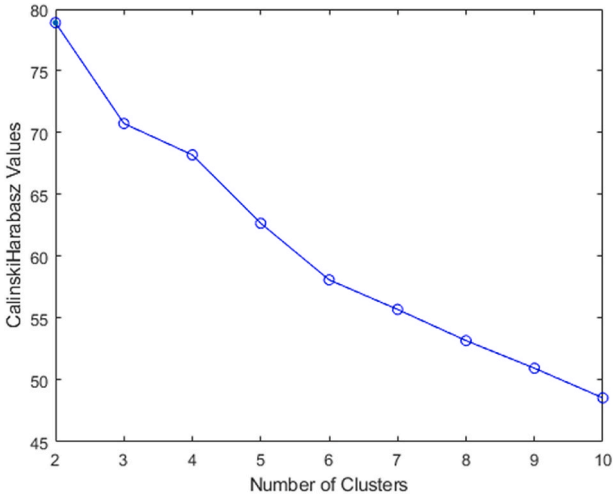

Fig. 1. Calinski Harabasz Criterion Evaluation Values for clustering of preference data

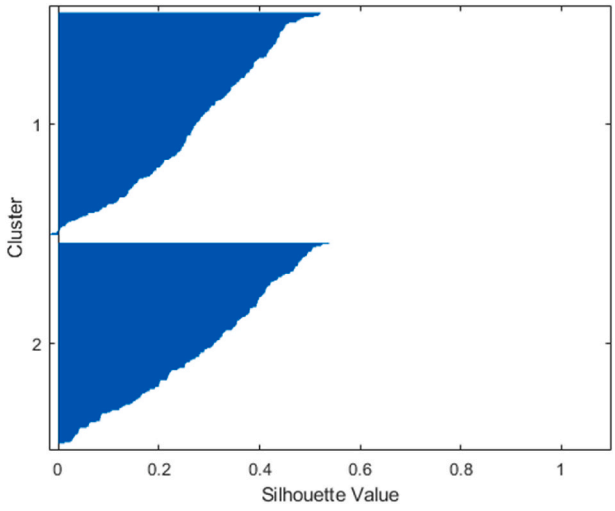

Fig. 2. Eulucidian silhouette cluster graph for preference data

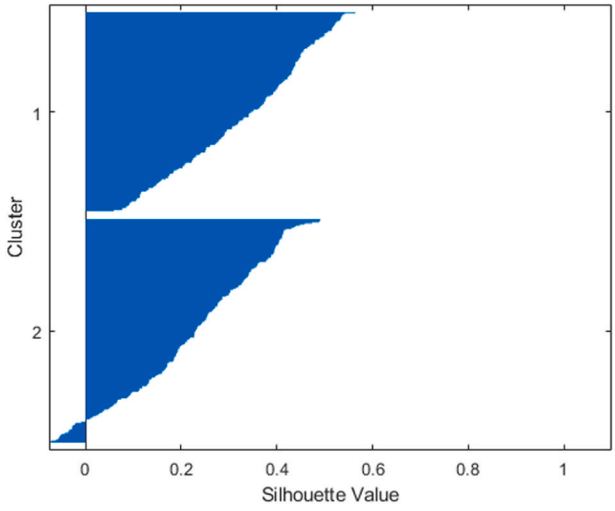

Fig. 3. Cosine silhouette cluster graph for preference data

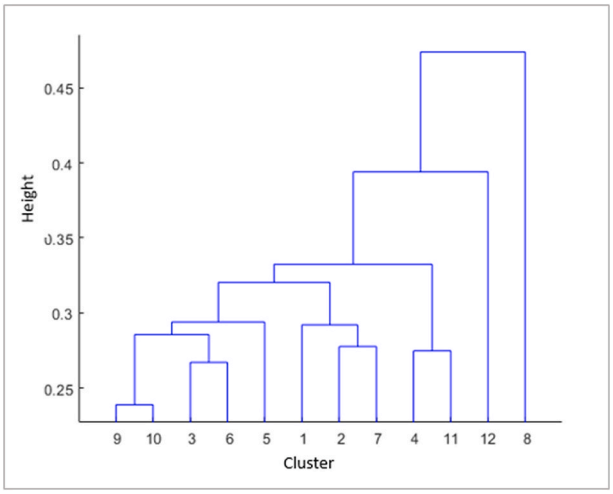

Fig. 4. Hierarchical clustering dendrogram using cosine distance for public's part worth utilities, dendrogram truncated at 12 branches

Appendix 4B

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

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