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Published in:
Environmental Impact Assessment Review

DOI:
10.1016/j.eiar.2022.106889

Published: 01/11/2022

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
Khanam, T., Rahman, A., Xiaoqian, X., Mola-Yudego, B., Moula, M. M. E., & Pelkonen, P. (2022). Assessing the awareness and willingness of European experts to reduce their carbon footprint in everyday consumption. *Environmental Impact Assessment Review*, *97*, Article 106889. https://doi.org/10.1016/j.eiar.2022.106889

Environmental Impact Assessment Review 97 (2022) 106889

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

Assessing the awareness and willingness of European experts to reduce their carbon footprint in everyday consumption

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A R T I C L E I N F O

Keywords:
Carbon footprint
Climate change mitigation
Principal component analysis (PCA)
Willingness to decrease carbon footprint index (WDC_i)

A B S T R A C T

This study investigates and evaluates the European expert's selection and conjoined degree of willingness to decrease the carbon footprint (WDC) of consuming products and services to mitigate climate change. The survey respondents were segregated into four European regions based on their nationality viz. Nordic, Baltic, and Eastern Europe (NBE), Central and South-eastern Europe (CSE), Western and southern Europe (WSE), and North-western Europe (NWE). The WDC are represented by four index categories viz. low willing, moderate willing, willing, and highly willing. The WDC indicators such as housing, food, energy, waste and transport were used to identify the trend and correlation, gender-specific density distribution, and overall regional comparison analysis. The trend and correlation analysis between energy vs. transport, waste vs. food, and a separate state of housing represented the current global carbon emission situation, where four overlapping clusters indicated the respondent's closest or similar selection at their consumption level. The gender-specific density suggests that the male respondent's average WDC for housing and food index ranges from moderate to highly willing. In contrast, the female average WDC for food, waste, energy and transport index ranges from moderate willing to willing and bimodal for other scenarios. Among the regional comparisons, NBE in housing (moderate willing to willing), CSE in food (willing to highly willing), WSE and CSE in energy and all the regions in waste management (willing to highly willing) presented better indices. In transport, Europe as a whole exhibits poor index. In case of WDC index, the regional comparison indicates that the CSE region exhibited better outcomes than the other regions, except for housing. The findings of this study will be beneficial for the common people, researchers, policymakers, and regulators to enrich their future thoughts and contributes to the development and improvement of the existing carbon reduction policies, especially in the transport sector.

1. Introduction

Worldwide development and economic progress have increased Greenhouse Gas (GHG) emissions. Consequently, Global environments and the climate are changing (Peter, 2018). Reducing GHG emissions by minimising the carbon footprint (CF) is widely discussed in the scientific community. A CF is the total amount of GHGs (including carbon dioxide and methane) that are generated by our actions, measured in tonnes of carbon dioxide equivalent (tCO2e) (ISO14067:, 2018). According to Lee et al. (2021), CF is a yardstick that helps us realise the overall participation of an individual, a sector, a country and the world in climate-changing activities such as global emissions which are mostly caused

Abbreviations: CF, Carbon footprint; CSE, Central and South-eastern Europe; GHG, Greenhouse gas; PCA, Principal component analysis; PC, Principal component; NBE, Nordic, Baltic and Eastern Europe; NWE, North-western Europe; WSE, Western and Southern Europe; WDC, Willingness to decrease carbon footprint; WDC_e, Individual respondents' sectional average willingness to decrease carbon footprint in energy; WDC_f, Individual respondents' sectional average willingness to decrease carbon footprint in food; WDC_h, Individual respondents' sectional average willingness to decrease carbon footprint in housing; WDC_t, Individual respondents' sectional average willingness to decrease carbon footprint in transport; WDC_w, Individual respondents' sectional average willingness to decrease carbon footprint in waste; WDC_{Ei}, Regional average willingness to decrease carbon footprint in energy; WDC_{Fi}, Regional average willingness to decrease carbon footprint in food; WDC_{Hi}, Regional average willingness to decrease carbon footprint in housing; WDC_{Ti}, Regional average willingness to decrease carbon footprint in transport; WDC_{Wi}, Regional average willingness to decrease carbon footprint in waste; WDC_i, Regional average willingness to decrease carbon footprint index; WTP, Willingness to pay.

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https://doi.org/10.1016/j.eiar.2022.106889
Received 9 November 2021; Received in revised form 10 August 2022; Accepted 11 August 2022
Available online 26 August 2022

by energy consumption for goods and services and maintaining supply chains.

In 2019, CF was 6.7 t of CO_2 per person in European Union (EU) countries (EC, 2021a, 2021b, 2021c). In the EU, dwelling heating consumes 63.6% of the total residential sector-related energy supply (EC, 2018). Although the EU reduced 24% of overall CO_2 emissions from its 1990 level, it still has a long way to go to achieve carbon neutrality by 2050 (EEA, 2021). Lombardi et al. (2017) observed that there is no 'Global Agreed Upon- Protocol' to assess CF. It is not easy to reduce such substantial amounts of CF within a short period of time. A small change in everyone's lifestyle could bring about a significant change for all of Europe. Everyday lifestyle is a major influencing factor in reducing CF. Dwelling category, energy consumption pattern, food habit, waste management and transportation type are primary influencing factors to reduce CF in daily life. Further, transformation of urban life, dwelling consumption and social practice are vital factors for promoting necessary change (O'Rourke and Lollo, 2015). A study by Ivanova et al. (2020) indicates that dwelling consumptions are directly and indirectly associated with the global GHG emissions of CO_2 6 tCO_2eq/cap.

Many studies have shown that the economic or financial situation of a person is the most influential factor in increasing CF, as income is directly related to lifestyle and consumption pattern (Büchs and Schnepf, 2013; Zhang et al., 2015). Improvement in living standards contributes to CFs, while advanced technology helps in CF regulation (Zhuang et al., 2011). Income and CF are correlated, as 30–40% of emissions are contributed by the top decile income people (Ivanova et al., 2017; Moran et al., 2018). Furthermore, Zhang et al. (2022) showed that reducing the regional income gap increases the entire society's willingness to pay (WTP) for the environment. In contrast, other studies indicated income as a less important factor than others to influence emissions (Minx et al., 2013; Vita et al., 2020). Dwelling size with income difference is a vital factor in reducing CF (Fremstad et al., 2018) as dwelling inhabitant's living space and consumption habits are dependent on their income level. Usually, a detached house emits more carbon than an apartment house. This is because an apartment house has lower number of external walls than a single house. Further, ceilings and floors of apartment houses are shared between neighbouring apartments. Thus, heating, lighting and other electricity consumption are also very efficient in apartment houses. Collaboration in energy consumption in the housing sector has a high potential to reduce CF (Ala-Mantila et al., 2016). In addition to dwelling consumption, consumers need to pay attention to food consumption for reducing individual CF. Hartikainen et al. (2014) mentioned that consumers need to be educated about food consumption to reduce CF. Generally, concerned people are willing to pay more to become healthier and generate less CF for food (Macdiarmid et al., 2021).

The demographic variables also influence CF. An assessment of age-related CF proposed that, among the aged people, the 50–64 years age group has a higher CF than other age groups (Haq et al., 2009). Further, a gender-based study by Koengkan and Fuinhas (2021) indicated that gender inequality and environmental degradation are strongly related. Differences in people's psychology causes them to act differently towards climate change risk (Lacroix and Gifford, 2017). Many studies investigated the relationship between an individual's willingness to act and their psychological behaviour (van Birgelen et al., 2011; Kim et al., 2015). Adaptability and risk assessment capability have a substantial and positive impact on the respondent's desire to adapt to climate change (Xue et al., 2021). Knowledge and information can help the consumer make correct decisions to minimize the negative impact on the environment (Delmas and Burbano, 2011; Cheng and Wu, 2014). Knowledge provides consumers with environmental awareness and solutions to environmental problems (Lee et al., 2006). Consumer attitudes are shaped by their own knowledge level (Stutzman and Green, 1982), and their behaviour becomes uncertain due to inadequate knowledge (Chiou, 1998). Consumers are concerned about environmental damage, especially the climate change and biodiversity loss caused by their daily activities (Liu et al., 2017). Promoting fundamental environmental awareness among people to encourage them to change their behaviour is challenging (Rettie et al., 2014). Currently, the EU is the only region that identified the urgency to apply consumption-based carbon counting termed 'footprint'. The EU already proposed a resource-efficient roadmap 'dashboard of indicators' that includes carbon, water, land, and materials (Tukker et al., 2016). For sustainable development, it is necessary to reduce the CF in every sector. Sustainable consumption and a sustainable lifestyle are essential to reduce resource consumption. Recycling products might help to reduce carbon emissions by reducing energy consumption in new product development. Furthermore, if the energy sources are renewable, it implies that the person is willing to reduce the energy CF. Also, suppose someone shares electronic appliances with others, it creates a room for scheduled consumption of the devices. As a consequence, it increases the potential of reducing the consumption and emission from those devices and thus, it reduces e-wastes. Adams (2018) reported that 20–25 million tons of e-waste are disposed of every year. After burning, harmful chemicals such as polybrominated biphenyls and polybrominated diphenyl ethers (PBDEs) are released into the atmosphere that ultimately contribute to climate change (Adams, 2018). In another instance, the PBDE concentration was reported to be 21.5 ng/m in the e-waste recycling area of Guiyu, China (Ni et al., 2010; Ni, 2012).

Based on this background, the source of CF is categorized into five elementary categories, namely, housing, food, waste, energy, and transport, and a questionnaire was prepared. The questions were prepared based on the author's understanding about the key questions necessary to evaluate experts' willingness to reduce their CF. It should be noted that the current study questionnaire considered only the short distance travel linked to daily activities in the analysis of the transport section. It is worth informing that besides CO_2, this study considered other GHGs equivalent to CO_2 that emits through an individual's CF. Current research considers CF-based environmental management on the attitude, perception, and behaviour of European experts. Expert judgments are always experiential to explore to correct WTP (Breidert et al., 2006). Owing to their relevant experience and educational background in a particular field, expert prediction and judgment are more acceptable than predictions based on randomly selected respondents (Nessim and Dodge, 1995).

This study aims to evaluate the willingness of respondents to reduce their CFs despite being aware of climate change issues. The study identifies expert respondents' willingness to reduce CF index and provides a regional distribution of those indexes. Many methods can reduce carbon footprint, and thus, the causal relationship between applying those methods and carbon reduction is direct. The study's questionnaire is prepared to based on this idea. Here notable that the corresponding research does not intend to provide any suggestive method or solution to reduce CF. It only considers daily activities and a consumption-based questionnaire considering the fact that people can reduce CF by managing their daily activities and consumption level, such as by using a bike, public transport, living in an apartment, eating vegetables, consuming recyclable and local products, using clean energy, and avoiding wastage of water and energy.

The study is novel in various aspects as previous studies (e.g., Hartikainen et al., 2014; Shah and Kaka, 2022) focused mainly on the WTP, especially on the contingent valuation approach (e.g., Ginsburgh, 2017). The current study also focuses on the expert's level of willingness to reduce CF rather than estimating CF. Considering the respondents of the study being resourceful, it was more reasonable to identify their level of willingness and options to reduce CF rather than identifying WTP. Further, this study differs from previous studies (e.g., Lombardi et al., 2017; Shi et al., 2022) in that it considers the perspective of CF analysis. This study also focuses on the daily and usual consumption-based CF (e.g., the transport category considers daily and regular transport that people use every day). In addition, rather than one or some specific sectors, this study focuses on all the five elementary sectors i.e., housing, food, waste, energy, and transport.

Section one of this paper provides the introduction and background of the study. The methods of the study regarding questionnaire design and data collection, application analysis methods and questionnaire's reliability test are presented in section two. Three different forms of analysis were executed to estimate experts' willingness to decrease CF (WDC's), which are discussed in section three as follows: WDC's trend in the first part, gender basis comparison in the second part and regional distribution in the final part. Discussion and conclusions are presented in the last section.

2. Methods

This section is organized as follows: questionnaire design and data collection, analysis method (organization of questionnaire, applying different analysis techniques, justification for analysis techniques) and testing the reliability of the questionnaire.

2.1. Questionnaire design and data collection

The target group in this study is the dwelling representatives, who are well informed about climate change issues. The study used the term "experts" for the respondents, as the dwelling representatives are involved in and contributing to global environmental improvement through their profession. The experts were searched through their institutional web pages and chosen randomly. The questionnaires were distributed to approximately 500 experts either in person or through emails. A total of 167 dwelling representative's data were collected from 26 European countries between August 2018 and May 2020. The dwelling representative sample size is rational and sufficient to develop a high-quality study design and accomplish the objectives set for the current study because (i) these expert groups belong to part of a regional cross-sectional study, (ii) they are educated, and (iii) well informed about climate change issues. Further, compared to the sample size of previous expert-based studies (e.g. Stefan et al., 2022; Stričević et al., 2020), the sample size of the current study is larger.

The entire dataset was divided into four European zones based on their geographic locations, namely, Nordic, Baltic and Eastern Europe (NBE), Central and South-eastern Europe (CSE), Western and Southern Europe (WSE), and North-western Europe (NWE) countries (Table 1).

2.2. Analysis method

The entire questionnaire has 21 questions, where question 1–4 was respondent's basic information (refers to age, gender, nationality and profession) and question 5–21 was WDC related questions, those were divided into housing, food, waste, energy and transport sections (Table 2). Based on the author's insights, the questions that will help determine the expert's level of willingness to reduce CF from the CF calculation questions are determined here for the corresponding study questionnaire.

Q10 is a negative statement question, so the answer of this statement was reversely coded and converted the statement into positive. Further, Q19 is a positive statement and as the question is already in positive form, it is not necessary to reverse the question statement but having a car means increasing CF, so in the coding, 2 will be coded for no and 0 will be coded for yes. Thus, out of the 17 questions an individual who is strongly agree (2), agree (1.5), no opinion (1), disagree (0.5) and strongly disagree (0) to reduce carbon, his total score will be 34 (or 17×2), 25.5 (or 17×1.5), 17 (or 17×1), 8.5 (or 17×0.50) and 0 respectively.

Table 1
European regions based on respondent's nationality.

Zone	Country (Number of respondents in a country)	Number of respondents in a region (per cent)
NBE	Finland (6), Norway (4), Sweden (5), Latvia (4), Lithuania (3), Ukraine (3)	25 (15)
CSE	Poland (3), Germany (7), Czech Republic (4), Switzerland (4), Hungary (3), Bulgaria (3), Romania (3), Serbia (3), Croatia (3), Bosnia (2)	35 (21)
WSE	Netherlands (6), Belgium (3), France (6), Portugal (7), Spain (4), Italy (7), Greece (7), Malta (2)	42 (25)
NWE	United Kingdom (59), Ireland (6)	65 (39)

NBE = Nordic, Baltic and Eastern Europe; CSE = Central and South-eastern Europe, WSE = Western and Southern Europe, and NEW=North-western Europe.

2.3. PCA analysis: covariance and correlation matrix of willingness to consumption

Principal Component Analysis (PCA) is an approach that expounds the variance-covariance relation of a set of variables to reduce dimensionality through the linear combinations. PCA is used for the strong correlation-based variables where the correlation coefficients are usually >0.3.

Applying PCA in data achieves dimension reduction, data visualization and feature extraction. Thus, PCA explores three things: how variables are associated with each other (by covariance matrix), data scattering directions (Eigenvectors), and the relative importance of the directions (Eigenvalues). Among these, eigenvectors characterise a certain direction of the multidimensional scatterplots and eigenvalues characterise magnitude. The higher eigenvalues represent a correlation with higher significant directions. Higher variability in a specific path indicates less noise and high signal to the relationship with the dependent variable. By reducing the dimensionality, PCA reduces the number of variables and makes the analysis easier.

The principal vector is considered as the significant line when the projected observations become closer to the original data observations (James et al., 2013). After combining predictors, PCA drops the unimportant eigenvectors, which is a more meaningful approach than others. However, PCA analysis in the current study intended to identify unimportant variables, not to exclude them from the subsequent analysis. Another objective of the PCA analysis was to identify expert's average willingness to decrease CF trend.

2.4. Willingness to decrease carbon emission index

Willingness to decrease the CF index indicates a person's willingness to reduce carbon emissions during their daily life. The current questionnaire also includes the respondent's current daily activities, performance and consumption habits to estimate their WDC. The concept of WDC is similar to the WTP as both focus on the idea of real choice. The WTP is the maximum or highest point a person willing to sacrifice or pay for a service or a product (Marine Le Gall-Ely, 2009; Venkatachalam, 2004). WTP reflects the values related to environmental services that people use (e.g., fresh air that we breathe) and do not use (e.g., from a biodiversity perspective that we never visited or used) (Henrik et al., 2007).

Similar to WTP, the WDC in this study investigates the willingness level of the expert who is forfeiting the other options to choose the CF-reducing choice. The significant difference between WDC and the WTP is that, instead of only identifying the actual payment in return for environmental improvement, it determines the respondent's degree of willingness and a single option to improve the environment. Thus, the concept of WDC is broader than WTP. It identifies respondents' degree of willingness to select a product or service with lower CF, as well as a single choice of WTP to reduce global carbon emissions.

The WDC analysis identifies the respondent's degree of willingness in questions 6–21, plus a single option selection procedure for questions 5,12,13, and 19 to improve the environment.

Table 2
Coding the questionnaire for willingness to decrease carbon footprint index (WDC_i).

QN	Definition/Question	Consequence	Coding				
Housing			Strongly agree	Agree	No opinion	Disagree	Strongly disagree
5	*I live in a single house/apartment*	Single house ➔ CI	*Single house 0; Apartment house 2*				
14	*I prefer to live in an apartment rather than a single house*	Apartment house➔CD	*2*	*1.5*	*1*	*0.5*	*0*
Food							
6	*I always prefer vegetables to meat*	Vegetable consumption➔CD	*2*	*1.5*	*1*	*0.5*	*0*
7	*I always prefer to eat organic food (It grows without chemical fertilizers and sells without adding any synthetic food enhancers or preservatives)*	Eat Organic food➔CD	*2*	*1.5*	*1*	*0.5*	*0*
Waste							
8	*In my home, I do not have any leaky faucets as I am very aware of unnecessarily water wastage*	No leaky faucets➔CD	*2*	*1.5*	*1*	*0.5*	*0*
9	*I wish to use recycling product*	Recycling➔CD	*2*	*1.5*	*1*	*0.5*	*0*
10	*Households should not pay waste management charges*	Waste not management➔CI	*0*	*0.5*	*1*	*1.5*	*2*
11	*I am utilizing the centralized bio-waste collection*	Bio-waste collection➔WDC	*2*	*1.5*	*1*	*0.5*	*0*
Energy							
12	*Are you concerned about the sources of your home energy/electricity?*	Aware to green source➔ WDC	*Yes 2; No + I do not know 0*				
13	*If you are concerned about your home energy sources, then, what is your home energy source?*	Using renewable➔CD	*Non-renewable energy 0; Renewable energy 2*				
15	*I prefer to use energy efficient bulbs (e.g. Compact Fluorescent Lamp (CFL))*	Use energy efficient bulbs➔CD	*2*	*1.5*	*1*	*0.5*	*0*
16	*I always look at energy saving label before buying home appliances*	look at energy saving label ➔WDC	*2*	*1.5*	*1*	*0.5*	*0*
17	*I unplug and turn off all switches when not using or leaving rooms*	unplugged and turn off➔ WDC	*2*	*1.5*	*1*	*0.5*	*0*
18	*I share my electronic appliances with others*	Sharing equipment➔CD	*2*	*1.5*	*1*	*0.5*	*0*
Transport							
19	*I have a car*	Having car➔CI	*Yes 0; No 2*				
20	*I always prefer public transport rather than a personal one*	Prefer public transport➔CD	*2*	*1.5*	*1*	*0.5*	*0*
21	*I always prefer walking/cycling in less than three kilometers distance*	Prefer walking/ cycling➔CD	*2*	*1.5*	*1*	*0.5*	*0*

CI = Carbon increase; CD = Carbon decrease; QN = Question number; WDC=Willingness to decrease carbon footprint.

$$WDC_h = \frac{WDC_H}{q_h} \tag{1}$$

$$WDC_f = \frac{WDC_F}{q_f} \tag{2}$$

$$WDC_w = \frac{WDC_W}{q_w} \tag{3}$$

$$WDC_e = \frac{WDC_E}{q_e} \tag{4}$$

$$WDC_t = \frac{WDC_T}{q_t} \tag{5}$$

In Eqs. (1) to (5), the willingness to decrease CF in housing (WDC_h), food (WDC_f), waste (WDC_w), energy (WDC_e) and transport (WDC_t) are the summation of section specific total coded values divided by section specific number of questions. Section specific total coded values are WDC_H, WDC_F, WDC_W, WDC_E and WDC_T and it is the summation of all the values in each section that were coded or assigned according to Table 2. Number of questions in each section is indicated by q_h, q_f, q_w, q_e and q_t (total q = 17, excluding demographic questions). Thus, WDC_h, WDC_f, WDC_w, WDC_e and WDC_t are section specific individual respondent's willingness to decrease CF in housing, food, waste, energy and transport, respectively.

The country's average willingness to decrease CF is estimated in eq. 6, where, an individual respondent of a country is indicated by r and the total number of respondents in a country is indicated by n.

$$WDC_{Hc,\ldots\ldots,Tc}\ (or\ Country\ average) = \frac{\sum_{r=1}^{n} WDC_h, \ldots\ldots\ldots\ldots\ldots, WDC_t}{n} \tag{6}$$

Thus, regional average willingness to decrease CF is a sequential process from Eq. (1) to Eq. (7), where a country is indicated by φ and the total number of countries in the region is indicated by nφ. The country average WDC for housing, food, waste, energy and transport is indicated by WDC_{Hc}, WDC_{Fc}, WDC_{Wc}, WDC_{Ec} and WDC_{Tc}, respectively.

$$WDC_{Hi,\ldots\ldots,Ti}\ (or\ Regional\ average) = \frac{\sum_{\varphi=1}^{n\varphi} WDC_{Hc}, \ldots\ldots\ldots\ldots\ldots, WDC_{TC}}{n\varphi} \tag{7}$$

The individual respondent's sectional total value has been considered in the PCA (to estimate the overall trend and the relation between each indicator of WDC) and average value (i.e., eq. 1 to 5) density distribution of the gender studies. Furthermore, the regional findings (i.e. findings of eq. 7) will be indexed into four levels; 0–0.50 for low willing to decrease, 0.51–1 is moderate willing to decrease, 1.01–1.5 willing to decrease and 1.51–2 is highly willing to decrease CF. These four indices together frequently will be termed as respondents' willingness to decrease CF index (WDC_i). Therefore, the regional indexed value for housing (WDC_{Hi}), food (WDC_{Fi}), waste (WDC_{Wi}), energy (WDC_{Ei}) and transport (WDC_{Ti}) will be represented in R-mapping to observe the regional index distribution.

Thus, the corresponding study will calculate the individual expert's WDC, estimate the country's average from the individual WDC and estimate the regional average from the country average to observe the regional scenarios (Fig. 1).

It is a pretty rationale that the sequential steps will be followed to represent the regional WDCi into the r mapping to observe and compare the regional scenarios through the regional distribution of the indexes. Further, the exploratory basis analysis also signifies gender basis distribution of experts' WDC trend. It is because the section specific

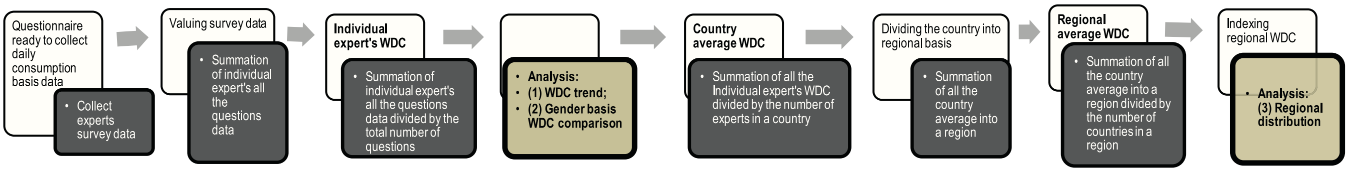

Fig. 1. Methods of the study.

people's consumption habits might be different. Hence, section-wise, gender-specific expert reactions are significant in identifying the five elementary categories. It is also substantial to notify that this kind of analysis concerning the regional distribution of experts' level of willingness to reduce CF is unique and has never been conducted before.

Further, it is worthy to inform that the gender basis WDC skewness distribution of density curve indicates that the density curves don't refers to the plot's looks but instead refer to the skewness of the data.

Respondents' willingness to decrease CF index by regional basis and other simple cross tabulation analysis is carried out by using SPSS software. R package leaflet (Cheng et al., 2021), tidyverse (Wickham, 2021), ggmap (Kahle et al., 2019), leaflet.extras (Karambelkar et al., 2018), ggplot2 (Wickham et al., 2021), maps (Becker and Wilks, 2021), mapproj (McIlroy et al., 2020), mapdata (Becker et al., 2018) are utilised to produce the r mapping (R Core Team, 2021).

2.5. Questionnaire reliability test

The reliability test of a questionnaire is a method of weighing the similarity, quality, and reproducibility of the collected data to fulfil the research purpose. It is an approach for predicting the internal uniformity of the survey questions based on identical factors. A low alpha value obtained from the reliability test of a questionnaire indicates an inadequate number of questions or heterogeneity or poor interlinking between the study items (Tavakol and Dennick, 2011).

In this study, to test the reliability of the questionnaire, Cronbach's alpha was applied. As mentioned earlier, the uniformity among the questions is very important and it is necessary to check all the questionnaire statement texts to attain an acceptable Cronbach's alpha value. In the reliability test of the questionnaire, all questions were reversely coded as positive statements, except Q10. Therefore, to estimate Cronbach alpha, Q10 was constructed in an affirmative way. Thus, the respondent's negative responses were reversely coded to perform the reliability test of the questionnaire.

Further, the survey questions related to some areas were divided into two directions, assuming that it would not affect the reliability test. It is also to be noted that, although some of the questions fell into situational reliability or observational reliability, all questions were similar. All questions were aimed to measure and obtain data with similar characteristics, focusing on a single phenomenon and following similar types of question formats (e.g., checklist and scale format).

The significance or acceptance value of the internal consistency of the reliability test is within 0.5 to 0.7 (Ursachi et al., 2015). The Cronbach alpha value of the survey questions were 0.63 or 63%, confirming the acceptability of the questionnaire to attain reliable data. Thus, the designed questions were reliable, as most of the questions (except basic questions) helped to deliver inference on the comprehensiveness of the entire questionnaire.

3. Results

Among the dwelling key representatives, professors and senior researchers, junior scientists and doctoral researchers, environmentalists, and policymakers constituted 17%, 78%, 4% and 1% of the total experts, respectively. The findings also indicated that 67% of the total respondents were female and 37% were male. Among the survey respondents, 71%, 24%, 3% and 2% belonged to age groups ≤ 30, 30–45, 45–60 and > 60, respectively. In addition to these, the research basics of the questions were presented as percentages to demonstrate the overall aspects of the observations (Table 3).

3.1. Willingness to decrease CF (WDC) trend

The trend of overall European expert's WDC is indicated by the PCA that explains the level of acceptance that depended on the application.

In the PCA, the total number of variabilities is 100%. For all the principal components (PC's) (i.e., PC1 + PC2 + … + PC5), 1 to 5 were number of continuous variables, where the sum of these was 100%.

Table 3
Overall results of the study.

QN	Question	Result (percentage)				
		SA	A	NO	D	SD
Housing						
5	*I live in a single house/apartment house*	SH (37); AH (63)				
14	*I prefer to live in an apartment house rather than a single house*	11	19	24	25	21
Food						
6	*I always prefer vegetable than meat*	17	24	15	34	10
7	*I always prefer to eat organic food (It grows without chemical fertilizers and sells without adding any synthetic food enhancers or preservatives)*	17	36	20	19	8
Waste						
8	*In my home, I do not have any leaky faucets as I am very aware of unnecessarily water wastage*	34	48	7	9	2
9	*I wish to use recycling product*	45	46	6	2	1
10	*Households should not pay waste management charges*	9	24	32	27	8
11	*I am utilizing the centralized bio-waste collection*	8	24	35	25	8
Energy						
12	*Are you concerned about the sources of your home energy/electricity?*	Yes (61); N (39)				
13	*If you are concerned about your home energy sources, then, what is your home energy source?*	NRE (54); RE(46)				
15	*I prefer to use energy efficient bulbs (e.g., Compact Fluorescent Lamp (CFL))*	41	45	11	2	1
16	*I always look at energy saving label before buying home appliances*	22	40	18	15	5
17	*I unplugged and turned off all switches when not using or leaving rooms*	33	35	6	19	7
18	*I share my electronic appliances with others*	23	46	10	17	4
Transport						
19	*I have a car*	Yes (45); N (55)				
20	*I always prefer public transport rather than a personal one*	16	26	16	27	15
21	*I always prefer walking/cycling in less than three kilometers distance*	29	39	14	12	6

A = Agree; AH = Apartment house; D=Disagree; NO=No opinion; N = No+ I do not know; NRE = Non-renewable energy; QN = Question number; RE = Renewable energy; SH = Single house; SA = Strongly agree; SD=Strongly disagree.

Based on the cumulative proportion of the variance, PC3 and PC4 represented 87% and 100% of variance (Table 4). Thus, to perform other analysis, the acceptable level of variance was >90%. Hence, PC5 did not play a significant role in terms of variability.

The scree plot displays the eigen value from largest to smallest to identify the number of components that explain most of the variation in the data. The ideal pattern is a steep curve that indicates the reduction of the variation with the increase of clustering. The x-axis represents the number of clusters, and the y-axis represents the group's sum of squares or variances. If all the identification is in the same cluster, there are high variations that represent in the first cluster (in the top, first circle to second circle). In this study, it is obvious because all identifications under one variable were distinctly placed. When the clusters were further divided into two more clusters, the variability reduced significantly as the identification under one variable was closest to another. Thus, with increase in clustering, the variability between the identification would decrease. Therefore, from the first cluster to the second one, the variability was significant, after which the variability gradually decreased among others (Fig. 2a).

The loading plot visually interprets the first two components—component 1 (PC1) and component 2 (PC2)—that could explain approximately half of the variability (57.23%) among the five variables (Fig. 2b). Notably, the loadings express the proportion of variance of a variable that is explicated by a principal component. However, the PC1's middle location was 0 and the right side of it exhibited positive values, while the left side exhibited negative values. The five arrows represent the data. The overlapping line between WDC_e and WDC_t indicated high correlation between the two variables (although not directly estimated here). But we could not determine whether one of the variables was redundant here, as the plotting was two dimensional, and the space could be spanned based on the number of variables i.e., three or four or five dimensional. The variables WDC_w and WDC_f also correlated with each other. Compared to other correlation variables i.e., WDC_e vs. WDC_t and WDC_f vs. WDC_w, WDC_h was distinct.

WDC_h, WDC_e, WDC_w, WDC_t, WDC_f had large positive loadings on component 1. It indicated that, variables were positively correlated with component 1. Therefore, an expansion in one result may result in impacts on other results. There were no negative loadings on components 2. The cluster plot considered four clustering. The objective of cluster plot is to identify what customers are related to each other. Among the four basic clustering techniques, this study considered centre clustering. In the clustering, two important components among the five components PC1 and PC2 were compared to others. The different shapes (o, x, +, Δ) indicated different clustering that was generated from first four variables i.e., WDC for housing, food, energy, and waste. The cluster plot also showed that, in some areas, the four clusters were overlapping each other while in other parts three clusters were overlapping each other. It indicates that the distance between each identification to the other was less and the data were closest to each other or centroid (Fig. 2c).

3.2. Distribution of willingness to decrease CF (WDC): gender basis comparison

It is interesting to explore gender basis WDC estimation and comparison according to their willingness level. Density plots are used to execute this analysis, as it perceives the dispersal of a variable in the dataset to represent their probabilities. The highest points of the density plot is where all values over the interval become intense.

Table 4
Principal component analysis summary.

	PC1	PC2	PC3	PC4	PC5
Standard deviation	1.505	1.067	0.978	0.800	0.0136
Proportion of Variance	0.453	0.228	0.191	0.128	0.0000
Cumulative Proportion	0.453	0.681	0.872	1.000	1.0000

PC = Principal component.

The gender distribution is represented in the density plot by using a continuous distribution of WDC_h, WDC_f, WDCw, WDC_e, and WDC_t variables (Fig. 3). The study considers different bandwidth (smaller to large), since the aim of the density plot is to represent the overall estimation scenario, and not how smoother or coarse the distribution path is. The kernel density is estimated in the y-axis by using the probability density function, whether the x-axis is estimated as per unit probability. The area under the density curve for a specific interval is needed to estimate on the x-axis to convert to an actual probability. The area under the density curve is always equal to 1 (a = 1/2*base*height) or provides the percentage; in another way 100% of all the probabilities. In the symmetric density mean ($\bar{x}$) = median, where, in the left-skewed density, mean is less than median and vice versa for the right-skewed density.

The gender distribution for WDC_h indicates male distribution is rightly skewed and female distribution is slightly bimodal (represent two distinct scenarios). The rightly skewed density curve for men indicates that the mean value is more than the median. The density plot provides a precise peak location that is around 0.78 for male and around 0.48 for female at 0 of WDC_h. Thus, it indicates that the average WDC of the male respondents for housing is more than the median value of the male respondents ($0.5 \leq \bar{x} \leq 2$), while it is bimodal for the female (Fig. 3a).

The gender distribution for WDC_f indicates male distribution is rightly skewed and female distribution is left skewed. The right-skewed male distribution indicates the mean to be at the right side of the median, and the left skewed female distribution indicates the mean value is to the left of the median. The density plot provides the highest peak location for male just over 0.80 and for females at about 0.65 at 0 and 2, respectively for WDC_f. The second highest density point for females is located over about 0.43 at 1. Thus, it indicates that the average of the male respondents WDC for food is more than the median value of the male respondents ($0.5 \leq \bar{x} \leq 2$), while it is $0.5 \leq \bar{x} \leq 1.5$ for the female (Fig. 3b).

The gender distribution for WDC_w indicates that male distribution is rightly skewed, and female distribution is left skewed. The y-axis density ranges from 0 to 1.2. The left skewed distribution for female indicates that mean value is less than the median and vice versa for male. The density plot provides the peak point for male around 0.60 and the second peak point is just under 0.60. While for the female, the peak is around 1.2 at 0.60 for WDC_w. Thus, it indicates that the average of the female respondents WDC for waste is less than the median value of the female respondents ($0.5 \leq \bar{x} \leq 1.5$), while it is bimodal for the male (Fig. 3c).

The gender distribution for WDC_e indicates male distributions are slightly bimodal and female distributions are left skewed. The left skewed pattern indicates that the mean value is left and less than the median. The density plot provides the highest peak location for male at just over 0.50 and for female, just under 2 for WDC_e. Thus, it indicates that the average of the female respondents WDC for energy is less than the median value of the female respondents ($\bar{x} \leq 1.5$) and it is bimodal for the male (Fig. 3d).

The gender distribution for WDC_t indicates male distribution is rightly skewed and female distribution is left skewed. Although the figures for WDC_t resemble that of WDC_w, they are different as the y axis range from 0 to around 3.4 in case of WDC_t. The peak values of male are concentrated just over 1.73. Thus, it indicates that the average of the female respondents WDC for transport is less than the median number of the female respondents ($\bar{x} \leq 1.5$) and it is bimodal for the male (Fig. 3e).

3.3. Willingness to decrease CF index (WDCi): regional comparison

The regional willingness to decrease CF for housing index (WDC_{Hi}) distribution represents that among all the regions only NBE regions are willing (index 1.01–1.50) to decrease their CFs in housing. Whereas the

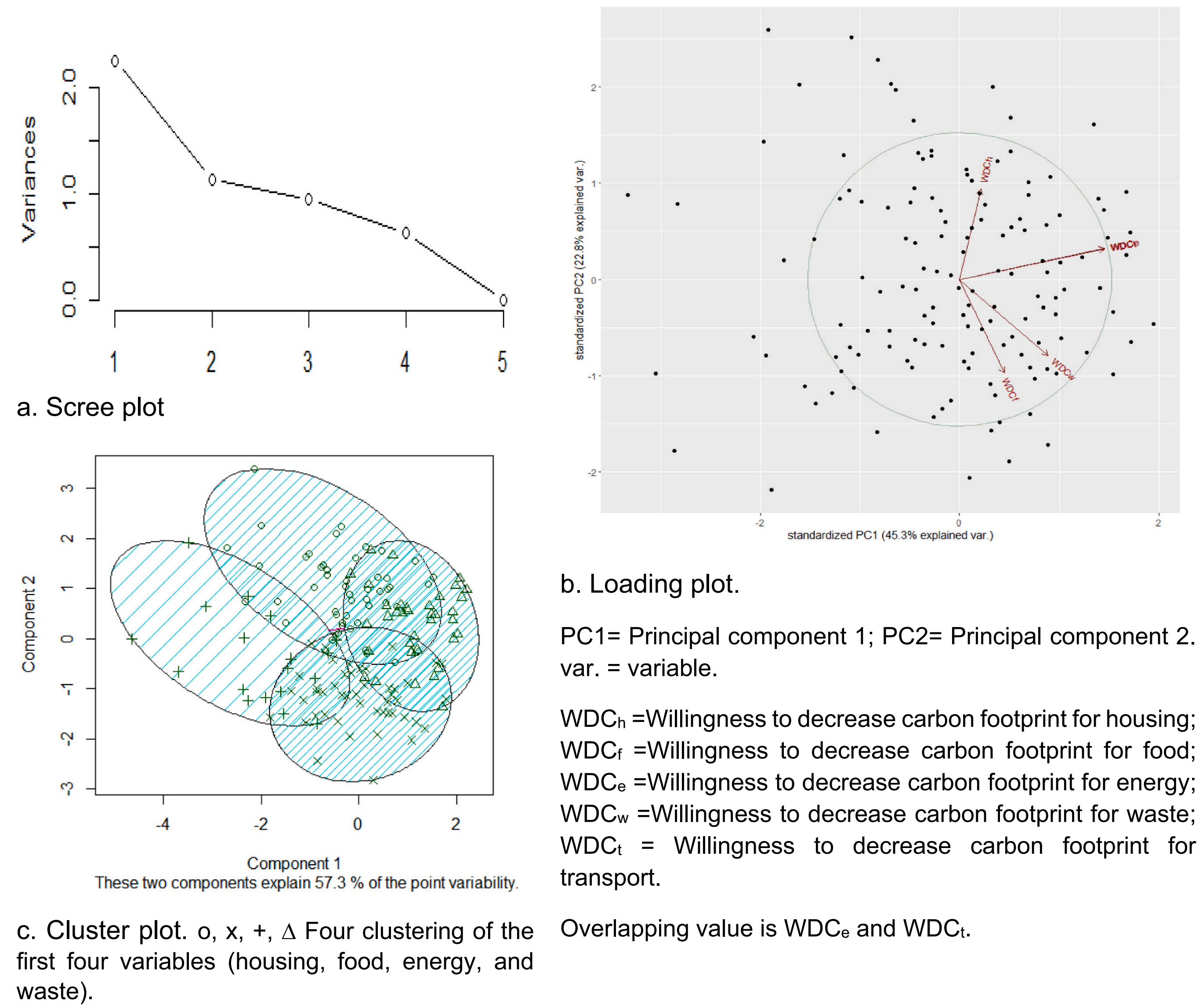

Fig. 2. Principal component analysis of the European experts' willingness to decrease carbon footprint (WDC).

other region respondents are moderate willing to decrease (0.51–1) their WDC_{Hi} (Fig. 4a).

The regional willingness to decrease CF for food index (WDC_{Fi}) distribution represents a quite better picture than the housing index scenario. Among all the regions only NBE regions are moderate willing (index 0.51–1) to decrease their CFs in food. WSE and NWE region respondents are willing to decrease their CF (index 1.01–1.50). Whereas the WDC_{Fi} scenario in the CSE region is very upright here as they are highly willing to reduce their carbon emission in the food consumption (index 1.51–2) (Fig. 4b).

The regional willingness to decrease CF for waste index (WDC_{Wi}) distribution represents a brighter scenario than other section's index scenarios as all the index scenario of all the regions is very upright. They are highly willing to reduce their carbon emission in the waste management (index 1.51–2) (Fig. 4c).

The regional willingness to decrease CF for energy index (WDC_{Ei}) distribution represent NBE and NWE regions are willing to decrease (index 1.01–1.50) their CFs in energy. WSE and CSE region respondents are highly willing to decrease their CF in the energy consumption (index 1.51–2) (Fig. 4d).

Compared to waste management and energy consumption reduction, the transport scenario is very worse in all over Europe concerning the respondent's willingness to reduce carbon emission. The entire Europe poorly indexed (0–0.50) as they are low willing to reduce their CF in the transport sector (Fig. 4e). Therefore, the index of all sections (WDC_i), CSE region is providing a better picture compared to other regions except housing and transport.

4. Discussions and conclusions

The data from the survey on EU experts about WDC was evaluated to identify the interaction between different variables of WDC and to understand the distribution of WDC based on gender and regionality. The interaction and trend of WDC variables are evaluated by the PCA analysis. The intention of the PCA in the study is to identify insignificant variables, not to avoid these from the subsequent analysis. Therefore, although PC5 did not play a significant role in variability, our study took this into account. The low variability indicates its low contribution to respondent's CF reduction willingness. Thus, the correlation between energy versus transport and waste versus food and a separate identifiable location of the housing is supported by the current state of the global carbon emission scenario. A global perspective study concerning

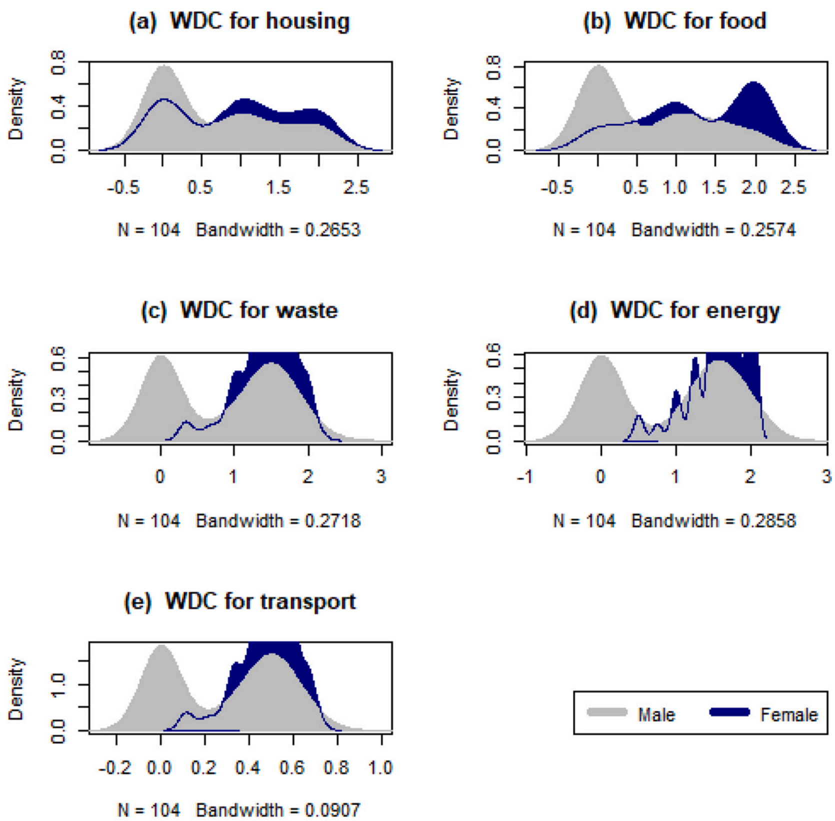

Fig. 3. Gender basis distribution of willingness to decrease carbon footprint (WDC).

GHG emission found that the emission trend of energy usage for domestic purposes is similar to that of transport (17.5% and 16.2%, respectively; Ritchie et al., 2020). Further, four overlapping clusters indicate that the distance between each identification is centroid and closest. It indicates that respondents had similar mentality, trend and demand concerning the consumption and emission of CF that centroid them into the similar rejoinder under different regions.

Gender basis WDC skewness distribution of density curve indicates that the density curves do not refer to the plot's appearance but the skewness of the data. The average male respondents WDC for housing and food is more positive than that of female respondents. On an average, the male respondents are persisting between moderate willing to highly willing indices, while it is bimodal and falls within low willing to willing category, respectively for the female. Further, the female respondent's average WDC for waste, energy and transport is more positive than that of male respondents. Although the current study indicated higher male WDC than female, previous similar studies reported opposite results. The study found that a male in Sweden emits average of 16% more GHGs than a female as they eat more meat and have cars (Ryan, 2021). Another study using 2001–2008 Gallup Poll data shows that women are more concerned about climate issues than men (Rastogi, 2010).

In the regional comparison of WDC_i, NBE respondents displayed better willing index in housing (willing index) than all the regions. It is worthy to say that the situation might have changed in the Nordic countries. A study over the demand and price of a single house in the Nordic area reported that, after the pandemic, both the demand and price of a single house increased, and it will remain elevated during 2021 (Nordea Group, 2021). In the housing, it is apparent that a single house has more outside walls, roofs and direct floors that are close to the ground part, whereas those of apartments are shared. So, less energy (for lighting, heating) is needed in an apartment house than in a single-detached house. Although, it is also true that some single houses have more windows resulting in less lighting usage. In general, a single house consumes more energy than an apartment house and they have higher scope for solar radiation use, where there are only one or two walls for windows. Location of dwellings also contributes to increasing CF. A study in United States found that communities located nearby the public transportation area can reduce carbon emissions by 37 million metric tons/year (C2ES, 2021).

In the food scenario, CSE regions are highly willing (1.51–2) to reduce their CF. Whereas, respondents from WSE and NWE fall within willing (1.01–1.50), and that from NBE within willing (0.51–1) category to reduce their CF. In the food or eating habits, an average meat-eater is responsible for emitting about 1.5 tons more GHGs per year than a vegan (Cleveland and Gee, 2017). Further, importing goods from other countries involving long transportation emits a considerable amount of carbon. Sometimes, although the overall national carbon emissions decrease, consuming food produced in other countries increases the territorial emissions (Salo and Nissinen, 2017).

Dwelling wastes that are handled by the municipalities consider a waste management cost incurred by waste transportation to treatment facilities (Ymparisto, 2019). Imposing charges on the waste collection encourages people to cut their faeces, which in turn offers a better environment. Weidner et al. (2020) reported that the carbon sinks over the centralised systems are severely reliant on some factors such as the renewable share of the electricity grid and population density. Therefore, in the waste management scenario, all the regional indices were 2, indicating high willingness of respondents to reduce their WDC_w. European citizens from different zones are inevitably aware of waste pollution. From the CSE zone, Germany is the best recycling handling country globally (Gray, 2017). From the NBE zone, Sweden recycles almost all of its municipal waste (Gray, 2017). However, a zero-waste European target has been welcomed recently in the European parliament to manage carbon emission and accelerate the circular economy (EU, 2021).

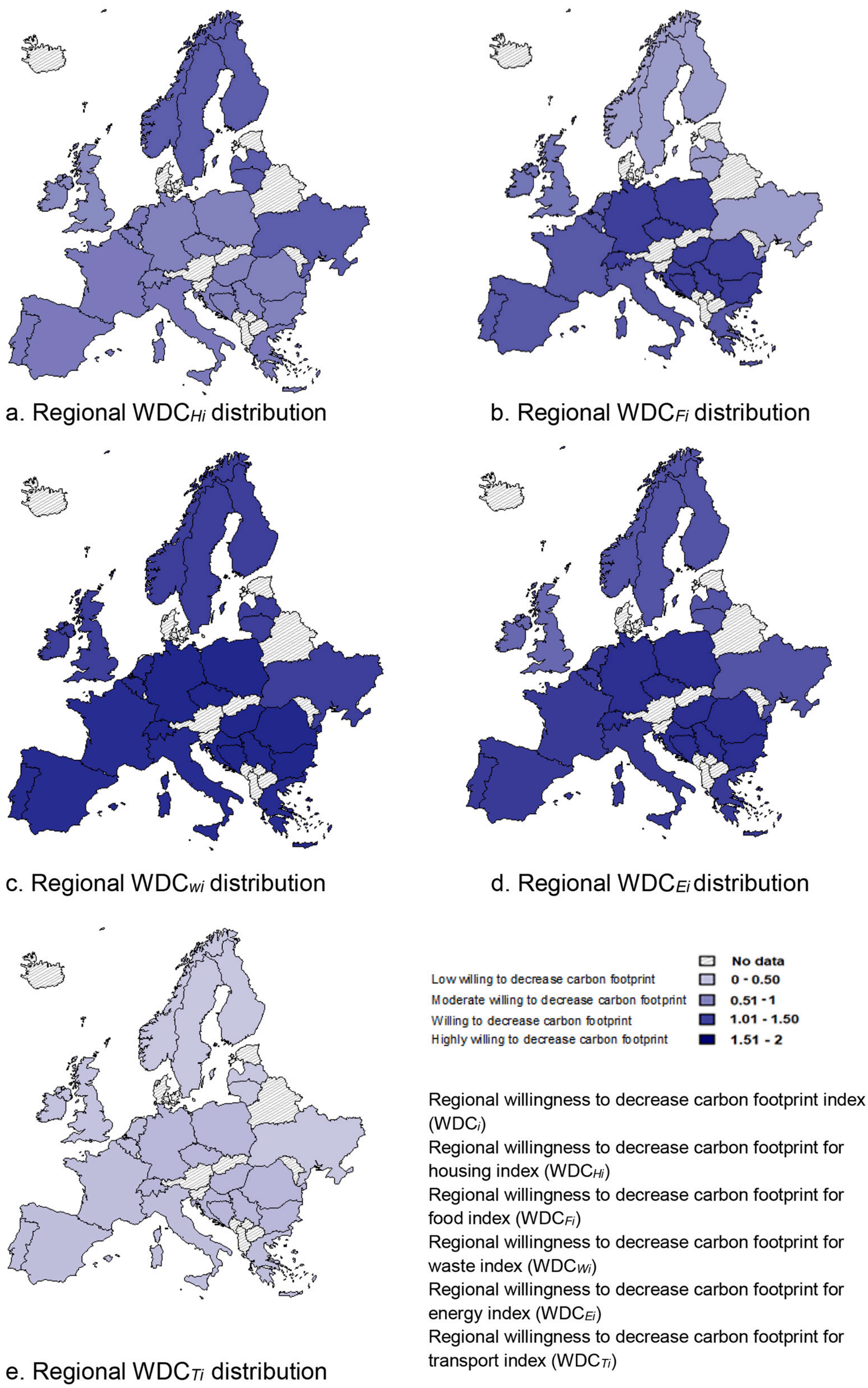

Fig. 4. Regional willingness to decrease carbon footprint index (WDC$_i$) distribution.

Although all the zone displayed satisfactory indications to reduce carbon emission, some consumption indicators should be taken into account. In the energy sector, respondents from CSE and WSE region are highly willing to decrease their CF (index 1.51–2), and in transport, the entire Europe is low indexed (0–0.50). Therefore, compared to all sectional indices (WDC$_i$), the CSE region exhibited better willingness than the other regions except housing and transport. A typical passenger car release approximately 4.6 metric tons of CO_2/ year. Thus, burning every gallon of gasoline and diesel emits 8887 and 10,180 g of CO_2, respectively (USEPA (United States Environmental Protection Agency), 2018). Using public transportation instead of personal vehicle one can save approximately \$9738/year. Thereby, commuting a round trip of about 20 miles using public transport could reduce the CF equivalent to the cost of 4800 pounds/year (USDTFTA (U.S. Department of Transportation Federal Transit Administration), 2010). People who have cycling and walking habits not only help to reduce CO_2 emission but also contribute to reducing traffic congestion, fuel consumption, and noise level (EC, 2021b). Living a car-free life, shifting to an electric car could offer the highest mitigation potential in transport sector (Diana Ivanova et al., 2020).

In energy sector, although CSE and WSE are providing a satisfactory WDC signal, some of the countries, e.g., the UK, Germany, Italy and Spain are still vastly dependent on natural gas for their energy sources. According to the BP Statistical Review of World Energy (EIA, 2017), in 2016, liquid fuels and natural gas accounted for around 46% and 19% of Spain's total primary energy consumption, respectively. Among the countries from the CSE zone, Germany is the largest natural gas consumer. In 2019, the country consumed 8.6 billion cubic feet natural gas per day (Bcf/d), which was 25% of the country's total primary energy consumption (EIA, 2020). Thus, a gas boiler based single house emits 2 tons of CO_2/year, where an apartment emits half of it (Cito, 2021). The energy label is a key mean for the consumers for picking energy-efficient products. It also delivers information about related features of usage, e.g., water consumption, noise emissions etc. In Europe, six comparative scales G to A (the least to most efficient) labelling categories exist. Study by Peters et al. (2013) indicated that accessibility to eco-friendly products showed positive impact on reducing CFs. To identify the eco-friendly product, the popularity of energy labelling products is increasing gradually. In 2006, two-thirds A category washing machines and refrigerators were sold, and, in 2019, 93% of the products sold were from A+, A++ or A+++ energy labels (Eurobarometer, 2019). Accordingly, checking energy savings labels before purchasing an electronic appliance is expanding. It is estimated that the EU eco-design planning for energy labelling will save about 230 Mtoe (million tonnes of oil equivalent) energy by 2030, reducing €285/year dwelling energy bills (EC, 2021a). Thus, energy efficiency will create extra revenue of €66 billion for the EU companies (EC, 2021a). Further, plugged electronic appliances consume energy even when they are not powered on. A study in the USA shows this "vampire power" cost to reach up to $19 billion/year (Delforge, 2015). Therefore, anytime plugged-in electronic appliances may continue to draw energy and increase energy bills that contribute to raising one's CF (Co2living, 2019). Wath and Majumdar (2014) reported that replacing the FTs with CFLs and LEDs could save around 129,870 and 164,970 kWh of electricity in India, thereby saving electricity cost of about US$ 21,935 and US$ 27,864, respectively and reducing approximately 47,127 and 59,864 kg of CO_2/year.

The NBE and NWE regions fell within moderate willing (index 1.01–1.50) category to decrease their CFs in energy sector compared to CSE and WSE. Statistics in the UK addressed that although renewable energy consumption in the electric power sector doubled from 2007 to 2016, natural gas and petroleum still accounted for 38% of the total energy consumption (EIA, 2018). Though the Carbon capture and storage (CCS) technology is widely adopted in the UK, its application is limited only to the industrial site. The application of CCS is rare in the dwelling sector due to its high cost. The situation of NBE is unlike other regions. In one-way, renewable energy contributes a significant share (51% of the final energy consumption in 2018; Ranta et al., 2020) of NBE's total energy supply. In addition, geographically, the winter season in NBE is more extended and colder than that of the CSE and WSE regions that upsurge their heating demand more than other regions.

Further, in transport sector, during freezing weather in the NBE region, waiting for the public bus is difficult and therefore people of those region have more personal cars compared to others (e.g. 63% in Finland versus 37% and 33% in Hungary and Romania passenger car/per inhabitant (Eurostat, 2018)). Although the weather condition of different regions is not as critical as it is in the Nordic, the entire Europe is poorly indexed in the transport sector. Thus, similar to China and any other region of the developing and developed world, transport sector is the crucial reason for the growth of CF in Europe (Zhang et al., 2016).

In transportation, considering only the regular usage or short distance transportation could be a limitation of the current study affecting carbon emission. In the future, the study's findings could be expanded by considering long-distance travel and emission issues. Despite this, the scope and relevance of the corresponding research are significant as the study assessed five major dwelling carbon emission sectors, which is novel. From the findings, it is apparent that expert people's views towards WDC varied depending on their gender and regional criteria. Thus, their willingness to reduce CF might have impact on realizing the commercial carbon emission reduction target.

The CF reduction situation is still poor all over the world. The EU has taken initiative to cut down its GHG emissions by about 40% by 2030. Therefore, carbon and CF have progressively become understandable and accountable routinely in the production and consumption sections (Ormond and Goodman, 2015). According to the analysis of the EUREAPA tool 2011 (based on 2004 data), a climate concerned country Finland's per capita CF is relatively high on the European scale (Salo and Nissinen, 2017), and this situation is likely to be much worse in other countries in the future.

In this perspective, achieving zero or negative per capita CF is difficult (not impossible) but reduction in per capita CF can be achieved. Although all the European countries are not a member of the EU, if they follow a similar strategy suggested by EU to attain 40% GHG reduction by 2030, they could also attain the target of carbon emission reduction. This study tried to highlight the facts behind the willingness of carbon footprint reduction by professionals. The general people and researchers will be able to evaluate the overall findings of the study and will be beneficial for shaping their future thoughts. All the local, national and regional strategies and plans will be successful only when carbon reduction is attempted at personal level in parallel with the commercial initiatives for carbon emission reductions. The policymakers and regulators can also evaluate the study findings and accordingly can develop and modify the existing carbon reduction policies to achieve carbon reduction targets, especially in the transport sector.

Credit authorship contribution statement

Tahamina Khanam (TK): Conceptualization, Data collection and Curation, Methodology, Formal analysis and Writing - original draft. Abul Rahman (AR): Formal analysis, Data curation and Writing, Xiaoqian Xu (XX): Writing and Reviewing, Blas Mola-Yudego (BMY): Reviewing and Editing, Md. Munjur E. Moula (MM): Data collection and writing, Paavo Pelkonen (PP): Reviewing, editing and supervising.

Declaration of Competing Interest

The authors would like to thank the Finnish Cultural Foundation for providing financial support as a grant to TK to accomplish this manuscript. The grant number was 00210526.

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