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# DEVELOPMENT OF A CONSUMER MATURITY MODEL FOR CARBON FOOTPRINT REDUCTION

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**Purpose:** The aim of the paper is to present the concept and practical implementation of a consumer maturity model for reducing the carbon footprint. The developed model allows the evaluation of consumers' awareness and behaviors regarding carbon footprint reduction.
**Design/methodology/approach**: The research was based on a comprehensive literature review covering the concepts of carbon footprint and maturity models. Based on the findings, an original consumer maturity model was constructed, followed by its testing using the Proof of Concept (PoC) approach. A Python application was developed to assess consumer maturity based on user responses.
**Findings:** The study resulted in the creation of a consumer maturity model consisting of key dimensions and variables influencing carbon footprint reduction. The model was successfully implemented in an application that allows classification of consumers into different maturity levels based on their behaviors and decisions.
**Research limitations/implications**: The model was tested in a controlled environment, which may limit its generalizability. Future research should involve testing with a broader and more diverse group of consumers.
**Practical implications:** The model and application can be used by organizations and institutions to diagnose consumer readiness to adopt more sustainable behaviors and to design educational or marketing interventions tailored to different maturity levels.
**Social implications:** Promoting awareness and behavioral change among consumers can significantly contribute to reducing greenhouse gas emissions at the individual level, supporting broader climate protection efforts.
**Originality/value:** The paper introduces a novel model specifically targeting consumer behavior in the context of carbon footprint reduction, addressing a gap in existing maturity models which primarily focus on organizational or industrial practices.
**Keywords:** carbon footprint, consumer maturity, maturity model, greenhouse gases.
**Category of paper:** Choose one or two of the possibilities.

## Introduction

With the climate crisis intensifying, reducing the carbon footprint of daily consumption is becoming one of the key challenges of modern societies. Rising average temperatures, extreme weather events, and accelerating loss of biodiversity are not just abstract threats, but real consequences of excessive greenhouse gas emissions (Calvin et al., 2023). This is accompanied by the depletion of natural resources – both non-renewable and renewable, which cannot keep up with regeneration in the face of growing demand (Kryńska et al., 2014). It is therefore necessary to move to the path of sustainable development.

Action to reduce the carbon footprint cannot be limited to the system or industry level – individual consumer decisions also play a key role. It has been estimated that as much as 65% of global greenhouse gas emissions are directly or indirectly linked to households (Ivanova et al., 2016). Consumers must not only be aware of the climate impact of their choices, but also be actively supported in changing their shopping, transportation or eating habits. In addition, consumers consciously reducing their carbon footprint may cause manufacturers and service providers to also reduce their emissions to meet consumers' expectations.

The main objective of the study is to develop a model of consumer maturity in reducing carbon footprint. The cognitive goal is to define the dimensions and variables that should be included in this model. The methodological objective is to develop the concept of the model, and the application objective is to software this model in an application that will determine the degree of consumer maturity in reducing carbon footprint based on the user's responses. In view of this objective, the work was carried out in three stages.

Stage 1 was dedicated to the cognitive objective. The following research questions were posed:

**RQ1.** What dimensions describe consumer maturity in reducing carbon footprint?

**RQ2.** By what variables are the dimensions in question defined?

**RQ3.** What values should each variable take in order to be considered as degrees of the maturity model being developed?

Answers to questions RQ1-RQ3 were sought based on an analysis of the literature on carbon footprint and maturity models.

Stage 2 was dedicated to the methodological objective. Answers to questions RQ1-RQ3 were used to create the author's concept of a consumer maturity model for reducing carbon footprint. Thus, it proposed: 1) the dimensions of consumer maturity, 2) the observable variables measuring these dimensions, and 3) the values taken by the variables in accordance with the gradation’s characteristic of the maturity model. In addition, each variable within a dimension was assigned a weight substantively related to its impact on carbon footprint. Then, based on the variables and their weights, a method for calculating the level of maturity within each dimension was proposed.

Stage 3 focused on the application objective. The concept of the consumer maturity model for reducing carbon footprint, developed in stage 2, was used. At this stage the Proof of Concept (PoC) method was applied. For this purpose, one of the dimensions of the consumer maturity model under development (food) was selected and code was written to implement its variables with values. The written code was then tested on various scenarios. These scenarios were intended to verify the responses of potential users of the application and therefore tested by scenario for: (1) a user fully aware of ways to reduce carbon footprint, (2) a user completely unaware and (3) a user half-familiar with ways to reduce carbon footprint. This test was intended to validate the code and verify the sense and feasibility of developing a consumer maturity model concept. After testing on one dimension, code was written for the other dimensions.

The uniqueness of our article lies in the fact that, for the first time, we have created a consumer maturity model for reducing carbon footprints for Polish consumers. We have developed dimensions and maturity levels and implemented a preliminary version of the application.

## 1. Literature review: theoretical background to the concept of consumer maturity in reducing the carbon footprint

The carbon footprint concept is the result of numerous international environmental agreements to combat global warming. At the 1997 Kyoto Climate Conference, European Union countries committed to reducing emissions of the following greenhouse gases: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride ($SF_6$) (Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997).

A number of definitions of the carbon footprint can be found in scientific literature, which mainly differ in the selection of greenhouse gases and activities considered in its assessment. Examples of definitions of this concept are shown in table 1.

**Table 1.**
*Definitions of the carbon footprint*

| Source | Definition |
|---|---|
| Wiedmann, Minx, 2007 | A carbon footprint is a measure of the total amount of carbon dioxide ($CO_2$) emissions alone that is directly and indirectly caused by an activity or is accumulated during the life cycle of a product. (Wiedmann, Minx, 2007) |
| Peters, 2010 | A carbon footprint is the climate impact of a functional unit defined by a specific metric that takes into account all relevant sources of emissions, removals and storage during both consumption and production within the spatially and temporally defined boundaries of the system. (Peters, 2010) |

Cont. table 1.

| | |
|---|---|
| Wright, Kemp, Williams, 2014 | A carbon footprint is a measure of the total $CO_2$ and $CH_4$ emissions of a specific population, system or activity, taking into account all relevant sources, sinks and storage within the spatial and temporal boundaries of the population, system or activity of interest. Calculated as carbon dioxide equivalent ($CO_2e$) using the respective 100-year global warming potential ($GWP_{100}$) (Wright et al., 2011). |
| ISO 14067:2018 | A carbon footprint is the sum of greenhouse gases emitted and absorbed by a product, expressed as carbon dioxide equivalent and based on a life-cycle assessment using a specific climate change impact category (International Organization for Standardization, 2018). |

Source: own work based on (Wiedmann, Minx, 2007; Peters, 2010; Wright et al., 2011; International Organization for Standardization, 2018).

The most common approach is to include all greenhouse gases listed in the Kyoto Protocol in the carbon footprint. The impact of each on global warming is different, so a global warming potential (GWP) was calculated for each of them. This indicator is based on the radiative properties of greenhouse gases and their residence time in the atmosphere compared to carbon dioxide. GWP expresses the potential impact of 1 kg of a selected greenhouse gas on global warming over a specified period of time compared to the impact of 1 kg of carbon dioxide over the same period (Intergouvernemental panel on climate change, 2007). Table 2 shows the GWP values over the 100-year period on which the Kyoto Protocol is based. To convert the mass of greenhouse gas emitted into $CO_2e$, it is necessary to multiply it by the corresponding global warming potential. Then the carbon footprint is termed the sum of these products, usually expressed in tons of $CO_2e$.

**Table 2.**
*Global warming potential of gases included in the Kyoto Protocol and their emission sources*

| **Greenhouse gas** | **$GWP_{100}$** |
|---|---|
| Carbon dioxide $CO_2$ | 1 |
| Methane $CH_4$ | 25 |
| Nitrous oxide $N_2O$ | 298 |
| Hydrofluorocarbons HFC | 124-14800 |
| Perfluorocarbons PFC | 7390-12200 |
| Sulfur hexafluoride $SF_6$ | 22800 |

Source: own work based on (Intergouvernemental panel on climate change, 2007).

This article adopts the definition of carbon footprint according to ISO 14067:2018, as the use of definitions that do not consider all greenhouse gases described in the Kyoto Protocol may lead to a significant proportion of greenhouse gas emissions being overlooked. The result of focusing on fewer gases may be to reduce carbon dioxide emissions at the expense of increasing emissions of another gas, which may have a greater impact on the environment.

## 2. Methods: concept development

### 2.1. Definitions of the model and its dimensions

Maturity usually means a certain level of development leading to a target state (perfection). It is the degree to which an entity operates in an organized, predictable, and improvable manner, based on established and measurable practices (Wiśniewska et al., 2023).

Thus, consumer maturity in terms of reducing the carbon footprint was defined as the level of consumer development reflecting the degree of transition in their daily consumption behavior on a continuum from haphazard practices to established, organized and measurable actions that reduce the carbon footprint.

*A maturity model conceptually represents phases of increasing quantitative or qualitative capability changes of a maturing element in order to assess its advances with respect to defined focus areas* (Kohlegger et al., 2009). The maturing element in the model is usually a person, object or social system. The area of interest determines which maturity indicators can be used to assess the maturing element. The model divides the development of maturing elements into an appropriate number of stages, which are separated by appropriate conditions. These stages are called maturity levels (Kohlegger et al., 2009).

The maturity model consists of maturity levels and dimensions. The levels represent the maturity level of the maturing element in different dimensions. Each level is assigned a descriptor specifying its purpose and a detailed description of its characteristics. Dimensions are the same as areas of interest. Each dimension is described by the number of variables (elements, activities or measures) at each level. Maturity models can be unidimensional, multidimensional or hierarchical (when using sub-dimensions). Dimensions divide the study area into smaller areas, so they should be separate and comprehensive. Hierarchical models are more complex, so they offer the possibility of separate maturity assessments for each dimension. Maturity assessment can be descriptive or quantitative. For quantitative assessment, a Likert scale is used (Lahrmann, Marx, 2010).

Maturity levels represent the development of an element of the model from total immaturity, lack of organization and chaos to the highest maturity understood as continuous improvement and enhancement. In management science, five-level maturity models are most commonly used, distinguishing levels: first – initial, second – managed, third – standardized, fourth – quantitatively managed and fifth – optimized (Pieńkowski, 2019).

Thus, the consumer maturity model for reducing carbon footprint has been defined as an ordered structure consisting of dimensions and maturity levels. It describes within the dimensions the sequence of consumer development levels (stages of their maturity) in the area of reducing carbon footprint in everyday consumption behavior. The concept of dimensions in such a maturity model should be understood as a set of conditions that will enable effective implementation and development in the field of carbon footprint reduction in everyday consumer behavior.

### 2.2. Operationalization of dimensions

Based on insights obtained from the literature, a conceptual model of consumer maturity was developed. The model defines six key dimensions that characterize consumer behaviors in the context of carbon footprint reduction:

1. food – a set of actions aimed at reducing the carbon footprint resulting from the production, transportation, and subsequent waste of food chosen by the consumer,
2. transport – a set of actions aimed at reducing the carbon footprint resulting from consumer mobility and the delivery of online orders to the consumer,
3. waste – a set of actions aimed at reducing the carbon footprint resulting from the production and disposal of products and their packaging purchased by the consumer,
4. clothing – a set of actions aimed at reducing the carbon footprint resulting from the production and disposal of clothing purchased by the consumer,
5. energy – a set of actions aimed at reducing the carbon footprint resulting from the production of electricity used by the consumer in the household,
6. digital carbon footprint – a set of actions aimed at reducing the carbon footprint resulting from the production, use, and transmission of data through digital devices and infrastructure by the consumer as an individual unit.

Building on the framework proposed by J. Wei, H. Chen, R. Long and F. Zhao (Wei et al., 2019), the consumer maturity model identifies five levels of behavioral advancement: Initial, Developing, Standard, Above Average, and Optimal. These levels reflect increasing awareness and commitment to carbon footprint reduction.

Each consumer is evaluated within individual dimensions based on a weighted average of their responses, as defined by:

$$\mathrm{m_{sc}} = \frac{\sum v_{ij} \cdot w_{ij}}{\sum w_{ij}} \tag{1}$$

where $v_{ij}$ and $w_{ij}$ represent the value and weight of the $j$-th variable in dimension $i$, respectively.

The resulting maturity score is mapped onto predefined intervals that determine the consumer's level. Table 3 summarizes the behavioral characteristics corresponding to each level, ranging from minimal awareness and action (Level 1) to proactive and socially influential behaviors (Level 5).

**Table 3.**
*Definition of maturity levels*

| Maturity level | Criterion | Characteristics |
|---|---|---|
| Level one – initial | $\mathrm{m_{sc}} \in [1; 1{,}5]$ | The consumer at this level shows low awareness of reducing his or her carbon footprint or deliberately fails to reduce his or her greenhouse gas emissions. |
| Level two – developing | $\mathrm{m_{sc}} \in (1{,}5; 2{,}5]$ | The consumer at this level shows some awareness of reducing their carbon footprint but rarely takes action to reduce their GHG emissions. |

Cont. table 3.

| | | |
|---|---|---|
| Level three – standard | $m_{sc} \in (2{,}5; 3{,}5]$ | The consumer at this level shows a fairly high awareness and knowledge of reducing his or her carbon footprint, which manifests itself in his or her frequent actions to reduce his or her greenhouse gas emissions. |
| Level four – above average | $m_{sc} \in (3{,}5; 4{,}5]$ | A consumer at this level shows a high awareness and knowledge of carbon footprint reduction; they almost always or always take action to reduce their GHG emissions. |
| Level five – optimal. | $m_{sc} \in (4{,}5; 5]$ | A consumer at this level shows a high awareness and knowledge of carbon footprint reduction; they almost always or always take action to reduce their GHG emissions and encourage their environment to do so. |

Source: own work.

Each dimension was operationalized with a set of observable measurable variables in the form of consumer-directed questions. A five-point Likert scale was then used to develop responses to the questions. The variable takes on a value corresponding to the number of the selected answer, where 1 indicates a low degree in reducing the carbon footprint and 5 indicates a high degree. Each variable was given a weight that assesses its impact (the action described in the question) on reducing the consumer's carbon footprint also on a scale of 1 to 5.

The amount of greenhouse gases emitted in 2018 in the food system, including production emissions, post-production emissions and LULUCF emissions – caused by land use change and deforestation – was estimated at 17Gt $CO_2$e, which accounted for 31% of global, anthropogenic emissions that year. More than 17% of emissions from the food system were methane emissions from enteric fermentation in ruminants (cows, sheep and goats) (Cerutti et al., 2023). This is one of the main reasons, along with emissions from animal respiration and food production for them, why limiting meat and dairy consumption has a significant impact on reducing the consumer's carbon footprint. Buying local and seasonal produce and growing your own crops helps reduce emissions from food transportation, which accounted for about 5% of the area's emissions (Cerutti et al., 2023). Striving to minimize the food waste generated reduces the emissions resulting from its disposal. These emissions contributed 9% of the food system's emissions this year (Cerutti et al., 2023). The structure of the food dimension is shown in table 4.

**Table 4.**
*Structure of food dimension*

| Observable variable | Value | Weight |
|---|---|---|
| I limit my meat eating. | 1. I do not limit my meat eating. I even eat it several times a day.<br>2. I eat meat once a day.<br>3. I eat meat less than once a day.<br>4. I eat meat less than once a week or not at all.<br>5. I do not eat meat at all and encourage others to do so. | 5 |
| I limit my consumption of dairy products. | 1. I do not restrict the eating of dairy products. I even eat it several times a day.<br>2. I eat dairy products once a day.<br>3. I eat dairy products less than once a day.<br>4. I eat dairy products less than once a week or not at all.<br>5. I do not eat at all and encourage others to do so. | 4 |

Cont. table 4.

| | | |
|---|---|---|
| I try to eat mainly local and seasonal produce. | 1. I do not pay attention to whether the products I eat are local and seasonal.<br>2. Less than 50% of the products I eat are local and seasonal.<br>3. 50 to 90% of the products I eat are local and seasonal.<br>4. More than 90% of the products I eat are local and seasonal.<br>5. More than 90% of the products I eat are local and seasonal. I encourage others to buy such products. | 5 |
| I only buy what I need to avoid food waste. | 1. When I buy food, I do not think about whether it will go to waste.<br>2. I throw away more than 50% of the food I buy.<br>3. I throw away between 10 and 50% of the food I buy.<br>4. I throw away less than 10% of the food I buy.<br>5. I throw away less than 10% of the food I buy and encourage others to buy thoughtfully. | 5 |
| I plant my own vegetables and/or fruit in the garden (or in pots e.g., on the balcony, windowsill). | 1. I do not plant my own fruit and vegetables.<br>2. The fruit and vegetables I plant account for less than 50% of my requirement for them.<br>3. The fruit and vegetables I plant account for between 50 and 90% of my fruit and vegetable requirements.<br>4. The fruit and vegetables I plant account for more than 90% of my fruit and vegetable requirements.<br>5. The fruit and vegetables I plant account for more than 90% of my requirements and I encourage others to plant them. | 4 |
| I choose organic food. | 1. I do not pay attention to whether the food I buy is organic.<br>2. Less than 50% of the food I buy is organic.<br>3. 50 to 90% of the food I buy is organic.<br>4. More than 90% of the food I buy is organic.<br>5. More than 90% of the food I buy is organic. I encourage others to buy such food. | 4 |
| I plan meal sizes so that food does not go to waste. | 1. When planning meals, I do not pay attention to whether food will go to waste.<br>2. I plan the size of meals so that I waste more than 50% of the food I have prepared.<br>3. I plan meal sizes so that I waste between 10 and 50% of the food I have prepared.<br>4. I plan the size of meals so that I waste less than 10% of the food I have prepared.<br>5. I plan my meal sizes so that less than 10% of the food I prepare is wasted and encourage others to do the same. | 4 |
| I am giving up ready meals in favor of home-cooked meals. | 1. I eat ready food several times a day.<br>2. I eat ready food several times a week.<br>3. I eat ready food once a week.<br>4. I eat ready food less than once a week.<br>5. I eat ready food less than once every 2 weeks and encourage others to do the same. | 4 |

Source: own work based on (Vermeulen et al., 2012; Cerutti et al., 2023; Dubois et al., 2019).

Direct and indirect greenhouse gas emissions from transportation in 2018 were estimated at 8.5Gt $CO_2e$, accounting for 14% of the global carbon footprint that year (Lamb et al., 2021). Direct emissions are due to the combustion of fuel by vehicles, and indirect emissions are due to the extraction of fuel and the generation of electricity consumed by electric vehicles. Any reduction in car travel reduces the consumer's carbon footprint. Moving by bicycle instead of car for short distances would reduce travel emissions by about 75%. Traveling by train instead of car over medium distances would reduce emissions by about 80% (Ritchie, 2023). Taking passengers who are going to the same place does not significantly increase the emitted carbon footprint; in fact, the opposite is true. The additional passengers will not move by

another means of transportation, which will sum up to reducing the emissions generated. Likewise, when we order packages to pickup points instead of home, the courier has to go to fewer places, which also reduces the carbon footprint. Table 5 shows the structure of the transportation dimension.

**Table 5.**
*Structure of transport dimension*

| Observable variable | Value | Weight |
|---|---|---|
| Instead of driving, I get around on foot, on a bicycle/scooter or use public transportation. | 1. I do not restrict driving. I drive everywhere by car, even for short distances.<br>2. When I want to get somewhere, I choose a car as a means of transportation at least 50% of the time.<br>3. When I want to get somewhere, I choose a car as a means of transportation 10 to 50% of the time.<br>4. When I want to get somewhere, I choose a car as a means of transportation less than 10% of the time.<br>5. When I want to get somewhere, I choose a car as a means of transportation less than 10% of the time and encourage others to do the same. | 5 |
| When I need to get somewhere by car (for example, to work), I try to take people with me who are also going there (such as co-workers). | 1. Never, I always drive alone.<br>2. When I need to get somewhere, I take other people with me less than 50% of the time.<br>3. When I need to get somewhere, I take other people with me 50 to 90% of the time.<br>4. When I need to get somewhere, I take other people with me more than 90% of the time.<br>5. When I need to get somewhere, I take other people with me more than 90% of the time. I encourage others to do the same. | 4 |
| I choose the stairs instead of the elevator. | 1. I always use the elevator.<br>2. I choose the stairs less than 50% of the time.<br>3. I choose the stairs 50 to 90% of the time.<br>4. I choose stairs more than 90% of the time.<br>5. I choose the stairs more than 90% of the time and encourage others to do so. | 3 |
| When I buy online, I order products for pick-up points instead of at home. | 1. I never order packages to pick-up points. I always choose delivery to a designated address.<br>2. Less than 50% of packages I order to pick-up points.<br>3. 50 to 90% of packages I order to pick-up points.<br>4. More than 90% of packages I order to pick-up points.<br>5. More than 90% of packages I order to pick-up points and encourage others to do so. | 4 |

Source: own work based on (Lamb et al., 2021; Dubois et al., 2019; Ritchie, 2023).

Municipal waste management emitted 1.4 Gt $CO_2$e in 2018, accounting for about 3% of global emissions for the year. This result consists of emissions of:

- methane arising from the decomposition of landfilled waste, its incineration and composting,
- carbon dioxide formed during their incineration,
- nitrous oxide arising from their incineration and composting (Chen et al., 2020).

Each product used only once and quickly discarded generates avoidable emissions. Using reusable bags, containers and everyday items instead of disposable ones reduces the frequency of waste production and incineration and the production of more disposable products.

Segregating and composting waste allows it to be recycled and reused, reducing greenhouse gas emissions. Table 6 shows the waste dimension structure.

**Table 6.**
*Structure of waste dimension*

| Observable variable | Value | Weight |
|---|---|---|
| I segregate my trash. | 1. I do not segregate my trash. I do not consider it important.<br>2. I segregate less than 50% of the recyclable garbage I produce.<br>3. I segregate between 50 and 90% of the recyclable garbage I produce.<br>4. I segregate more than 90% of the recyclable garbage I produce.<br>5. I segregate more than 90% of the recyclable garbage I produce and encourage others to do so. | 4 |
| I take reusable bags or a basket, backpack, etc. with me when shopping. | 1. I buy disposable bags every time I shop.<br>2. For less than 50% of purchases I take a bag (or something else).<br>3. For 50 to 90% of purchases I take a bag (or something else).<br>4. For more than 90% of purchases I take a bag (or something else).<br>5. For more than 90% of purchases, I take a bag (or something else) and encourage others to do the same. | 4 |
| When I buy vegetables and fruits, I do not pack them in plastic bags. | 1. I always use plastic bags to pack fruits and vegetables.<br>2. When buying fruits and vegetables, I pack more than 50% of them into plastic bags.<br>3. When buying fruits and vegetables between 10% and 50% of them I pack them in plastic bags.<br>4. When buying fruits and vegetables, less than 10% of them are packed in plastic bags.<br>5. When buying fruits and vegetables, less than 10% of them are packed in plastic bags. I encourage others to do the same. | 4 |
| Instead of buying bottled water, I drink tap or filtered water. | 1. I always buy bottled water.<br>2. Tap or filtered water makes up less than 50% of the water I drink.<br>3. Tap or filtered water makes up 50 to 90% of the water I drink.<br>4. Tap or filtered water makes up more than 90% of the water I drink.<br>5. Tap or filtered water makes up more than 90% of the water I drink. I encourage others not to buy bottled water. | 5 |
| I compost biodegradable waste. | 1. I do not compost biodegradable waste.<br>2. I compost less than 50% of the biodegradable waste I generate.<br>3. I compost between 50 and 90% of the biodegradable waste I generate.<br>4. I compost more than 90% of the biodegradable waste I generate.<br>5. I compost more than 90% of the biodegradable waste I produce and encourage others to do so. | 5 |
| If possible, I choose products packaged in environmentally friendly packaging (for example, chocolate in paper packaging instead of plastic). | 1. I do not pay attention to product packaging.<br>2. I choose products packaged in environmentally friendly packaging less than 50% of the time.<br>3. I choose products packaged in environmentally friendly packaging 50 to 90% of the time.<br>4. I choose products packaged in environmentally friendly packaging more than 90% of the time.<br>5. I choose products packaged in environmentally friendly packaging more than 90% of the time and encourage others to do the same. | 4 |
| When an appliance breaks down, I put it in for repair. | 1. I always buy a new device.<br>2. I repair less than 50% of broken devices.<br>3. I repair less than 50 to 90% of broken devices.<br>4. I repair more than 90% of broken devices.<br>5. I repair more than 90% of broken appliances and encourage others to do the same. | 4 |

Cont. table 6.

| | | |
|---|---|---|
| I replace disposable products with products that can be used repeatedly (e.g., an electric razor instead of a disposable one, reusable cotton balls for makeup removal, a bottle instead of a disposable bottle). | 1. I do not pay attention to whether the products I use are disposable or reusable.<br>2. Less than 50% of the products I use are reusable products.<br>3. Between 50 and 90% of the products I use are reusable products.<br>4. More than 90% of the products I use are reusable products.<br>5. More than 90% of the products I use are reusable products. I encourage others to choose such products. | 5 |
| Instead of typical cosmetics (shampoo, shower gel), I opt for counterparts in cubes (which use less water to produce) or cosmetics in refills. | 1. I do not pay attention to the type of cosmetics.<br>2. Less than 50% of the cosmetics I buy are in cubes or have been packaged in a refill.<br>3. Between 50 and 90% of the cosmetics I buy are in cubes or have been packaged in a refill.<br>4. More than 90% of the cosmetics I buy are in cubes or have been packaged in a refill.<br>5. More than 90% of the cosmetics I buy are in cubes or have been packaged in a refill. I encourage others to buy such products. | 4 |
| I pay attention when I am shopping whether product manufacturers are reducing their carbon footprint, conducting green activities, etc. | 1. I do not pay attention to manufacturers' green operations when I shop.<br>2. Less than 50% of the products I buy have been produced by manufacturers that have green operations.<br>3. Between 50 and 90% of the products I buy have been produced by producers who conduct ecological activities.<br>4. More than 90% of the products I buy have been produced by manufacturers that have organic operations.<br>5. More than 90% of the products I buy have been produced by manufacturers that have organic operations. I encourage others to do the same. | 5 |
| If I have the opportunity, I rent an item instead of buying a new one. | 1. No, I always prefer to buy new items.<br>2. If there is an opportunity, I rent items less than 50% of the time.<br>3. If there is an opportunity, I rent items 50 to 90% of the time.<br>4. If there is an opportunity, I rent items in more than 90% of cases.<br>5. If there is an opportunity, I rent items in more than 90% of cases. I encourage others to do the same. | 4 |

Source: own work based on (Chen et al., 2020).

The fashion industry was responsible for 2.1 Gt $CO_2$e emissions in 2018, approximately 4% of global greenhouse gas emissions. Subsequent apparel and footwear manufacturing processes were responsible for 71% of emissions in this area. The remaining emissions were due to their disposal and withdrawal from exploration (23%), transportation (3%) and retail (3%) (Berg et al., 2020).

Fast fashion increases greenhouse gas emissions through overproduction, poor quality garments and short wear cycles. Buying only what you need and choosing higher quality or sustainably produced clothing reduces the environmental burden throughout the product's life cycle. Buying used clothing and extending its life through repair, reuse, donation or resale significantly reduces emissions by avoiding new production and reducing textile waste. Table 7 shows the structure of the clothing consumption dimension.

**Table 7.**
*Structure of clothing dimension*

| Observable variable | Value | Weight |
|---|---|---|
| I try to buy second-hand clothes. | 1. I never buy second-hand clothes.<br>2. Less than 50% of the clothes I buy are second-hand.<br>3. Between 50 and 90% of the clothes I buy are second-hand.<br>4. More than 90% of the clothes I buy are second-hand.<br>5. More than 90% of the clothes I buy are second-hand. I encourage others to buy such clothes. | 5 |
| I do not throw away clothes that are in good condition but instead give them away to friends or people in need, sell them or exchange them for others. | 1. I throw away clothes, even if they are in good condition.<br>2. Less than 50% of clothes are in good condition that I no longer wear, I give away, sell or exchange for others.<br>3. Between 50 and 90% of clothes that I no longer wear, I give away, sell or exchange for others.<br>4. More than 90% of clothes in good condition that I no longer wear, I give away, sell or exchange for others.<br>5. More than 90% of clothes in good condition that I no longer wear, I give away, sell or exchange for others. I encourage others to do the same. | 4 |
| I buy new clothes only when I need them. | 1. No, I buy new clothes for pleasure.<br>2. Less than 50% of the clothes I buy I need.<br>3. Between 50 and 90% of the clothes I buy I need.<br>4. More than 90% of the clothes I buy I need.<br>5. More than 90% of the clothes I buy I need. I encourage others to reduce buying unnecessary clothes. | 5 |
| When I buy new clothes, I choose high-quality ones. | 1. This is not important to me.<br>2. Less than 50% of the clothes I buy are of high quality.<br>3. Between 50 and 90% of the clothes I buy are of high quality.<br>4. More than 90% of the clothes I buy are of high quality.<br>5. More than 90% of the clothes I buy are of high quality. I encourage others to choose such clothes. | 4 |
| When I buy new clothes, I choose those made in a sustainable and responsible way (e.g., made from recycled materials). | 1. This is not important to me.<br>2. Less than 50% of the new clothes I buy have been produced in a sustainable and responsive way.<br>3. Between 50 and 90% of the new clothes I buy have been produced in a sustainable and responsive manner.<br>4. More than 90% of the new clothes I buy have been produced in a sustainable and responsive manner.<br>5. More than 90% of the new clothes I buy have been produced in a sustainable and responsive manner. I encourage others to buy such clothes. | 5 |
| I repair my clothes instead of throwing them away. | 1. I never repair my clothes.<br>2. I repair less than 50% of my clothes.<br>3. I repair between 50 and 90% of my clothes.<br>4. I repair more than 90% of my clothes.<br>5. I repair more than 90% of my clothes and encourage others to do so. | 5 |

Source: own work based on (Niinimäki et al., 2020; Berg et al., 2020).

The energy sector contributed 20Gt $CO_2$e in 2018, accounting for 34% of global greenhouse gas emissions that year (Lamb et al., 2021). Households are directly responsible for about 26% of total energy consumption in the European Union (European Commission. Statistical Office of the European Union, 2020). Reducing household energy demand is therefore crucial to achieving climate goals. Choosing energy-efficient "A" class appliances, using LED lighting and unplugging unused appliances directly reduces electricity consumption. Minimizing heating and cooling demand through temperature control and thermal upgrading also leads to

significant reductions in greenhouse gas emissions. Lowering the temperature during the heating season and not lowering it on hot days significantly reduces energy consumption. Table 8 shows the structure of the energy dimension.

**Table 8.**
*Structure of energy dimension*

| Observable variable | Value | Weight |
|---|---|---|
| I choose "A" class energy-efficient household appliances. | 1. I do not pay attention to the energy class of household appliances.<br>2. I most often choose household appliances with low energy class ("E", "F", "G").<br>3. I most often choose household appliances with medium energy class ("C", "D").<br>4. I most often choose energy-efficient appliances of "A" or "B" class.<br>5. I always choose "A" class energy-efficient appliances and encourage others to do the same. | 5 |
| I unplug devices that don't need constant access to electricity when not in use. | 1. I never unplug unused devices from electricity.<br>2. Less than 50% of the time, I unplug unused devices from electricity.<br>3. Between 50 and 90% of the time, I unplug unused devices from electricity.<br>4. In more than 90% of cases, I unplug unused devices from electricity.<br>5. In more than 90% of cases, I unplug unused devices from electricity and encourage others to do the same. | 4 |
| I use energy-saving light bulbs. | 1. I don't pay attention to what kind of light bulbs I buy or choose non-energy-efficient ones.<br>2. Less than 50% of the light bulbs in my home are energy efficient.<br>3. Between 50 and 90% of the light bulbs in my home are energy efficient.<br>4. More than 90% of the light bulbs in my home are energy efficient.<br>5. More than 90% of the light bulbs in my home are energy efficient. I encourage others to buy such. | 4 |
| I turn off the light when it is not needed. | 1. No, I always leave the light on.<br>2. In less than 50% of cases when the light is not needed, I turn it off.<br>3. In 50 to 90% of cases when the light is not needed, I turn it off.<br>4. In more than 90% of cases when the light is not needed, I turn it off.<br>5. In more than 90% of cases when the light is not needed, I turn it off. I encourage others to do the same. | 4 |
| I don't use a hair dryer. | 1. I always use a hair dryer after washing my hair.<br>2. After washing my hair, I use a hair dryer more than 50% of the time.<br>3. After washing my hair, I use a hair dryer for between 10 and 50% of the time.<br>4. After washing my hair, I use a hair dryer less than 10% of the time.<br>5. After washing my hair, I use a hair dryer less than 10% of the time. I encourage others not to use it. | 3 |
| I own photovoltaic panels. | 1. I do not own photovoltaic panels.<br>2. I have photovoltaic panels that provide my electricity needs at less than 50%.<br>3. I have photovoltaic panels that provide my electricity needs between 50 and 90%.<br>4. I have photovoltaic panels that provide my electricity needs at more than 90%.<br>5. I have photovoltaic panels that provide my electricity needs at more than 90%. I encourage others to install photovoltaic panels. | 5 |
| In winter, I keep the temperature in the house low. | 1. No, I keep the temperature above 22°C.<br>2. I keep the temperature at 20-22°C.<br>3. I try to keep the temperature at home at 20°C.<br>4. I keep the temperature at home at 18°C.<br>5. I keep my home temperature at 18°C or lower and encourage others to do the same. | 4 |

Cont. table 8.

| | | |
|---|---|---|
| In the summer, I do not lower the temperature in the house with air conditioning, fan, etc. | 1. When it is hot, I always lower the temperature with air conditioning (or a fan, etc.).<br>2. When it is hot, I lower the temperature with air conditioning (or a fan, etc.) more than 50% of the time.<br>3. When it is hot, I lower the temperature with air conditioning (or a fan, etc.) between 10 and 50% of the time.<br>4. When it is hot, I lower the temperature with air conditioning (or a fan, etc.) less than 10% of the time.<br>5. When it is hot, I never lower the temperature with air conditioning (or a fan, etc.) and encourage others to do the same. | 4 |
| I heat my home using clean thermal technologies. | 1. I do not use clean thermal technologies to heat my home.<br>2. I obtain energy to heat my home in less than 50% from clean technologies.<br>3. I obtain energy to heat my home between 50 and 90% from clean technologies.<br>4. I obtain energy to heat my home more than 90% from clean technologies.<br>5. I obtain energy to heat my home more than 90% from clean technologies. I encourage others to do the same. | 5 |
| I turn on the dishwasher when it is already full of dishes. | 1. It is not important to me.<br>2. I'll even turn it on with a few things.<br>3. It has to be at least half full.<br>4. I try to make it full.<br>5. It has to be full. I encourage others to turn on the dishwasher only when it is full. | 4 |
| I do laundry when the washing machine is already full. | 1. It is not important to me.<br>2. I'll even turn it on with one thing if I want to dress it.<br>3. It has to be at least half full.<br>4. I try to make it full.<br>5. It has to be full. I encourage others to turn on the washing machine only when it is full. | 4 |
| I wash clothes at low temperatures. | 1. No, I always wash clothes at high temperatures.<br>2. I wash clothes at low temperatures less than 50% of the time.<br>3. I wash clothes at low temperatures 50 to 90% of the time.<br>4. I wash clothes at low temperatures more than 90% of the time.<br>5. I wash clothes at low temperatures more than 90% of the time and encourage others to do so. | 4 |
| I do not use a tumble dryer for clothes. | 1. I always tumble dry my clothes.<br>2. I tumble dry clothes more than 50% of the time.<br>3. I dry clothes in a tumble dryer between 10 and 50% of the time.<br>4. I dry clothes in a tumble dryer less than 10% of the time.<br>5. I never tumble dry clothes and encourage others to do the same. | 4 |

Source: own work based on (European Commission. Statistical Office of the European Union, 2020; Ritchie, 2023).

The ICT (information and communications technology) sector was responsible for 1.2-2.2 Gt $CO_2$e in 2020, accounting for 2.1-3.9% of the global carbon footprint that year (Freitag et al., 2021). These emissions result from the extraction of needed raw materials, the production and transportation process, the use and operation, and the disposal of digital equipment and infrastructure. Leaving phones or routers unnecessarily connected, overusing high-definition video and storing redundant data in the cloud all contribute to avoidable energy consumption. Streaming video has a particularly high energy consumption when viewed in HD or 4K, so choosing a lower video quality helps reduce the impact on carbon footprint. Choosing audio instead of video only when listening, unsubscribing from unused mailing lists and turning off devices during periods of inactivity can reduce this impact (Jaciow et al., 2023). Using energy-

efficient search engines, limiting time spent on bandwidth-intensive activities such as gaming or social media, and moving storage to local drives are small but significant steps to reduce the digital footprint. Table 9 shows the structure of the digital footprint dimension.

**Table 9.**
*Structure of digital carbon footprint dimension*

| Observable variable | Value | Weight |
|---|---|---|
| I do not leave my phone plugged in when it is already charged. | 1. I do not pay attention to it.<br>2. I leave my phone plugged in more than 50% of the time when it is already charged.<br>3. I leave my phone plugged in between 10 and 50% of the time when it is already charged.<br>4. I leave my phone plugged in less than 10% of the time when it is already charged.<br>5. I leave my phone plugged in less than 10% of the time when it is already charged. I encourage others to do the same. | 4 |
| I do not store unnecessary data in the cloud. | 1. I do not think about the usefulness of the data I keep in the cloud.<br>2. More than 50% of the data I keep in the cloud is redundant.<br>3. Between 10 and 50% of the data I store in the cloud is redundant.<br>4. Less than 10% of the data I store in the cloud is redundant.<br>5. Less than 10% of the data I store in the cloud is redundant. I encourage others to delete unnecessary data. | 4 |
| I delete unnecessary messages from my email inbox. | 1. I never delete unnecessary messages in my email inbox.<br>2. I delete less than 50% of unnecessary messages.<br>3. I delete between 50 and 90% of unnecessary messages.<br>4. I delete more than 90% of unnecessary messages.<br>5. I delete more than 90% of unnecessary messages and encourage others to do so. | 4 |
| When I step away from the computer for an extended period of time, I turn it off instead of putting it to sleep. | 1. I never turn off the computer.<br>2. I turn off the computer in less than 50% of such cases.<br>3. I turn off the computer in 50% to 90% of such cases.<br>4. I turn off the computer in more than 90% of such cases.<br>5. I turn off the computer in more than 90% of such cases and encourage others to do so. | 4 |
| My computer was set to go into sleep mode after a few minutes of inactivity. | 1. My computer is not set to go to sleep mode automatically.<br>2. My computer is set to go to sleep mode after 30 or more minutes of non-use.<br>3. My computer is set to enter sleep mode after 6-29 minutes of non-use.<br>4. My computer is set to enter sleep mode after 5 minutes or less of non-use.<br>5. My computer is set to enter sleep mode after 5 minutes or less of non-use. I encourage others to set their computers this way. | 4 |
| Before leaving home, I turn off my Wi-Fi router. | 1. I never turn off my Wi-Fi router before leaving home.<br>2. Less than 50% of the time, I turn off my Wi-Fi router before leaving home.<br>3. Between 50 and 90 percent of the time, I turn off my Wi-Fi router before leaving home.<br>4. More than 90% of the time I turn off my Wi-Fi router before leaving home.<br>5. More than 90% of the time, I turn off my Wi-Fi router before leaving home and encourage others to do so. | 3 |

Cont. table 9.

| | | |
|---|---|---|
| I use environmentally friendly search engines (e.g. Ecosia.org, Lilo.org - they run on renewable energy sources and offset their carbon footprint through tree plantations and similar projects). | 1. I don't pay attention to whether search engines are environmentally friendly.<br>2. I use environmentally friendly search engines less than 50% of the time.<br>3. I use environmentally friendly search engines 50 to 90% of the time.<br>4. I use environmentally friendly search engines more than 90% of the time.<br>5. I use environmentally friendly search engines more than 90% of the time and encourage others to do so. | 4 |
| When possible, I search for information/products on a relevant site (e.g. Wikipedia, Allegro) instead of all over the web. | 1. I never search for information/products on the right site. I always use general search engines.<br>2. I search for information/products on the right site less than 50% of the time.<br>3. I search for information/products on the right site 50 to 90% of the time.<br>4. I search for information/products on a relevant site more than 90% of the time.<br>5. I search for information/products on the right site more than 90% of the time and encourage others to do so. | 4 |
| I unsubscribe from commercial lists and newsletters that I do not need. | 1. I never unsubscribe from commercial lists and newsletters I do not need.<br>2. I unsubscribe from commercial lists and newsletters I do not need less than 50% of the time.<br>3. I unsubscribe from commercial lists and newsletters I do not need 50 to 90% of the time.<br>4. I unsubscribe from commercial lists and newsletters I do not need more than 90% of the time.<br>5. I unsubscribe from commercial lists and newsletters I do not need more than 90% of the time. I encourage others to do the same. | 4 |
| I send links to files instead of large attachments. | 1. I only send links when it is impossible to send such a large file through any platform.<br>2. I send file links instead of large attachments less than 50% of the time.<br>3. I send links to files instead of large attachments 50 to 90% of the time.<br>4. I send file links instead of large attachments more than 90% of the time.<br>5. I send links to files instead of large attachments more than 90% of the time and encourage others to do the same. | 4 |
| When I send an email, I only send it to the people who need to receive it (e.g., when responding to an email asking about availability that was sent to a group, I only send the response to the person from whom it came). | 1. I don't pay attention to that.<br>2. When I send an email, I only send it to people who need to receive it less than 50% of the time.<br>3. When I send an email, I only send it to people who need to receive it 50 to 90% of the time.<br>4. When I send an email, I only send it to people who need to receive it more than 90% of the time.<br>5. When I send an email, I only send it to people who need to receive it more than 90% of the time I encourage others to do the same. | 4 |
| I limit playing online games. | 1. I play online games without restriction.<br>2. I try to limit playing online games, but I still play no more than 50% of my free time.<br>3. I limit playing online games, I play between 10 and 50% of my free time.<br>4. I play online games in less than 10% of my free time.<br>5. I play online games in less than 10% of my free time and encourage others to limit playing. | 4 |

Cont. table 9.

| | | |
|---|---|---|
| I try to choose audio files instead of video (for example, when listening to music, I choose YouTube Music instead of YouTube, where I can watch a music video in addition to the audio). | 1. No, I choose video, even if I only listen from audio.<br>2. I choose audio files over video less than 50% of the time.<br>3. I choose audio files over video between 50 and 90% of the time.<br>4. I choose audio files over video more than 90% of the time.<br>5. I choose audio files over video files more than 90% of the time and encourage others to do the same. | 4 |
| When I want to download a large file or watch a movie I choose Wi-Fi instead of a mobile network. | 1. I don't pay attention to what network I use.<br>2. I use Wi-Fi instead of a mobile network to download large files and watch videos less than 50% of the time.<br>3. I use Wi-Fi instead of a cellular network to download large files and watch movies 50 to 90 percent of the time.<br>4. I use Wi-Fi instead of a cellular network to download large files and watch videos more than 90% of the time.<br>5. I use Wi-Fi instead of a cellular network to download large files and watch videos more than 90% of the time. I encourage others to do the same. | 4 |
| I limit the sharing of photos and videos on social media. | 1. I do not limit, I share a lot of photos and/or videos on social media.<br>2. I share more than one photo or video on social media per week.<br>3. I share less than one photo or video on social media per week, but more than one per month.<br>4. I share less than one photo or video on social media per month.<br>5. I share less than one photo or video on social media per month. I encourage others to limit publishing content on social media. | 4 |
| I store large files on external drives instead of in the cloud. | 1. No, I use the cloud to store large files.<br>2. I store less than 50% of large files on external drives.<br>3. Between 50 and 90% of my large files I store on external drives.<br>4. More than 90% of my large files I store on external drives.<br>5. More than 90% of my large files I store on external drives. I encourage others to do the same. | 5 |
| I regularly clean the data I store. | 1. I never clean the data I store.<br>2. I clean stored data less than once a year.<br>3. I clean stored data more than once a year, but less than once a quarter.<br>4. I clean stored data more often than once a quarter, but less than once a month.<br>5. I clean stored data more often than once a month and encourage others to do so. | 4 |
| I limit my phone and computer use. | 1. I use the computer and phone without restriction.<br>2. I try to limit my use of the phone and computer, but I use them more than 50% of my free time.<br>3. I limit my use of the phone and computer, using them between 10 and 50% of my free time.<br>4. I use the phone and computer in less than 10% of my free time.<br>5. I use the phone and computer in less than 10% of my free time and encourage others to do the same. | 4 |
| I try to watch movies in lower quality. | 1. I always watch movies in the highest quality available.<br>2. I choose a lower quality when watching less than 50% of movies.<br>3. I choose a lower quality when watching between 50 and 90% of movies.<br>4. I choose a lower quality when watching more than 90% of movies.<br>5. I choose lower quality when watching more than 90% of movies and encourage others to do the same. | 4 |

Source: own work based on (Rizk, 2019; Jaciow et al., 2023).

# 3. Results: application prototype

## 3.1. Proof of Concept Implementation

Proof of Concept (PoC) approach was employed to validate the feasibility of the model. A prototype application was developed using the Python programming language and the Tkinter graphical library.

Initially, a single dimension (food) was implemented and tested with three user scenarios:

1. a user fully aware of carbon footprint reduction practices,
2. a user completely unaware,
3. a user with partial awareness.

The user in the first scenario shows a high awareness and knowledge of carbon footprint reduction. The user almost always or always takes action to reduce their emissions and encourages others to do the same. Such a person would be very likely to choose the fifth answer when answering questions in the application. According to the model's assumptions, the program calculated a maturity score equal to 5 and, based on this, classified the user at level five.

The user in the second scenario has a low awareness of reducing his or her carbon footprint and does not take action to reduce it. Such a person would be very likely to choose the first answers when answering questions in the application. According to the model's assumptions, the program calculated a maturity score equal to 1 and, based on this, classified the user at level one.

The user in this scenario shows relatively high awareness and knowledge of carbon footprint reduction. In half of the cases, the user takes action to reduce their emissions. Such a person would be very likely to choose the third answer when answering questions in the application. According to the model's assumptions, the algorithm application calculated a maturity score of 3 and, based on this, classified the user at level three. The results obtained confirm the effectiveness of the targeted application.

## 3.2. Description of the application

After positive proof of concept, a final application was written that assessed the user in all dimensions. The application counts a weighted average of the scores within each dimension based on the answers given to questions from that dimension. It then assigns the appropriate maturity level in each dimension according to the criterion in table 3. A diagram of how the application works is shown in figure 1.

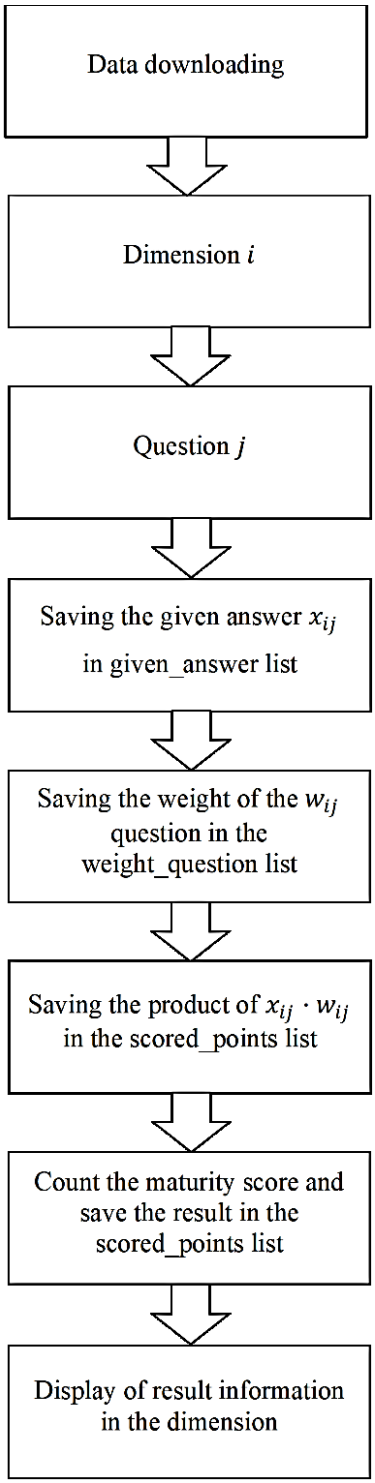


**Figure 1.** Application diagram.

Source: own work.

The graphical user interface was created using the Tkinter library. The application consists of three parts: loading the data, the *Maturity* class in which the application was implemented and the creation of the GUI window.

## 4. Discussion and conclusions

This paper presents the development and validation of a consumer maturity model application to reduce carbon footprint. The model identifies critical dimensions of consumer behavior that significantly influence greenhouse gas emissions and provides a structured method for assessing individual maturity levels. In this way, our work is consistent with the concept proposed in the following works: (Wiśniewska et al., 2023; Kohlegger et al., 2009; Pieńkowski, 2019; Wei et al., 2019; Cerutti et al., 2023; Lamb et al., 2021; Dubois et al., 2019; Ritchie, 2023; Chen et al., 2020; Niinimäki et al., 2020; Berg et al., 2020; Rizk, 2019; Jaciow et al., 2023).

Based on an extensive literature review and an analysis of maturity models, a framework was created that links observable consumer behaviors with specific maturity stages. The model consists of six dimensions. Each dimension is measured by several observable variables that assume one of five maturity levels. The model was successfully implemented in a prototype application, which was tested using different user profiles. The results confirmed the application's ability to accurately distinguish between varying levels of consumer environmental awareness. Based on this, a final app was developed to assess the user's consumer maturity in terms of reducing carbon footprint.

The study contributes to the field of sustainable consumption by introducing a practical tool that can be used to diagnose consumer readiness for pro-environmental behaviors (Calvin et al., 2023; Kryńska et al., 2014). It offers a foundation for future interventions aimed at promoting more sustainable lifestyles.

We realize that our work is not free from limitations. We did not validate our scales across dimensions for convergent or discriminant validity. Such validation would require survey research with a sample size exceeding 100 respondents. Therefore, such research should be conducted in the future.

The application should also be developed in the future. A possible development path is to turn it into a web or mobile application and improve the visual aspects. Another path is to add more dimensions in which the user will be evaluated or questions to the dimensions already in place. This would allow for an even more detailed review of user behavior, resulting in a more precise evaluation. These paths are not mutually exclusive, and it is possible to implement both in the future.

The developed model and application have significant potential for use in educational, research, and commercial contexts, supporting broader efforts to mitigate climate change through individual action.

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