



Evaluating circular economy strategies and practices in households: A self-assessment tool

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ABSTRACT

Household daily activities, such as food acquisition, housing, and mobility, are closely linked to sustainability impacts, including climate change, raw material use, quality of life, and waste production. Multiple studies have been conducted to understand circular economy assessment in products, private or public organizations, eco-industrial parks, and cities. However, there is still a lack of knowledge regarding the assessment of circular economy practices implemented at the household level, including current strategies, and indicators. Thus, the present work aims at developing a self-assessment tool to assess and report the implementation of circular economy-based strategies and practices at the household level, including the definition of related consumption activities and indicators. This study is supported by a two-stage methodology, based on a mixed-method approach, focusing collaboration with residents'/family representatives, through a questionnaire survey and semi-structured interviews. The main findings from the survey enabled the identification of householders' consumption priorities, encompassing different circular economy related strategies and practices. This allowed a qualitative triangulation with an integrative literature review, resulting in a set of 38 household circular economy indicators that enable self-assessment and foster circular economy at the consumer level. Then, the developed tool was evaluated by a selection of interviewed stakeholders to gain insights into its usage, leading to the identification of several practical recommendations to enhance understandability and operability, including technicalities and language related issues. The developed self-assessment tool could encourage individuals and families to start considering voluntary CE evaluations and reporting, particularly as municipalities and other relevant stakeholders begin to recognize and request this information. This research contributes to the ongoing debate regarding the role of a circular household in the transition to sustainability, including its inherent assessment, and communication.

1. Introduction

Household consumption practices are associated with major environmental impacts and sustainability challenges, including climate change, freshwater eutrophication, air pollution, raw material use, acidification, well-being, and waste production (Castellani et al., 2019). In this context, food acquisition, housing – which includes construction, renovations, and energy consumption by the house –, and mobility are main drivers of impact (Castellani et al., 2019; Kalbar et al., 2018; Saleem and Ali, 2019). Although dependent on income level and age, among other factors, lifestyle practices are linked to the aforementioned environmental impacts (Kalbar et al., 2018). When comparing the environmental impact in countries such as Pakistan and China, Saleem

and Ali (2019) understood that, aligned with an increase in people's income, in the past 50 years, there was a higher energy, and product consumption-based lifestyle. Thus, economic growth and consumption patterns are closely associated (Caeiro et al., 2012; Distefano and Kelly, 2017), namely in food (Gerbens-Leenes et al., 2010) and electricity acquisition (Shi et al., 2020). The concept of sustainable consumption was brought forward, centralizing the need for individuals, organizations, and nations to reduce their pressure on the environment and society (Anantharaman, 2018).

The origin of sustainable consumption is found in the term of Sustainable Consumption and Production (SCP), which was introduced at the United Nations Conference on Environment and Development (UNCED), in Rio de Janeiro, in 1992 (Glavič, 2021). This concept was

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brought forward, with Agenda 21, stating that there was a resource over-consumption (Anantharaman, 2018). Recently, as a key global initiative, the Agenda 2030; UN, 2016) has been promoting the concept of Responsible Consumption and Production (RCP), in the form of the 12th Sustainable Development Goal (SDG) (Glavič, 2021); therefore, fostering all United Nations Member States to invest in this matter (Orellano et al., 2020). This has been further stressed in the Circular Economy Action Plan, which constitutes of the core fragments of the European Green Deal (Mhatre et al., 2021). However, for the consumer, the main benefits are of psychological nature, as sustainable consumption takes on a symbolic role (Abdulrazak and Quoquab, 2018). Nonetheless, through circular economy-based strategies, the consumer can also find a financial benefit, which then acts as the main driver towards a circular economy (CE) model (van Weelden et al., 2016).

Following this reasoning, when linked with SCP, CE can work as one of the strategies to tackle the environmental impacts associated with consumption patterns (Goyal et al., 2022). In a comprehensive and systematic analysis of 114 CE definitions, Kirchherr et al. (2017, p. 229) characterize CE as “an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations”. In Potting et al. (2017), the scope of circular economy-based strategies is expanded, including: (i) refuse; (ii) rethink; (iii) repair; (iv) refurbish; (v) remanufacture; and (vi) repurpose. Among the ones mentioned in the definition proposed by Kirchherr et al. (2017). Furthermore, Potting et al. (2017) ranks the strategies from linear to circular economy, prioritizing the ones that allow the consumption of fewer natural resources and a lower output in environmental pressures. In this vein, in the form of a consumer, the household takes on a central role, in enabling the CE transition (Shevchenko et al., 2023). Although these dimensions can be overlapped, Shevchenko et al. (2023) and den Hollander et al. (2017) argue that the circular consumer holds three roles: (i) as a customer, acquire products with the minimum environmental impact and refrain from buying; (ii) as a user, careful use, and maintenance, acquire technical services and repair, and sell or donate the products if no longer needed; and (iii) as an EoL product holder, timely discard and use the appropriate circular discarding channel.

To foster CE progress at the macro, meso and micro level, performance evaluation and communication represents a core step (Droege et al., 2021a; Sassanelli et al., 2019). Through a systematic literature review, Sassanelli et al. (2019) understand that, in function of the CE domain, different assessment methods are used, which can highlight certain aspects of the CE model. Nevertheless, and despite the diverse range of assessment methods and approaches in CE, multiple authors underline the use of indicators to assess, monitor, and communicate CE progress (de Oliveira et al., 2021; Howard et al., 2019; Saidani et al., 2019). However, most developed CE indicators measure material flow or recirculated value of a system, and consequently, dominant assessment method and tools are focused on cleaner production, resource-efficiency, material stocks and flows, and product-centric areas (Droege et al., 2021; 2021a; Opferkuch et al., 2022, 2023)); whereas, the consumer level, including customer, user and EoL product holder (Shevchenko et al., 2023), is being poorly analyzed (Harris et al., 2021). Nonetheless, CE indicators can foster circularity, namely in public policy decision making (De Pascale et al., 2021; Droege et al., 2021a).

In the context of Household Sustainable Consumption (HSC), Caeiro et al. (2012, p. 80) recommend the use of metrics to assess this matter, as communication represents a major challenge, in which the indicator system should be: “(i) easily comprehensible and meaningful to family members; (ii) developed with a bottom-up process with emphasis on public participation and empowerment; (iii) use an integrative approach

among the different domains; (iv) facilitate practical dynamic behaviors, actions and routines in implementing HSC; (v) provide transparent evaluation of the HSC performance; (vi) provide guidance via illustrative best practices; and (vii) provide financial and non-financial incentives for achieving continuous HSC improvements”. Thus, to foster a CE transition at the household level, empowerment can play a complementary role, since it enhances people’s skills, increases community ownership, and awareness towards sustainability related issues (Marchesi and Tweed, 2021). This can be achieved through the implementation of self-assessment tools that help individuals gain awareness over the actions they can perform, the benefits of completing them, what they are lacking, and how to improve their actions, representing a behavior change catalyst (Kocaadam-Bozkurt and Bozkurt, 2023). Indeed, a higher awareness over these aspects is positively linked with the adoption of more sustainable behaviors.

However, there is a knowledge gap in how CE should be assessed at the household level. Multiple studies have been conducted to understand CE assessment at the organizational level (Sassanelli et al., 2019), products and processes (Ahmed et al., 2022), eco-industrial parks (Zhao et al., 2017), and cities (Gravagnuolo et al., 2019), and the role of the circular consumer was analyzed (Shevchenko et al., 2023). Furthermore, in the context of HSC, Caeiro et al. (2012) developed an approach to define the main criteria to build HSC assessment tools based on indicators sets. Through a Life Cycle Analysis (LCA), Castellani et al. (2019) determined the environmental impacts of household consumption, in Europe. With a similar objective, Peng et al. (2021) defined the consumption activities of rural households. Nonetheless, little attention has been given to the assessment of CE at the household level, similar to how regular organizations and their individuals are assessed, including their inputs, processes, outputs, outcomes/impacts, and related indicators. Moreover, in the form of a consumer, the household represents a key element, in enabling a transition towards a CE model (Camacho-Otero et al., 2018; Shevchenko et al., 2023). Therefore, the present work aims at developing a self-assessment tool to assess and report the implementation of circular economy-based strategies and practices at the household level. This includes defining circular indicators specifically tailored for householders, with support from a collaborative approach. Thus, to develop a household CE self-assessment tool, the present study aims to answer the following research questions.

- i) How important are the CE initiatives at the household level?
- ii) What are the indicators that can be used to enable the self-assessment of CE implementation into households?

This paper is structured as follows, after this chapter: (i) Section 2 presents an overview of the studies conducted in the matter of Household Circular Economy (HCE) practices, in the context of the CE framework (Potting et al., 2017), a description of CE indicators, and a review multiple self-assessment tools; (ii) Section 3 indicates the steps taken to evaluate the CE practices at the household level and indicators, through the use of a mixed-method approach, based on a questionnaire survey and semi-structured interviews; (iii) In Section 4, the results are presented, with the illustration of the aforementioned components; (iv) afterwards, Section 5 explores the main findings with the existing literature; and (v) lastly, in Section 6, conclusions, limitations, and further research are presented.

2. Overview of household circular economy assessment approaches

2.1. Household circular economy practices

At the household level, refusing strategies follow the definition proposed by Potting et al. (2017), in which the individual abandons the function or acquires it through a different product or service. Therefore, acquiring products certified with an eco-label, as it communicates, in

general, an object with a lower environmental pressures and resource consumption, enables a high circularity role for the household (Gullstrand Edbring et al., 2016; Zotti and Bigano, 2019). This can also be achieved through minimization of packaging, and decorative elements (Wang et al., 2022). These functions can be acquired in the form of a service, intensifying product use, and including practices that range from washing machines sharing systems (Potting et al., 2017), to vehicles (Atstaja et al., 2022), or bicycles (Henriksson and Göransson Scalzotto, 2023). However, the lack of information and economic incentives, and availability of a product or service replacement for a given function, can act as a barrier, in the household transition towards a CE (Grafström and Aasma, 2021).

Reduce, re-use, recycle and recover strategies, at the household level, have been documented in environmental related concerns, regarding resource consumption and environmental pressures, including (Kumar et al., 2022; Paparella et al., 2023): (i) the consumption of energy (Adan and Fuerst, 2016); (ii) the use of water (Gómez-Monsalve et al., 2022); and (iii) waste production (Varotto and Spagnoli, 2017). For the first, products characterized by their energy efficient design, in the use phase, allow a reduction in the consumption of resources, which can be further improved through behavioral practices (Barkhausen et al., 2022; Richter, 2010). Regarding the second, water consumption is constricted by multiple barriers, including lack of motivation, information, and financial incentives to engage in conservation behavior, since water efficient products are costly (Addo et al., 2018). McCarton et al. (2022) proposes a strategic hierarchy to foster the transition towards the CE of water, in which reduction shows the highest priority, followed by re-use, recycle, and recover measures. In regard of the waste domain, through a literature review, Ghisellini et al. (2016) states that the use of materials, in the form of waste, represents one of the core elements of CE. At the household level, multiple studies have been conducted, in the context of household waste sorting and recycling behaviour, regarding organic, and electrical and electronic equipment (Nainggolan et al., 2019; Parajuly and Wenzel, 2017; Varotto and Spagnoli, 2017; Zhang et al., 2022). In these studies, household participation represents a core element, in enabling CE and reducing the respective waste quantities. Additionally, in some situations, the product still holds a monetary value (Parajuly and Wenzel, 2017).

Repair, refurbish, remanufacture, and repurpose strategies are linked with the extension of the lifespan of products and its parts (Potting et al., 2017). Thus, these actions foster a slower loop, with a lower environmental pressure and resource consumption (Rizan et al., 2022). However, Terzioğlu (2021) found that multiple barriers restrict the individual from repairing the product, including technical, value and emotional variables. For instance, it requires time and effort, skills and knowledge.

These practices can be applied to reduce food waste at the household level, integrating scientific research on categories that range from general attitude, perception, behavior, food sharing, to packaging, and purchasing actions (Principato et al., 2021). Although it depends on several factors – such as planning, cooking, storage, consumption, disposition, psychological, and demographic –, householders can reduce their collective impact by creating a food waste diary, cooking, and eating leftovers, educating others, reuse for feed animal, and composting, among others (Lehtokunnas et al., 2022; Oliveira et al., 2021; Principato et al., 2021).

However, to help individuals reflect CE principles in their lifestyle, they require an understanding of the range of actions that can be adopted, their financial and non-financial benefits, as well as an overview of their performance (Kocaadam-Bozkurt and Bozkurt, 2023). Towards this end, a self-assessment tool can be advantageous. Nevertheless, there is a knowledge gap on how this evaluation process can be conducted.

2.2. Circular economy indicators

CE indicators can be defined as a quantitative or qualitative measuring instrument of several CE strategies individually or simultaneously, accounting for the material flows, and, although with its limitations, the use phase of a product (de Oliveira and Oliveira, 2023). In recent studies, other descriptions have been brought forward. Khadim et al. (2022) critically reviewed multiple micro-level circularity indicators and frameworks, suggesting that most CE Key Performance Indicators (KPIs) focus on material loop, disassembly, adaptability, and reusability evaluation. These metrics can be characterized as a method to assess the performance and progress of, and towards, a CE model (Saidani et al., 2019).

As stressed by Saidani et al. (2019), CE indicators enable assessment, reporting and communication across all CE levels (micro, meso, macro). In fact, multiple types of CE indicators and frameworks have been developed (Droege et al., 2021; Helander et al., 2019; Padilla-Rivera et al., 2021; Rincón-Moreno et al., 2021; Sánchez-Ortiz et al., 2020; Yadav et al., 2020). However, at the household level, there is a knowledge gap, as several authors focus on the evaluation of the consumer perception, attitude, and intention, lacking the use of an assessment framework tailored towards performance analysis (Henao-Hincapié et al., 2024; Shashi et al., 2023; Sousa et al., 2021). For instance, Henao-Hincapié et al. (2024) conducted a frequency evaluation of the adoption of CE practices, focusing its questions on resource efficiency, recycling, and conscious consumption, but lacking a categorized approach. Other researchers approached this task, using a LCA procedure, which enables the comprehension of its environmental impacts, instead of behavior (Sala and Castellani, 2019; Severis et al., 2019). This process has been documented as a trend on product centric CE assessment frameworks, where it can also be possible to capture the influence of the householder (Corona et al., 2019). Although the continuous increase in scientific literature regarding CE assessment, Corona et al. (2019) and Shevchenko et al. (2023) stressed on the literature gap regarding consumer-based metrics.

Among multiple other benefits, CE assessment through indicators promotes an extensive comprehension of the current state of CE. Although it depends on the evaluated level (micro, meso, macro) and on the implemented strategy and practice (e.g., refuse, rethink, repair, amidst similar others, see Potting et al., 2017), CE indicators allow and foster benchmarking, decision making, learning and identification of improvement opportunities (Saidani et al., 2019; Sánchez-Ortiz et al., 2020). Additionally, most CE indicators show a multi scale applicability, and can be used across different industrial sectors (Rincón-Moreno et al., 2021).

Overall, CE indicators is still an underexplored field of research with multiple limitations and challenges. In fact, as stressed by Droege et al. (2021) and Harris et al. (2021), in a scoping review, CE assessment practices mostly depend on a LCA, Material Flow Analysis (MFA) and Input/Output Analysis approach. However, these methods have numerous limitations and disadvantages, including (Droege et al., 2021a; T. Lu and Halog, 2020; van Stijn et al., 2021): (i) time intense execution; (ii) dependence on data quality and availability; (iii) requirement of technical expertise; (iv) lack of indicator diversity; (v) greenwashing impacts; and (vi) non-applicability in ex-post assessments and certification. To measure efficiency in CE, data gathering represents a significant barrier (Sánchez-Ortiz et al., 2020). Due to the multiple CE definitions and levels, the indicators may be poorly positioned or inadequately address the issue at hand (Saidani et al., 2019). According to Helander et al. (2019), CE indicators are not able to properly assess the environmental pressures derived from CE activities, recommending a complementary approach with tailored metrics. Additionally, most CE indicators focus on the analysis of a single CE activity, which can enable problem shifting and a rebound effect. Padilla-Rivera et al. (2021) and Luthin et al. (2023) propose the same arguments for the social impacts derived from CE activities. Moraga et al. (2019) were unable to identify

CE indicators capable of measuring higher circularity strategies, including refuse, rethink, and reduce. Jerome et al. (2022) understood that most CE indicators cannot assess the use phase of a product, and lifetime extension strategies (e.g., repair, remanufacturing, repurposing, refurbish).

2.3. Household assessment tools

According to Fahim et al. (2021, p. 45), self-assessment can be defined as “the process of critically observing one’s own self in order to assess important aspects of one’s personality”. Thus, it relies on the assumption that the individual can assess themselves (Elimelech et al., 2019). Multiple types of household self-assessment tools have been developed, to analyze individually or aggregately the domains of sustainability (Fang et al., 2016; Vanham et al., 2019; Wu et al., 2021; Xie et al., 2020). Within the sustainability spectrum, the “footprint”, based upon the original concept of ecological footprint developed by Rees (1992), is a tool commonly used for the household or individual self-assessment (Castellani et al., 2019; Syrovátka, 2020). Nevertheless, it also displays other scales of application, such as cities, countries, regions, higher education institutes and private and public sector organizations (Friedland and Balkin, 2023; Tolppanen and Kang, 2021).

However, multiple authors criticize the methodological weaknesses of footprints, such as the EF, associated with the construction of the indices, inability to account for some pollutants and/or calculate the ratio between land use and land availability (Franz and Papyrakis, 2011; Kharrazi et al., 2014; Lin et al., 2015; Sutcliffe et al., 2008). Among other aspects, the lack of encouragement of pro-environmental and community engagement actions in these footprints (e.g., beach cleaning, tree planting, amidst similar other environmental impact offset measures) suggest that individuals can not achieve a sustainable lifestyle (Franz and Papyrakis, 2011). In the vein policy setting, Kharrazi et al. (2014) acknowledge that there are methodological short comes.

The work conducted by Čuček et al. (2012) presents a review of footprints (Table A1), namely the ones highly associated with the individual and household assessment. Furthermore, for the analysis carried out in the present research, those approaches were aligned with the CE framework proposed by Potting et al. (2017). The footprints present a trend, in which resource flow quantification is stressed (Matušík and Kočí, 2021). Thus, most identified tools target consumption-based behaviors, in which refusing and reducing represent a nuclear role (Castellani et al., 2019).

As stressed by Rondoni and Grasso (2021), consumption behavior greatly influences the performance assessed by environmental footprints, including the actions directly correlated with resource and/or land use (e.g., energy footprint [ENF]). Although socio-economic status influence resource consumption (Eisenmenger et al., 2020), economic, and social footprints (e.g., financial footprint [FF]) don’t focus on the use of raw materials; thus, not allowing an assessment of circular economy-based strategies.

Additionally, consumption and waste related footprints (e.g., consumption footprint [CSF]) provide a broader spectrum of assessment criteria, including the sharing aspects of mobility, and the EoL of consumer goods and services (Buhl et al., 2019; Kok and Barendregt, 2021; Salas et al., 2022). This allows a higher influence in the CE framework, since it considers rethinking and re-use, among the aforementioned strategies. Assessment tools that consider the multiple phases of the life cycle of a product display a greater positive impact on the CE model (Lei et al., 2021).

3. Methods

To develop the Household Circular Economy (HCE) self-assessment tool, an exploratory mixed-method approach was adopted, combining the methods of an integrative literature review and sequential explanatory research design, supported by a questionnaire survey and semi-

structure interviews. Denscombe (2017) and Saunders et al. (2019) stress that this process is highly recommended to provide an adequate answer, as both approaches complement each other. It results in a wider understanding of the aims being researched, since it offers more than one perspective. Also, it allows the collection of information, based on the lived experiences of the participants (Mayoh and Onwuegbuzie, 2015). This methodological architecture forms the nucleus of a collaborative process recommended by Caeiro et al. (2012) for the development of household sustainable consumption tools.

In this research, residents/family’s representatives (henceforth designated as householders) took the role of citizen as a co-designer of the developed assessment tool. Citizen as a co-designer can be characterized as involvement regarding the content and process of service delivery (Voorberg et al., 2015). Caeiro et al. (2012) suggested a collaborative and participatory process for the development of a HSC assessment tool, stating that it should be built on the views and opinions gathered from the stakeholder engagement, along the process. By using a collaborative approach, it can be possible to reduce the conceptual distance between the project and the benefits of its realization, enabling the shaping of the self-assessment tool in function of the stakeholder’s perspective (Keeyes and Huemann, 2017).

Based on the literature review, the initial set of the HCE dimensions and indicators was formulated. The integrative literature review was qualitatively triangulated with the results of the quantitative empirical stage (i.e., questionnaire survey). A triangulation approach allowed a deeper understanding of the results (Saunders et al., 2019). In the present research, it permitted the study of HCE practices and indicators.

The overall methodological approach was elaborated based on four stages (Fig. 1): (i) HCE metrics were identified, from the results of the integrative literature review; (ii) the HCE indicators were qualitatively triangulated with the data collected from the quantitative method (i.e., questionnaire survey), resulting in a clustering of metrics; (iii) the self-assessment tool was evaluated with stakeholders, based on a qualitative procedure (i.e., semi-structured interviews), providing insights over the use of the tool developed by the research team; and (iv) the results were analyzed, using descriptive statistics techniques for close-ended questions and content analysis for open-ended questions.

3.1. Stage 1: identifying HCE metrics

To identify the initial set of HCE metrics, an integrative literature review of scientific articles was developed. Through synthesizing and studying the existing body of papers, this approach allows the test of hypotheses and the advancement of knowledge, based on previous work (Xiao and Watson, 2019). The Scopus database from Elsevier was selected, since it is the largest data base for scientific journals, comparable to Web of Knowledge (Valderrama-Zurián et al., 2015). The search was conducted, using the string TITLE-ABS-KEY (“circular econom*” OR “circularity”) AND (“indicator*” OR “indice*” OR “index*”) AND (“individual*” OR “famil*” OR “household*” OR “consumer*”), resulting in the identification of the initial set of scientific articles (n = 375). These keywords were selected, as they encompass a wide range of metrics relevant to the research questions.

After the removal of duplicates, as recommended by Valderrama-Zurián et al. (2015), 375 publications were manually screened by title and abstract, to exclude articles with content unrelated to the research questions. Furthermore, inclusion and exclusion criteria were established, in function of the research questions, to further refine the screening process (Xiao and Watson, 2019). Regarding the exclusion criteria, publications focusing on CE at nano, meso and macro levels or non-consumption related practices (Shevchenko et al., 2023) were removed. Additional records were identified through forward backward searches, based on inclusion criterion related to CE assessment frameworks (n = 23). A total of 71 full-text articles were assessed for eligibility and quality, since they provided an outline of HCE indicators and practices. The HCE activities were characterized in relation to the CE

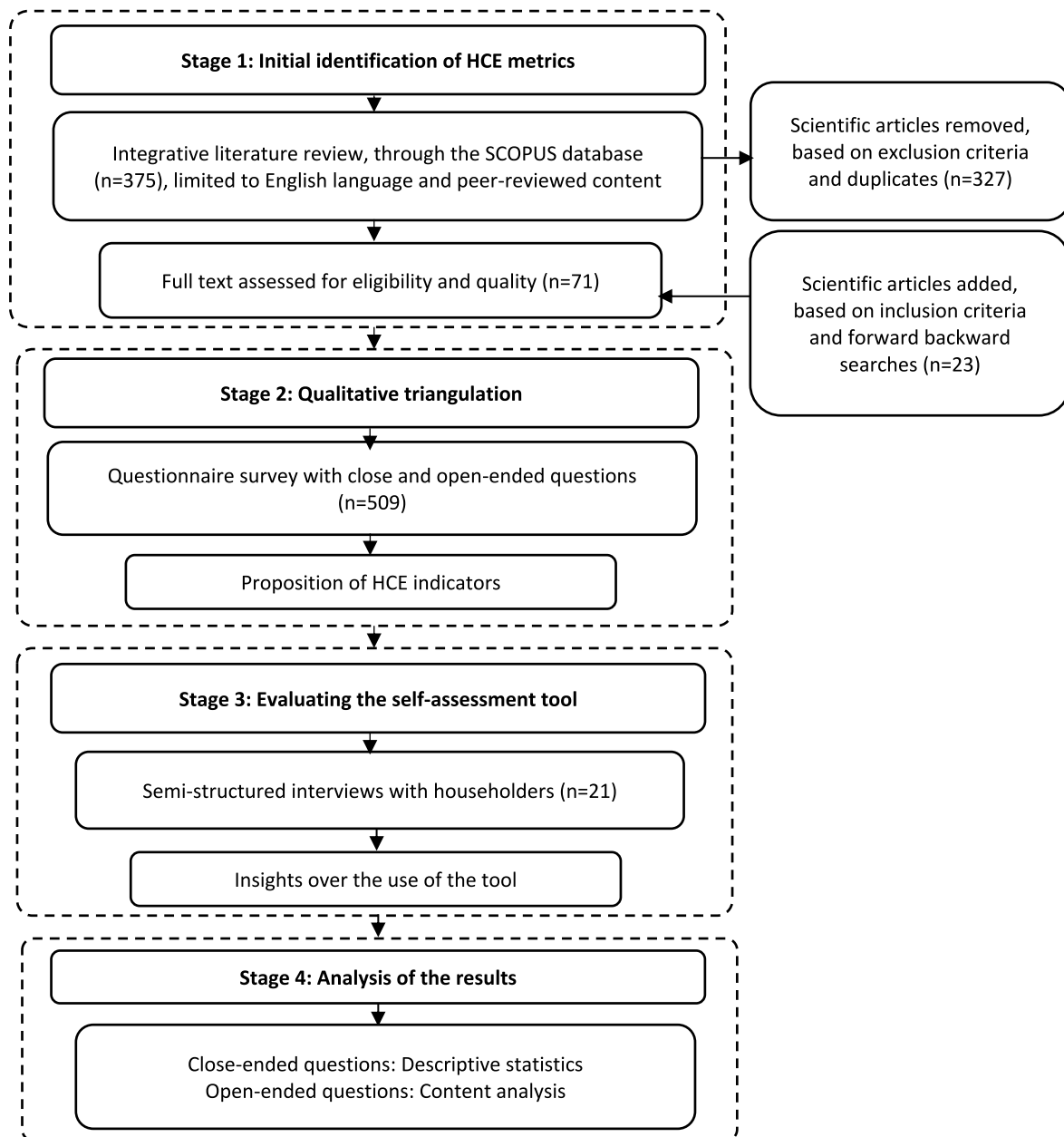


Fig. 1. Methodological approach towards the understanding of CE practices implemented in a household, identification of CE indicators, and evaluation of the self-assessment tool.

strategies defined by Potting et al. (2017) and the tri-dimensional role of the circular consumer described by Shevchenko et al. (2023), see Table A2.

3.2. Stage 2: clustering of HCE indicators

The householders' knowledge and perceptions allow an in-depth understanding of the daily activities inherent to a household. Therefore, a survey research approach grounded on a web-based questionnaire survey was used to collect a quantitative description of the importance of HCE strategies and activities, from which HCE indicators were established. The HCE indicators were defined based on the importance level that the respondents attributed to the HCE practices and further weighted based on insights derived from the literature.

The survey was distributed through online channels, and as stated by Bethlehem (2009), online surveys allow access to a large pool of potential respondents, while being cost-effective and time efficient. The

survey consisted of open-ended and close-ended questions. The questionnaire had 42 questions divided into three main sections (see Appendix B), which were defined based on the main thematic groups of HCE strategies and activities, identified through the literature review. In particular, those sections were based on the tri-dimensional role of the circular consumer described by Shevchenko et al. (2023), to help understand consumer behavior in the CE. Table 1 presents a description of the main sections considered in this survey.

Close-ended questions were used in two situations: (i) A five-point Likert scale was designed to quantitatively assess the level of importance of a HCE practice, as a *customer* – “When buying, do you consider important ...”, as a *user* – “When using, do you consider important ...”, and as an *EoL product holder* – “When discarding, do you consider important ...”. The rating was from one (“Not important at all”) as the lowest to five (“Absolutely essential”) as the highest. For instance, one question asked if the participant frequently

Table 1

Summary description of the topics covered in each section of the questionnaire survey.

Section	Description
Customer in a CE	Aimed to understand CE oriented activities conducted by the consumer, in the form of a customer. According to Shevchenko et al. (2023) , the customer should prioritize product acquisition with the least environmental impact, and, when possible, refrain from buying.
User in a CE	Structured to determine circular economy-based activities conducted by the consumer, in the form of a user. In this category, careful use and maintenance of the product, search for technical services and repair, and sell or donate the products, when no longer needed, should be the main role (Shevchenko et al., 2023).
EoL product holder in a CE	This section goals are to define the activities conducted by the consumer, in the form of an EoL product holder. As stressed by Shevchenko et al. (2023) , the individual should timely discard the product, and use the appropriate discarding channel.

avoids products with excess packaging, to understand if the refusal strategy is relevant in this situation; (ii) A binary, and multiple-choice questions were used to allow the respondents to indicate the adoption of a CE practice, and for which consumption domains (e.g., clothes, electric and electronics equipment), respectively. This type of questions enables a lower and easier survey response time, and are easier to compare ([Saunders et al., 2019](#)). The open-ended questions were used to provide the respondent the opportunity to comment on the CE strategies they adopted, as similarly done in [Klein et al. \(2022\)](#). Since it allows the participant to give a more in-depth answer, where they can use their own words ([Bethlehem, 2009](#); [Saunders et al., 2019](#)).

The questionnaire survey was launched in May 2023, and remained for two weeks. As stressed by [Saunders et al. \(2019\)](#), a two-week distribution period is deemed reasonable. Although certain household consumption domains are seasonally influenced ([Spence, 2021](#)), the data retrieving period did not affect the results, since, unlike certain industries ([Dissanayake and Weerasinghe, 2022](#)), most HCE practices can be applied independently of the season. A non-probability convenience sampling technique was used. Although this procedure is prone to bias and offers less accuracy to the results, it is used widely, since it provides an adequate approach to exploratory studies ([Saunders et al., 2019](#)). In this study, it allowed the collection of insights of householders regarding the relevance of HCE activities. It targeted the general population of individuals with 15 years or above living in Portugal, since consumers become more aware of their consumption habits, and associated consequences, in their adolescence and early adulthood ([Busse and Menzel, 2014](#)). Other nationalities were not considered, since, in some situations (e.g., organic food products, energy, apparel), consumer behavior depends on the cultural and sociodemographic background of the individual ([Frederiks et al., 2015](#); [Scheerder et al., 2011](#)).

Before the aforementioned period of data collection, the survey was sent to 30 individuals from the householders' category, and academia to ensure the clarity, understandability, and validity of the questions ([Bethlehem, 2009](#)). In fact, [Bethlehem \(2009\)](#) suggests a population of 25–75 individuals, during the pre-test. Moreover, to determine the internal consistency of the responses across the five-point Likert scales used to inquire about the HCE practices implemented by customers, users and EoL product holders, the Cronbach's alpha was calculated with a threshold of 0.7 or above. The Cronbach's alpha of the first, second and third Likert scale were 0.93, 0.82, and 0.72, respectively. Thus, the questionnaire survey had a high reliability ([Saunders et al., 2019](#)).

The questionnaire survey yielded 509 valid responses. According to [INE \(2023\)](#), Portugal has a total population of 9 011 878 individuals with an age equal or above 15 years. A sample size of 509 allowed for a

95 % confidence level with a margin of error of 5.0 %, which is above the minimum size ($n = 384$). The minimum sample size was determined through the methodology from [Bartlett et al. \(2001\)](#), for categorical survey data analysis.

3.3. Stage 3: evaluating the self-assessment tool

[Caeiro et al. \(2012\)](#) recommended that the indicators should be “easily comprehensible and meaningful to family members”. The householders' perspective enables an in-depth understanding of the clarity of the self-assessment tool, and its influence on their everyday actions. Thus, to evaluate the understandability and operability of the self-assessment tool, semi-structured interviews with open-ended questions were conducted. This approach is a qualitative method, in which the interviewer is recommended to be flexible, and explore the ideas developed by the interviewee ([Denscombe, 2017](#)). In this case, the interviews were conducted to gather insight into the use of the self-assessment tool and develop the final list of indicators. For instance, if the interviewee wouldn't understand an indicator, the latter would be removed or adjusted, in function of the interviewee's suggestion.

The interviewees were selected through a snowball method ([Bryman, 2016](#)). The interviews were elaborated between June 04, 2023 and June 18, 2023, until data saturation was reached – where new data confirmed the existing one instead of adding input ([Denscombe, 2017](#)) -, resulting in 21 interviews with an average duration of 22 min.

At the beginning of the interview, the participant used the self-assessment tool and provided insight over its use. As recommended by [Saunders et al. \(2019\)](#), a document was created to structure and guide the interview (see [Appendix C](#)). The document consisted of 6 open-ended questions concerning the general evaluation of the self-assessment tool. All semi-structured interviews were conducted on-line, and audio recorded. This provides a cost and time-effective approach to this method ([Denscombe, 2017](#)). Furthermore, these were transcribed, and reviewed with the respondent, as recommended by [Denscombe \(2017\)](#). As stressed by [Saunders et al. \(2019\)](#), ethical issues regarding the audio recording, confidentiality, and anonymity were considered. The interviewees were free to withdraw from the interview and ask for the deletion of the data. The interviewees' approval was obtained through informed consent.

3.4. Data analysis

To analyze the results of the questionnaire survey and interviews two techniques were applied: (i) for close-ended questions, descriptive statistics was used to measure the central tendency, and dispersion of each answer, in absolute (numerical) and relative (percentual) terms ([Saunders et al., 2019](#)); and (ii) for open-ended questions, content analysis, as a supplementary technique, was used to code and categorize the retrieved qualitative data ([Krippendorff, 2019](#); [Saunders et al., 2019](#)). In the case of the descriptive statistics, the data showed a nominal, and ordinal nature. Hence, it required different statistical tests ([Saunders et al., 2019](#)). For the nominal data, a frequency table with percentages was used to summarize the categorical data. For the ordinal variables, the mean score was used to compare the importance level of the HCE practices. According to [Chu and Hwang \(2008\)](#), the minimum requirement to include any particular item in a study is a combined participation agreement of 75%. As stressed by [Saunders et al. \(2019\)](#), if respondents have insufficient knowledge, they may guess at the answer or overestimate the relevance of the item. Based on these criteria, the HCE practices with a mean score under 3.75 (within the five-point Likert scale) were given a negative connotation. Regarding the open-ended questions, the tri-dimensional role of the circular consumer described by [Shevchenko et al. \(2023\)](#) and the CE strategies described by [Potting et al. \(2017\)](#) were used to support the content analysis of the qualitative data.

A collaborative approach helps bridge the gap between theory and

practice. However, communication difficulties between the general public or practitioners and researchers can undermine the results (Kieser and Leiner, 2012). Thus, as recommended by Saunders et al. (2019), the results were triangulated with the current scientific body of literature on the topic (Table A2). In this context, only the empirical data collected from the questionnaire survey that is supported by scientific literature was considered in stage 2. For instance, HCE practices related with dietary activities showed a mean score below 3.75 but are described as one of the main pillars in CE (Kumar et al., 2022; Paparella et al., 2023; van Loon et al., 2023). Hence, it was accepted for stage 2.

4. Results

In this section, an overview of the HCE practices and indicators was conducted, while lining out the surveyed participants' perceptions over the use of the self-assessment tool in two parts: (i) in Section 4.1, the surveyed participants profile, HCE practices and initial clustering of indicators were analyzed; and (ii) Section 4.2 shows the interviewed participants characteristics as well as insights over the use of the self-assessment tool.

4.1. Overview of HCE practices and indicators

4.1.1. Participants profile and HCE practices

In total, 509 valid responses were received from 510 individuals. Among the participants, 38.1 % were male, 61.7 % were female, and 0.2 % were nonbinary. The largest number (37.3 %) of respondents had 15–24 years, and 19.4 % had 25–34 years. All age-groups were covered by the questionnaire survey, with individuals over the age of 65 years representing the lowest relative weight (4.5 %) (Table 2). The participants had different education levels: 15.9 % of them did not pursue an university degree, whereas 48.5 % had a bachelor's degree, 30.1 % held a master's degree, and 5.5 % obtained a PhD degree. About 63.9 % and 36.1 % reside in apartments and houses, respectively. Amidst the surveyed, 9.8 % live alone, whereas the remaining participants cohabite with one or more individuals. The majority (78.8 %) of the respondents were familiarized with the concept of circular economy, demonstrating the high level of awareness in this topic.

Table 3 presents the scoring of the surveyed HCE practices. As stressed in the Methods section, the HCE practices with a mean score below 3.75 were cut-off from the initial list. However, negatively

Table 2
Surveyed participants characteristics.

		Respondents	
		(No.)	(%)
Gender	Male	194	38.1%
	Female	314	61.7%
	Nonbinary	1	0.20%
Age group	15–24 years	190	37.3%
	25–34 years	99	19.4%
	35–44 years	53	10.4%
	45–54 years	87	17.1%
	55–64 years	57	11.2%
	>65 years	23	4.5%
Education	Non-university	81	15.9%
	Bachelor	247	48.5%
	Master	153	30.1%
	PhD	28	5.5%
Type of housing	Apartment	325	63.9%
	House	184	36.1%
Household dimension (no. of individuals)	1	50	9.8%
	2	129	25.3%
	3	146	28.7%
	4	143	28.1%
	>4	41	8.1%
Familiarity with the concept of CE	Yes	401	78.8%
	No	108	21.2%

Table 3

HCE selected and removed practices.

Dimension	HCE practice	Mean score	Std. Deviation	Eligibility for stage 2
Customer	Acquiring eco-labelled products	3.0	0.89	×
	Reject/avoid products produced through child labor or in other abusive and objectionable ways	5.0	0.85	✓
	Search for the shop with the least negative environmental impact (with a recognized environmental certification)	3.0	0.95	×
	Search for the shop with the least negative social impact (with a social responsibility certification)	3.0	0.98	×
	Looking for the product in the form of a service	3.0	1.13	×
	Looking for electrical or electronic products with the best performance in the energy certificate	4.0	0.86	✓
	Seek out locally produced foods/food products	4.0	0.89	✓
	Reject/avoid products with excessive packaging or packaging quantities where possible	4.0	0.96	✓
	Look for bulk products or with reduced packaging quantities if packaging is unavoidable	4.0	0.97	✓
	Looking to buy second-hand rather than new products	3.0	1.17	✓
	Trying to buy repaired products instead of new ones	3.0	1.11	×
	Seek to purchase refurbished/reconditioned products (e.g. an old product that has been upgraded to current quality standards) rather than new ones	3.0	1.09	×
	Try to buy "remanufactured" products (made from parts of another product with the same function) rather than new ones	3.0	1.07	×
	Try to buy "re-purposed" products (products that have acquired a new function) rather than new ones	3.0	1.08	×
	Try to buy products made from recycled materials rather than new ones	4.0	0.98	✓
	Try to buy recyclable products or products that can be dismantled	4.0	0.96	✓
	Seek to purchase the product in its dematerialized format, where possible	3.0	1.13	×
	Try to buy the product with the longest possible durability	5.0	0.81	✓
	Look for reusable products, rather than single-use items	4.0	0.89	✓
	Look for products that can be shared, when bought together	4.0	1.13	✓

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Table 3 (continued)

Dimension	HCE practice	Mean score	Std. Deviation	Eligibility for stage 2
User	Seek to rent the product rather than own it	3.0	1.17	×
	Seek dietary alternatives with better environmental performance	3.0	1.25	✓
	Seek to buy foods that partially replace animal-based consumption	3.0	1.29	✓
	Try to satisfy the residence's energy needs through renewable sources	4.0	1.12	✓
	Try to buy products that minimize energy consumption needs without losing thermal comfort	4.0	0.95	✓
	Try to buy products that increase the durability of the main product	4.0	0.90	✓
	Look for multifunctional products, rather than one product for each function	4.0	0.99	✓
	Try to buy products with a money-back guarantee	4.0	0.95	✓
	Use the product in the most resource-saving way	4.0	0.79	✓
	Avoid/reject using the product if there is a more sustainable alternative	4.0	0.89	✓
	Use the product as intensively as possible	4.0	1.0	✓
	Save leftovers, to be consumed at another time, when possible, instead of discarding them	5.0	0.79	✓
	Repair the product or purchase a repair service, rather than disposing of it when necessary	4.0	0.87	✓
	Renovate/recondition the product or purchase a renovation/reconditioning service rather than dispose of it	4.0	0.88	✓
	"Remanufacture" the product or purchase a "remanufacturing" service, rather than discarding it	4.0	1.0	✓
	"Repurposing" the product or acquiring a service that allows you to "repurpose" it, rather than discard it	4.0	0.93	✓
	Use the land/area of your residence to produce your food, when possible	4.0	1.1	✓
	Sell or donate the product, rather than dispose of it, if it is still in good condition and able to fulfil its function	5.0	0.85	✓
	Give priority to using the recycling containers, when appropriate, instead of the undifferentiated waste containers	5.0	0.80	✓
	Give priority to sending organic waste for composting, rather than using the undifferentiated waste container	4.0	1.1	✓
EoL product holder	Give priority to using a container or special waste collection service rather than disposing of the waste in a public place or littering	5.0	0.81	✓
	Separating waste at home	5.0	0.84	✓

Legend.

✓ - Eligible; and.

× - Ineligible.

marked empirical data collected from the survey that is supported by scientific literature was considered for stage 2 of this study (Coutinho et al., 2018). Although HCE practices concerning dietary choices and second-hand product acquisition were scored below the cut off value, they were made eligible for stage 2, due to its relevance in promoting CE (Coutinho et al., 2018). Among the HCE practices, 10 were considered ineligible, all of them belonging to the customer dimension. No HCE practices were removed from the remaining dimensions. Nonetheless, it should be noted that the HCE practices were excluded to prioritize the main consumption activities. To foster circularity, the eliminated HCE practices still hold a significant relevance, as stressed in multiple studies (Ahmed et al., 2023; I. R. R. Lu and Kwan, 2023; Prakash and Ambedkar, 2022; Valls-Val et al., 2023; van Bueren et al., 2023).

In terms of the customer dimension, the participants' response showed two main tendencies: First, product acquisition with an indirect and unclear environmental or financial benefit showed a lower importance level. The acquisition of products produced through lesser-known CE strategies (e.g., remanufactured/repurposed/refurbished) received a lower mean score. Whereas products with more recognizable advantages (e.g., durability, multifunctionality, reusability, recyclability, among similar others) had a higher mean score (4.0 and above). On the other hand, practices that involve products with direct social and environmental benefits were prioritized by the respondents. In fact, refusing practices (e.g., rejecting products produced through child labor or with excessive packaging) were highly favored. Second, physical product ownership was an important criterion for the surveyed individuals. As shown in Table 3, dematerialization, renting and product as a service practices were classified with a lower importance level (3.0).

Among the remaining HCE dimensions (*user* and *EoL product holder*), all HCE practices were given a positive connotation. Service acquisition practices to extend the lifetime of a product or its parts (e.g., repairing, remanufacturing, refurbishing, repurposing) were given a high importance. Similar behaviors were classified with the same mean score. For instance, for the respondents, using resource saving/more sustainable approaches in day-to-day activities (e.g., public transport or active mode of transport usage, energy, and water efficient practices) or donating/selling the product in its EoL constituted a priority. Moreover, lower circularity-based strategies, including waste separation system, recycling, and composting, were also highlighted.

4.1.2. Clustering of HCE indicators

The initial list of HCE indicators was obtained through the results of the questionnaire survey and integrative literature review (Table 4). These metrics were obtained through a qualitative triangulation between the HCE practices with a mean score above 3.75, and the CE indicators derived from the integrative literature review (see Table A2). In addition, some HCE practices required more than one indicator. For instance, for the HCE practice "Try to buy products that minimize energy consumption needs without losing thermal comfort", three variables were selected: (i) Comfort; (ii) Electric or electronic products acquired or replaced to reduce energy consumption; and (iii) Energy consumption per m². The present set of indicators allow the self-assessment of circular economy-based strategies at the household level, and consider key criteria defined by Caeiro et al. (2012) for household indicators. Thus, it enables the evaluation of the HCE practices showcased in Table 3.

As shown in Table 4, a total of 38 HCE indicators were identified. Among the indicators, 22 are integrated into the *customer* dimension, followed by 12 in the *user* dimension, and 4 in the *EoL product holder* dimension. To ensure the key criteria defined by Caeiro et al. (2012), namely comparability and robustness, actions and routines, and comprehensibility and communication, among others, multiple indicators adopted a frequency and percentage-based assessment, while

Table 4

List of HCE indicators for the self-assessment tool.

Dimension	HCE indicator	Code	Description	Reference
Customer	Socially irresponsibly produced products refused (dimensionless)	C1	Measures the frequency a customer refuses to acquire a product, for socially responsible reasons (e.g., produced from child labor, poor working conditions, unpaid labor).	(Bianchini et al., 2022; Blinova et al., 2023; Padilla-Rivera et al., 2021)
	Electric or electronic products acquired or replaced to reduce energy consumption (no.)	C2	Describes the amount a customer acquired or replaced an electric or electronic product to reduce energy consumption, per type of product (e.g., procurement of a refrigerator, freezer, laptop, dishwasher, among similar others with high energy efficiency).	(Ahmed et al., 2023; Andreou et al., 2022; Scarpellini et al., 2020; Yazan et al., 2022)
	Acquisition of locally produced food (dimensionless)	C3	Determines the frequency of locally produced food purchased, relatively to the total amount of food purchased, per type of food (e.g., poultry meat, vegetables, nuts, seasonal fruit).	(Bux et al., 2022; Lami et al., 2022; Trollman et al., 2021)
	Products with excessive packaging refused (dimensionless)	C4	Measures the frequency a customer refuses to acquire a product, due to excessive amounts of packaging.	(Colasante and D'Adamo, 2021; Droege et al., 2021; Klug and Niemand, 2021; Kovacs, 2021; Otto et al., 2021)
	In bulk products acquired (dimensionless)	C5	Measures the frequency of products acquired in bulk, to reduce the amount of packaging per type of product.	(Klug and Niemand, 2021; Lami et al., 2022)
	Second-hand products acquired (%)	C6	Measures the share of second-hand products procured, relative to total product acquisition, per type of product.	(Andreou et al., 2022; Chun et al., 2022; Klug and Niemand, 2021; Kovacs, 2021; Valls-Val et al., 2023)
	Products acquisition with recycled materials (%)	C7	Measures the share of products produced with recycled	(Boyer et al., 2021; Jiang et al., 2022; Lizundia et al., 2023)

Table 4 (continued)

Dimension	HCE indicator	Code	Description	Reference
	Recyclable products acquired (%)	C8	material acquired, in relation to total product acquisition, per type of product. Measures the share of recyclable products acquired, in relation to total product acquisition, per type of product.	(Colasante and D'Adamo, 2021; Lami et al., 2022)
	Dismantlable products acquired (%)	C9	Measures the share of dismantlable products acquired, in relation to total product acquisition, per type of product.	(Abadi and Moore, 2022; Mazzoli et al., 2022)
	Durable products acquisition (%)	C10	Measures the share of products acquired with durability as a priority, in relation to total product acquisition, per type of product.	(Abadi and Moore, 2022; Baratsas et al., 2022; Trollman et al., 2021)
	Reusable products acquired (%)	C11	Measures the share of reusable products acquired, in comparison to total product acquisition (reusable and single use), per type of product.	(Baratsas et al., 2022; Colasante and D'Adamo, 2021)
	Product sharing among owners (dimensionless)	C12	Measures the frequency an acquired product was shared, among owners, per type of product.	(Ahmed et al., 2022; Andreou et al., 2022)
	Animal dietary products acquired (no.)	C13	Measures the quantity of animal dietary products acquired per type of animal dietary product (e.g., poultry meat, beef meat, fresh seafood, eggs).	(Droege et al., 2021; Frehner et al., 2022)
	Non-animal dietary products acquired (no.)	C14	Measures the quantity of non-animal dietary products acquired, per type of non-animal dietary product (e.g., vegetables, seasonal fruit, legumes).	(Droege et al., 2021; Frehner et al., 2022)

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Table 4 (continued)

Dimension	HCE indicator	Code	Description	Reference
	Renewable energy consumption (%)	C15	Measures the share of renewable energy consumed to satisfy the household energy needs, in relation to total energy consumption.	(Motte et al., 2022; Sadowski, 2021)
	Water self-sufficiency (%)	C16	Measures the share of water self-sufficiency in a household, including rainwater harvesting, water re-use and wastewater recycling, in relation to total water consumption.	(Kim et al., 2022; Nadal et al., 2018; Sadowski, 2021)
	Energy consumption per m ² (J/m ²)	C17	Measures energy consumption (J) per area (m ²) of the household.	(Droege et al., 2021a; Kosanović et al., 2021; Sadowski, 2021)
	Water consumption (l) per m ² (l/m ²)	C18	Measures water consumption (l) per area (m ²) of the household.	(Cozzolino and De Giovanni, 2023; Kim et al., 2022; Sadowski, 2021)
	Comfort (dimensionless)	C19	Measures how frequent an individual feels comfortable inside their household, including thermal comfort and basic sanitation.	(Kosanović et al., 2021; Padilla-Rivera et al., 2021; Sadowski, 2021)
	Products with increased durability (dimensionless)	C20	Measures if the customer acquired protective equipment for the main product, to increase longevity (e.g., procurement of a phone protective cape, to promote the phones' durability), per type of product.	(Baratsas et al., 2022; Yamamoto and Murakami, 2021)
	Multi-functional products acquired (%)	C21	Measures the share of products with multiple functionalities, in relation to the total products that would have been needed for the same amount of functions (e.g., acquiring one Swiss blade, instead of a knife, corkscrew), per type of product.	(Scarpellini et al., 2020; Trollman et al., 2021)

Table 4 (continued)

	Products with a take-back policy acquired (%)	C22	Measures the share of products that the customer acquired with a take-back policy, per type of product.	(Baier et al., 2020; Bruno et al., 2021)
User	Energy saving usage of a product (dimensionless)	U1	Measures the frequency the user practices the most resource saving method of a product (e.g., using the dishwasher/ washing machine in the lowest temperature option and when completely full).	(Lami et al., 2022; Stamminger et al., 2020)
	Water saving usage of a product (dimensionless)	U2	Measures the frequency the user practices the most resource saving method of a product (e.g., using the dishwasher/ washing machine when completely full).	(Lami et al., 2022; Stamminger et al., 2020)
	Public transport usage (dimensionless)	U3	Measures the frequency the user travels by public transport, per public transport, instead of using a private vehicle.	(Ahmed et al., 2022; Colasante and D'Adamo, 2021; Lami et al., 2022)
	Active mode of transport usage (dimensionless)	U4	Measures the frequency the user travels by bicycle or by walking, instead of using a private vehicle.	(Andreou et al., 2022; Lami et al., 2022)
	Carpool frequency (dimensionless)	U5	Measures the frequency the user carpooled or used a carpooling service while travelling by private vehicle.	(Andreou et al., 2022)
	Time in use per product (hours)	U6	Measures the amount of time (hours) a product was used.	(Droege et al., 2021)
	Leftovers rate (%)	U7	Measures the share of leftovers that are consumed, instead of discarded, in relation to total leftovers production.	(Bux et al., 2022)
	Post-sale services (no.)	U8	Measures the use of post-sale services, to	(Bianchini et al., 2022; Bradley and Persson, 2022;

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Table 4 (continued)

Dimension	HCE indicator	Code	Description	Reference
	Product maintenance (no.)	U9	prolong the longevity of the original product or create a new product from the parts of the product, including repair, refurbish, remanufacture, and repurpose.	Lanaras-Mamounis et al., 2022)
			Measures the independent use of product or part of product lifetime extension practices, including repair, refurbish, remanufacture, and repurpose.	Lanaras-Mamounis et al. (2022)
			Measures the number of products produced independently (e.g., gardening vegetables, producing own cosmetics).	(Klug and Niemand, 2021; Nadal et al., 2018; Sadowski, 2021)
			Measures the frequency of products that were donated in a good condition and able to fulfil its function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
	Product self-sufficiency (no.)	U10	Measures the frequency of products that were sold in good condition and able to fulfil their function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
			Measures the frequency of products that were sold in good condition and able to fulfil their function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
EoL product holder	Recycling frequency (dimensionless)	E1	Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
	Donated products (dimensionless)	U11	Measures the frequency of products that were donated in a good condition and able to fulfil its function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
			Measures the frequency of products that were sold in good condition and able to fulfil their function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
	Sold products (dimensionless)	U12	Measures the frequency of products that were sold in good condition and able to fulfil their function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
			Measures the frequency of products that were sold in good condition and able to fulfil their function, instead of discarded.	(Kręziak et al., 2020; Shittu et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
	Recycling frequency (dimensionless)	E2	Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
	Composting frequency (dimensionless)	E3	Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
	Littering frequency (dimensionless)	E4	Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
	Household waste sorting (dimensionless)	E5	Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)
			Measures the frequency an EoL product holder recycles the product at its EoL.	(Adu-Gyamfi et al., 2023; Ng and Yang, 2023)
			Measures the frequency an organic EoL product holder composites the organic product at its EoL.	(Boesen et al., 2019; Do et al., 2021)

lining out denominators, including household area (m²) and per capita.

Although the time horizon for the implementation of HCE practices differs in function of the product and activity, the self-assessment tool is designed to be adaptable for periodic use by the householders or related entities (e.g., municipal services, condominium management). The frequency of the assessment can be adjusted, such as quarterly, based on socio-cultural contexts and needs. The process begins by selecting the relevant indicators that reflect the users' consumption habits, such as recycling, food acquisition or public transport usage. The tool provides specific instruction for each metric, asking users to consider typical time frames (e.g., a week for "Recycling frequency") and input corresponding data. This flexibility allows for both immediate and long-term tracking of sustainable household practices. For example, while recycling can be monitored weekly, activities like vehicle maintenance may be assessed less frequently. This approach has been similarly done in other assessment tools (Beylot et al., 2018; Kok and Barendregt, 2021; Salas et al., 2022), see Table A1.

Regarding the customer dimension, the HCE indicators focus on the evaluation of procurement practices adopted by consumers, reflecting the implementation of higher circularity-based strategies described by Potting et al. (2017), including refuse, rethink, reduce and re-use. It provides a set of metrics that unlock the potential of lifespan extension approaches or lower circularity strategies. For instance, procuring dismantlable equipment allows an easier repair, refurbishment, repurposing, or remanufacturing service.

For the user dimension, practices to extend the lifespan of products and their parts are a key probe in the assessment process. The nucleus of this dimension is the evaluation of public services and community engagement activities. For the former, public transport usage represents the core indicator. Regarding the latter, localized post-sale services, donating, second-hand selling, and product self-sufficiency represent the main metrics.

Lastly, EoL product holder indicators unlock the potential of materials in upcycling and downcycling activities, through waste management strategies. This set of metrics aims to reduce output flow, by providing useful applications to products and its parts at their EoL, through recycling and household waste sorting.

4.2. Evaluating the self-assessment tool

The findings of the questionnaire survey enabled the development of a HCE self-assessment tool (Appendix D) supported by indicators, which were presented in the previous section. However, to evaluate the presence of the key factors described by Caeiro et al. (2012), including the comprehensibility and meaningfulness of the indicators, 21 semi-structured interviews were conducted with householders. Appendix E provides additional details regarding the list of interviewees. In this context, five criteria were applied to evaluate the proposed indicators and respective assessment scheme, based on deductive and inductive coding: (i) usability; (ii) usefulness; (iii) indicator comprehensibility/difficulties; (iv) recommendations; and (v) meaningfulness.

Concerning the criterion usability, the majority of the interviewees (e.g., I2; I3; I6; I11; I14; among others) were able to use the self-assessment tool with ease, stating: "Yes, it was intuitive" (I11). However, some participants noted that it was long, and, for some indicators, difficult to answer. For instance, I3 and I21 argued that "It was easy to use, although extensive" (I21). Regarding the latter, the interviewees (I7; I10; I15; I17) indicated that they were unable to provide the information requested by the indicator, as a result of the lack of awareness over their own consumption habits, "I didn't know the answer for some of the questions. (...) sometimes I don't know if something has excessive packaging" (I15). This was specifically seen in the questions that aimed to collect relative values from the user, as underlined by I4 and I7: "It was easy to use; however, it would have been easier if I had ranges to select from in the questions that asked

for percentages" (I7). Albeit the positive feedback, one interviewee (I12) lined out some difficulties that represented a challenge in the use of the tool: "I was able to use it more or less, but I don't think it was easy. (...) certain technical terms are being used that I do not understand".

Although for different reasons, all interviewees considered the self-assessment tool useful. The majority underlined that it was a very informative tool, helping in introspection exercises regarding daily household activities, as stressed by I2, I4, I8, I9, I10, and I11, among others: "Yes, it was useful, in the way that it increased the perception I have over my consumption habits and everything else" (I4). Interviewee I6 also added that: "It is useful to understand better, for my family and I, the activities we do around the house". In addition, some participants (I1; I10; I12; I15; I20) argued that certain habits are rooted in their daily activities, due to convenience: "I consider it useful, (...), and to remind myself of certain habits that, due to convenience, I tend to slouch" (I20).

Regarding the difficulties associated with the use of the HCE self-assessment tool, the opinions are divided among the participants: (i) The tool and indicators were easy to use, understand, and answer, albeit aforementioned difficulties associated with the lack of awareness over their consumption habits; and (ii) The metrics were challenging to comprehend, and answer. In relation with the former, some participants (I5; I7; I17) argued that: "Yes, none were particularly difficult to interpret or answer, except for the fact that I do not know my own data" (I17). However, in householders with a higher awareness over their consumption activities (I3; I11; I13; I19; I21), no challenges were identified, "(The indicators were) easy to answer and comprehend" (I21). However, in the context of latter, multiple barriers were identified (I4; I5; I6; I7; I12; I15; I16; I18): (i) Difficulty in understanding technical terms, "I am not familiarized with the concepts of all of the indicators, definition wise" (I1); (ii) Lack of information regarding consumption habits, including energy, water and/or product characteristics (recyclability, locally produced, among similar others), "For the questions regarding if a product was recyclable or (...), most of the times I do not know that or the store itself does not make that information available" (I5); and (iii) Inability to provide a relative value, "In some situations, it was a little difficult to write a percentage value. It requires effort to think of my household activities" (I6).

However, multiple recommendations were made by the interviewees (I3; I5; I7; I10; I12; I14; I15; I16; I18; I19): (i) Provide a description/definition/example of the technical terms used, "I think that a description and providing some examples would help understand and answer the questions" (I16); (ii) Indicate reference values, "I think there should be some base information (to compare). For instance, I do not know how much water I consume, but I am more or less aware that I consume less than the average (Portuguese) person" (I7); (iii) Create ranges of values for the metrics that ask for percentages, "For the percentage questions, also have ranges, instead of a free answer" (I19); and (iv) Indicate that certain information (e.g. energy consumption, water consumption) will be needed beforehand, "For the indicators that need quantitative data, pre warn the person to bring the information" (I3). Thus, since the present amendments enable a more in-depth understanding of the HCE indicators, no metrics were removed from Table 4.

Lastly, multiple interviewees (e.g., I1; I2; I3; I4; I5; among others) found the self-assessment tool meaningful, as the participants were able to reflect over their actions and adopt new circular economy-based behaviors. As a customer, some individuals (I1; I4; I6) reflected over the lack of consciousness in procurement practices: "Yes, I understood that I give little attention to whether a product was locally or sustainably produced. (...). I realized I could have a higher environmental and social influence (in my daily habits)" (I1). For the user dimension, the participants (I1; I2; I15) underlined that certain

practices are rooted in routine, due to convenience, such as private transport usage, "(...) most of the things I do are defined by routine. (This tool) forces us to think about what we do (on our daily activities)" (I2). Since most of the interviewees had already implemented EoL product holder practices, the self-reflection exercise took two roles (I8; I12; I20): (i) reviewer, "Yes, I believe, in this case, the actions I do were confirmed by the tool" (I8); and (ii) self-satisfaction, "Yes, the only thing I do not is compost. In the remaining practices, I reviewed myself with satisfaction" (I20). In addition, the majority of the interviewees (e.g., I3; I4; I5; I8; I10; among others) were willing to adopt a new circular economy-based behavior, after using this tool. Among them, the user dimension was privileged by the participants (I14; I16; I19; I20), "There is one practice I would like to implement, which is repairing. I tend to throw away the product when it stops working and buy a new one, but I am going to start repairing" (I20).

5. Discussion

5.1. HCE practices and indicators

The present results indicate that the importance of certain HCE practices depends on the phase of the consumer role. Although the *customer* dimension is the starting point in the circular consumer roles (Shevchenko et al., 2023), the *user* and *EoL product holder* dimensions constituted a higher priority. This could have resulted from the inherent motivations and barriers associated with consumption practices. According to Terzioğlu (2021) and Varotto and Spagnoli (2017), *user* and *EoL product holder* related strategies (e.g. repairing and recycling, respectively) are driven by emotional and value aspects, including environmental and social concerns. When compared with product replacement, lifespan extension practices represent, in general, lower costs. Nonetheless, although second-hand repaired/remanufactured/repurposed/refurbished products tend to cost less, when there are clear traces of the previous owners the consumer feels reluctant to acquire them (Gullstrand Edbring et al., 2016).

Among the customer HCE practices and in the context of the first research question, the results suggest that products with a clear or direct financial, environmental, and/or social advantage(s) (e.g., high energy certificate, multifunctionality, durability, recyclability) are more favored by the consumers. This finding is in line with scientific literature. For instance, Richter (2010) stressed that the majority of the consumers prioritize an higher energy labelled product, when acquiring dishwashers, due to financial reasons and convenience. Barkhausen et al. (2022) underlined the importance of fostering the durability criteria in product design, as a result of environmental and economic metrics: On the one hand, it is more cost effective; and, on the other hand, it reduces the need for constant product replacement, avoiding toxic substances release, among other environmental benefits. Furthermore, these advantages can also derive from the implementation of the refuse practice, described in Potting et al. (2017). Although the increasing need for consumer responsibility in procurement practices (Ghisellini et al., 2016), lack of awareness of the production process inherent in a product represents one of the main CE barriers (Grafström and Aasma, 2021). However, when backed by perceivable benefits, the consumer refuses unsustainably made products; thus, increasing demand for circular economy-based market opportunities with social and environmental benefits (Grafström and Aasma, 2021). In addition, as emphasized in multiple studies (Ghisellini et al., 2016; Grafström and Aasma, 2021; Gullstrand Edbring et al., 2016), product ownership was identified as an important factor for consumers, since dematerialization, renting and product as a service practices were characterized with a lower importance level. This result derives from a modern culture social norm that expresses a desire to own and is mostly connected to products that are consumed for their primary function than for products that have

high associated social status (Gullstrand Edbring et al., 2016). For example, albeit a bike sharing initiative addresses several sustainability challenges, including climate change and wellbeing, privately owned bicycles constitute a consumer preference (Henriksson and Göransson Scalzotto, 2023). In fact, Gullstrand Edbring et al. (2016) found that, in situations of short-term renting, consumer attitude is largely positive, since it provides the opportunity to test the product, before acquiring it. On the other hand, long-term renting is linked with a negative perception.

As a product of the second research question, the present set of HCE indicators obtained by the triangulation between the integrative literature review and the questionnaire survey define a comprehensive evaluation system, considering the multiple aspects of the circular consumer defined by Shevchenko et al. (2023) and CE strategies described by Potting et al. (2017). On the one hand, the self-assessment tool could foster circularity in a householder lifestyle, increasing awareness and consumer responsibility. On the other hand, as a key enabler in circular economy business models and urban metabolism (Shevchenko et al., 2023), indicators and related assessment tools aim to help consumers unlock the potential of circular economy-based management/strategies at their multiple levels of implementation (micro, meso, macro), by the aid of a bottom-up approach (Corona et al., 2019; Gravagnuolo et al., 2019).

The proposed HCE indicators are in line with current trends that aim to challenge the LCA approach in circular economy assessment practices (Droege et al., 2021; Padilla-Rivera et al., 2021), which tends to be more expensive, highly dependent on data quality, and technical expertise (T. Lu and Halog, 2020; van Stijn et al., 2021). The present tool addresses these issues, by providing a relatively simple and context-dependent evaluation process, as seen in other frameworks (Droege et al., 2021; Ramos et al., 2021; Saidani et al., 2019). Although the present list of metrics was collaboratively designed for consumers self-assessment, Rincón-Moreno et al. (2021) suggest that most CE indicators show a multi scale applicability. Thus, the present framework can be adapted to other levels, including organizations, cities, regions, or nations, since – according to Opferkuch et al. (2023) and Gravagnuolo et al. (2019) – all are concerned with smarter product or service use, product/resource acquisition, extending the lifespan of products and its parts, and the useful application of materials (following the descriptions of Potting et al. (2017)).

The self-assessment tool development depended on a collaborative approach with householders. Therefore, the process allowed the consumers to indicate the most important aspects of their consumption practices, especially their demands. This process is in line with similar studies: (i) in CE corporate disclosure, see Opferkuch et al. (2023); and (ii) in CE assessment for public sector organizations, see Droege et al. (2021). The proposed framework is also aligned with other self-assessment tools, such as the ones developed by Salas et al. (2022), and discussed in the works of Kok and Barendregt (2021), and Čuček et al. (2012). It focusses the evaluation process on the key factors that represent the environmental profile of an individual lifestyle, while addressing it through the HCE lens: (i) Food; (ii) Mobility; (iii) Appliances; and (iv) Household goods. This innovative approach captures these domains, and applies efficiency gains, longevity extension methods, waste management practices, and social values.

Moreover, despite being part of the CE nucleus (Kumar et al., 2022; Paparella et al., 2023), second-hand acquisition, and less animal-dependent dietary choices were scored with a lower importance level. This could have resulted from the use of a collaborative approach; and thus, the communication difficulties between the general public and practitioners/researchers (Kieser and Leiner, 2012). However, to ensure the comprehensibility and meaningfulness of the HCE indicators and self-assessment tool, semi-structured interviews were conducted.

5.2. Self-assessment tool insights

Results indicate that the self-assessment tool and HCE indicators were relatively simple to understand and respond to, providing opportunity for equitable benchmarking. This feedback is in line with the overall consensus over the characteristics needed for a self-assessment tool (Caeiro et al., 2012; Matušítk and Kočí, 2021): (i) comprehensibility; and (ii) meaningfulness. In relation with the former, context provision (Vanham et al., 2019), selecting a comprehensive set of questions around the object of evaluation (Franz and Papyrakis, 2011), and making the general design, and data input clear and fun (Kok and Barendregt, 2021) is highly recommended, fostering communication and empowerment for more sustainable lifestyles (Kok and Barendregt, 2021). These types of features should be carefully considered during the initial stages of planning and implementation of the CE self-assessment tool.

Although some individuals are willing to overlook certain difficulties and the extensiveness of the metrics, the majority aims to explore and compare their daily activities, in a given context (Kok and Barendregt, 2021). Regarding the latter, results suggest that the self-assessment tool was highly meaningful, as an informative and self-reflection aiding mechanism. In fact, multiple interviewees were interested in adopting new circular economy-based practices into their lifestyle. These findings are in line with the works of Kok and Barendregt (2021) and Buhl et al. (2019), which underlined that people were more willing to engage in pro-environmental behavior after using a sustainability-based self-assessment tool, when compared to the general public.

However, some difficulties were mentioned regarding understandability of technical terms, length of the evaluation process, and consumer lack of awareness over their own procurement habits, including data availability for metrics that aim to collect relative values. Similar challenges have been noted by multiple authors (Kharrazi et al., 2014; Kok and Barendregt, 2021; Syrovátka, 2020; Tolppanen and Kang, 2021). For instance, Kok and Barendregt (2021) indicate that a trade-off between completeness and usability exist. Buhl et al. (2019) also argue that lack of information hinders one's ability to evaluate themselves. Furthermore, a discrepancy in opinions was found over the self-assessment tool difficulty. According to Kok and Barendregt (2021), this could have resulted from the participant's profile: environmentalists are willing to put more effort into getting more accurate results; whereas the general public does not want to spend a lot of time on data entry without any clear beneficial outcome.

5.3. Theoretical and practical implications

Multiple insights were drawn from this study, from a theoretical perspective. First, the self-assessment tool aims to break some of the CE barriers defined by Grafström and Aasma (2021), specifically the social/cultural challenges, by increasing consumer awareness and enthusiasm, acceptance for circular economy models, and overall knowledge of a more sustainable lifestyle. Hence, it aims to expand on the number of HCE practices that can be implemented by a householder. Based on the integrative literature review (Table A2), no study has compiled a list of circular economy practices that could be executed by consumers at household level. Shevchenko et al. (2023) described the tri-dimensional role of the consumer in the CE. In addition, multiple authors (Addo et al., 2018; Gullstrand Edbring et al., 2016; Paparella et al., 2023; Terzioğlu, 2021; Varotto and Spagnoli, 2017) have studied single aspects of CE at the consumer level, including resource (e.g. water, energy, food), acceptance of circular economy-based business models (e.g. sharing, renting, second-hand consumption), and individual circular economy strategies (e.g. repairing, recycling, reducing, re-using). However, to the best of our knowledge, so far, no study has developed a list of HCE practices and/or associated it with the consumer importance level.

Second, the list of HCE indicators (Table 4) attempts to resolve some

of the limitations and challenges integrated in the CE indicators field of research, including the gaps identified by Moraga et al. (2019), Jerome et al. (2022), and Shevchenko et al. (2023). Regarding the first, the authors were not able to identify CE indicators capable of measuring the higher circularity strategies described by Potting et al. (2017). Among the HCE metrics, two indicators (e.g., “Socially irresponsibly produced products refused” and “Products with excessive packaging refused”) were defined to measure the refuse strategy. For the second, the researchers mentioned that most CE indicators cannot evaluate the use phase of a product, and lifetime extension strategies. Similarly, among the HCE indicators, three metrics that can address those issues were proposed (e.g., “Time in use per product” and “post-sale services”). In relation with the third, the authors emphasize the significant lack of metrics for the consumer, in the CE context. The present research proposes several tailored HCE indicators to address this gap.

Third, the results provide a set of recommendations to improve the comprehensibility and meaningfulness of the proposed self-assessment tool. These suggestions can be used in the development of future similar mechanisms. The interviewees emphasized that the indicators should be more intuitive, by providing a description of technical terms, indicate reference values, to enable benchmarking with the national average, and create ranges of values for the metrics that ask for percentages, to facilitate the user’s ability to answer. These findings are in line with other research, namely the work of Kok and Barendregt (2021), where among the aforementioned suggestions, also underlines that a self-assessment tool should also mention clear financial and health benefits associated with the implementation of these practices. In addition, householders are interested in receiving advice to improve performance, in function of the answers.

From a practical perspective, several implications/lessons can be drawn from this study. In particular, the proposed HCE tool could support local organizations and municipalities in understanding what consumers prioritize in the circular economy scope, and help future HCE assessment initiatives, conducted at municipal, parish, neighborhood, condominium, or other specific scale. This could also enable tailored product design and business opportunities that follows CE strategies, as emphasized by Shevchenko et al. (2023), and plans and programs that foster circularity in cities, according to Gravagnuolo et al. (2019). Thus, it aims to bridge the gap between householders and entities/plans/programs, as mentioned by Grafström and Aasma (2021).

6. Conclusions

Household consumption practices play a significant role in sustainability challenges, including climate change and well-being. While economic motivations often drive procurement habits, CE practices can offer both financial and environmental incentives for more sustainable lifestyles. Through a collaborative research approach, this explanatory study developed a self-assessment tool to support households in adopting CE practices, by: (i) identifying the priority levels consumers assign to various CE activities; and (ii) proposing a set of CE metrics to enhance awareness and communication around HCE strategies.

Key findings reveal that economic barriers, lack of trust in second-hand products, and cultural norms hinder the adoption of some CE practices, while simpler, EoL and user-related activities are more readily embraced. The triangulation between the understanding of the most important HCE practices and an integrative literature review reflected a list of 38 indicators that enable the individual’s self-assessment. Semi-structured interviews confirmed the tool’s meaningfulness, and improved its usability, refining the assessment framework. In fact, participants expressed their willingness to improve their lifestyle in this regard, despite facing challenges such as the limited awareness of their own consumption behaviors.

This research addresses gaps in CE literature by introducing household-level indicators and provides a foundation for future exploration in HCE strategies. Broader implications include empowering

individuals to align their behaviors with CE principles, directly supporting SDG 12th and the Circular Economy Action Plan. Additionally, these insights have the potential to inform policymakers and drive innovation, investment, and job creation in public and private sectors. These insights allow professionals to design targeted interventions (e.g., financial incentives, awareness campaigns, or regulatory frameworks that encourage HCE practices), while highlighting new opportunities for businesses to develop products and services that cater to CE needs (e.g., rental services, repair hubs, or modular, reusable designs), among other factors.

However, several potential limitations inherent to the methodological approach could have constrained this study, including sample size, oversimplification of certain aspects, and under representation, since the findings only reflect the Portuguese context.

Future research should refine the tool by exploring scoring and standardization mechanisms, stakeholder collaboration to further refine the framework, and the integration impact metrics. This is currently an underdeveloped field of CE research. Indeed, throughout this research several gaps were identified, including: (i) how can the user of the self-assessment tool be scored (i.e. what are the relative weights of each metric); and (ii) which environmental and social impact assessment metrics can be paired with the developed list of indicators. This effort aims to advance CE at the household level, enabling both sustainable consumption and broader systemic change.

CRedit authorship contribution statement

Alexandre Rodrigues da Silva: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Tomás B. Ramos:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.clrc.2025.100262>.

Data availability

Data will be made available on request.

References

- Abadi, M., Moore, D.R., 2022. Selection of circular proposals in building projects: an MCDM model for lifecycle circularity assessments using AHP. *Buildings* 12 (8). <https://doi.org/10.3390/buildings12081110>. Article 8.
- Abdulrazak, S., Quoquab, F., 2018. Exploring consumers’ motivations for sustainable consumption: a self-deterministic approach. *J. Int. Consum. Market.* 30 (1), 14–28. <https://doi.org/10.1080/08961530.2017.1354350>.
- Adan, H., Fuerst, F., 2016. Do energy efficiency measures really reduce household energy consumption? A difference-in-difference analysis. *Energy Efficiency* 9 (5), 1207–1219. <https://doi.org/10.1007/s12053-015-9418-3>.

- Addo, I.B., Thoms, M.C., Parsons, M., 2018. Barriers and drivers of household water-conservation behavior: a profiling approach. *Water* 10 (12). <https://doi.org/10.3390/w10121794>. Article 12.
- Adu-Gyamfi, G., Asamoah, A.N., Nketiah, E., Obuobi, B., Adjei, M., Cudjoe, D., Zhu, B., 2023. Reducing waste management challenges: empirical assessment of waste sorting intention among corporate employees in Ghana. *J. Retailing Consum. Serv.* 72, 103261. <https://doi.org/10.1016/j.jretconser.2023.103261>.
- Ahmed, A.A., Nazzal, M.A., Darras, B.M., Deiab, I.M., 2022. A comprehensive multi-level circular economy assessment framework. *Sustain. Prod. Consum.* 32, 700–717. <https://doi.org/10.1016/j.spc.2022.05.025>.
- Ahmed, A.A., Nazzal, M.A., Darras, B.M., Deiab, I.M., 2023. A comprehensive sustainability assessment of battery electric vehicles, fuel cell electric vehicles, and internal combustion engine vehicles through a comparative circular economy assessment approach. *Sustainability* 15 (1). <https://doi.org/10.3390/su15010171>. Article 1.
- Anantharaman, M., 2018. Critical sustainable consumption: a research agenda. *Journal of Environmental Studies and Sciences* 8 (4), 553–561. <https://doi.org/10.1007/s13412-018-0487-4>.
- Andreou, A., Fragkos, P., Fotiou, T., Filippidou, F., 2022. Assessing lifestyle transformations and their systemic effects in energy-system and integrated assessment models: a review of current methods and data. *Energies* 15 (14). <https://doi.org/10.3390/en15030939>. Article 14.
- Atstaja, D., Koval, V., Grasis, J., Kalina, I., Kryshal, H., Mikhno, I., 2022. Sharing model in circular economy towards rational use in sustainable production. *Energies* 15 (3). <https://doi.org/10.3390/en15030939>. Article 3.
- Baier, D., Rausch, T.M., Wagner, T.F., 2020. The drivers of sustainable apparel and sportswear consumption: a segmented kano perspective. *Sustainability* 12 (7). <https://doi.org/10.3390/su12072788>. Article 7.
- Baratsas, S.G., Pistikopoulos, E.N., Avraimidou, S., 2022. A quantitative and holistic circular economy assessment framework at the micro level. *Comput. Chem. Eng.* 160, 107697. <https://doi.org/10.1016/j.compchemeng.2022.107697>.
- Barkhausen, R., Durand, A., Fick, K., 2022. Review and analysis of ecodesign directive implementing measures: product regulations shifting from energy efficiency towards a circular economy. *Sustainability* 14 (16). <https://doi.org/10.3390/su141610318>. Article 16.
- Bartlett, J., Kotrlik, J., Higgins, C., 2001. Organizational research: determining appropriate sample size in survey research, 19(1), 43–50. <https://www.opalco.com/wp-content/uploads/2014/10/Reading-Sample-Size1.pdf>.
- Bethlehem, J., 2009. *Applied Survey Methods: A Statistical Perspective*, first ed. John Wiley & Sons, Inc.
- Beylot, A., Boitier, B., Lancesseur, N., Villeneuve, J., 2018. The waste footprint of French households in 2020: a comparison of scenarios of consumption growth using input-output analysis. *J. Ind. Ecol.* 22 (2), 356–368. <https://doi.org/10.1111/jiec.12566>.
- Bianchini, A., Guarnieri, P., Rossi, J., 2022. A framework to assess social indicators in a circular economy perspective. *Sustainability* 14 (13). <https://doi.org/10.3390/su14137970>. Article 13.
- Blinova, E., Ponomarenko, T., Tesovskaya, S., 2023. Key corporate sustainability assessment methods for coal companies. *Sustainability* 15 (7). <https://doi.org/10.3390/su15075763>. Article 7.
- Boesen, S., Bey, N., Niero, M., 2019. Environmental sustainability of liquid food packaging: is there a gap between Danish consumers' perception and learnings from life cycle assessment? *J. Clean. Prod.* 210, 1193–1206. <https://doi.org/10.1016/j.jclepro.2018.11.055>.
- Boyer, R.H.W., Hunka, A.D., Whalen, K.A., 2021. Consumer demand for circular products: identifying customer segments in the circular economy. *Sustainability* 13 (22). <https://doi.org/10.3390/su132212348>. Article 22.
- Bradley, K., Persson, O., 2022. Community repair in the circular economy – fixing more than stuff. *Local Environ.* 27 (10–11), 1321–1337. <https://doi.org/10.1080/13549839.2022.2041580>.
- Bruno, G., Diglio, A., Passaro, R., Piccolo, C., Quinto, I., 2021. Measuring spatial access to the recovery networks for WEEE: an in-depth analysis of the Italian case. *Int. J. Prod. Econ.* 240, 108210. <https://doi.org/10.1016/j.jpe.2021.108210>.
- Bryman, A., 2016. *Social Research Methods*, fifth ed. Oxford University Press Inc.
- Buhl, J., Liedtke, C., Teubler, J., Biengen, K., 2019. The Material Footprint of private households in Germany: linking the natural resource use and socioeconomic characteristics of users from an online footprint calculator in Germany. *Sustain. Prod. Consum.* 20, 74–83. <https://doi.org/10.1016/j.spc.2019.05.001>.
- Busse, M., Menzel, S., 2014. The role of perceived socio-spatial distance in adolescents' willingness to engage in pro-environmental behavior. *J. Environ. Psychol.* 40, 412–420. <https://doi.org/10.1016/j.jenvp.2014.10.002>.
- Bux, C., Aluculesi, A.C., Moagăr-Poladian, S., 2022. How to monitor the transition to sustainable food services and lodging accommodation activities: a bibliometric approach. *Sustainability* 14 (15). <https://doi.org/10.3390/su14159102>. Article 15.
- Caeiro, S., Ramos, T.B., Huisingsh, D., 2012. Procedures and criteria to develop and evaluate household sustainable consumption indicators. *J. Clean. Prod.* 27, 72–91. <https://doi.org/10.1016/j.jclepro.2011.12.026>.
- Camacho-Otero, J., Boks, C., Pettersen, I.N., 2018. Consumption in the circular economy: a literature review. *Sustainability* 10 (8). <https://doi.org/10.3390/su10082758>. Article 8.
- Castellani, V., Beylot, A., Sala, S., 2019. Environmental impacts of household consumption in Europe: comparing process-based LCA and environmentally extended input-output analysis. *J. Clean. Prod.* 240, 117966. <https://doi.org/10.1016/j.jclepro.2019.117966>.
- Chu, H.-C., Hwang, G.-J., 2008. A Delphi-based approach to developing expert systems with the cooperation of multiple experts. *Expert Syst. Appl.* 34 (4), 2826–2840. <https://doi.org/10.1016/j.eswa.2007.05.034>.
- Chun, Y.-Y., Matsumoto, M., Chinen, K., Endo, H., Gan, S.-S., Tahara, K., 2022. What will lead Asian consumers into circular consumption? An empirical study of purchasing refurbished smartphones in Japan and Indonesia. *Sustain. Prod. Consum.* 33, 158–167. <https://doi.org/10.1016/j.spc.2022.06.015>.
- Colasante, A., D'Adamo, I., 2021. The circular economy and bioeconomy in the fashion sector: emergence of a “sustainability bias.”. *J. Clean. Prod.* 329, 129774. <https://doi.org/10.1016/j.jclepro.2021.129774>.
- Corona, B., Shen, L., Reike, D., Rosales Carreón, J., Worrell, E., 2019. Towards sustainable development through the circular economy—a review and critical assessment on current circularity metrics. *Resour. Conserv. Recycl.* 151, 104498. <https://doi.org/10.1016/j.resconrec.2019.104498>.
- Coutinho, V., Domingues, A.R., Caeiro, S., Painho, M., Antunes, P., Santos, R., Videira, N., Walker, R.M., Huisingsh, D., Ramos, T.B., 2018. Employee-driven sustainability performance assessment in public organisations. *Corp. Soc. Responsib. Environ. Manag.* 25 (1), 29–46. <https://doi.org/10.1002/csr.1438>.
- Cozzolino, A., De Giovanni, P., 2023. Portfolios of sustainable practices for packaging in the circular economy: an analysis of Italian firms. *Int. J. Logist. Manag.* 34 (7), 24–49. <https://doi.org/10.1108/IJLM-03-2022-0132>.
- Čuček, L., Klemes, J.J., Kravanja, Z., 2012. A Review of Footprint analysis tools for monitoring impacts on sustainability. *J. Clean. Prod.* 34, 9–20. <https://doi.org/10.1016/j.jclepro.2012.02.036>.
- de Oliveira, C.T., Dantas, T.E.T., Soares, S.R., 2021. Nano and micro level circular economy indicators: assisting decision-makers in circularity assessments. *Sustain. Prod. Consum.* 26, 455–468. <https://doi.org/10.1016/j.spc.2020.11.024>.
- de Oliveira, C.T., Oliveira, G.G.A., 2023. What Circular economy indicators really measure? An overview of circular economy principles and sustainable development goals. *Resour. Conserv. Recycl.* 190, 106850. <https://doi.org/10.1016/j.resconrec.2022.106850>.
- De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M., Ioppolo, G., 2021. A systematic review for measuring circular economy: the 61 indicators. *J. Clean. Prod.* 281, 124942. <https://doi.org/10.1016/j.jclepro.2020.124942>.
- den Hollander, M.C., Bakker, C.A., Hultink, E.J., 2017. Product design in a circular economy: development of a typology of key concepts and terms. *J. Ind. Ecol.* 21 (3), 517–525. <https://doi.org/10.1111/jiec.12610>.
- Denscombe, M., 2017. *The Good Research Guide: for Small-Scale Social Research Projects*, sixth ed. Open University Press McGraw-Hill.
- Dissanayake, D.G.K., Weerasinghe, D., 2022. Towards circular economy in fashion: review of strategies, barriers and enablers. *Circular Economy and Sustainability* 2 (1), 25–45. <https://doi.org/10.1007/s43615-021-00090-5>.
- Distefano, T., Kelly, S., 2017. Are we in deep water? Water scarcity and its limits to economic growth. *Ecol. Econ.* 142, 130–147. <https://doi.org/10.1016/j.ecolecon.2017.06.019>.
- Do, Q., Ramudhin, A., Colicchia, C., Creazza, A., Li, D., 2021. A systematic review of research on food loss and waste prevention and management for the circular economy. *Int. J. Prod. Econ.* 239, 108209. <https://doi.org/10.1016/j.jipe.2021.108209>.
- Droege, H., Raggi, A., Ramos, T.B., 2021a. Co-development of a framework for circular economy assessment in organisations: learnings from the public sector. *Corp. Soc. Responsib. Environ. Manag.* 28 (6), 1715–1729. <https://doi.org/10.1002/csr.2140>.
- Droege, H., Raggi, A., Ramos, T.B., 2021b. Overcoming current challenges for circular economy assessment implementation in public sector organisations. *Sustainability* 13 (3). <https://doi.org/10.3390/su13031182>. Article 3.
- Eisenmenger, N., Pichler, M., Krenmayr, N., Noll, D., Plank, B., Schalmann, E., Wandl, M.-T., Gingrich, S., 2020. The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. *Sustain. Sci.* 15 (4), 1101–1110. <https://doi.org/10.1007/s11625-020-00813-x>.
- Elimelech, E., Ert, E., Ayalon, O., 2019. Bridging the gap between self-assessments and measured household food waste: a hybrid valuation approach. *Waste Management* 95, 259–270. <https://doi.org/10.1016/j.wasman.2019.06.015>.
- Fahim, A., Ilyas, M., 2021. *SELF-ASSESSMENT TOOL FOR RESEARCH PROPOSAL*.
- Fang, K., Song, S., Heijungs, R., de Groot, S., Dong, L., Song, J., Wiloso, E.I., 2016. The footprint's fingerprint: on the classification of the footprint family. *Curr. Opin. Environ. Sustain.* 23, 54–62. <https://doi.org/10.1016/j.cosust.2016.12.002>.
- Franz, J., Papyrakis, E., 2011. Online calculators of ecological footprint: do they promote or dissuade sustainable behaviour? *Sustain. Dev.* 19 (6), 391–401. <https://doi.org/10.1002/sd.446>.
- Frederiks, E.R., Stenner, K., Hobman, E.V., 2015. The socio-demographic and psychological predictors of residential energy consumption: a comprehensive review. *Energies* 8 (1). <https://doi.org/10.3390/en8010573>. Article 1.
- Frehner, A., De Boer, I., Muller, A., Van Zanten, H., Schader, C., 2022. Consumer strategies towards a more sustainable food system: insights from Switzerland. *Am. J. Clin. Nutr.* 115 (4), 1039–1047. <https://doi.org/10.1093/ajcn/nqab401>.
- Friedland, J., Balkin, D.B., 2023. When gig workers become essential: leveraging customer moral self-awareness beyond COVID-19. *Bus. Horiz.* 66 (2), 181–190. <https://doi.org/10.1016/j.bushor.2022.05.003>.
- Gerbens-Leenes, P.W., Nonhebel, S., Krol, M.S., 2010. Food consumption patterns and economic growth. Increasing affluence and the use of natural resources. *Appetite* 55 (3), 597–608. <https://doi.org/10.1016/j.appet.2010.09.013>.
- Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* 114, 11–32. <https://doi.org/10.1016/j.jclepro.2015.09.007>.
- Glavic, P., 2021. Evolution and current challenges of sustainable consumption and production. *Sustainability* 13 (16). <https://doi.org/10.3390/su13169379>. Article 16.

- Gómez-Monsalve, M., Domínguez, I.C., Yan, X., Ward, S., Oviedo-Ocaña, E.R., 2022. Environmental performance of a hybrid rainwater harvesting and greywater reuse system: a case study on a high water consumption household in Colombia. *J. Clean. Prod.* 345, 131125. <https://doi.org/10.1016/j.jclepro.2022.131125>.
- Goyal, S., Garg, D., Luthra, S., 2022. Analyzing critical success factors to adopt sustainable consumption and production linked with circular economy. *Environ. Dev. Sustain.* 24 (4), 5195–5224. <https://doi.org/10.1007/s10668-021-01655-y>.
- Grafström, J., Aasma, S., 2021. Breaking circular economy barriers. *J. Clean. Prod.* 292, 126002. <https://doi.org/10.1016/j.jclepro.2021.126002>.
- Gravagnuolo, A., Angrisano, M., Fusco Girard, L., 2019. Circular economy strategies in eight historic port cities: criteria and indicators towards a circular city assessment framework. *Sustainability* 11 (13). <https://doi.org/10.3390/su11133512>. Article 13.
- Gullstrand Edbring, E., Lehner, M., Mont, O., 2016. Exploring consumer attitudes to alternative models of consumption: motivations and barriers. *J. Clean. Prod.* 123, 5–15. <https://doi.org/10.1016/j.jclepro.2015.10.107>.
- Harris, S., Martin, M., Diener, D., 2021. Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy. *Sustain. Prod. Consum.* 26, 172–186. <https://doi.org/10.1016/j.spc.2020.09.018>.
- Helander, H., Petit-Boix, A., Leipold, S., Bringezu, S., 2019. How to monitor environmental pressures of a circular economy: an assessment of indicators. *J. Ind. Ecol.* 23 (5), 1278–1291. <https://doi.org/10.1111/jiec.12924>.
- Henao-Hincapié, L.J., Leyes, M., Loebber-Vizcaino, G.E., Cruz-Pérez, A., Romero-Perdomo, F., González-Curbelo, M.A., 2024. Assessing consumer knowledge, attitudes, and adoption of circular economy practices in Colombia. *Sustain. Prod. Consum.* 46, 256–267. <https://doi.org/10.1016/j.spc.2024.02.030>.
- Henriksson, M., Göransson Scalzotto, J., 2023. Bike-sharing under pressure: the role of cycling in building circular cycling futures. *J. Clean. Prod.* 395, 136368. <https://doi.org/10.1016/j.jclepro.2023.136368>.
- Howard, M., Hopkinson, P., Miemczyk, J., 2019. The regenerative supply chain: a framework for developing circular economy indicators. *Int. J. Prod. Res.* 57 (23), 7300–7318. <https://doi.org/10.1080/00207543.2018.1524166>.
- INE, 2023. *Indicador. População residente (N.º) por Local de residência à data dos Censos [2021] (NUTS - 2013), Sexo e Grupo etário (Por ciclos de vida)*. <https://tabulador.ine.pt/indicador/?id=0011609>.
- Jerome, A., Helander, H., Ljunggren, M., Janssen, M., 2022. Mapping and testing circular economy product-level indicators: a critical review. *Resour. Conserv. Recycl.* 178, 106080. <https://doi.org/10.1016/j.resconrec.2021.106080>.
- Jiang, L., Bhochhibhoya, S., Slot, N., de Graaf, R., 2022. Measuring product-level circularity performance: an economic value-based metric with the indicator of residual value. *Resour. Conserv. Recycl.* 186, 106541. <https://doi.org/10.1016/j.resconrec.2022.106541>.
- Kalbar, P.P., Birkved, M., Hauschild, M., Kabins, S., Nygaard, S.E., 2018. Environmental impact of urban consumption patterns: drivers and focus points. *Resour. Conserv. Recycl.* 137, 260–269. <https://doi.org/10.1016/j.resconrec.2018.06.019>.
- Keely, L.A., Huemann, M., 2017. Project benefits co-creation: shaping sustainable development benefits. *Int. J. Proj. Manag.* 35 (6), 1196–1212. <https://doi.org/10.1016/j.jproman.2017.02.008>.
- Khadim, N., Agliata, R., Marino, A., Thaheem, M.J., Mollo, L., 2022. Critical review of nano and micro-level building circularity indicators and frameworks. *J. Clean. Prod.* 357, 131859. <https://doi.org/10.1016/j.jclepro.2022.131859>.
- Kharrazi, A., Kraines, S., Hoang, L., Yarime, M., 2014. Advancing quantification methods of sustainability: a critical examination energy, exergy, ecological footprint, and ecological information-based approaches. *Ecol. Indic.* 37, 81–89. <https://doi.org/10.1016/j.ecolind.2013.10.003>.
- Kieser, A., Leiner, L., 2012. Collaborate with practitioners: but beware of collaborative research. *Journal of Management Inquiry - J MANAGE INQUIRY* 21, 14–28. <https://doi.org/10.1177/1056492611411923>.
- Kim, J.E., Humphrey, D., Hofman, J., 2022. Evaluation of harvesting urban water resources for sustainable water management: case study in Filton Airfield, UK. *J. Environ. Manag.* 322, 116049. <https://doi.org/10.1016/j.jenvman.2022.116049>.
- Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. *Resour. Conserv. Recycl.* 127, 221–232. <https://doi.org/10.1016/j.resconrec.2017.09.005>.
- Klein, N., Deutz, P., Ramos, T.B., 2022. A survey of Circular Economy initiatives in Portuguese central public sector organisations: national outlook for implementation. *J. Environ. Manag.* 314, 114982. <https://doi.org/10.1016/j.jenvman.2022.114982>.
- Klemeš, J.J., Fan, Y.V., Jiang, P., 2021. Plastics: friends or foes? The circularity and plastic waste footprint. *Energy Sources, Part A Recovery, Util. Environ. Eff.* 43 (13), 1549–1565. <https://doi.org/10.1080/15567036.2020.1801906>.
- Klug, K., Niemand, T., 2021. The lifestyle of sustainability: testing a behavioral measure of precycling. *J. Clean. Prod.* 297, 126699. <https://doi.org/10.1016/j.jclepro.2021.126699>.
- Kocaadam-Bozkurt, B., Bozkurt, O., 2023. Relationship between adherence to the Mediterranean diet, sustainable and healthy eating behaviors, and awareness of reducing the ecological footprint. *Int. J. Environ. Health Res.* 33 (4), 430–440. <https://www.tandfonline.com/doi/abs/10.1080/09603123.2023.2172384>.
- Kok, A.L., Barendregt, W., 2021. Understanding the adoption, use, and effects of ecological footprint calculators among Dutch citizens. *J. Clean. Prod.* 326, 129341. <https://doi.org/10.1016/j.jclepro.2021.129341>.
- Kosanović, S., Miletić, M., Marković, L., 2021. Energy refurbishment of family houses in Serbia in line with the principles of circular economy. *Sustainability* 13 (10). <https://doi.org/10.3390/su13105463>. Article 10.
- Kovacs, I., 2021. Perceptions and attitudes of generation Z consumers towards sustainable clothing: managerial implications based on a summative content analysis. *23(1)*, 257–276. <https://doi.org/10.17512/pjms.2021.23.1.16>.
- Kréziak, D., Prim-Allaz, I., Robinot, E., 2020. The destiny of replaced technological products: the influence of perceived residual value. *Rech. Appl. Market.* 35 (2), 24–47. <https://doi.org/10.1177/2051570719891037>.
- Krippendorff, K., 2019. *Content Analysis: an Introduction to its Methodology*, fourth ed. Sage Publications, Inc. <https://doi.org/10.4135/9781071878781>.
- Kumar, M., Sharma, M., Raut, R.D., Mangla, S.K., Choubey, V.K., 2022. Performance assessment of circular driven sustainable agri-food supply chain towards achieving sustainable consumption and production. *J. Clean. Prod.* 372, 133698. <https://doi.org/10.1016/j.jclepro.2022.133698>.
- Lami, O., Mesías, F.J., Balas, C., Díaz-Caro, C., Escibano, M., Horrillo, A., 2022. Does carbon footprint play a relevant role in food consumer behaviour? A focus on Spanish beef. *Foods* 11 (23). <https://doi.org/10.3390/foods11233899>. Article 23.
- Lanaras-Mamounis, G., Tsalis, T.A., Anagnostopoulou, K., Vatalis, K.I., Nikolaou, I.E., 2022. The development of an index for assessing the circularity level of eco-labels. *Sustain. Prod. Consum.* 33, 586–596. <https://doi.org/10.1016/j.spc.2022.07.019>.
- Lehtokunnas, T., Mattila, M., Näränen, E., Mesiranta, N., 2022. Towards a circular economy in food consumption: food waste reduction practices as ethical work. *J. Consum. Cult.* 22 (1), 227–245. <https://doi.org/10.1177/1469540520926252>.
- Lei, H., Li, L., Yang, W., Bian, Y., Li, C.-Q., 2021. An analytical review on application of life cycle assessment in circular economy for built environment. *J. Build. Eng.* 44, 103374. <https://doi.org/10.1016/j.jobe.2021.103374>.
- Lin, D., Wackernagel, M., Galli, A., Kelly, R., 2015. Ecological footprint: informative and evolving – a response to van den bergh and grazi (2014). *Ecol. Indic.* 58, 464–468. <https://doi.org/10.1016/j.ecolind.2015.05.001>.
- Lizundia, E., Iturrondobetia, M., Akizu-Gardoki, O., Saez-de-Camara, E., Minguez, R., 2023. Product design evolves to implement circular economy principles. In: Cavas-Martínez, F., Marín Granados, M.D., Miralles Buil, R., de-Cózar-Macías, O.D. (Eds.), *Advances in Design Engineering III*. Springer International Publishing, pp. 127–137. https://doi.org/10.1007/978-3-031-20325-1_9.
- Lu, I.R.R., Kwan, E., 2023. An investigation of two remedial measures for retailers to address the impact of disease threat on sustainable consumption: a moderated moderated mediation model. *J. Retailing Consum. Serv.* 72, 103254. <https://doi.org/10.1016/j.jretconser.2023.103254>.
- Lu, T., Halog, A., 2020. Towards better life cycle assessment and circular economy: on recent studies on interrelationships among environmental sustainability, food systems and diet. *Int. J. Sustain. Dev. World Ecol.* 27 (6), 515–523. <https://doi.org/10.1080/13504509.2020.1734984>.
- Luthin, A., Traverso, M., Crawford, R.H., 2023. Assessing the social life cycle impacts of circular economy. *J. Clean. Prod.* 386, 135725. <https://doi.org/10.1016/j.jclepro.2022.135725>.
- Marchesi, M., Tweed, C., 2021. Social innovation for a circular economy in social housing. *Sustain. Cities Soc.* 71, 102925. <https://doi.org/10.1016/j.scs.2021.102925>.
- Matušík, J., Koci, V., 2021. What is a footprint? A conceptual analysis of environmental footprint indicators. *J. Clean. Prod.* 285, 124833. <https://doi.org/10.1016/j.jclepro.2020.124833>.
- Mayoh, J., Onwuegbuzie, A.J., 2015. Toward a conceptualization of mixed methods phenomenological research. *J. Mix. Methods Res.* 9 (1), 91–107. <https://doi.org/10.1177/1558689813505358>.
- Mazzoli, C., Corticelli, R., Dragonetti, L., Ferrante, A., Van Oorschot, J., Ritzen, M., 2022. Assessing and developing circular deep renovation interventions towards decarbonisation: the Italian pilot case of “corte palazzo” in argelato. *Sustainability* 14 (20). <https://doi.org/10.3390/su142013150>. Article 20.
- McCarton, L., O'Hogain, S., Nasr, A., 2022. Special issue: NBS for resilient cities and communities — how understanding the micro components of domestic water consumption can provide multiple water uses to facilitate a transition to a Circular Economy of Water. *Nature-Based Solutions* 2, 100028. <https://doi.org/10.1016/j.nbsj.2022.100028>.
- Mhatre, P., Panchal, R., Singh, A., Bibyan, S., 2021. A systematic literature review on the circular economy initiatives in the European Union. *Sustain. Prod. Consum.* 26, 187–202. <https://doi.org/10.1016/j.spc.2020.09.008>.
- Moraga, G., Huysveld, S., Mathieux, F., Blengini, G.A., Alaerts, L., Van Acker, K., de Meester, S., Dewulf, J., 2019. Circular economy indicators: what do they measure? *Resour. Conserv. Recycl.* 146, 452–461. <https://doi.org/10.1016/j.resconrec.2019.03.045>.
- Motte, J., Nachtergaele, P., Mahmoud, M., Vleeming, H., Thybaut, J.W., Poissonnier, J., Dewulf, J., 2022. Developing circularity, renewability and efficiency indicators for sustainable resource management: propanol production as a showcase. *J. Clean. Prod.* 379, 134843. <https://doi.org/10.1016/j.jclepro.2022.134843>.
- Nadal, A., Pons, O., Cuerva, E., Rieradevall, J., Josa, A., 2018. Rooftop greenhouses in educational centers: a sustainability assessment of urban agriculture in compact cities. *Sci. Total Environ.* 626, 1319–1331. <https://doi.org/10.1016/j.scitotenv.2018.01.191>.
- Nainggolan, D., Pedersen, A.B., Smed, S., Zemo, K.H., Hasler, B., Termansen, M., 2019. Consumers in a circular economy: economic analysis of household waste sorting behaviour. *Ecol. Econ.* 166, 106402. <https://doi.org/10.1016/j.ecolecon.2019.106402>.
- Ng, K.S., Yang, A., 2023. Development of a system model to predict flows and performance of regional waste management planning: a case study of England. *J. Environ. Manag.* 325, 116585. <https://doi.org/10.1016/j.jenvman.2022.116585>.
- Oliveira, M. M. de, Lago, A., Dal' Magro, G.P., 2021. Food loss and waste in the context of the circular economy: a systematic review. *J. Clean. Prod.* 294, 126284. <https://doi.org/10.1016/j.jclepro.2021.126284>.
- Opferkuch, K., Caeiro, S., Salomone, R., Ramos, T.B., 2022. Circular economy disclosure in corporate sustainability reports: the case of European companies in sustainability

- rankings. *Sustain. Prod. Consum.* 32, 436–456. <https://doi.org/10.1016/j.spc.2022.05.003>.
- Opferkuch, K., Walker, A.M., Roos Lindgreen, E., Caeiro, S., Salomone, R., Ramos, T.B., 2023. Towards a framework for corporate disclosure of circular economy: company perspectives and recommendations. *Corp. Soc. Responsib. Environ. Manag.* 30 (5), 2457–2474. <https://doi.org/10.1002/csr.2497>.
- Orellano, A., Valor, C., Chuvieco, E., 2020. The influence of religion on sustainable consumption: a systematic review and future research agenda. *Sustainability* 12 (19). <https://doi.org/10.3390/su12197901>. Article 19.
- Otto, S., Strenger, M., Maier-Nöth, A., Schmid, M., 2021. Food packaging and sustainability – consumer perception vs. correlated scientific facts: a review. *J. Clean. Prod.* 298, 126733. <https://doi.org/10.1016/j.jclepro.2021.126733>.
- Padilla-Rivera, A., do Carmo, B.B.T., Arcese, G., Merveille, N., 2021. Social circular economy indicators: selection through fuzzy delphi method. *Sustain. Prod. Consum.* 26, 101–110. <https://doi.org/10.1016/j.spc.2020.09.015>.
- Paparella, A., Vecchio, R., Cembalo, L., Lombardi, A., 2023. Measuring consumer effort in circular economy initiatives in the food domain: an exploratory analysis. *Heliyon* 9 (2), e13373. <https://doi.org/10.1016/j.heliyon.2023.e13373>.
- Parajuly, N., Wenzel, H., 2017. Potential for circular economy in household WEEE management. *J. Clean. Prod.* 151, 272–285. <https://doi.org/10.1016/j.jclepro.2017.03.045>.
- Peng, Y., Yang, L.E., Scheffran, J., 2021. A life-cycle assessment framework for quantifying the carbon footprint of rural households based on survey data. *MethodsX* 8, 101411. <https://doi.org/10.1016/j.mex.2021.101411>.
- Potting, J., Hekkert, M.P., Worrell, E., Hanemaaijer, A., 2017. Circular economy: measuring innovation in the product chain. *Planbureau Voor de Leefomgeving* 2544. <https://dspace.library.uu.nl/handle/1874/358310>.
- Prakash, G., Ambedkar, K., 2022. Digitalization of manufacturing for implanting value, configuring circularity and achieving sustainability. *Journal of Advances in Management Research* 20 (1), 116–139. <https://doi.org/10.1108/JAMR-01-2022-0010>.
- Principato, L., Mattia, G., Di Leo, A., Pratesi, C.A., 2021. The household wasteful behaviour framework: a systematic review of consumer food waste. *Ind. Mark. Manag.* 93, 641–649. <https://doi.org/10.1016/j.indmarman.2020.07.010>.
- Ramos, T.B., Domingues, A.R., Caeiro, S., Cartaxo, J., Painho, M., Antunes, P., Santos, R., Videira, N., Walker, R.M., Huisingsh, D., 2021. Co-creating a sustainability performance assessment tool for public sector organisations. *J. Clean. Prod.* 320, 128738. <https://doi.org/10.1016/j.jclepro.2021.128738>.
- Rees, W.E., 1992. Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environ. Urbanization* 4 (2), 121–130. <https://doi.org/10.1177/095624789200400212>.
- Richter, C.P., 2010. Automatic dishwashers: efficient machines or less efficient consumer habits? *Int. J. Consum. Stud.* 34 (2), 228–234. <https://doi.org/10.1111/j.1470-6431.2009.00839.x>.
- Rincón-Moreno, J., Ormazábal, M., Álvarez, M.J., Jaca, C., 2021. Advancing circular economy performance indicators and their application in Spanish companies. *J. Clean. Prod.* 279, 123605. <https://doi.org/10.1016/j.jclepro.2020.123605>.
- Rizan, C., Brophy, T., Lillywhite, R., Reed, M., Bhutta, M.F., 2022. Life cycle assessment and life cycle cost of repairing surgical scissors. *Int. J. Life Cycle Assess.* 27 (6), 780–795. <https://doi.org/10.1007/s11367-022-02064-7>.
- Rondoni, A., Grasso, S., 2021. Consumers behaviour towards carbon footprint labels on food: a review of the literature and discussion of industry implications. *J. Clean. Prod.* 301, 127031. <https://doi.org/10.1016/j.jclepro.2021.127031>.
- Sadowski, K., 2021. Implementation of the new European bauhaus principles as a context for teaching sustainable architecture. *Sustainability* 13 (19). <https://doi.org/10.3390/su131910715>. Article 19.
- Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., Kendall, A., 2019. A taxonomy of circular economy indicators. *J. Clean. Prod.* 207, 542–559. <https://doi.org/10.1016/j.jclepro.2018.10.014>.
- Sala, S., Castellani, V., 2019. The consumer footprint: monitoring sustainable development goal 12 with process-based life cycle assessment. *J. Clean. Prod.* 240, 118050. <https://doi.org/10.1016/j.jclepro.2019.118050>.
- Salas, S., de Laurentis, V., Vignola, G., Marelli, L., Mengual, E., 2022. The Consumer Footprint Calculator. European Commission. https://eplca.jrc.ec.europa.eu/uploads/JRC129382_TR_Consumer_footprint_calculator_ONLINE.pdf.
- Saleem, S.B., Ali, Y., 2019. Effect of lifestyle changes and consumption patterns on environmental impact: a comparison study of Pakistan and China. *Chinese Journal of Population Resources and Environment* 17 (2), 113–122. <https://doi.org/10.1080/10042857.2019.1574454>.
- Sánchez-Ortiz, J., Rodríguez-Cornejo, V., Del Río-Sánchez, R., García-Valderrama, T., 2020. Indicators to measure efficiency in circular economies. *Sustainability* 12 (11). <https://doi.org/10.3390/su12114483>. Article 11.
- Sassanelli, C., Rosa, P., Rocca, R., Terzi, S., 2019. Circular economy performance assessment methods: a systematic literature review. *J. Clean. Prod.* 229, 440–453. <https://doi.org/10.1016/j.jclepro.2019.05.019>.
- Saunders, M., Lewis, P., Thornhill, A., 2019. *Research Methods for Business Students*, eighth ed. Pearson Education Limited <https://www.pearson.com/nl/en/NL/higher-education/subject-catalogue/business-and-management/Research-methods-for-business-students-8e-saunders.html>.
- Scarpellini, S., Marín-Vinuesa, L.M., Aranda-Usón, A., Portillo-Tarragona, P., 2020. Dynamic capabilities and environmental accounting for the circular economy in businesses. *Sustainability Accounting, Management and Policy Journal* 11 (7), 1129–1158. <https://doi.org/10.1108/SAMPJ-04-2019-0150>.
- Scheerder, J., Vos, S., Taks, M., 2011. Expenditures on sport apparel: creating consumer profiles through interval regression modelling. *Eur. Sport Manag. Q.* 11 (3), 251–274. <https://doi.org/10.1080/16184742.2011.577931>.
- Severis, R.M., Simioni, F.J., Moreira, J.M.M.A.P., Alvarenga, R.A.F., 2019. Sustainable consumption in mobility from a life cycle assessment perspective. *J. Clean. Prod.* 234, 579–587. <https://doi.org/10.1016/j.jclepro.2019.06.203>.
- Shashi, Centobelli, P., Cerchione, R., Jhamb, D., 2023. Double-edged circularity: comparative assessment of circular and non-circular consumers. *Ecol. Econ.* 212, 107931. <https://doi.org/10.1016/j.ecolecon.2023.107931>.
- Shevchenko, T., Saidani, M., Ranjbari, M., Kronenberg, J., Danko, Y., Laitala, K., 2023. Consumer behavior in the circular economy: developing a product-centric framework. *J. Clean. Prod.* 384, 135568. <https://doi.org/10.1016/j.jclepro.2022.135568>.
- Shi, Y., Ren, X., Guo, K., Zhou, Y., Wang, J., 2020. Research on the economic development pattern of Chinese counties based on electricity consumption. *Energy Policy* 147, 111881. <https://doi.org/10.1016/j.enpol.2020.111881>.
- Shittu, O.S., Williams, I.D., Shaw, P., Montiero, N., Creffield, R., 2021. Demonstrating EEE recovery for reuse in a distinct urban mine: a case study. *Detritus* 15, 78. <https://doi.org/10.31025/2611-4135/2021.15091>.
- Sousa, P.M., Moreira, M.J., de Moura, A.P., Lima, R.C., Cunha, L.M., 2021. Consumer perception of the circular economy concept applied to the food domain: an exploratory approach. *Sustainability* 13 (20). <https://doi.org/10.3390/su132011340>. Article 20.
- Spence, C., 2021. Explaining seasonal patterns of food consumption. *Int. J. Gastron. Food Sci.* 24, 100332. <https://doi.org/10.1016/j.ijgfs.2021.100332>.
- Stamming, R., Bues, A., Alfieri, F., Cordella, M., 2020. Durability of washing machines under real life conditions: definition and application of a testing procedure. *J. Clean. Prod.* 261, 121222. <https://doi.org/10.1016/j.jclepro.2020.121222>.
- Sutcliffe, M., Hooper, P., Howell, R., 2008. Can eco-footprinting analysis be used successfully to encourage more sustainable behaviour at the household level? *Sustain. Dev.* 16 (1), 1–16. <https://doi.org/10.1002/sd.327>.
- Syrovátka, M., 2020. On sustainability interpretations of the Ecological Footprint. *Ecol. Econ.* 169, 106543. <https://doi.org/10.1016/j.ecolecon.2019.106543>.
- Terzioğlu, N., 2021. Repair motivation and barriers model: investigating user perspectives related to product repair towards a circular economy. *J. Clean. Prod.* 289, 125644. <https://doi.org/10.1016/j.jclepro.2020.125644>.
- Tolppanen, S., Kang, J., 2021. The effect of values on carbon footprint and attitudes towards pro-environmental behavior. *J. Clean. Prod.* 282, 124524. <https://doi.org/10.1016/j.jclepro.2020.124524>.
- Trollman, H., Colwill, J., Jagtap, S., 2021. A circularity indicator tool for measuring the ecological embeddedness of manufacturing. *Sustainability* 13 (16). <https://doi.org/10.3390/su13168773>. Article 16.
- Valderrama-Zurián, J.-C., Aguilar-Moya, R., Melero-Fuentes, D., Alexandre-Benavent, R., 2015. A systematic analysis of duplicate records in Scopus. *Journal of Informetrics* 9 (3), 570–576. <https://doi.org/10.1016/j.joi.2015.05.002>.
- Valls-Val, K., Ibáñez-Forés, V., Bovea, M.D., 2023. Tools for assessing qualitatively the level of circularity of organisations: applicability to different sectors. *Sustain. Prod. Consum.* 36, 513–525. <https://doi.org/10.1016/j.spc.2023.01.023>.
- van Bueren, B.J.A., Argus, K., Iyer-Raniga, U., Leenders, M.A.M., 2023. The circular economy operating and stakeholder model “eco-5HM” to avoid circular fallacies that prevent sustainability. *J. Clean. Prod.* 391, 136096. <https://doi.org/10.1016/j.jclepro.2023.136096>.
- van Loon, M.P., Vonk, W.J., Hijbeek, R., van Ittersum, M.K., ten Berge, H.F.M., 2023. Circularity indicators and their relation with nutrient use efficiency in agriculture and food systems. *Agric. Syst.* 207, 103610. <https://doi.org/10.1016/j.agry.2023.103610>.
- van Stijn, A., Malabi Eberhardt, L.C., Wouterszoon Jansen, B., Meijer, A., 2021. A circular economy life cycle assessment (CE-LCA) model for building components. *Resour. Conserv. Recycl.* 174, 105683. <https://doi.org/10.1016/j.resconrec.2021.105683>.
- van Weelden, E., Mugge, R., Bakker, C., 2016. Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market. *J. Clean. Prod.* 113, 743–754. <https://doi.org/10.1016/j.jclepro.2015.11.065>.
- Vanham, D., Leip, A., Galli, A., Kastner, T., Bruckner, M., Uwizeye, A., van Dijk, K., Erzin, E., Dalin, C., Brandão, M., Bastianoni, S., Fang, K., Leach, A., Chapagain, A., Van der Velde, M., Sala, S., Pant, R., Mancini, L., Monforti-Ferrario, F., et al., 2019. Environmental footprint family to address local to planetary sustainability and deliver on the SDGs. *Sci. Total Environ.* 693, 133642. <https://doi.org/10.1016/j.scitotenv.2019.133642>.
- Varotto, A., Spagnoli, A., 2017. Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *J. Environ. Psychol.* 51, 168–188. <https://doi.org/10.1016/j.jenvp.2017.03.011>.
- Voorberg, W.H., Bekkers, V.J.J.M., Tummers, L.G., 2015. A Systematic Review of Co-Creation and Co-Production: embarking on the social innovation journey. *Public Manag. Rev.* 17 (9), 1333–1357. <https://doi.org/10.1080/14719037.2014.930505>.
- Wang, W., Wei, J., Wu, D., 2022. The optimal strategy of China's plastic drinking straws ban based on consumer heterogeneity and retailer competition. *Sustainability* 14 (2). <https://doi.org/10.3390/su14020745>. Article 2.
- Wu, L., Huang, K., Ridoutt, B.G., Yu, Y., Chen, Y., 2021. A planetary boundary-based environmental footprint family: from impacts to boundaries. *Sci. Total Environ.* 785, 147383. <https://doi.org/10.1016/j.scitotenv.2021.147383>.
- Xiao, Y., Watson, M., 2019. Guidance on conducting a systematic literature review. *J. Plann. Educ. Res.* 39 (1), 93–112. <https://doi.org/10.1177/0739456X17723971>.
- Xie, Y., Li, X., Hu, X., Hu, X., 2020. The landscape of academic articles in environmental footprint family research: a bibliometric analysis during 1996–2018. *Ecol. Indic.* 118, 106733. <https://doi.org/10.1016/j.ecolind.2020.106733>.

- Yadav, G., Mangla, S.K., Bhattacharya, A., Luthra, S., 2020. Exploring indicators of circular economy adoption framework through a hybrid decision support approach. *J. Clean. Prod.* 277, 124186. <https://doi.org/10.1016/j.jclepro.2020.124186>.
- Yamamoto, H., Murakami, S., 2021. Product obsolescence and its relationship with product lifetime: an empirical case study of consumer appliances in Japan. *Resour. Conserv. Recycl.* 174, 105798. <https://doi.org/10.1016/j.resconrec.2021.105798>.
- Yazan, D.M., van, C.G., Fraccascia, L., 2022. Decision-support tools for smart transition to circular economy. In: Bondarouk, T., Olivas-Luján, M.R. (Eds.), *Smart Industry – Better Management*, vol. 28. Emerald Publishing Limited, pp. 151–169. <https://doi.org/10.1108/S1877-636120220000028010>.
- Zhang, Q., Dhir, A., Kaur, P., 2022. Circular economy and the food sector: a systematic literature review. *Sustain. Prod. Consum.* 32, 655–668. <https://doi.org/10.1016/j.spc.2022.05.010>.
- Zhao, H., Zhao, H., Guo, S., 2017. Evaluating the comprehensive benefit of eco-industrial parks by employing multi-criteria decision making approach for circular economy. *J. Clean. Prod.* 142, 2262–2276. <https://doi.org/10.1016/j.jclepro.2016.11.041>.