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Priority Products for Sustainability Information and Recommendation Software: Insights in the Context of the EU's Action Plan Circular Economy

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Abstract: The diffusion of sustainable products is a global objective, particularly reflected by the UN's vision of ensuring sustainable development. Mobilising the potential of product information's digitalization is an important topic in this context, particularly in the EU's circular economy plan CEAP. Cross-sector analyses on the need for digital sustainability recommendation systems and related product-specific requirements do not yet exist. **Questions:** This article aims to deepen the insight of information requirements and recommendation software to facilitate sustainability-oriented product decisions based on three questions: (1) to identify products specifically requiring four types of sustainability information, (2) to unveil needs for software that recommends sustainable products, and (3) to specify the information it shall provide. **Method:** As part of the ConCirMy recommendation system project, we conducted an exploratory survey among 134 sustainability experts from 5 circular and bio-economy networks, mainly from Germany. The results show priority products regarding four sustainability information needs and recommendation software, making specific relations between European regulation and stakeholders' interests visible. In addition, ten factors influencing these needs and facilitating further product-related sustainability classifications were unveiled. **Conclusions:** Our findings reflect the significance of CEAP's priority products regarding the need for sustainability information and provide conclusions for four target groups.

Keywords: circular economy; bio-based; biobased; social sustainability; recommendation systems; recycling; bioplastic; bioeconomy

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1. Introduction

1.1. Sustainable Development and Information Technology

Sustainable development, specified by the 17 Sustainable Development Goals of the United Nations (UN SDGs), has become one of the 21st century's key objectives [1,2], and implementing the circular economy (CE) is a global concern [3]. Four figures show the need for the CE illustratively. Resource extraction and processing are the reasons for about 50% of global greenhouse gas (GHG) emissions and more than 90% of biodiversity loss and water pollution. Consumption of materials such as biomass, fossil fuels, metals, and minerals is expected to increase by 100% over the next 40 years and annual waste generation by 70% by 2050. Therefore, the UN seeks to ensure sustainable consumption and production patterns [4]. Likewise, Europe aims to switch to sustainable, long-lasting products and slow down the use and flow of resources through the economy [5]. Information technology plays an essential role in this context, while digitalization's potential is not yet exploited. Therefore, mobilising the potential of product information's digitalization, including solutions such as digital passports, tagging, and watermarks [5,6], is an important goal of the European Union (EU) and, similarly, of many additional countries outside Europe. A summary of the considerations of digitalization in the EU's New Circular Economy Action

Plan of March 2020 is shown in Section 1.2. Given this need for action, we identified a gap in the literature on sustainability and information systems: studies that focus on software that recommends products based on sustainability characteristics.

This article is dedicated to the various needs for sustainability information and recommendation software to support the circular economy, the bioeconomy, socially sustainable products, and products addressing the SDGs with a broader scope. Based on a survey, specific needs and their causes are unveiled. Besides the article's contribution to overcoming the current research gap, it aims to motivate practitioners to make the relevant information available, if necessary, supported by research and to encourage software engineers to develop corresponding recommender software and platforms.

1.2. Literature Review and Research Gap

1.2.1. Sustainability Perspectives

Our article refers to products with four specific characteristics: 'sustainable' (in general), 'circular', 'socially sustainable', and 'bio-based', whose perspectives and key aspects are clarified in this section. According to the UN, sustainability refers to people, the planet, and prosperity [1]. Likewise, ref. [7] defines sustainability as the 'goal of sustainable development which encompasses environmental, social and economic aspects, in which the needs of the present are met without compromising the ability of future generations to meet their needs'. In particular, this includes ending poverty and other deprivations, reducing inequality, and realizing economic growth combined with tackling climate change and working to preserve oceans and forests internationally [1,2]. Sustainability can be described by three pillars on environmental, social, and economic aspects. See, e.g., [8]. In this context, ref. [9] provide an index with indicators on all three dimensions. However, weights are missing, and a common score would be useful. In addition, the considerations refer to company levels, not specific products. Usually, research in this area (also carried out by [10]) presents a holistic approach for evaluating bio-based products, considering the three sustainability pillars as in the European standard EN 16751. Ref. [11] shows the industry's condensed sustainability criteria and indicators for biobased products. Elements of its environmental pillar include, e.g., criteria and indicators regarding climate protection and air quality, water, soil, biodiversity, energy, and material resources; and waste.

Regarding social sustainability, ref. [10] present a comprehensive overview of 14 indicators: fair salary and competition; forced and child labour; food security; health and safety of workers, local communities and users; feedback mechanisms; land use rights; economic development; local employment; transparency; and equal opportunities. Other work also includes, e.g., [12] with their social life cycle approach, ref. [13] regarding end-of-life strategies, and [14], which nonetheless do not provide product-level but sector-related information. Like [11], this article refers to a product as socially sustainable if the core working standards of the International Labour Organization (ILO) are met in the product's value chain. These core working standards include elimination of forced labour; elimination of child labour; prohibition against discrimination at the job site, and the principle of equal pay for the same work, freedom of association, free collective bargaining, and the right to collective agreements (see [15] for details). On this basis, ref. [11] provides three sets of criteria and indicators on employee rights, working conditions, and living conditions. Elements of its environmental pillar include, e.g., criteria and indicators regarding climate protection and air quality, water, soil, biodiversity, energy and material resources, and waste. Concerning economic sustainability, the set of criteria in [11] refers to fair business practices while [10] also integrate the minimization of life cycle costs associated with the entire value chain. Various contributions analyse sustainability in specific industries or give guidance on particular sectors. See, for example, [16] on electronic products, [17,18] on textiles, [19,20] on cars, and [21] on textiles and vehicles, supplemented by a rich source base of contributions on electric vehicles' batteries: see, e.g., [22].

From a different perspective, the circular economy is a powerful sustainability concept influencing public policies. In this context, the Ellen MacArthur Foundation, a close

collaborator of the World Economic Forum, formulated in 2015 the now common CE definition as '(an economy) that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times' [23,24]. The CE represents a production and consumption model in which materials and products are shared, leased, reused, repaired, refurbished, and recycled for as long as possible, and their life cycle is extended [25]. Various SDGs are addressed by the CE concept, especially SDG 11 (sustainable cities and communities) and SDG 12 (responsible consumption and production), closely linked with SDG 6 (clean water), 8 (decent work), and 15 (life on land) [3]. On this basis, the description 'circular' product refers to a product for which one or more of the above-mentioned activities are practiced (as explained/defined in [25]). A taxonomy of 55 circular economy indicators, including 20 micro-indicators, is provided by [26]. Specific indicators on circular products are, for example, provided by the MCI [27] and Madaster [28] (on buildings). Various indicators are also supplied by [10].

Another important sustainability concept is the bioeconomy, defined as 'an emerging paradigm under which the creation, development, and revitalization of economic systems based on a sustainable use of renewable biological resources in a balanced way is rapidly spreading globally' [29]. However, the bioeconomy is not sustainable *per se* [30]. This is mirrored by international research in various domains to maximize its contribution to sustainable development. In particular, the bioeconomy aims to contribute to the above-mentioned SDGs 6, 8, 11, and 12 and also to SDGs 2 (zero hunger), 3 (good health and well-being), 7 (affordable and clean energy), and 9 (industry, innovation, and infrastructure), see [31]. In this context, bio-based products (products of the bioeconomy) are defined as those made, wholly or in part, with resources of biological origin and can substitute products traditionally made with fossil resources [32]. CEN [11] extends this definition as follows: 'The term "bio-based" means 'derived from biomass'. Bio-based products (bottles, insulation materials, wood and wood products, paper, solvents, chemical intermediates, composite materials, et cetera) are products which are wholly or partly derived from biomass'. The source adds: 'It is essential to characterize the amount of biomass contained in the product by for instance, its bio-based content or bio-based carbon content'. Sustainability indicators of bio-based products are, for example, considered by [10,11]. In this context, ref. [10] provides a case study of a hypothetical bio-based rigid packaging.

The EU Strategy for Plastics in the Circular Economy (COM(2018) 28 final) highlight the importance of plastics in the CE specifically. In addition, the EU's New Circular Economy Action Plan (CEAP) makes specific references to bio-based plastics and biodegradable and compostable plastics. In the bioeconomy, plastics also play an important role with a value-added of €3.48 billion in the EU, together with rubber (data EU27, 2019) [33]. According to market data from European Bioplastics and nova-Institute, global production capacities for bioplastics will increase from around 2417 million tons in 2020 to approximately 7593 million tons in 2026 [34]. Its most important segments (starting with the biggest) are packaging, consumer goods, textiles, agriculture & horticulture, automotive & transport, coatings & adhesives, building & construction, and electrics & electronics; see [35]. Figure 1 illustrates how the four main sustainability perspectives and their key aspects are linked in our research.

1.2.2. Priority Products for Sustainability Goals and Related Information Needs

The circular economy provides a role model for specifying priority products to implement SDG-oriented practices. As a significant starting measure, the European Commission defined six priority products and sectors to implement sustainable circular economy principles in 2014 (cf. [36], e.g., p. 23): packaging, food, electronic and electrical equipment, transport, including the automotive industry, furniture, and, last but not least, buildings and construction. Six years later, the EU's New Circular Economy Action Plan (CEAP) specified seven key areas that proved to be essential for achieving the CE: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction industry and

buildings, and, food, water, and nutrients, see [37]. Likewise, Germany bundles activities in its Standardization Roadmap Circular Economy, mirroring CEAP priorities.

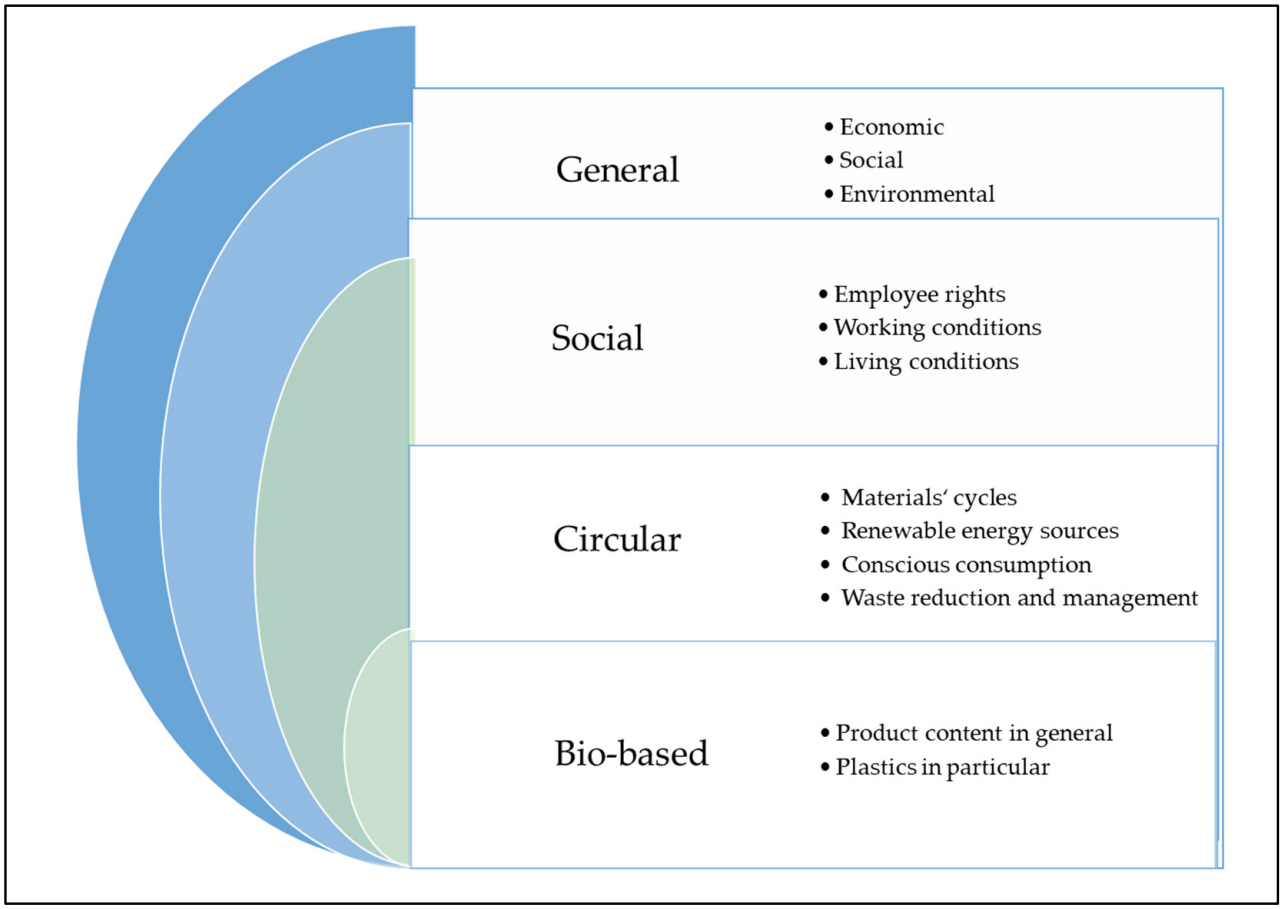

Figure 1. Sustainability perspectives and their key aspects considered in our research. Source: Own elaboration based on texts [9–11], on general, social, circular, and bio-based sustainability information.

A further question is how stakeholders' information needs and interests reflect the CEAP's political goals and which sustainability information needs and interests they have beyond the priorities of this strategic EU plan. The importance of product information on the perception of sustainable products is shown by [38–40], and the absence of details on sustainability may pose a barrier to these products' adoption. In addition, ref. [41] highlights that the acceptance of information disclosure schemes depends on their credibility and how the information is deployed. For example, the EU Ecolabel has strongly promoted the uptake of some product categories [42]. Sustainable public procurement has additional information needs regarding environmental and socially-friendly products, see e.g., [43]. Likewise, businesses have many incentives to behave sustainably, e.g., for marketing reasons, and are often even forced to do so by law, such as the German Lieferkettengesetz (Supply Chain Act). Last but not least, as one of the key stakeholders of European sustainable development, the European Commission not only specified priority products but also identified the value of information as a critical accelerator for the circular economy in its territory. On this basis, it unveiled its plan to introduce a 'digital product passport' early in 2023 containing information about the composition of goods on the European market to help boost their chances of being reused and recycled. The goal is to identify the most important information about the makeup of each product so that users across the supply chain can reuse it or treat it correctly at waste management facilities [5].

The individual interest in sustainability information varies. Reasons for this include, e.g., different local and product-specific framework conditions, company priorities, and

implementations of Porter's generic strategies, particularly regarding differentiation. Another example is public procurement, where various laws to consider social sustainability criteria and ILO core working standards in tenders exist; see, e.g., [43]. Consumers provide a third example with their different approaches to prioritize sustainability characteristics and product prices in their consumption decisions [38–40].

1.2.3. Digital Sustainability Information and Recommendation Software

As described in Section 1, pursuing the SDGs needs to be linked with mobilizing digitalization's potential for product information, particularly in the EU's CE strategy; see Box 1.

Box 1. Consideration of digitalization in the EU's New Circular Economy Action Plan (highlights made by the authors).

> 'Building on the single market and the **potential of digital technologies**, the circular economy can strengthen the EU's industrial base'. (p. 4)
> 'Innovative models based on a closer relationship with customers, mass customisation, (…) and powered by **digital technologies**, such as the internet of things, big data, blockchain and artificial intelligence, will not only accelerate circularity but also the dematerialisation of our economy and make Europe less dependent on primary materials.' (p. 4)
> 'A whole new range of sustainable services, product-as-service models and **digital solutions** will bring about a better quality of life, innovative jobs and upgraded knowledge and skills.' (p. 5)
> 'The Commission will consider establishing sustainability principles and other appropriate ways to regulate the following aspects: (…) mobilising the **potential of digitalisation** of product information, including solutions such as digital passports, tagging and watermarks'. (p. 7)

Recommender systems, also known as recommendation systems, provide many opportunities in this context. According to [44], they belong to the most promising technical opportunities to handle the current information overload and support users in their decision-making processes. In recent years, they have gained ground and their use has been extended to various application domains [45].

Recommender systems are software systems that provide 'a single target user within a single context with personalized recommendations of items such as goods, services or information to guide the target user to find (the) most relevant items using ratings on a single relevance criterion (i.e., overall) and where both users and items are in a single domain' [46]. On this basis, they represent 'a specific type of advice-giving or decision support system that guides users in a personalized way to interesting or useful objects in a large space of possible options' [47]. Specifically, their task is 'to turn data on users and their preferences into predictions of users' possible future likes and interests' [48]. They are utilized where users come across many alternatives and information that must be discovered, processed, and used [45]. As highlighted by Vinson et al. [49], they are most often artificial intelligence (AI) systems that recommend 'various products, services, articles, or social connections to a user based on the user's profile.' As a specific variant [50] showed the feasibility of mass customization recommender systems. As part of the ConCirMy project (see Sections 1.2.4 and 2.2 for details), this research explicitly focuses on recommendation systems that also apply AI and mass customization where necessary.

1.2.4. Research Gap, Questions, and Hypothesis

A Web of Science analysis revealed a research gap regarding recommendation systems for sustainable products and the Circular Economy in various disciplines, particularly missing systematic, cross-sectoral socio-economic analyses. Besides the work of [45] focusing on industrial symbioses, the Web of Science provides only two more hits for the search combination 'recommender system' and 'circular economy', which, however, refer again to industrial symbioses [51] and waste [52] with a technical focus, not explicitly on specific product groups. In the same way, the product-related gap was visible in the ten hits for

the search combination 'recommender system' and 'sustain.' The search combination with 'bio-based' and 'biobased' led to zero hits.

Nevertheless, practical, product-specific examples of sustainability-oriented recommender systems exist. Digimind's CirNet is an already existing technical solution. This AI-based design platform explicitly serves the packaging industry to make packaging ready to meet the demands for greater sustainability without sacrificing performance through lightweighting, lifecycle analysis, and material comparisons. The AI component facilitates its advanced recommendations. Other platforms that mainly provide standardized information are, particularly addressing public procurement, the German Kompass Nachhaltigkeit [53] and WECOBIS [54]. Information platforms and software for sustainable products, in general, are considered by Zeng et al. [55] under the umbrella of 'green information systems'. Several sustainability software solutions—in particular, databases— exist already, such as ecoinvent [56], Global LCA [57], and GaBi ('Ganzheitliche Bilanzierung') [58]. Another example is the circular economy software platform Madaster [59], which provides the opportunity to create a material passport for buildings.

Various digitalization and data projects for the CE with a broad technical scope have been funded by the German measure ReziProK ('Resource-efficient circular economy—Innovative product cycles). Examples are the projects ConCirMy (Configurator for the Circular Economy), DIBICHAIN (digital mapping of circular systems by blockchain), Di-Link (digital solutions for industrial plastic cycles), DiTex (on digital technologies as enablers of a resource-efficient circular B2B textile economy, also including the development of digital product passports), EffizientNutzen (data-based business models for cascade use and extended product use of electronic products), PERMA (Platform for efficient resource utilisation in the furniture and furnishing industry), and EIBA; see [60]. EIBA stands for sensory acquisition, automated identification, and evaluation of old parts based on product data and information about previous deliveries. The project works with digitalization and AI to support the identification of products and to equip products with appropriate parts with suitable characteristics [61]. In contrast to EIBA, this article refers to customized product recommendations based on the users' sustainability preferences, not only to technical product matching. The products' sustainability characteristics are at the centre.

Besides the ReziProK projects, which all started in 2019, a consortium led by acatech announced the project Battery Pass in April 2022 [62]. Other examples of sustainability information systems and platforms with different sustainability foci include the Biokunststofftool [63], the former European OpenBio project's database with bio-based products [64], and CE trading platforms such as CirPlus. There are also activities regarding sustainability and digitalization on the international standardization level.

An example is a current standardization project on a product circularity data sheet at the international standardization organization ISO. Various additional practical measures have been conducted on a global level. However, cross-sector analyses, which allow for systematic sector comparisons on the need for recommender systems, have been missing so far. Specifically, scientific publications on product-specific requirements for sustainability recommender software do not yet exist, reflecting the newness of these topics. This article aims to close this gap as part of the ReziProK project ConCirMy, which develops an AI-based sustainability recommendation system capable of mass customization with car tyres as a first application. It also initiated the development of an open data exchange format for sustainability data. On this basis, the analysis shall show additional application areas for such software. Three questions were raised based on the gaps shown above: For circular economy and bioeconomy experts, which products require sustainability information (Q1) and related recommendation software (Q2)? Which specific types of sustainability information are required (Q3)? As a general hypothesis related to the three answers, the sustainability perspectives of the respondents are expected to be in line with CEAP's seven key areas, presented in Section 2.2.

The answers shall stimulate the development of product life cycle-oriented recommendation software and, consequently, facilitate sustainability-oriented decisions in the various

product life cycle stages with the help of such software. They shall also support future work with digital product passports and, generally speaking, promote the realization of the SDGs. The material and methods to answer the research questions are described in Section 2. Section 3 presents the survey with experts. This broader contribution is discussed in Section 4, followed by conclusions in Section 5.

2. Materials and Methods

2.1. Application of an Exploratory Survey Research Method

This article aims to unveil sustainability information needs and to deepen the research on software for sustainability recommendations to support the circular economy, the bioeconomy, socially sustainable products, and products addressing the SDGs in general. Specifically, it aims to deepen the insight into priority products for sustainability information and the characteristics of the specific information needs. Exploratory research methods were chosen for this purpose. See [65,66] regarding their application in social science.

To consider the two physical product characteristics 'circular' and 'bio-based' appropriately, the views of experts from the circular and bioeconomy should be analysed specifically. Initially, a series of expert interviews was planned to provide the information. An in-depth analysis showed however that a limited number of interviews would not sufficiently answer the research questions. Therefore, an online survey was organized to reach a bigger target group. Via this survey, experts were asked explicitly about the need for sustainability information and software support for sustainable product selection decisions, which would allow us to understand if the initial hypothesis on the similarity to CEAP was correct.

To address Q1, the survey had a targeted question to identify the most important products for which specific sustainability information is needed from experts' point of view. Four aspects were covered by separate sub-questions: sustainability in general, circular economy aspects, social sustainability, and issues related to using renewable materials for bio-based products. For each sub-question, specific classes of information needs were created, comprising at least two responses with the same meaning. If a product class was created for the answers to one part of this fourfold question and was also visible in single answers on other sub-questions, the figure was modified accordingly to provide a broader view of this product group's information needs. An example provides the class 'toys'. The answers not only show a need for circular economy-related information on toys but also included single mentions of this topic in the responses to all the other sub-questions on sustainability-related information needs. Another observation was that participants often entered several products in a single-entry box. The evaluation took this into account by counting all products separately. To address question Q2, the participants were asked for which products it would be helpful to have recommendation software with suggestions on product variants. They could specify up to three products.

To specify the information needs described by research question Q3, the survey provided nine options for determining sustainability information that the software should provide for developing, producing, or purchasing the selected products. Two important answer options were 'Other' and 'Depending on the types of products, different types of sustainability information should be given.' On this basis, various helpful inputs were collected, leading to two tables in Section 3. Details on the survey's content are shown in Table 1 and Appendix A.

The survey was available in German and English and intended to receive the answers of at least 100 experts.

2.2. Survey Participants

The survey was distributed via five expert networks of the ConCirMy project and four broader expert networks in the circular and bio-economy. Specifically, it was disseminated via the networks of ConCirMy and ReziProK, among experts of Germany's Standardisation

Roadmap Circular Economy, DECHEMA's bioeconomy network, and EuBio-Net (see Figure 2).

Table 1. Content of the survey.

Introduction
• Occupation of the participant • Familiarity with the circular economy and the bioeconomy • Product segments for which sustainability information is required
Software to support sustainable product selection decisions
• Products with the attractiveness of a software system that suggests products or components based on the sustainability preferences of the users • Sustainability information that the software system should provide • Products with a need for software that proposes bio-based materials, components, or products • Market segments of bioplastics in need of software systems that suggest bio-based materials, components, or products • Further proposals for software development to support the development, production, purchase, and use of sustainable products
Additional information on the participants
• Type of organization, possible SME status, industry affiliation • Country of residence

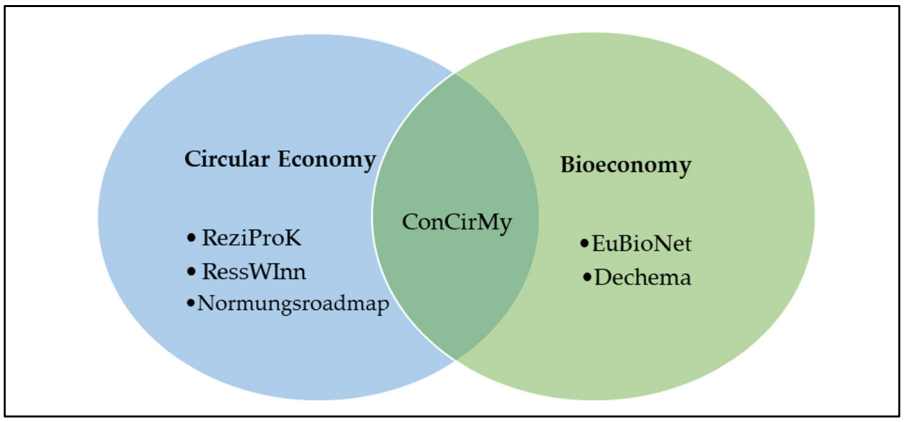

Figure 2. Groups of experts involved in the survey: research projects' samples and their main topics.

1. Experts of ConCirMy core expert network: As described in Section 1.2.4, ConCirMy is a circular economy research project funded by the German Federal Ministry of Education and Research. Its partners established an extensive network of circular economy experts, including, e.g., circular economy lecturers and speakers at national Circular economy research workshops. ConCirMy's network also includes bioeconomy researchers and those with circular-bioeconomic expertise, e.g., expressed by EU-level research.
2. ReziProK experts: With the research concept 'Resource-efficient circular economy' (ReziProK), the German ministry BMBF supports the transformation of the German economy from a linear economy to a resource-efficient circular economy. A total of €150 million was dedicated to be used to fund new technologies and services, design concepts, and business models for the circular economy. The first funding measure, "Resource-efficient circular economy—innovative product cycles (ReziProK)," shall enable new business models, design concepts or digital technologies for closed product cycles. See [67] for details. The project RessWInn (Networking and transfer project for the BMBF funding measure "Resource-efficient recycling management—innovative product cycles [67]) is entrusted with supportive networking and transfer measures

for these 25 ReziProK projects. On this basis, it helped to distribute the survey among ReziProK scientists.

3. Experts of Germany's Standardization Roadmap Circular Economy of DIN, DKE, and VDI. These persons passed an initial screening process at DIN and are regarded as recognized circular economy representatives in Germany.
4. DECHEMA bioeconomy network: DECHEMA is Germany's expert network for chemical engineering and biotechnology. As a non-profit professional society, it represents these fields in science, industry, politics, and the general public. DECHEMA promotes scientific and technical exchange among experts from different disciplines and consolidates the know-how of over 5800 individual and sustaining members, including a sub-group in the bioeconomy.
5. EuBioNet: The European Bioeconomy Network (EuBioNet) is a proactive alliance of 108 EU-funded projects and initiatives dealing with bioeconomy promotion, communication, and support. The main goal is to maximise the efforts, increasing knowledge sharing, networking, mutual learning, and coordination of joint activities and events.

The survey was conducted from 30 March to 7 May 2022. Finally, 134 experts participated. Data minimization was strictly practiced during the study. No personal data, e-mail addresses, etc., were collected. However, participants could send individual messages outside the survey indicating an interest in the results. The survey administration received numerous e-mails communicating this interest. Most senders have Ph.D. degrees, are professors, or are Ph.D. candidates. On this basis, impressive additional information on the survey participants could be gained. Table 2 shows the participant's occupation, primarily in research and development. Another significant group is entrusted with management tasks. The table also provides information on the type of organization. In this regard, it shows data collected at the end of the survey with a lower response rate. The table shows a balanced composition of research organisations and company representatives, particularly in manufacturing, construction, and trade. In addition, they represent various other types of enterprises such as automotive suppliers, consulting and chemicals companies, services providers, mechanical engineering companies, and companies from the recycling and packaging industry.

Table 2. Background information on the participants.

Occupation		Type of Organization	
R&D	45%	University or research institution	41%
Other	24%	Company	40% *
Management	19%	NGO	6%
Marketing	4%	Gov., public authority/agency	6%
No answer	4%	Other	5%
Production	2%	Industry association	1%
Admin./accounting	1%		
Distribution	1%		
	n = 134		n = 80 **

* 17.5% SME, 17.5% larger companies, 5% no information on firm size, ** lower response rate because the question was asked at the end of the survey.

Seventy-eight participants noted their place of residence, including 74 people from Germany, two from Spain, one from Italy, and one from Bolivia. Therefore, the study mainly represents German experts' views. Initially, they were asked to indicate their familiarity with the circular economy and bioeconomy. In each case, five response categories were provided. The vast majority of participants is very familiar with the circular economy. Regarding the bioeconomy, there is more variance, while medium familiarity with this topic dominates.

3. Results

3.1. Products Characterised by Specific Needs for Sustainability Information

Information was collected on products linked with general sustainability information needs and information needs on circular economy, social sustainability, and bio-based characteristics.

In response to the open question about which products sustainability information is needed in general, the participants referred to a wide range of products. The answers were ordered and classified, as shown in Figure 3's first column. As a result, 22 product classes with a need for general sustainability information were developed. As shown in Figure 3, the analysis of the additional answers led to five more categories. The most frequently mentioned products include food products, textiles & clothing, and electronic & electrical products, followed by packaging and building products. In addition, the second largest category in the figure, 'miscellaneous', refers to various other products presented in Table 3. Multiple Table 3 entries refer to energy topics, reflecting environmental concerns and current tensions in global energy markets. Other products include, for example, paints and varnishes, cleaning products, smartphones, and tyres.

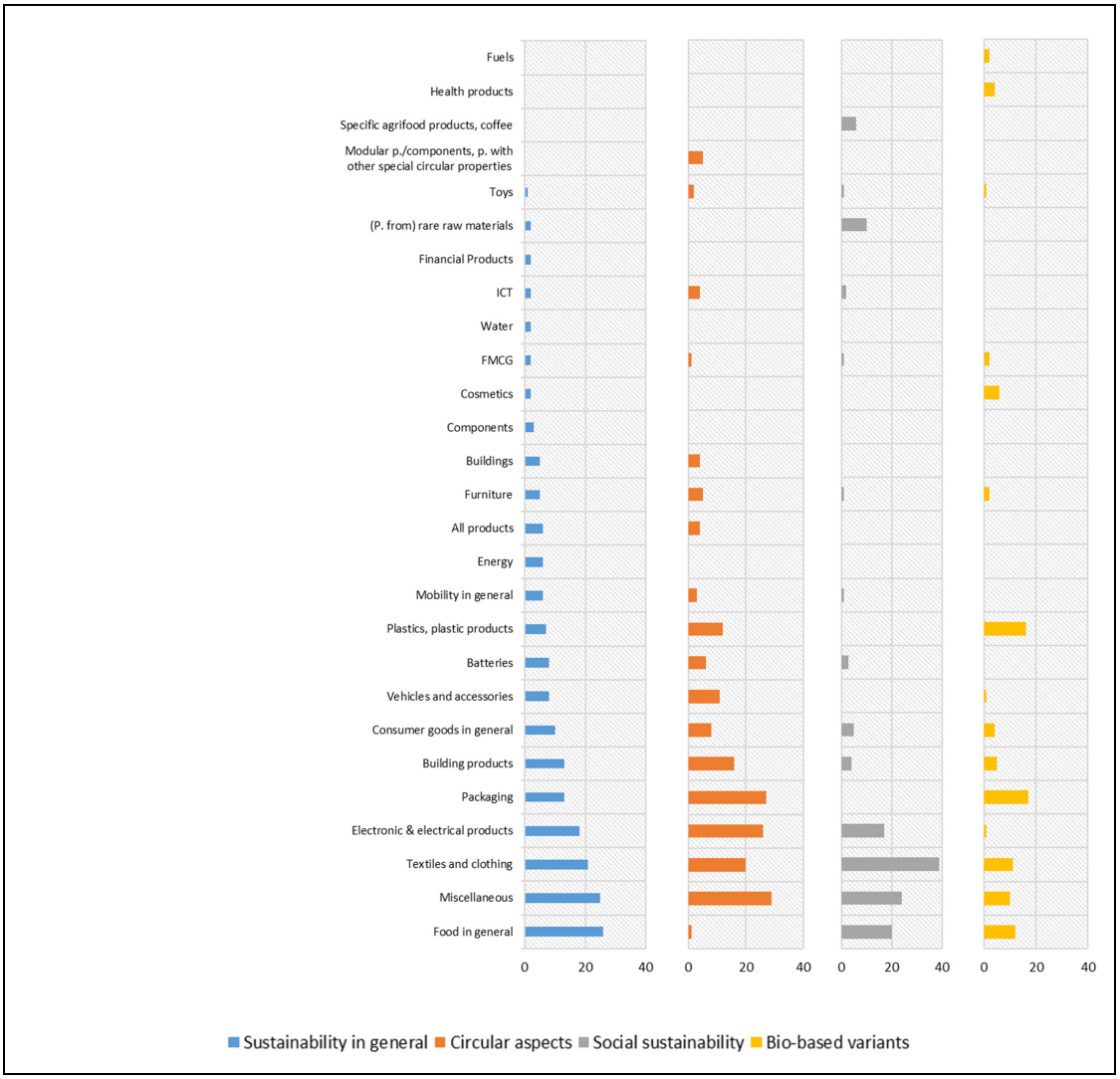

Figure 3. Products with a need for sustainability information, according to the interviews.

Table 3. Overview of other products with a need for sustainability information according to the interviews.

Sustainability in General	Circular Econ. Aspects	Social Sustainability	Bio-Based Variants
Energy-related	*Energy-related*	*Energy-related*	*Energy-related*
- All products (p.) with energy-intensive production (e.g., steel, plastics)	- All products that are now disposed of as residual waste energetically	- Energy sources	- Energy sources
- All p. with energy-intensive production (suggestion as above but without examples)	- Turbines	*Miscellaneous*	*Miscellaneous*
- Energy sources	- Wind turbines	- All goods that are traded globally, i.e., have global and highly ramified supply chains	- Additives
- Energy storage for gases and liquids	*Miscellaneous*	- All p. imported from third countries outside the EU	- B2C products (Fast Moving Consumer Goods -FMCGs that are recycled)
- P. made from rare raw materials, with a high energy input or high hazard potential	- Aircrafts	- Building	- Chemicals
- Heating & electricity in buildings	- All consumer and capital goods	- Capital goods	- Cleaning agents
- Turbines	- All end consumer products	- Cars and accessories	- Disposable products
Miscellaneous	- B2B products	- Consumables with high quantities	- Household goods
- (All with) rare and precious raw materials	- Capital goods	- Cosmetic products	- Polymer products
- Aircrafts	- Cement	- EEE	- SMCG
- All recyclable products	- Convenience	- Everything specifically dealing with hazardous substances and resources	
- All end-consumer p.	- Crystal-made products mistaken for glass	- Healthcare	
- Basic products	- Fungible products	- Industrial products	
- Cleaning Products	- Gardening	- Jewellery products	
- Colours/varnishes	- GRP (glass fibre reinforced plastic) components	- Nutraceuticals	
- EEE (not explained)	- Household goods	- P. of global markets	
- Everything, especially dealing with hazardous substances and resources	- Housing	- P. with a high proportion of manual work	
- Facilities	- Industrial products with a long lifetime	- P. with complex supply chains	
- Fungible products	- Kitchen	- P. with risk materials from the Global South	
- High-impact products	- Liquid reservoirs	- Raw material intensive products	
- Multimedia	- Machines	- Semi-finished metal p.	
- P. that increase resource efficiency (heat pumps, etc.)	- Materials used in combination	- Shoes	
- Smartphones	- Metal products	- Smartphones	
- Sports	- Multimedia products	- SMCG	
- Tyres	- Paper	- - P. recycled from waste that create jobs in the waste management sector	
- If there is a risk to biodiversity and health, everything that comes into contact with the environment	- Particularly short-lived products and products with high material value/rare materials		
	- Products relevant for public procurement		
	- Slow Moving Consumer Goods (SMCG)		
	- Smartphones		
	- Steel		

Note: All entries in the table and similar tables or figures of this article are translated.

For the respondents, the most critical products needing information on circular economy are, according to Figure 3, packaging, electronic & electrical products, and textiles & clothing—showing a strong relationship with CEAP key priorities. A wide variety of individual mentions were grouped in the category 'miscellaneous.' Further information on this group is provided in Table 3. According to the table, the other information refers, e.g., to relevant products for public procurement, airplanes, and wind turbines. Further explanations emphasized, for example, the importance of information on products from rare raw materials and energy-intensive production. The comparison with the findings for sustainability information in general indicates that different products are prioritised for the various dimensions of sustainability information. For example, food is the most important category with information needs on general sustainability aspects but was only mentioned once concerning information needs on circular economy aspects. This finding will be explored further with the support of the results in the following sub-sections.

Regarding social sustainability, participants referred to ten product groups needing the provision of sustainability information. According to Figure 3, textiles & clothing, food, and electronic & electrical products were mentioned most often. Combining the data for all topics, we see the perceived importance of textiles and clothing's social sustainability compared with other information on textiles' sustainability.

The additional food category 'specific agri-food products and coffee' includes the entries 'coffee' (2 times), 'certain vegan products like soy and quinoa', 'bananas', 'commodities value chain (chocolate, coffee, and other raw materials needed for industrially

processed food)', and 'agri-food products'. A particular category is also raw materials, which could only be created for the responses to the open question on the need for social sustainability information. Specific contributions include, for example: 'raw materials sourced from countries with lower standards than in the EU', 'origin of raw materials from developing/emerging countries', 'mineral raw materials from mining', and 'critical raw materials, e.g., Lithium.' The participants also made a special reference to workers' needs: 'Products made from raw materials where working conditions could be unsafe'. The statement 'products with a high proportion of manual labour', recorded under 'miscellaneous', also made a special reference to labour aspects. The answers summarized by the category 'miscellaneous' are shown in Table 3. The product origin was also a matter of concern. The participants call for more information on social sustainability, e.g., on products from global and complex supply chains, products 'with risk materials from the global south', and 'products from third countries outside the EU'.

Products for which information on bio-based aspects is required cover twelve areas, according to Figure 3 and Table 3, starting with packaging, plastics, and food. Compared with the answers to the previous questions, the number of other products is the lowest. Examples of these other products include chemicals and additives. Interestingly, cleaning products, paints, and varnishes were not mentioned again. Possibly, participants regarded mentioning them in the broader context of sustainability information in general as sufficient. An interesting observation is that the number of entries per bar on the 2nd to 4th figure is sometimes higher than on the first one.

3.2. Products Characterised by Specific Needs for Software to Support Sustainable Decisions and Drivers of the Need for Information

3.2.1. Relevant Products

The sustainability of products is essential in all life cycle stages, for example, in product development, manufacturing, and purchasing decisions. Software systems can provide customised information for this. To address research question Q2, the participants could specify up to three products. Figure 4 shows the answers, which are also in line with CEAP. According to the respondents, electronic & electrical products and components, textiles & clothing, food, and miscellaneous products, dominate the 1st and 2nd ranks. Food, textiles, & clothing, and 'miscellaneous' were also most often mentioned in the 3rd entry box. In addition, the figure shows the total number of mentions. Again, electronic & electrical products and components, textiles & clothing, and food are in the lead. Compared with Figure 3's bars for sustainability in general, Figure 4 also shows the same top-3 priorities, including electronic & electrical products, textiles & clothing, and food, although in another order. All results together stress the importance of the three product groups regarding information and recommendation software. The various explanations for the top-3 priorities in Section 3.2.2 stress their importance.

3.2.2. Drivers of the Need for Information

In the next step, the participants were asked to describe why software is important to support sustainability-oriented decisions regarding these particular products.

As Table 4 shows, the needs for software vary. Frequently mentioned reasons include, e.g., energy aspects, high sales quantities, and the fact that a product is a consumer product.

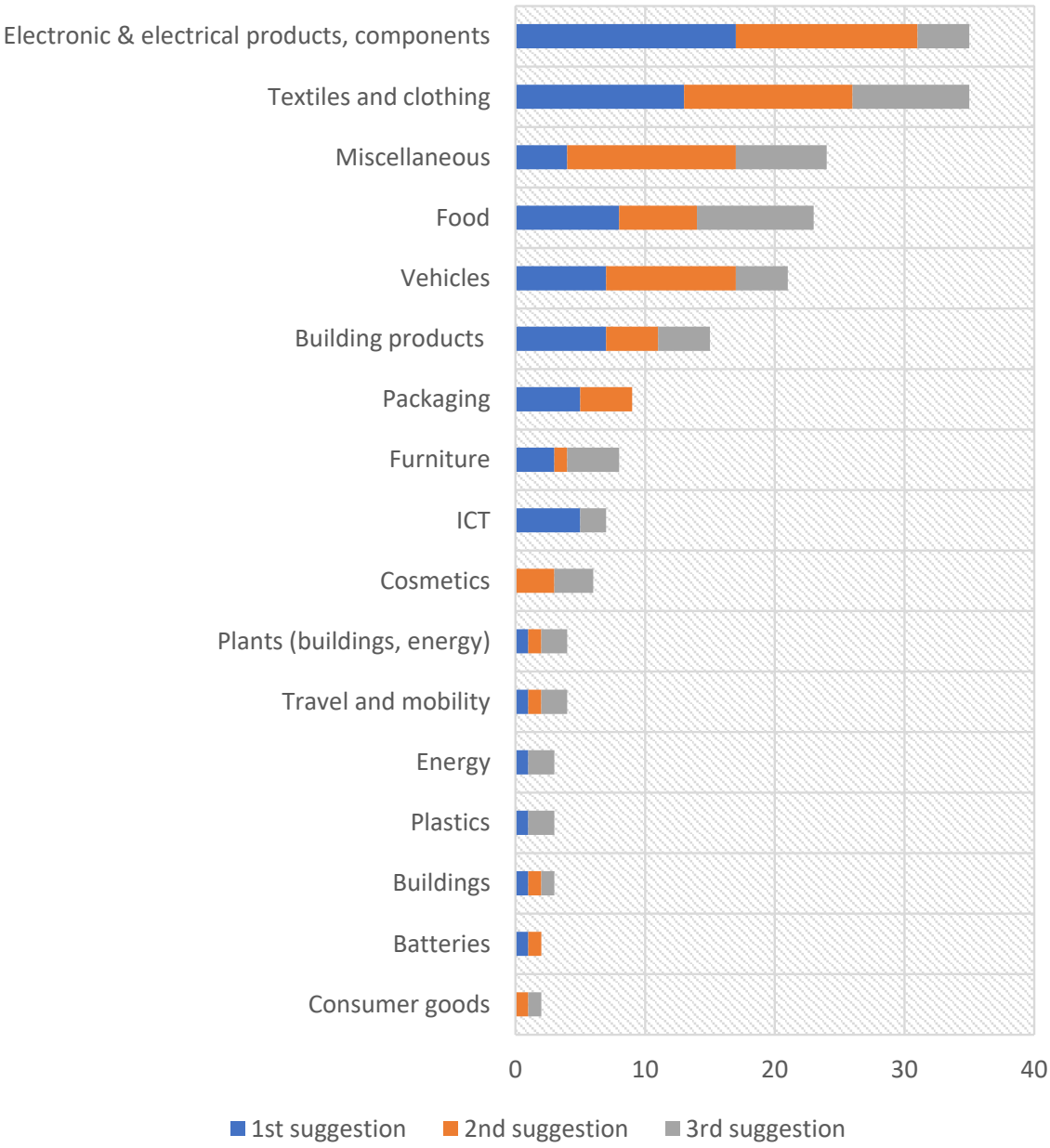

Figure 4. Products with a need for sustainability recommendation software. Note: examples for the clustering: Electronic & electrical products, components: e.g., 'Electrical appliances', 'electronic appliances', 'electronic components', 'household appliances', 'white goods', Textiles, clothing: 'textiles', 'clothing', 'textile products', Food: e.g., 'food', 'nourishment', Building products: e.g., 'Building materials', 'Building materials', 'Roofing materials', Vehicles: e.g., 'cars', 'passenger cars', 'motor vehicles', Packaging: e.g., 'Packaging', 'Packaging, ICT: e.g., 'IT', 'Computer, Miscellaneous: e.g., 'all products for which SCOPE 1-3 emissions are recorded', Furniture: e.g., 'Möbel', 'Furniture, Installations (building, energy, heating) e.g., 'Energy installations', 'Heating, solar installations, Heating, solar systems etc'., Travel & Mobility: 'mobility', 'travel', Energy: e.g., 'energy', 'electricity, Plastics: e.g., 'Plastics', 'Plastics for housings of industrial products (e.g., converters, control electronics . . .)', Buildings: 'Buildings', 'Structures', 'real estate', Batteries e.g., 'Batteries from rare raw materials', 'Battery system'., Cosmetics: e.g., 'Products of the cosmetics industry', 'Cosmetics', Consumer goods: 'Consumer goods', 'Non-food consumer goods'.

Table 4. Selected product-specific explanations on the need for software-based sustainability information.

1. Selected reasons for the top-ranked categories.
General information on SMCG and complex products, including e.g., electrical appliances
Energy aspects • 'The size of household appliances determines their energy consumption (comment on complex products such as household appliances (washing machines, refrigerators . . .))'
Consumer products • 'In SMCG, the software can support [selection processes], as the selection of SMCG often follows specific, non-path-depended processes (Internet research, conversation among family or friends, etc.). Where it is not helpful: FMCG, as their selection is intuitive and 'path-depended."'
Electronic & electrical products, components
Energy aspects • 'High sales, strong focus on energy efficiency.'
Modularity • 'Use of modular or less modular equipment, etc.' • '(Relevant questions are:) Are there other modular products? Can I buy spare parts later?' • 'Because there could probably be greater differences in sustainability for these products, e.g., due to modular or less modular devices, etc.'
High sales quantities • 'High sales, strong focus on energy efficiency' (see above)
Consumer products • 'These are complex products (for consumers) (. . .). Here, software-based decision support can be of great added value.'
Various • 'Those who are very interested in (these) devices inform themselves about the selection online anyway, and the purchase usually also takes place online.'
Textiles/clothing
Consumer products • 'End consumers can make the biggest impact with their purchasing decisions. (. . .) There is an urgent need to focus more on sustainable actions.' • 'With clothes in general, I think there is a strong trend towards sustainability when H&M already offers to bring back clothes for recycling. (. . .)'
Various • 'Because there could probably be greater differences in sustainability for these products, e.g., through the use of organic cotton / conventional cotton, different dyestuffs, etc.'
Food
High sales quantities • 'Quick comparability, high quantities, frequent purchase.' • 'Products with high sales figures among private customers.'
Various • '(. . .) Especially in the case of food, information is available but often hardly readable.'
2. Selected reasons for the other categories.
General information on SMCG and complex products, including cars
Energy aspects • See line on SMCG in this table's section 1
Consumer products • See line on SMCG in this table's section 1

Table 4. *Cont.*

Cars
Various
• 'The use phase of the products is lenghty (several years), and thus the impact on the entire life cycle is high.'
• 'Sustainability depends on many individual parameters (frequency of use, mileage, . . .).'
Building materials
High sales quantities
• 'These products are used in large quantities and have a strong environmental impact.'
Various
• 'The products mentioned have a big sustainability footprint. Therefore, sustainability should be increasingly considered here in purchasing decisions.'
• 'Due to the large number and complexity of approvals and properties.'
Furniture
Various
• 'Because it has a huge use of computer-aided design (CAD) within its design.'
• 'High diversity of possible variants (. . .)'
• 'Until now, there is little information on sustainability aspects in the furniture industry for the customer.'
3. Supplementary explanations on products mentioned by individuals.
Smartphones
• 'The products must meet or be adapted to individual needs. This is not only a question of supply but also of demand. Let's take a mobile phone as an example. There are very simple card phones for simple conversations or smartphones with the processing power of a PC. One can hardly determine which device is "better". It is a question of needs and demands. But you can compare criteria: price, functions, user-friendliness, and much more. It is similar to leisure equipment and prostheses. These are products with a high degree of customisability.'
Outdoor products
• '(. . .) because most people who buy branded outdoor products like to be in nature and thus have a connection to nature and their environment. (. . .) If further criteria were transparently disclosed here, this would undoubtedly be met with approval. However, with many outdoor products, there is already more transparency than usual. (. . .)'

3.3. Specific Information Needs

To specify the information needs described by research question Q3, the survey determined the sustainability information that the software should provide. According to Figure 5, information on end-of-life options, life cycle assessment (LCA), and social aspects are indicated in particular.

The statement that the software should provide different types of sustainability information depending on the product type, selected by 42 participants, was specified by various descriptions. Participants indicated that differences exist regarding suitable sustainability information and indicators. According to Table 5, ten specific differences were unveiled.

Table 5. Factors influencing the need for products' sustainability information.

1.	General differences depending on the material used
•	'Depending on the material, e.g., (if I want to use) plastic (as thermoplastic, elastomer, duromer, glass or carbon fibre reinforced) or metals (e.g., steel or aluminum or gold from electrical contacts or rare earths in magnets) and recycle them later. You cannot achieve meaningful results with "one" sustainability information.'
•	'Depending on the value chain, products can be characterised by different challenges. E.g., steel has high environmental impacts, i.e., life cycle emissions would be (. . .) interesting. Furthermore, steel can be recycled. So the recycling share would be relevant. In contrast, recycling plays a minor role in cement.'
2.	Type of target group: 'Product types are subject to different uses and requirements. For example, textiles are used in the consumer sector and are usually recycled after use. Machines are used in industry, regularly maintained, resold if necessary, cannibalised at the end, and reused in individual parts.'

Table 5. *Cont.*

3.	Different material intensity: 'The purchase of a car is different from the purchase of a drill: For example, the effect on third parties plays a greater role with a car than with a drill. Communication should be tailored to this. (…).'
4.	Different energy intensity
•	'(…) Consumption data is relevant for long-used and energy-intensive products (e.g., hoover, washing machine).'
•	'Products with similar energy input, where the energy origin is more in focus: Different depths of sustainability information should be available. A traffic light system is sufficient for simple estimates, e.g., for certain product classes, the energy input is similar. For comparison (e.g., within the class "cement"), an assessment of the origin of the energy required is sufficient.'
5.	Different relevance of circularity
•	'Circularity may not be the major impact.'
•	'Depending on the product, certain information is helpful and important (recycled content in mineral building materials), while in others, it can be misleading or give the wrong impression. E.g., recycled content in clothing/textiles can suggest that the product is automatically more environmentally friendly/sustainable. This can encourage greenwashing.'
6.	Different relevance of recyclability
•	In general: 'With food, for example, recyclability is not relevant in the same way as with textiles.'
•	Specifically, long-life versus short-life products: 'For short-life products, possible recyclability and overall end-of-life options have greater weight.' (See also the next bullet point.)
7.	Different influences on social sustainability
•	'In the case of clothing, for example, information on working conditions during production must be assessed differently compared with technical products because of the higher proportion of manual labour. For batteries, using raw materials and mining conditions play a greater role.'
•	'The three pillars of sustainability (…) are of different relevance across sectors (…). E.g., in the food and clothing sectors, working conditions seem to be a particularly urgent concern. At the same time, the high investment volumes in building technology put the economic aspect in the centre.'
•	'E.g., textiles: social share in manufacturing and raw material extraction (cotton, for example), resource use (waste, pollution) in material production (dyeing, finishing), chemical use (fertilisers, pesticides, dyes)'.
8.	Different relevance of packaging: 'For textiles, for example, information about packaging does not play as big a role (anymore) as it does for food.'
9.	Different relevance of biobased variants: 'Depending on the product type, different information is necessary (e.g., textiles versus ICT), so information on biobased shares, for example, is not relevant for all products.'
10.	Use of rare raw materials: 'With smartphones, the production and recycling/refurbish possibilities are crucial.'

3.4. Specific Requirements in the Context of Bioplastics

Due to its relevance to the circular and the bio-economy, a particular question was dedicated to bioplastics. Participants were asked for which specific products sustainability software should provide information on variants made from bioplastics. They could specify 1–3 products. The participants made various suggestions, which are shown in Figure 6.

Packaging was mentioned most often, including 35 times in the first entry box, followed by textiles and consumer goods. The answers in the 2nd entry box include, in particular, the topics of textiles & clothing, as well as construction and consumer goods. Among the answers in the 3rd entry box, textiles & clothing also lead, followed by packaging and construction products. Regarding the total number of mentions, packaging, textiles & clothing are mentioned most frequently, followed by the construction sector. The importance of electronic & electrical products and textiles & clothing was highlighted again.

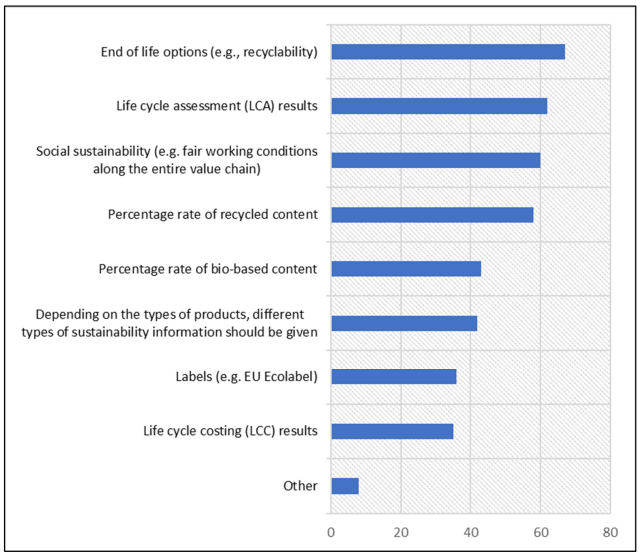

Figure 5. Sustainability information demanded from sustainability recommendation software. Note: Participants who selected 'other information' specified this by the following seven statements: 'Information on providers and owners, headquarters, certificates such as ISO 14001-certified or EMAS, link to sustainability strategy website'. 'Recyclable components (…)'. 'Functional product characteristics. Decisions are always made in the context of product functionality'. 'Alternative products with similar properties but a better rating concerning the Circular economy'. 'Since the life cycle costs depend on the respective prices, additional price information (…) should be provided. 'Toxicological profile of the products'. 'If relevant, traces of substances'.

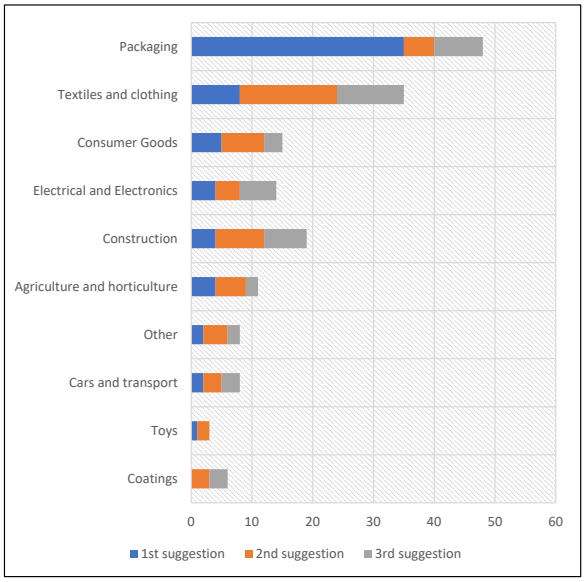

Figure 6. Products requiring information on variants made of bioplastics. Note: examples for the clustering: Packaging: e.g., 'packaging', 'wrappings', 'film packaging', 'food packaging', Textiles and clothing: e.g., 'clothing', 'clothing', 'textiles', Consumer goods: e.g., '*Konsumgüter*', 'consumer goods', Electronic & electrical products: e.g., '*Elektrik und Elektronik*', 'electrics & electronics', Construction: e.g., '*Bau und Konstruktion*', '*Bauwesen*', 'building & construction', Agriculture and horticulture: e.g., 'agriculture, 'horticulture', Other: e.g., 'food', 'tyres', Cars and transport: e.g., 'cars and transport', 'cars', Toys: toys, Coatings: e.g., 'coating & adhesives', 'coatings and adhesives'.

4. Discussion

4.1. Implications for Four Target Groups

Sustainable development, one of the 21st century's key objectives, requires appropriate information on products' sustainability characteristics. For this reason, mobilising the potential of digitalizing product information is an important goal in the EU and beyond. In this context, stakeholders along products' value chains have different sustainability priorities, also varying between product groups. Recommendation software to support their individual product decisions is, however, missing. This article on key products needing the provision of sustainability information and related recommendation software relies on a survey among 134 sustainability experts and offers four-fold implications explained in the next sections: it (1) contributes to the sustainability, CE, and applied software research, (2) provides information on bottom-up and follow-up priorities for CEAP stakeholders and policymakers, and (3) has practical implications for software developers by unveiling needs for specific recommendation software. Its benefits for users (4) are also explained, followed by a discussion on its limitations.

Besides all statistical figures and rankings, the qualitative information in Table 4 with product-specific explanations on the need for software-based sustainability information and Table 5 on Factors influencing the need for products' sustainability information provide helpful background details.

4.2. Contribution to Sustainability, CE, and Applied Software Research

Section 1 provided the state of the art in sustainability research and indicators. However, a still-open question refers to the products for which specificsustainability information and recommendation software is most important. The answers to our three questions contribute to the sustainability and CE literature and their specific gap regarding recommender software, which is also missing in software literature.

This article unveiled top information needs: 1. in four sustainability areas, 2. regarding sustainability information software, and 3. about bioplastics. In addition, ten factors influencing these needs and facilitating the development of further product-related sustainability classifications were unveiled.

Specifically, our analysis considered four sustainability aspects: in general, circularity, social, and bio-based. An important finding was the varying relation between the information interests regarding circularity, social sustainability, and bio-based aspects. The lists of the reasons for the different information needs provide valuable additional information here.

From a circular economy point of view, the high rates for information on social sustainability reflected the importance of considering circular and social sustainability together. Demonstrating the importance of sustainability information in the textile, electronics, and food domains also mirrors and extends the knowledge on the need for sustainable products in these areas (see besides [6], also, e.g., [68] for food and [17] for textiles). Both aspects also emphasize the need for R&D for continuous sustainability improvements in these industries. Section 1 of Table 4 provided valuable background information in this context, e.g., regarding the need to consider modularity in the design of electronic products.

While [10] described how the sustainability of bio-based products might be measured, this article not only shows bio-based products for which specific needs' recommendation systems exist, but also refers to a recommendation system that may suggest products based on users' specific sustainability interests. In Section 3.4, the major market segments of bioplastic were presented. This article supplements this knowledge regarding the most important needs for recommendation software.

In this context, this article is also one of the first contributions regarding sustainability recommendation software. It specified products with needs for such software and their specific information needs by also unveiling the reasons. The main drivers of the need for sustainability recommendation software for electronic & electrical products include the aspect of modularity, the importance of energy efficiency, and the relevance of searching

for product information on the internet for the target group. The need for information software for textiles is explained by the product characteristics and trends in the industry towards sustainability. Regarding food, participants referred to the high sales numbers and the problems of reading the information written in tiny fonts on the packages. Specific software needs are discussed in Section 4.5.

4.3. Disclosure of Bottom-Up and Follow-Up Priorities in the Context of the CEAP

The CEAP is an important milestone toward the circular economy in Europe. As described in Section 2, our findings rely on exploratory research. Likewise, our three questions had a broad scope. Therefore, one of the most remarkable findings was how closely our results were related to the CEAP's goals and, likewise, to the German Standardization Roadmap Circular Economy, which closely follows the CEAP.

As assumed in the research hypothesis, our findings reflect the significance of CEAP's priority products regarding the need for sustainability information and provide important insights into priority topics for various specific sustainability questions. They also show experts' sensitivity to numerous additional sustainability aspects besides circularity, which must not be ignored. Social sustainability is an essential issue in this context. In addition, the importance of energy issues was highlighted by the participants.

Concerning the need for sustainability information addressed by our question Q1, the three most important product groups regarding sustainability information in general are food, textiles & clothing, and electronic & electrical products.

In addition, several products ranked high across all the four sustainability categories (general, circular, social, bio-based), specifically, food (ranks 1, -, 2, 3, respectively, '-' means that the product was not included in the ranking), textiles & clothing (ranks 2, 3, 1, 4), electronic & electrical products (ranks 3 (excluding 'miscellaneous'), 2, 3, -), packaging (ranks 4, together with building products, 1, -, 1), and building products (ranks 4, 4, 5, 6), lead the way. Batteries and vehicles, two parts of a CEAP priority category, were also mentioned frequently. If their scores are combined, their significance indicated by the experts becomes even more visible. Regarding bioplastic product variants, a need for information on packaging, which is also described in the CEAP, was indicated most often.

The results for food require specific interpretation. Although food is a CEAP priority topic, the experts did not mention a need for circularity information on food, in contrast to the need for other sustainability information on these products. The reason is that the CEAP refers primarily to food waste, while our survey asked for product information. An interesting aspect in this context is also the frequently indicated need for recommender software with food information in Figure 5, also reflecting the need for social sustainability information shown in Figure 3.

Concerning Q2, addressing the need for sustainability recommendation software, electronic & electrical products and components, textiles & clothing, and food were mentioned most frequently. They are followed by vehicles, building products, and packaging, while the reasons for the needs vary. Together with ICT, electronic products are also the first products mentioned in the CEAP, making our and CEAP's categories with electronic products partly comparable. Integrating also the ICT-related answers into our class of electronic & electrical products would make that category even more significant. However, a separate ICT category provides the opportunity to consider these products separately. In this context, an additional survey, which we are currently analysing, already shows a particular interest in sustainability recommendation software in that area on the side of a specific public procurement stakeholder group. Therefore, we regard a separate category of ICT products as helpful for further research and practice. As described above, we also created separate categories for vehicles and batteries.

Six product groups of the CEAP also belong to the top six product categories with needs for sustainability recommendation software. Plastics were mentioned less frequently. This result is in line with the fact that plastic is a material, not a product. The fact that plastic plays an essential role in the packaging area strengthens the importance of this

category within our findings. The findings regarding Q3 discussed in Section 4.3 provide further information in the CEAP context. Several communicated needs for recommendation systems refer to areas in which platforms already exist (see Section 1.2). This observation requires follow-up analyses on: (i) which product life-cycle stages these needs address, (ii) whether the existing platforms are known and (iii) what the specific gaps are.

Although it is noteworthy that our results reflect CEAP priorities, the most important findings are participants' further suggestions. Regarding the standardization roadmap, the results provide synergies: the roadmap will lead to product specifications, and the recommendation system can ensure the provision of the necessary information on how the standards are addressed. As [6] highlighted, 'Horizon Europe will support the development of indicators and data, keeping in mind the role of digital tools (...) to achieve circular objectives'. This will be the next step of our research.

4.4. Contribution to Software Engineering

As described in Section 1, the EU aims to identify crucial information about the makeup of products so that users across the supply chain can use it. Sections 4.2 and 4.3 showed the need for sustainability recommendation software and unveiled for which specific products this need exists. Regarding the kind of information needs investigated by Q3, participants highlighted the importance of information on end-of-life options, life cycle assessment results, and social sustainability. In addition, they described that additional information might be relevant, e.g., on traces of substances. The participants also referred to various needs for information due to ten product characteristics: varying materials and material and energy intensity, different relevance of circularity, recyclability, packaging and bio-based variants, different framework of working conditions, and the possibility of regional production as well as the specific situation of products made from rare raw materials. Regarding current developments, we also expect that the relevance of product passports will vary, particularly between slow and fast-moving products and food whose life cycle ends with the consumption process.

Participants also highlighted the need for labels, simultaneously emphasizing the importance of standardisation. Likewise, Bowen et al. [41] described that the acceptance of information disclosure schemes very much depends on their credibility and the way the information is deployed. Standards-based (eco) labels may significantly promote the uptake of sustainable products [42].

Implications for further steps are described in Section 5. Regarding the EU's aim to identify the most important information about the makeup of products, the findings in Figure 4 and Table 5 provide a helpful foundation and help to specify the analysis towards more product-specific information. Nevertheless, much work remains. A follow-up discussion with an expert from the textile industry unveiled, for example, a high number of additional sustainability indicators discussed in that domain, which would need further consideration.

The overview of products requiring information on variants made of bioplastics also provides a helpful foundation for potential next steps to analyse in which way these findings also implicate a need for sustainability recommendation software.

4.5. Contribution for Future Software Users

Opportunities to select products based on their sustainability characteristics provide many advantages. In particular, they help individuals and professionals to contribute to environmental and social sustainability. However, there are also potential individual benefits, for example, in the context of several new possible policy measures in Germany. The relevant discussions refer to a new taxation system for company cars and taxes according to the cars' environmental impact (see [23]: 'In a concept paper, leading Green politicians proposed two tickets as successors to the 9-euro ticket: a regional ticket for €29 and a nationwide ticket for €49 a month. Both should continue to be valid for local and regional transport. To finance this, the Greens want to curtail the company car privilege,

which allows companies to deduct the cost of company cars from their taxes. Above all, CO_2 emissions are to be taken more into account' (translated)). The importance of sustainability recommendation software for vehicles was shown in Figure 4. Such a system could also give essential support to select cars to optimize taxation. If the new taxes are implemented, even a rise in the importance of sustainability recommendation systems for cars may be expected.

4.6. Limitations

Besides all contributions, we also identified three limitations of this study regarding the method, the participants, and the information depth to specify sustainability recommendation systems.

Limitation regarding the research method: As described in Section 3.1, most survey results were deduced from answers to open questions. An additional survey with predefined answer options based on Figure 3 and a discussion on the topics in Table 3 would provide even more insight into this context. Another limitation is that the participants described opinions in the questionnaire but did not make choice tests. A short choice experiment in the ConCirMy project will provide more insight into how consumers value sustainability characteristics and related information.

Limitation regarding the survey participants: The limited geographical distribution of the survey participants, the focus on experts, mainly from the R&D field with a theoretical perspective on the topic, and the low number of practitioners is also notable. Another observation was that the number of circular economy experts among the survey participants was much higher than that of bioeconomy experts. Therefore, the results are primarily relevant to the circular economy. In addition, bio-based products were the category with the fewest answers in Section 3.1. This result may reflect the participants' knowledge in the different areas and the order of the questions on information needs: participants may have regarded certain characteristics of bio-based products as covered by the previous answers in Section 3.1. Due to the limited participation of bioeconomy experts and the geographical coverage of the survey, an additional study, specifically on the European bioeconomy, is currently being considered with stakeholders.

Our focus was on researchers from the circular and bioeconomy. Additional input regarding sustainability aspects with a broader scope may come from research communities such as the STRN sustainability transition research network. While detailed product-specific knowledge seemed to be most important in the given context, working with additional researchers may be the next step.

Our additional public procurement study unveiled another limitation regarding the experts' overarching knowledge. The professionals of the public procurement survey mentioned in Section 4.3 must comply with specific requirements regarding product prices and LCC, resulting in significantly higher scores for LCC information. Although LCC is not an indicator related to the need for urgent environmental protection measures, the answers of 35% of the participants who indicate a need for LCC information must not be ignored.

Limitation regarding the implications for recommendation software: In addition to the aspects mentioned above, the survey does not specify the need for information and recommendation software regarding the different product life-cycle stages from the design until the end-of-life stage. Specifying this knowledge will be of particular relevance for software developers. Participants also identified gaps in areas with existing recommendation systems which requires additional analyses. Packaging is a good example in this regard, where CirNet helps to support sustainability decisions in the design stage already. Possible additional software requirements to support sustainability decisions on other life-cycle stages must be subject to future analyses. In addition, it is likely that the future development of product passports also creates new recommendation software requirements, which will need further investigation. In response to the current trends in developing product passports, more research is also suggested to analyse for what types of these passports recommender software would be most helpful.

5. Conclusions

Research on sustainability information and indicators determined the starting point of our study. On this basis, we made five particular contributions:

- While scholars such as [10] demonstrated how sustainability might be measured (for example, of bio-based products), this article does not only show products for which specific needs for sustainability recommendation systems exist, but also refers to a recommendation system that may suggest products based on users' specific sustainability interests.
- Ten factors influencing the need for sustainability information and facilitating further product-related sustainability classifications were unveiled.
- The EU's 2020 New CE Action Plan and the priorities of the German Standardisation Roadmap Circular Economy are enriched by further insights facilitating practical implementations and decisions. This includes, in particular, the identification of priority areas where information based on specific additional indicators is needed.
- Qualitative, product-specific explanations on the need for software-based sustainability information was provided (Table 4), and, finally,
- Potential support for an emerging new need for car-related sustainability information and recommendations was unveiled.

The top-3 priority products for sustainability information and recommendation software are, in different orders, electronic & electrical products, textiles & clothing, and food. In addition, we identified the most important product groups needing information on the specific sustainability characteristics 'circular', 'social sustainability', and 'bio-based'. Electronic & electrical products, textiles & clothing, and food dominate again, each belonging to two of these three specific top-3 groups. In addition, they refer to a wide variety of specific products. Therefore, these findings also indicate a need for further investigation. Food provides an illustrative example of this since the experts specified several food products for which sustainability information already has particular importance. A wide variety also characterizes the product-relevant energy-related issues highlighted by the experts in various parts of our survey. Supplementing the top priorities, our results present sustainability information needs for various additional products.

Besides all the aspects unveiled by our study, one remaining issue is how sustainability should be measured. While several aspects are product-specific, others seem to have more in common. One topic which is regarded as very important is social sustainability. Section 1 presented EN 16751 with sustainability criteria for bio-based products. According to our analysis, this standard also provides useful building blocks to evaluate other products, e.g., regarding social sustainability.

The successful provision of sustainability information also depends on various additional scientific, economic, and quality infrastructure factors, including standards but also, e.g., labels. Proven and accepted measures and approaches are required to collect relevant data and information. The creation of standards for the circular economy is also a current goal of the standards organisations ISO and IEC as well as CEN and CENELEC with their national member organisations. Since the development of circular economy standards has just begun, the number of corresponding labels is still limited. This limitation indicates an information gap, which also influences the provision of information by recommendation systems. The current work on the Standardization Roadmap Circular Economy [69] can help to boost the development of standards in this area. In this context, the results might be helpful for sustainability standardisation to focus on important product areas. However, the availability of the required information also depends on the product providers' willingness to share the relevant data. More research will be necessary to analyse how this information can be provided in the best way.

Regarding specific target groups of sustainability information and software, the survey participants referred not only to consumers and professionals but also to information needed by public procurement. This aspect is investigated further in the German project

ConCirMy. More detailed consideration of sustainability aspects by recommendation software will be subject to future research.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Raw data is stored at TU Berlin according to our privacy declaration describing that aggregated survey results are used for scientific research and lectures.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Survey

Survey on sustainable products and sustainability software

Thank you for taking part in this survey! It is part of the ConCirMy (Configurator for the Circular econoMy) research project. Your contribution supports our research on the promotion of environmentally friendly products and the development of sustainability software.

ConCirMy is particularly focused on promoting circular economy products (e.g., products made of recycled or recyclable materials). In addition, it aims to promote products of the bioeconomy (bio-based products), which we understand to be products which are, wholly or in part, made using resources of biological origin and can substitute products traditionally made with fossil resources.

ConCirMy is funded by the ReziProK ('Resource-efficient Circular Economy—Innovative Product Cycles') measure of the German Federal Ministry of Education and Research (BMBF).

Since we value your time, this questionnaire has been designed to be as short and simple as possible.

If you have any questions or experience technical difficulties, please do not hesitate to contact us:

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Data protection

In line with the EU General Data Protection Regulation (GDPR) we need your consent to process your data. Your answers to the survey are used for scientific purposes and will be scientifically processed by the ConCirMy project. Your data or contact details will not be passed on to third parties outside the ConCirMy project. Aggregated survey results are used for scientific research and lectures. This work shall be made public. Names and e-mail addresses of participants will not be used for data analysis. By clicking on 'Accept' you accept the Privacy Agreement. Please indicate your consent below to start the survey.

A Getting started

A.1 Which of the following keywords describes your professional role best?

- Management
- Administration/accounting

- Procurement
- Production
- Marketing
- Sales
- Research and development
- Other

A.2 Please rate your familiarity with the circular economy:

Very familiar	Moderately familiar	Somewhat familiar	Slightly familiar	Not at all familiar

A.3 Please rate your familiarity with the bioeconomy:

Very familiar	Moderately familiar	Somewhat familiar	Slightly familiar	Not at all familiar

A.4 From your point of view, what are the most important products for which sustainability information is needed? Please note the products in the relevant category.

Products with need for information on . . .

. . . sustainability in general:
. . . circularity (e.g., recycled content, recyclable products):
. . . social sustainability (e.g., regarding the working conditions in the product life cycle):
. . . bio-based content:

B Software to support sustainable product choices

B.1 The sustainability of products is important, for example, in product development, in manufacturing and in purchasing decisions. In this context, software systems can provide customised information. In your opinion, for which products is software helpful that suggests product variants or components based on the individual sustainability preferences of the users? Please make 1–3 suggestions.

B.2 Please briefly describe why software to support sustainability-oriented choices is particularly attractive for these specific products:

B.3 Which sustainability information should the software provide to support the development, production or purchasing of the products mentioned in your previous answers?

- Life cycle assessment (LCA) results
- Life cycle costing (LCC) results
- Percentage rate of recycled content
- Percentage rate of bio-based content
- End of life options (e.g., recyclability)
- Social sustainability (e.g., fair working conditions along the entire value chain)
- Labels (e.g., EU Ecolabel)
- Other
- Depending on the types of products, different types of sustainability information should be given

B.4 Bioplastics belong to the key elements of the bioeconomy and play an important role for the circular economy. Currently, the top market segments of bioplastics are (starting with the biggest): packaging, consumer goods, textiles, agriculture & horticulture, automotive & transport, coatings & adhesives, building & construction and electrics & electronics.

B.5 Based on the ranking above, which specific products do you think should become priority applications of sustainability software to provide information on versions made wholly or in part of bioplastics? Please specify 1–3 products.

C Your background

C.1 What kind of an organization do you work for?

- Business
- Government, public authority or agency
- Industry association
- Certification body
- NGO
- University or research organisation
- Other

C.2 In which area do you work?

- Agriculture
- Manufacturing
- Construction
- Energy
- Trade
- Transportation
- Information and communication
- Financing and insurance
- Real estate
- Health care
- Accommodation or food services
- Other

C.3 What is your country of residency?

- Belgium
- France
- Germany
- Greece
- Italy
- Poland
- Portugal
- Spain
- Netherlands
- Other

D Outlook

D.1 Do you have additional comments or recommendations for our project?

- Yes
- No

D.2 Please include your comments here:

Thank you very much for participating!

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