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Sustainable Circular Mobility: User-Integrated Innovation and Specifics of Electric Vehicle Owners

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Abstract: The circular economy (CE) represents an environmentally and sustainability-focused economic paradigm that has gained momentum in recent years. Innovation ecosystems are the evolving interconnected sets of actors, activities, artefacts, and institutions who are vital to the innovative performances of single actors or actor groups consisting largely of firms in the products and services sector. To develop sustainable CE ecosystems, participating firms need to involve the consumers and users in their innovation processes. The automotive industry is to a large extent an industry in which incorporating customer requirements in product development is critical to success. In addition, growing expectations and growing awareness of environmental issues drive the industry to develop environmentally friendly products. However, CE solutions and, specifically, sustainable tyres have not yet been given due consideration. Likewise, the specific preferences of the end-users of sustainability-focused cars such as electric vehicles (EVs) and users of biofuels are unknown in the CE context so far. Based on the current state of research, this article addresses an important, unexplored topic of product circularity. Being the first article on consumer interests and active contributions to CE automotive products, it also extends the first articles on CE software products. A survey of 168 traditional car owners (no EV/biofuels users), 29 users of biofuels, and 40 EV affine consumers was conducted in Germany to create an empirical foundation for the specification of CE configuration software for sustainable automotive products, particularly sustainable tyres. The results show different preferences among these user groups, but also the importance of other characteristics not captured by the distinction by car ownership. In particular, the perception of climate change and the use of test reports or rating portals were variables that had significant influence on configuration preferences.

Keywords: circular economy; sustainability; user integration; innovation ecosystems; cars; electric vehicles; biofuels

1. Introduction

1.1. CE Innovation Ecosystems and User Integration in the Automotive Industry

The United Nation's (UN's) Agenda for Sustainable Development defined 17 sustainable development goals (SDGs), which are intended to be reached by 2030. 'Sustainability' is defined by the UN Brundtland Commission as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' [1]. Sustainability topics include, for example, responsible consumption and construction (goal 12), climate action (goal 13), as well as economic growth, employment, decent work for all, and social protection in goal 8 [2]. The circular economy

(CE) plays an essential role in the pursuit of the UN's sustainability goals [3]. It represents an environmentally and sustainability-focused economic paradigm that has gained momentum in recent years [4]. A CE is an economic system with the following characteristics: 'The value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value' [5].

This article refers to the development of a CE ecosystem in the automotive sector, which relies on the principles of open innovation and the contributions of different user groups to specify CE configuration software for sustainable tyres and appropriate tyre characteristics. In this context, the attribute 'sustainable' does not only refer to CE aspects but also to the use of renewable resources and social factors, for example, appropriate working conditions in the product life cycle. More information on material-related aspects of sustainable tyres is, for example, provided in Section 1 of [6].

Innovation plays an essential role in the pursuit of economic growth as mentioned in goals 8.2 and 8.3 of [2]. Considered in SDG 9, fostering innovation is even an individual goal of the SDGs [2].

The concept of open innovation has generated 'an avalanche of interest' since its discovery by [7,8] Its fundamental goal is to help firms 'to span their boundaries in both the creation and commercialization of innovations' and 'to shift the dominant logic of R&D away from the internal discovery toward external engagement' [8].

Scholars also observed the development of the open innovation research direction beyond the dyadic interaction between two firms towards collaborations with external networks, ecosystems, and communities [8]. Likewise, Ref. [9] highlighted that, from a conceptual point of view, the innovation perspective, originally focused on product/service and business model innovation, has recently widened to include ecosystems.

Innovation ecosystems are defined as 'the evolving set(s) of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors' [10]. They require the creation of economically successful alliances of loosely coupled organizations to interact with each other to achieve a collective outcome and the alliances' continuous development to achieve lasting success [9] further developed this idea by also considering the creation of the ecosystem.

This article applies the innovation ecosystem approach to the CE concept. On that basis, we define a circular economy (CE) innovation ecosystem as the evolving set(s) of actors, activities, and artefacts, and the institutions and relations that are important for the innovative performance within a circular economy.

Research on the CE has various facets. From a linguistic point of view, a specific kind of wording can be observed. Frequently, the single term 'circular' replaces the composed name 'circular economy', for example, 'circular business model' and 'circular design' [11] 'circular goods' [12] and 'circular innovation' [9]. Likewise, this paper uses the term 'circular mobility' for CE solutions for the mobility sector.

Ref. [11] specified the CE strategies and business model archetypes 'narrow', 'slow', and 'close', complemented by [9] by the strategies 'regenerate' and 'inform'. 'Regenerate' refers to the minimised use of toxic substances and the need for an increase of renewable materials and energy in a circular economy. 'Inform' is a support strategy based on the importance of information technology in enabling a CE. An example for the 'inform' function is provided by material database ecosystems describing the characteristics of materials and components in products so that products can be more easily reused and their materials recovered [9].

CE ecosystems have to be innovative and user-centred (adopted from [13] which refers to 'human-centred'), to be sustainable. Linked with the user-centricity, another new view on open innovation has emerged in addition to the ecosystem perspective. Nowadays, the perception of innovation, something initially understood as a firm-centric activity, has shifted towards a 'joint accomplishment', where it also considers the users' and customers' abilities to contribute to value creation [14].

User integration into the product development process means the cooperative development of new products and services focusing on high customer benefits. By involving the customer in the development process at an early stage, specific demand and market conditions can be taken into account during the product development phase, thus reducing the risk of failures, see [15].

According to [16] the importance of user information and user participation for seeking business opportunities has been widely acknowledged in a variety of industries.

In the CE context, the recognition of the users as valuable contributors in shaping business strategies [14] has to be applied to ecosystems. Since users are one of the most significant stakeholder groups of economic activities [16], the supply side of the ecosystem needs to understand users' preferences and reflect these needs. It is critical to incorporate their needs, ideas, and feedback in the system's innovation management for its sustainable growth (see [16] in this context concerning sustainable business models in general).

Particular topics of innovation research on the user side thus far include

- Studies on different integration levels such as user behaviours, users as a source of innovation, and the user role in innovations;
- Comparisons of user innovation with supplier-driven innovation;
- Interactions between users and manufacturers and suitable forms of governance for user innovation; and
- User communities and crowdsourcing for innovation (see [14] for an overview).

User communities and crowdsourcing for innovation belong to the most recent research topics [14]. This article extends the user integration research in the context of CE innovation ecosystems.

Ref. [17] emphasized the importance of considering customer-perceived values in establishing selection criteria in innovation management decisions. Likewise, they stressed that the automotive industry is substantially a business-to-consumer sector, in which incorporating customer requirements is critical to innovation. It is also shaped by a growing awareness of environmental issues, driving the industry to strive to develop environmentally friendly vehicles. In addition, customer requirements are becoming more sophisticated [17]. Consumer values play a crucial role in this context. Nevertheless, little effort has been made to reflect customer-perceived value in establishing criteria to select innovation projects. This applies also, as [17] stated, to the reflection of their interest in innovative, environmentally friendly product features. In the CE context, specific preferences and the role of the end-users of more sustainable cars such as electric vehicles (EVs) and biofuels are unknown so far.

This article is structured as follows:

- Section 1: Introduction,
- Section 2: Materials and methods of this study,
- Section 3: Results,
- Sections 4 and 5: Discussion and conclusions.

1.2. Users as CE Innovation Partners in Literature

Various research gaps shape the user aspect in the CE. As an example, 'the consumers' purchase intention of recycled circular goods' is an 'important' '*unexplored*' topic of 'product circularity' [12]. While [12] addressed this gap with a survey on CE fashion products, our article is the first one on consumer views and contributions regarding CE automotive and mobility products and, in particular, on related software products. In addition, consumers are part of the innovation process, while [12] considered mainly their opinion only.

A key research stream on CE software is dedicated to software for industrial symbioses, 'interconnected network(s) which strives to mimic the functioning of ecological systems, within which energy and materials cycle continually with no waste products produced' [18]. An overview was provided by [18]. Industrial symbioses refer mainly to production waste, while the focus of the present article is on consumption waste. Furthermore, the innovation processes and the consumer focus are underexplored in the industrial symbioses articles in [18] overview.

Specific newer research work on CE software was provided, for example, by [9,19,20]. Ref. [19] focused on a design tool for architects based on the research question 'How can architects, non-expert to the CE, be stimulated and systematically guided towards circular design?' It refers to long-life products and considers consumers only in the definitions and in the annex. The authors of [20] which was published one year later, referred to 37 existing building design tools and aimed at identifying 'specific needs of building designers and advising engineers ... for design support tools (and their features) for circular building The users of the building are not explicitly considered. Ref. [9]'s focus was on a tool to create CE systems. A tool for frequent interactions with consumers within a CE was not a priority. Ref. [9]'s tool creation relied on workshops with participants from incumbent organizations and start-ups, also not including the consumers. The present article provides specific input on consumer contributions.

1.3. Sustainable Mobility, Electric Vehicles, and Sustainable Car Components

1.3.1. Sustainable Mobility: Electric Vehicles and Biofuels

This sub-section describes the general characteristics of EV owners and consumers who are inclined to use biofuels.

The topic of electric mobility and EVs is currently a large field of research, especially when it comes to the potential environmental effects of sustainable transport, energy transition, smart grids, as well as charging infrastructure and policy initiatives to promote the diffusion of electric mobility. The characteristics and motivations of early plug-in Electric Vehicle (PEV) buyers and user behaviour in the context of charging patterns and mobility habits are frequently analysed. Less is known, however, when it comes to the broader sustainability perception and behaviour of current EV owners and potential EV buyers.

According to [21], EV owners, in particular owners of PEVs, have normally the following characteristics:

- Demographics: higher income, middle age, male, higher education;
- Travel patterns (context): longer commutes;
- Motivations—identity, personality: agreeableness, pro-environmental identity;
- Motivations—priorities, beliefs: environmental impacts, low costs.

The use of EVs is linked with symbolic behaviour and social signalling. Scholars also found a range of ample examples of positive, but also negative and uncertain, perceptions of societal–functional impacts, such as ultimate impacts on CO_2 emissions, air pollution, noise, and safety [21].

In general, consumers interested in EVs are often interested in the car's sustainability. Inaccurate sustainability information may be a barrier to the adoption of EVs ('Show me they are truly sustainable.') [22]. However, [22] found, nevertheless, that sustainability has low importance in an EV purchase compared to cost and performance, which applies in particular to driving range or charging time and infrastructure.

The adoption of EVs can be improved by advancing these performance characteristics and addressing consumers' trust by appropriate measures. The development of credible rating systems for the cars' safety, in particular, regarding electric safety, and working with user profiles appear to be useful [21]. Ref. [23] also found that digitalisation is having a major impact on the transport and automotive industry, especially on EVs: owners of EVs are more interested in digital driving solutions than other car owners.

To improve the adoption of sustainable EVs, improving the charging infrastructure is a fundamental factor. In addition, Ref. [21] highlighted regarding the interrelations with the consumers that

- More pro-environmental users can be reached by improving the certainty of environmental benefits (e.g., by comparisons with traditional solutions);

- Marketing and framing should move beyond just 'pro-environmental framing' to include pro-technology, practicality, and other motives;
- A variety of innovation options should be offered (e.g., styles, models, membership packages) to reach a wide variety of user groups.

Likewise, as mentioned above, addressing consumers' trust by the development of credible systems for ratings and user profiles appears to be useful. At present, the current state of research refers to safety ratings mainly [21].

Regarding the characteristics of the users of biofuels, the state of research does not provide information of comparable depth. Significant findings were, however, provided by [24] who found that socio-demographics do not represent suitable predictors of drivers' willingness to pay for biofuels. On the other hand, consumer characteristics, which might be used for a target group segmentation, are usually not based on simple indicators and are not subject to demographic statistics. Ref. [25] identified two consumer characteristics that have a positive impact on the use of biofuels: (a) preferences for buying organic food, and (b) preferences for electric and hybrid vehicles. Based on these findings, buyers of organic food deserve further consideration in user-centric sustainable mobility research.

The findings above show three specific aspects:

- First hints exist that consumers interested in biofuels may also be interested in other sustainable car products,
- Consumers interested in EVs are often interested in sustainability information,
- Consumers interested in EVs have also a specific interest in digital solutions.

With regard to the price, it is essential to note that an EV requires a higher investment.

1.3.2. Sustainable Car Components, Tyres, and Research Questions

Environmental car characteristics go far beyond the type of energy used and the amount of energy consumption. The end-of-life stage is an additional essential aspect in this regard, both of the whole car and its individual components, as well. Components of the car requiring regular replacement, tyres specifically being a top concern, need far more careful consideration. According to [26], 5 million additional used tyres have to be managed daily worldwide. Solutions are available, but it is important to identify appropriate user segments. 'While consumers become more and more sensitive to sustainability and climate issues in various topics, e.g., regarding plastic bags, food packaging and mobility in general, car tyres are still not in the focus of the conscious consumer' [6]. For this reason, involving consumers in CE innovation processes in the context of car tyres requires at first an appropriate awareness-raising to make them aware of the tyre sustainability issue and the end-of-life tyre problem.

Various mixes of materials, functional and sustainability characteristics, and prices are possible in order to provide sustainable tyres, while specifying appropriate configurations is an essential task. CE configuration software, fed with suitable user input, may provide significant support in this context.

On this basis, an important research question is:

1. Which input can be gained by conscious consumers to specify
    (a) sustainable tyres,
    (b) innovative CE software to configure such tyres

after making them aware of the sustainability problems of tyres?

Users of EVs and biofuels proved to have a specific environmental orientation, which requires further exploration.

Sustainability-conscious drivers who use biofuels are also interested in other sustainable car features. Ref. [24] showed the positive relation with regard to the interest in biofuels and EVs. Therefore, it is important to learn whether car owners interested in environmentally friendly energy are also interested in additional environmentally friendly car characteristics concerning tyres. Specifically, it is important to answer the question:

2a. Are sustainability-conscious drivers who use biofuels also more interested in sustainable tyres than other car drivers?

The particular interests of EV owners require more in-depth analyses, as well. Tyres for EVs must have specific characteristics. Many EVs are, for example, heavier than comparable non-EVs, which means more strain for the tyres. For this reason, EV tyre sidewalls have to be stronger. The heavy battery also increases the weight. The tyre cavity's shape must ensure that the tread remain in contact with the road. An additional issue is the car's grip and rolling resistance. Proper grip and rolling resistance characteristics make EVs, which are in general quieter than other cars, even more quiet. Individual block and groove sizes play an essential role in this context. A few tyre manufacturers produce EV-specific tyres already, for example, Michelin or Continental with its Conti.eContact™. Alternatively, high-performance tyres can be used for EVs, as well [27].

Environmentally friendly tyres provide few opportunities for social signalling. This aspect raises the question of whether EV affine consumers have a specific interest in these tyres nevertheless. The next question is therefore:

2b. Are sustainability-conscious owners of EVs also more interested in sustainable tyres than other car drivers?

The next question refers to the intended innovative CE configuration software, its specification, and target groups, also considering the specific market segment for EV tyres. EV owners showed a specific interest in digital car solutions. The next question is therefore:

3 Are sustainability-conscious owners of EVs, due to their particular interest in digital solutions, more interested in tyre configuration software than others?

Our approach to address these question is explained in detail in Section 2.

The analysis of consumers within a CE innovation ecosystem in this article forms part of a larger, currently evolving stream of literature. Whereas the innovation ecosystem construct has been used to describe the joint development and commercialization of technologies, products, and services for several years now [28], it has only recently been applied to the sustainability context [29]. Exploring the phenomenon of CE innovation ecosystems, aiming at accelerating the transition towards a CE, is of particular interest in this regard, as the works of [9,30–33] illustrated. Interestingly, previous studies primarily focussed on triple helix structures, thus the cooperation between politics, science, and industry, as well as on inter-firm collaboration. Alternatively, an explicit user focus, as adopted in this article, sheds light on an ecosystem actor who has received little attention in the circular ecosystem context so far.

2. Materials and Methods

As described in Section 1, this article refers to the development of software to support an innovative CE system specifically focused on customised automotive solutions and sustainable tyres, whose features are defined by user integration. The intended ecosystem consists of four groups of actors. Suppliers (producers, retailers, etc.) (1), consumers (2), and (public or private) recyclers (3) are directly involved in the material flow of the recycling objects as well as indirect participants, actors who influence the material flow indirectly (e.g., the state and associations) (4).

In the automotive industry, the group of suppliers consists mainly of car manufacturers and dealers. Users or vehicle owners include private households and also organisations with cars or car fleets. The group of collectors, recyclers, shredders and recyclers belong to the group of disposers (see Figure 1). Landfills are not pictured, as landfilling tyres is forbidden in Europe.

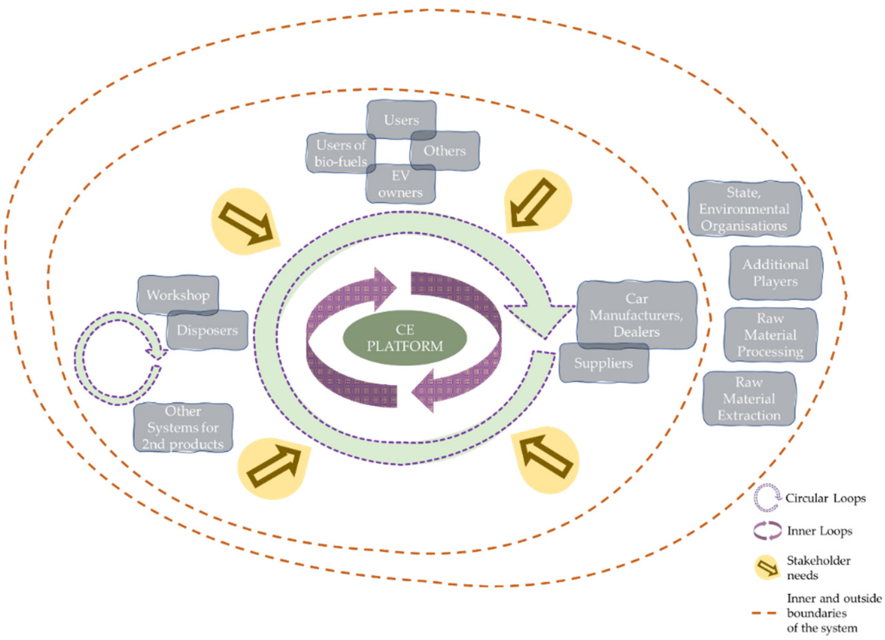


Figure 1. The ecosystem and stakeholder contributions to innovation.

The provision of new tyres, from day one during manufacturing, to the continued replacement of new tyres, is a supply service largely covered by tyre dealerships, workshops, or the internet.

A specific feature of the intended software system (refer to Figure 2) is a configuration software, which provides consumers with the opportunity to specify tyres according to their preferences, for example to purchase products from suppliers who guarantee sustainable sourcing throughout the whole value chain.

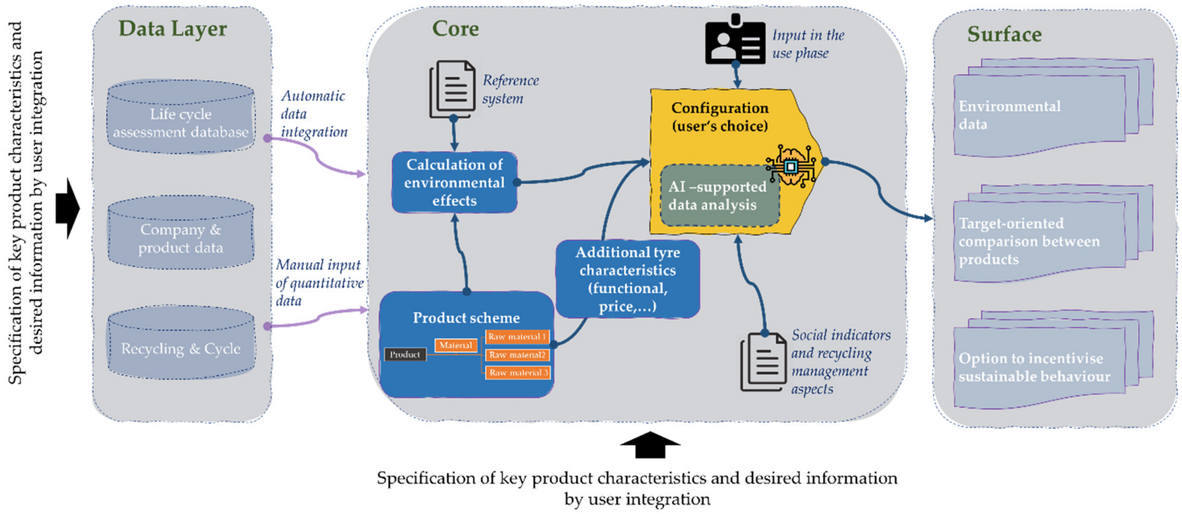


Figure 2. Intended circular economy (CE) software system and user integration in the development. Source: ConCirMy (modified).

The configuration shown in orange in the middle of Figure 2 relies on information on general characteristics of possible tyres as well as environmental information and social indicators, for example, regarding the treatment of workers in the value chain. To specify the tyre characteristics as part of the system's selection options, user integration methods were applied as a means to stimulate innovation (see frames of the figure). Ref. [16] distinguished four types of user innovation models: the workshop-based, the consortium-based, the crowdsourcing-based, and the platform-based models.

The workshop-based kind of user innovation refers to specific interaction with the stakeholders to specify early results of user interaction. Instead of workshops, surveys can also be used as a means of communication. Inspired by [16] the scientific approach of the present research is pictured in Figure 3.

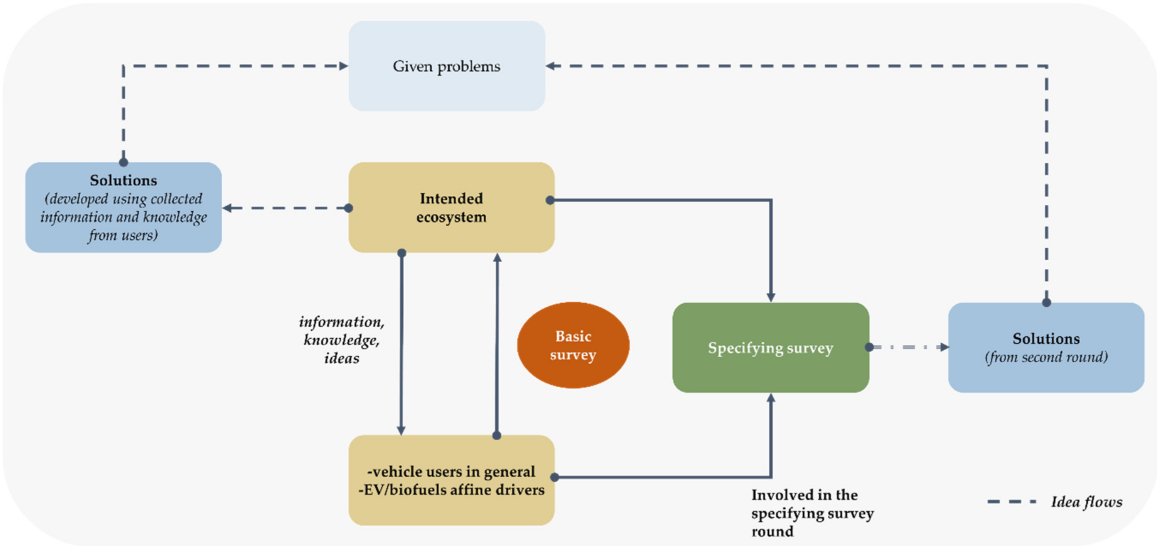


Figure 3. User integration concept of this research.

Illustrated in Figure 3, the user integration concept developed for this research has four key elements: vehicle users, the supply side of the intended ecosystem, a *basic* survey, and a *specifying* survey. This article presents the results of the basic survey.

Ref. [34] identified three possible consumer groups as target groups of CE business models: quality-oriented consumers, cost-oriented consumers and, in particular, 'green' consumers who are interested in environmentally friendly products. The survey relied on volunteer sampling among sustainability-conscious consumers, all of whom already purchase, high quality organic food. These participants responded to a nationwide advert in Germany among all newsletter subscribers of an online platform for food from regional organic farms that focuses on conscious meat consumption and transparency along the entire value chain.

In total, 5773 consumers were contacted. The survey was conducted from 16 January to 13 February 2020 and attracted 451 participants. 311 completed the survey, and 140 partially completed the survey. On this basis, the response rate was 7.8% (of total consumers contacted).

To sensitise consumers to the tyre sustainability issue and the problem of end-of-life tyres, the survey started with information on these aspects. The high volume of end-of-life tyres and their recycling as a global challenge were highlighted. Specific topics of the survey are shown in Table 1.

They included: 1. Demographic aspects and other fundamental user characteristics, and 2. Questions on user preferences. The general user characteristics included also, for example, the users' perceptions of climate change with three answer options: 'How do you estimate the impact of climate change for you personally and your family?'—'I regard the climate change for me and my family ... as an existential danger/ ... as a medium danger/ ... not as a danger'. Related to the consumers' use of information in the tyre purchase process, the survey also included, for example, the fundamental question 'Do you use test reports or rating portals to get information before buying a tyre?'—'Yes'/'No'.

The section on driving habits included filtering questions about whether the participant drives a car frequently, whether they own a car, etc. To identify users of EVs and biofuels, the following questions were used:

- Have you bought or leased a car privately in the past or were you involved in the selection decision?
- Do you or a member of your household currently own a car? If yes, is it an EV (fully electric or hybrid vehicle)?

- Do you plan to buy or lease a car in the next two years? If yes, an EV (fully electric or hybrid)?
- As a car driver, do you have any experience in the use of biofuel? If yes, could you imagine using this fuel in the future?

Table 1. Overview of the survey topics.

Topic Area	Survey Questions
Demographic aspects and other fundamental user characteristics	•Age, education, income •Attitudes towards sustainability in general •Driving habits (car ownership, brand, tyre purchase)
Questions on user preferences	•Preferred tyre brand •Place of tyre purchase •Use of information for tyre purchase •Importance of general tyre characteristics •Familiarity with EU tyre labelling •Importance of this label when buying tyres •Importance of information on environmental and social aspects in the purchasing of tyres •Importance of specific environmental and social aspects •Willingness to buy sustainable tyres in the future and relevant information in this context •Potential benefits of a sustainable tyre label to support purchasing decisions •Interest in innovative recycling management approaches •Innovative collaboration and software for sustainable tyres •Relevant functions of this software

Another filter question asked whether the participant had been involved in tyre purchase. Forty-three percent of the participants gave a non-confirmative answer or did not answer the question. These participants were not asked further questions on tyre purchasing and their preferences. Figure 4 illustrates the screening process.

Figure 5 shows the profiles of the participants with regard to the use of environmentally oriented energy sources in detail.

According to Figure 5, 66% (the clear majority) of the remaining participants had no relation to any of the sustainable mobility options. However, just over a quarter (26%) demonstrated sustainable interest and/or behaviour. These participants had an EV, planned to buy one, or confirmed an interest in the future use of biofuels. One percent of that group even applied multiple types of these sustainable practices. The research presented relied on the contribution of 237 persons (168 traditional car users, 29 users of biofuels, and 40 EV affine consumers (16 EV owners and 24 car owners who planned to buy an EV in the next two years)). Eight percent of the participants did not answer the question.

Concerning responses to general tyre characteristics, up to 98% of the EV affiliated participants selected performance characteristics on a four-part scale from very important to not important at all: driving behaviour of the car—92%, fuel consumption—88%, wet braking behaviour—98%, grip in ice and snow—98%, and mileage/life expectancy—90%. The rates of the whole group were a little lower (with driving behaviour of the car—74%, fuel consumption—54%, wet braking behaviour—81%, grip in ice and snow—82%, and mileage/life expectancy—58%). These figures suggest a clear correlation between the consumers who look to purchase an EV or HV, and a broader regard and interest in a holistic approach to sustainability when looking at the automotive industry as a whole.

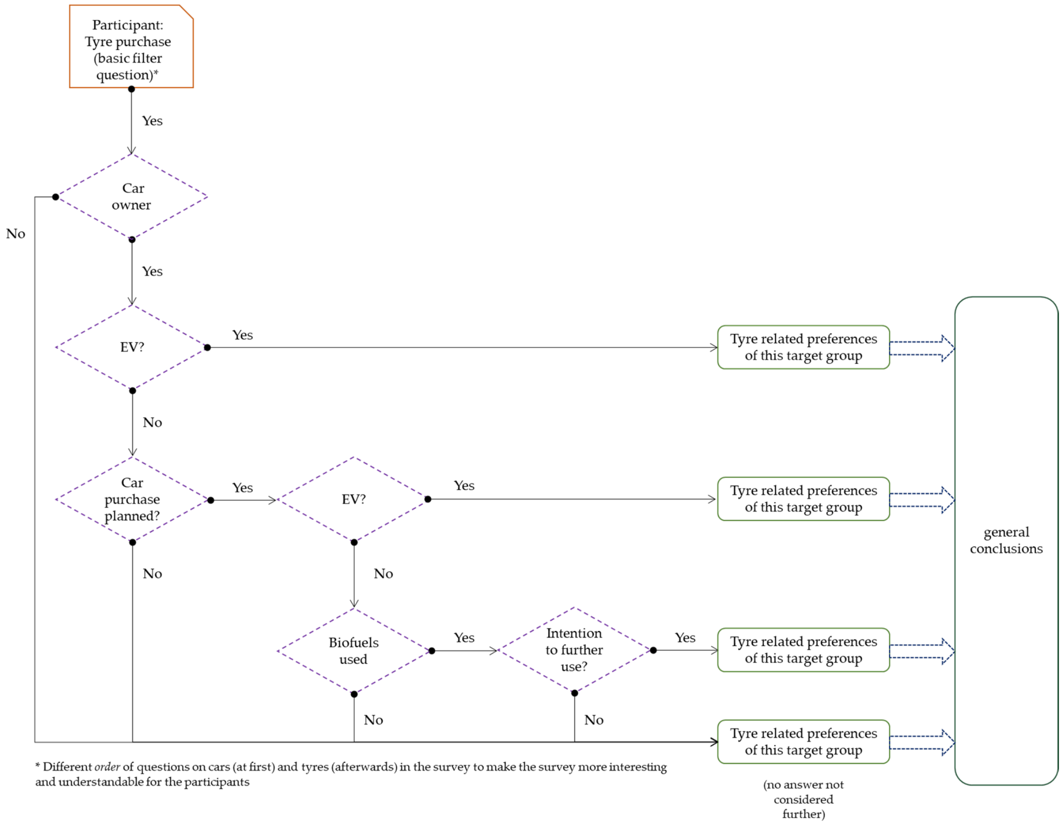


Figure 4. Identification of sustainability-oriented drivers in this study.

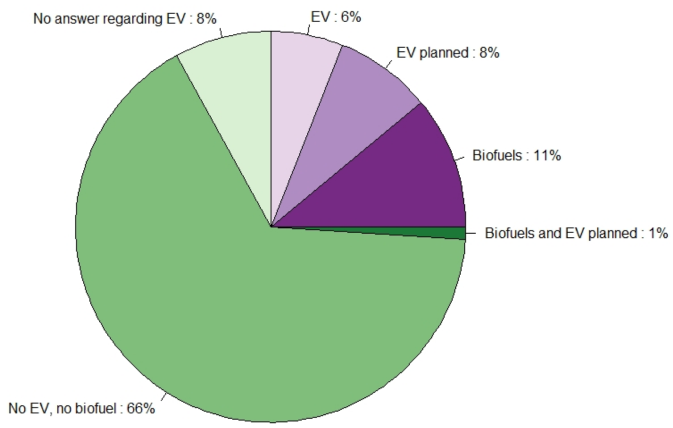


Figure 5. Distribution of car owners in the survey (N = 256).

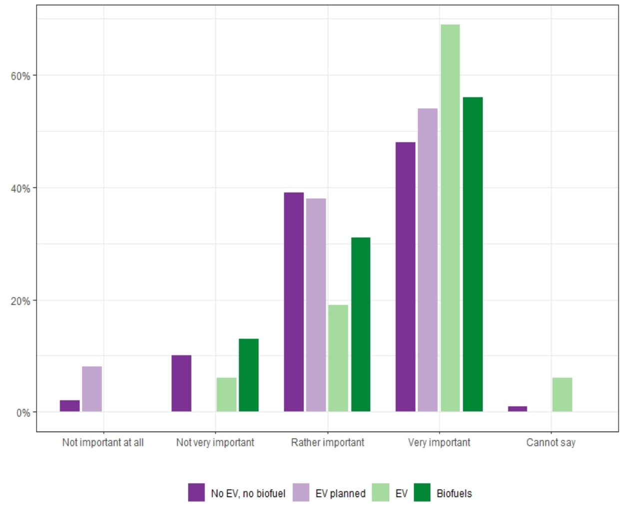
3. Results

3.1. Importance of Sustainability Information to the Target Groups

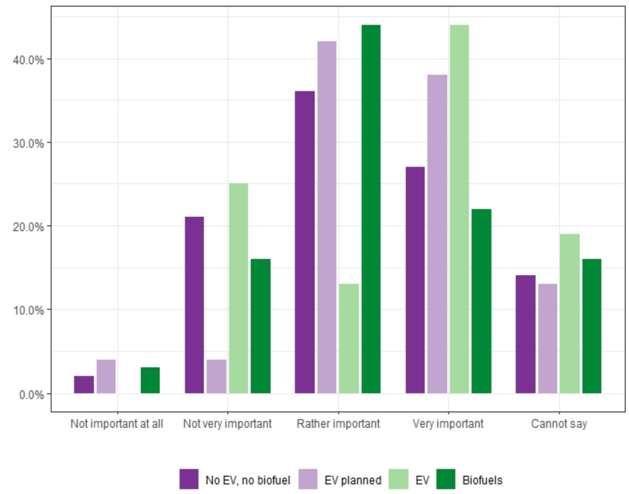
Based on the survey, data on the following topics was explored to specify the innovative CE configuration software and characteristics of sustainable tyres:

- Interest of different user groups in various types of sustainability aspects in the tyre purchase,
- Interest in specific sustainable tyres,
- Interest in individual tyre configuration and configuration software.

Of particular interest was the consumers' interest in sustainable tyre characteristics and specific types of sustainable tyres. A first question considered the importance of environmental information in the tyre purchase. Among the consumers who regarded environmental information as very important in their buying decisions, EV owners were, according to Figure 6, clearly leading with 69%, followed by biofuels users with 56% of the participants. Among consumers of the group 'no EV, no biofuel', the share was the lowest with 48%.



(**a**) Environmental information

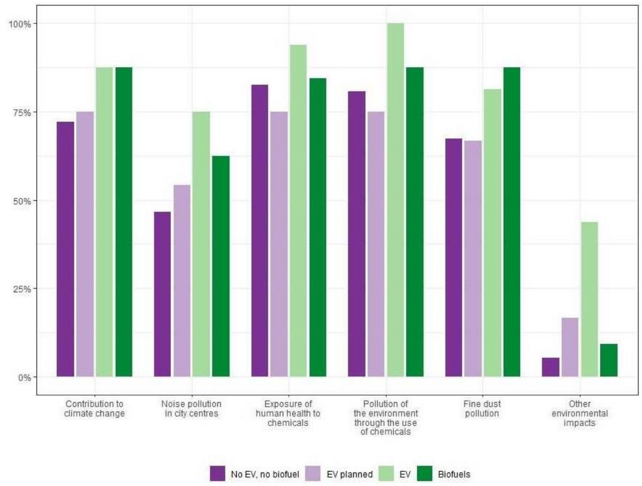


(**b**) Social information

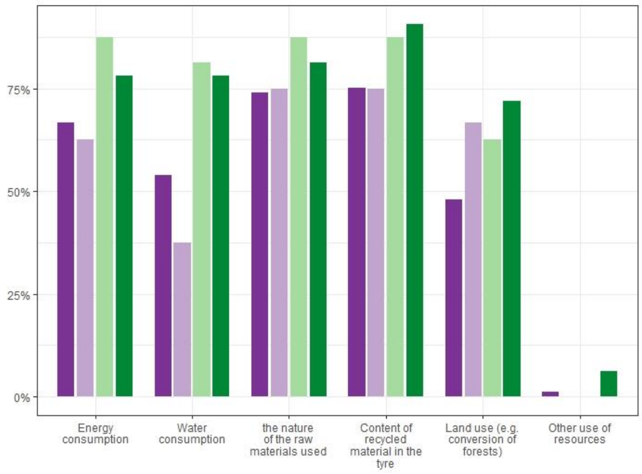
Figure 6. Importance of environmental and social information in tyre purchases for different tyre buyers (N = 236).

Regarding social issues, owners of EVs were once again the user group in which the most participants regarded information as very important for a tyre purchasing decision, according to Figure 6. A total of 44% of this user group's members gave this evaluation. However, compared to the results on the importance of environmental information, the results on social aspects were more varying. With regard to specific environmental aspects, resource-related information, and social issues, 16 items were discussed, from, for example, the content of recycled material in a tyre to fair play and working conditions. These items were only shown to consumers who expressed an interest in environmental and/or social information in the tyre purchase in general.

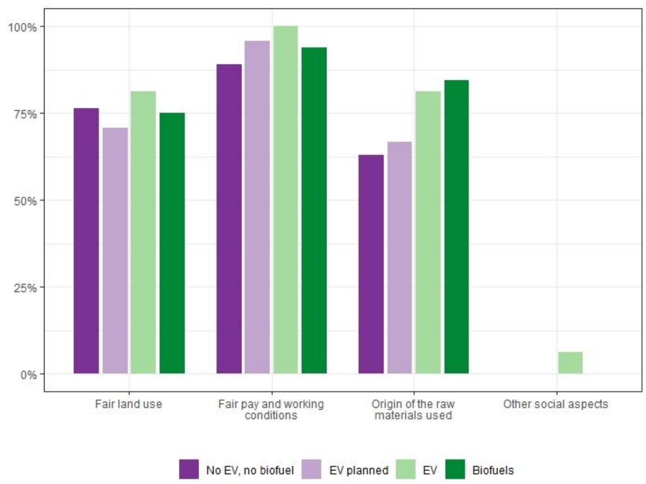
As shown by all segments of Figure 7, among all consumers with this general interest, the owners of EVs or biofuels users again selected the proposed specific criteria most often.



(a) Specific environmental information



(b) Specific resource-related information



(c) Specific information on social issues

Figure 7. Importance of specific sustainability aspects for tyre purchases (N = 233).

3.2. Interest in Sustainable Tyres and Software Tools

A particular question referred to the interest in sustainable tyres concerning three specific tyre types: tyres with a high proportion of materials from renewable resources, tyres with a high ratio of recycled content, and retreaded tyres.

The interest of biofuels users led for all three types of sustainable tyres, according to Figure 8, followed by the users of EVs.

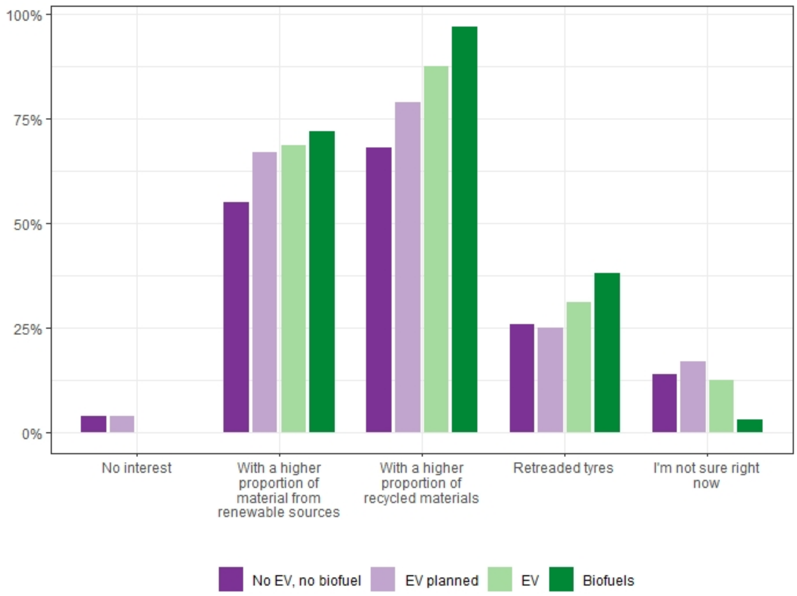


Figure 8. Interest in sustainable tyres per user group (N = 229).

With regard to an increase in interest in sustainable tyres due to options to select and configure tyre characteristics, EV users were the most affirmative with 100% positive answers to the question: 'In the ConCirMy project, software is being developed that suggests tyres based on preferences when buying a car. Would it be attractive for you to determine the characteristics of your tyres with this software or to configure them yourself during the ordering process?' (see Figure 9).

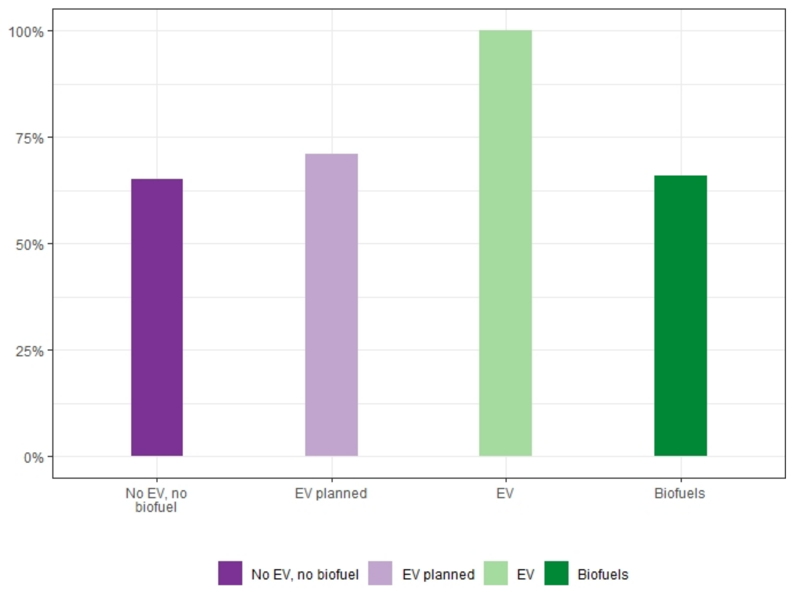


Figure 9. Interest in sustainable tyre configuration software per driver group (N = 217).

The question was introduced by a filtering question: 'Can your willingness to purchase environmentally friendly tyres be increased by an opportunity to select and configure tyre characteristics according to your preferences?'

Regarding specific selection features of the configuration software, the previously described interest in specific tyre characteristics was repeated with minor variations. Key preferences were observed, highlighting, for example, the importance of 'Wet breaking behaviour', 'Contribution to climate change', 'Pollution of the environment through the use of chemicals', 'Exposure of human health to chemicals', 'Recyclability', and 'Fair pay and working conditions'.

In summary, the results of the first statistical analyses suggested that car users are interested in innovative sustainable tyres and specific sustainability information for their purchasing decisions. In addition, the results showed that there is indeed interest in an innovative CE software system to specify tyres regarding individual sustainability preferences in combination with functional aspects. Section 3.3 analyses the data in more detail.

3.3. Multivariate Analyses

Following the analysis of descriptive survey statistics, a multivariate regression analysis was carried out in a second step to further investigate the variation across participant groups in their assessments of (1) the usage of configuration software, (2) the general interest in configuring tyres, and in tyres with a higher proportion of (3) recycled or (4) renewable materials. As the dependent variables were dichotomous, a logistic regression model was selected. The model controlled for demographic aspects and potential confounders and included the following variables:

- Age,
- Income,
- Perception of climate change,
- Use of tyre rating portals,
- The relevance of social and environmental aspects when buying tyres,
- Ownership of EVs or the willingness to purchase EVs in the future.

These variables were selected to represent the two main concepts that were theorised to be the underlying motivators for a more profound interest in environmentally friendly tyres:

(a) The perception of the relevance of environmental topics, and
(b) A general willingness to engage with the topic of tyres.

To avoid problems related to multicollinearity or a disproportion between the number of regressors and sample size, we selected specific variables (such as the perception of climate change) according to their correlation with similar variables and the extent to which they captured the relevant concept. Age and income were included in the model as continuous variables, based on the assumption of equidistant categories. Perceptions of climate change and EV ownership were modelled on three levels (no danger, medium danger, existential danger; no EV, EV planned, EV owned). The usage of tyre rating portals, and the relevance of social and, respectively, environmental aspects when buying tyres were represented by binary variables. Table 2 shows parameter estimates and associated standard errors for the logistic regression models (1) to (4).

Table 2. Result from logistic regression.

	Interested in	Using Configuration Software		Configuring Tyres		Tyres with a Higher Proportion of Recycled Materials		Tyres with a Higher Proportion of Materials from Renewable Resources	
Age		0.0748 (0.1732)		0.0751 (0.1614)		−0.5671 (0.1994)	**	−0.2031 (0.1602)	
Income		−0.1961 (0.184)		0.0073 (0.1673)		0.1444 (0.1921)		0.4367 (0.1713)	*
Perception of climate change	medium danger	0.8394 (0.5762)		0.0132 (0.5772)		−0.3587 (0.7431)		1.0331 (0.5845)	
	existential danger	1.2765 (0.621)	*	0.4711 (0.612)		−0.5873 (0.7682)		0.9122 (0.6033)	
Use of tyre rating portals		0.8257 (0.4095)	*	0.7828 (0.3791)	*	0.6543 (0.4406)		0.1717 (0.3849)	
Relevance when buying tyres	social aspects	−0.0101 (0.2841)		−0.4651 (0.2805)		0.0326 (0.3283)		0.2771 (0.2887)	
	environmental aspects	−0.0127 (0.3137)		0.2556 (0.2996)		0.1841 (0.3611)		−0.2357 (0.3278)	
EV	owns EV	16.4175 (1155.3287)		1.5169 (1.0779)		0.02 (0.8442)		0.3346 (0.7282)	
	plans to buy EV	0.0528 (0.6117)		−0.2773 (0.5631)		0.4387 (0.7154)		0.4572 (0.6387)	
Const		0.8772 (1.5659)		1.0306 (1.4596)		3.4838 (1.7638)	*	−0.8766 (1.4826)	
Observations		155		154		151		151	
Pseudo R^2		0.007		0.022		0.114		0.015	
AIC		181		202		165		202	

Logistic regression estimates with standard errors in parentheses. ** $p \leq 0.01$, * $p \leq 0.05$.

The interest to generally configure tyres was positively associated with a prior interest in tyres (expressed by the usage of tyre rating portals). This association was confirmed for the use of configuration software for environmentally friendly tyres, which was furthermore positively associated with the participants' perceptions of climate change as an existential danger. Interest in tyres with a higher proportion of recycled materials was negatively associated with age, while the interest in tyres with a higher proportion of materials from renewable sources was positively associated with income. Even though these relationships were significant on 0.95 confidence levels, the models have to be interpreted cautiously and do not necessarily represent conclusive robust results, as particularly EV ownership included very small sample sizes, and overall, most models did not manage to greatly outperform baseline models. However, the presented results are intuitive and can be considered input for subsequent studies.

Among the survey participants who perceived climate change as an existential threat to themselves and their families, a positive relationship was observed with regard to the willingness to use tyre configuration software.

The relation between age and the interest in tyres with a higher proportion of recycled materials was negative, which means that older people seem to have a lower willingness to buy these tyres. Survey participants using tyre rating portals had a higher interest in configuration software.

Furthermore, the relation between income and the interest in tyres with a higher proportion of material from renewable resources was positive, which means that people with a higher income seem to have a greater willingness to purchase tyres with a higher proportion of material from renewable resources.

While simple survey statistics showed that EV owners and users of biofuels were the most interested user groups, estimations from the regression model that controlled for demographic aspects rather suggested that the perception of climate change (as proxy for general environmental awareness) and the prior propensity to become informed about tyres were main influencing factors that determined interest in configuration software. The implications from these findings are discussed in the next section.

4. Discussion

User integration is an important method to develop and market products that meet consumer interest. Creating attractive, environmentally friendly products and marketing them successfully is of particular importance in this context.

The present research, which focused on an innovative CE automotive ecosystem and sustainable tyres, helped to specify product characteristics and target group characteristics, as well. Specifically, it aimed to provide answers to three questions:

1. Which input can be gained by conscious consumers to specify
    (a) sustainable tyres
    (b) innovative CE software to configure such tyres

    after making them aware of the sustainability problems of tyres?
2. Are sustainability-conscious
    (a) drivers who use biofuels
    (b) owners of EVs

    also more interested in sustainable tyres than other car drivers?
3. Are sustainability-conscious owners of EVs more interested in tyre configuration software than others?

With regard to Question 1, the majority of the conscious users showed interest in sustainable tyres with a higher proportion of materials from renewable resources and recycled materials, and in innovative configuration software for tyres. Their input to specify tyre characteristics focussed in particular on environmental properties. Even 48% of the consumers with no specific sustainability preferences regarding EVs or the use of biofuels so far regarded environmental information as very important for the purchase of tyres. However, regarding social aspects and information, the share was much lower. It ranged between 22% and 44%, depending on the type of car drivers.

Most specific environmental and resource-related aspects analysed by the survey were regarded as important by the majority of the participants. Examples included 'contribution to climate change' and 'pollution of the environment through the use of chemicals', chosen by more than 70%, which will encourage tyre producers and software developers to customise their products and product information accordingly.

Regarding Question 2, we did indeed observe a specific interest in sustainable tyres among car users who had a general interest in sustainable car characteristics. For the innovative ecosystem, their input was therefore of particular value.

Concerning Question 3, our descriptive survey statistics suggested a positive answer as well with regard to the conscious consumers of the present study. The results reflected the findings of (9,23) that consumers interested in EV show a specific interest in digital solutions and are also interested in sustainability information, requiring proof of true sustainability. In addition, the logistic regression showed the importance of the variables *perception of climate change* and *the use of tyre rating portals*.

As described in Section 2, all participants of the survey were quality-oriented consumers interested in environmentally friendly products, a target group of particular interest for CE products, according to [34]. The characteristics of EV owners were embedded in this context. Beyond this, they differed only slightly regarding additional attributes from the peers, for example, regarding the fact that the ownership of EVs, which are more expensive than cars in general, was often linked with a higher income. In this context, the logistic regression suggests also that people with a higher income have a greater willingness to purchase tyres with a higher proportion of material from renewable resources.

Because of the small sample size, especially in the case of EV owners, regression results might not sufficiently capture additional differences between EV, biofuel, and conventional fuel groups. For this reason, an additional study of 1000 average consumers with a driver's licence is prepared to launch. This may also provide tyre producers with additional hints as to what extent a stronger focus on producing more sustainable tyres suitable for EVs might be attractive. More studies should follow in the core phase of the majority stage of EV adoption.

5. Conclusions

5.1. Research on Sustainable Mobility

The present research used consumers as a valuable source of information to specify features of the output of an innovative CE ecosystem. Nevertheless, there are three limitations:

1. The results are based on an online survey, not on real behaviour and real buying decisions. The real behaviour will also depend on the marketing and perception of the configuration software.
2. The present study includes a relatively small sample of consumers with a specific sustainability focus in Germany only. Inspired by [24], the survey addressed consumers who showed a specific kind of sustainability behaviour by buying sustainable food to analyse additional mobility-related sustainability characteristics. Based on [34] s classification, they represented the specific characteristics of not only one but two CE target group(s): sustainability and quality-oriented customers. EV ownership was a frequent characteristic of the participants with higher income but was also embedded in the specific context of pro-environmental, quality-seeking behaviour.
3. The survey was conducted before the beginning of the Coronavirus crisis and therefore before current discussions to support the automotive industry during the crisis by providing incentives to buy new cars, and EVs, in particular. In future research, it will also be important to distinguish between early EV adopters and mainstream adopters buying EVs as a reaction to these stimuli. This will give more in-depth insight into what extent early and mainstream EV adopters are interesting target groups for additional sustainable car products.

In summary, more research will be necessary to update our results in the given context. A broader study with 1000 consumers with no specific sustainability-oriented habits is already prepared.

5.2. Research on Innovation Ecosystems

According to Section 1, an explicit user focus, as adopted in this article, sheds light on an ecosystem actor who has received little attention in the circular ecosystem context so far, despite being particularly interesting. On the one hand, such a perspective encompasses direct users, whose customer demands do not only need to be addressed for commercial reasons but also depict a valuable source of additional innovation impulses (see Section 5.3). On the other hand, the approach can easily be expanded to include non-users and the broader society, whose expectations should be taken into account, as broad societal acceptance (beyond immediate users) is indispensable for a successful transition towards the circular economy. Whereas the former perspective is at the core of this article, the latter opens up promising avenues for further inquiry. Future research may thus focus on questions of how to best integrate both users and societal stakeholders in (CE) innovation ecosystems, at what point in the innovation process such involvement should take place and which formats are best suited to enable fruitful collaboration. Only if both policy makers as well as innovation practitioners adopt a broad ecosystem understanding and commit to involving stakeholders beyond their immediate value chain will they be able to leverage the full potential of their ecosystem for a circular economy transition.

5.3. Research on User Innovation

Innovation processes with users can be differentiated according to different levels of user involvement and user contribution. Processes with a strong user involvement are those in which the users themselves are the innovators. Those users are also called user–innovators [35]. In the given context, the users gave input to shape the future ecosystem and its products, specifying important ecosystem and product characteristics. Nevertheless, the users in the given case were not involved in the decision-making to determine the final system and product features.

In contrast to this, various examples exist in which the users had a bigger influence on the innovation process, while innovation processes were also very successful, for example, in online user communities and with regard to smart energy innovations [35–37].

In the CE context, information on such processes so far barely exists. To exploit knowledge on successful user innovation, stimulating innovation with a higher level of user involvement to support the CE is suggested as well as an analysis of the factors that make such processes successful.

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