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Tailored information on alternative fuels: Segmenting future consumers' preferences for information and communication related to alternative fuels

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ABSTRACT

Increasing emissions in the mobility sector pose a significant challenge for modern society, contributing extensively to climate change. One promising approach to mitigating these emissions is the development of CO_2-based alternative fuels, which can reduce dependence on fossil fuels, such as gasoline and diesel, by capturing and reusing CO_2 emissions. While the technical feasibility of these fuels has been widely studied, limited research exists on consumer preferences regarding how information about alternative fuels is communicated. Understanding communication preferences is essential and critical for designing effective communication strategies that foster public acceptance and adoption, as they shape how individuals process information, form attitudes, and ultimately decide whether to adopt sustainable technologies. To address this gap, an online survey study ($N = 215$) was conducted to explore laypeople's perceptions of alternative fuels, focusing on their information needs and communication preferences. The results revealed two distinct consumer clusters with differing expectations for content, channels, and trusted sources of information and communication. One group preferred detailed, science-based information from institutions, while the other favored accessible, practice-oriented content from industry or media. These findings emphasize the need for tailored communication strategies that reflect varying trust dynamics and information preferences. They offer practical guidance for policymakers and industry actors aiming to increase public engagement and acceptance of CO_2-based alternative fuels.

1. Introduction

The ongoing dependence of our society on fossil fuels poses a persistent threat to the climate and the environment due to the continuous release of carbon dioxide (CO_2), contributing to global warming. The transportation sector accounted for over one-third of global emissions [1] representing the second-highest sector behind electricity and heat [2]. This sector's decarbonization is particularly urgent due to its direct reliance on fossil fuels, limited electrification in heavy transport, and high visibility in daily life.

Therefore, efforts are made to explore and implement more environmentally friendly alternatives to meet the fuel demands of the transport sector. Alternative fuels, such as biofuels or e-fuels [3], have the potential to reduce fossil fuel usage in high-emission sectors [4]. However, while their technical feasibility and climate benefits have been well-documented, the success of these innovations increasingly hinges on their societal acceptance. While these innovations offer benefits for climate protection, it is not guaranteed that they will be accepted and sustainably adopted by the public. In contrast, the introduction of new technologies often leads to public discussions and resistance [5]. The historical implementation of energy technologies emphasizes the importance of public perception and acceptance in successfully integrating a technology or innovation into existing energy infrastructure and systems [6]. This includes the role of values, risk perceptions, trust, and importantly, information and communication strategies.

Targeted, tailored, and timely information and communication are necessary and critical to prevent or at least minimize the risk of a lack of public support and willingness to adopt the integration of more environmentally friendly alternatives. Against this backdrop, this study focuses on this significant research gap. While prior studies have examined the general social acceptance of alternative fuels [7], there is a lack of in-depth understanding regarding how individuals – particularly future consumers – evaluate and respond to information and communication efforts concerning these fuels. Questions remain about what type of information is perceived as credible, timely, and relevant, and how communication strategies might influence willingness to adopt new fuel

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Nomenclature

α	Cronbach's alpha: reliability coefficient
χ^2	Chi-square of chi-squared test
CO_2	Carbon dioxide
F	F statistic of analysis of variance
M	Mean
M_P	Mean of preferred sources of information
M_T	Mean of trusted sources of information
N	Number of participants (whole sample)
n	Number of participants (subgroups)
n.s.	not significant
p	Level of significance
PT	Public transport
SD	Standard deviation
SD_P	of preferred information sources
SD_T	of trusted information sources

types in private transport contexts.

Therefore, the present study offers a novel contribution by analyzing future customers' informational and communicative preferences concerning alternative fuels. Based on a quantitative online survey, we investigate how tailored communication can enhance the public's readiness to engage with cleaner fuel technologies.

This study aims to examine how future consumers in the private transport sector perceive, evaluate, and prioritize different types of information and communication strategies related to alternative fuels. To achieve this aim, the study investigates general preferences for information and communication on alternative fuels as well as group-specific preferences based on applied cluster analyses. In doing so, this paper provides empirically grounded insights into how to better align public outreach with societal values and informational needs – an aspect crucial to the effectiveness of future mobility transitions.

In summary, this study addresses a critical gap in the literature by focusing not just on the general acceptance of alternative fuels, but on the specific informational and communicative preferences of future consumers in the private transport sector. Unlike previous research, which has largely emphasized technical or macro-social factors (e.g., [7,13,15]), this study takes a consumer-centered perspective rooted in communication needs. This novel focus is necessary to inform more effective public outreach and policy design, especially as technological readiness alone is insufficient to drive behavioral adoption. By offering empirical insights into how communication strategies can be better aligned with user expectations, this study contributes both to academic discourse and to the practical advancement of sustainable mobility solutions.

In the following, the theoretical background is presented, starting with the technical state on alternative fuels, followed by empirical research on the acceptance and perception of alternative fuels. Finally, the research aim and research questions of the present study are introduced.

1.1. Alternative fuels as an environmental measure

The mobility sector is a major contributor to global greenhouse gas emissions, accounting for around a quarter of direct CO_2 emissions from fuel combustion worldwide [8]: In the European Union, the transport sector is responsible for almost a quarter of total emissions, and, unlike other sectors, its emissions have continued to rise over the past few decades. This trend highlights the urgent need for solutions that go beyond electrification, especially in hard-to-abate areas such as aviation, shipping, and long-distance freight.

CO_2-based alternative fuels – also known as synthetic fuels or e-fuels – offer a promising pathway by enabling the use of renewable energy and captured carbon to produce drop-in fuels compatible with existing combustion engines and infrastructure [3,4]: These fuels are synthesized by combining green hydrogen (produced via electrolysis using renewable electricity) with captured CO_2 through processes such as Fischer–-Tropsch or methanol synthesis. The reuse of CO_2 emissions that replace fossil resources in the production of the fuel can significantly reduce life-cycle emissions, assuming low-carbon inputs are used throughout production.

Since there is no standardized definition for "alternative fuels" [9], we define alternative fuels in our studies and in this paper as any liquid or gaseous fuel [10] that can replace traditional gasoline and diesel in internal combustion engines and that is derived from renewable resources such as biomass or synthesized from CO_2, water, and green electricity [3]. The development and production of alternative fuels is driven by the need to reduce the use of fossil fuels in the transportation sector [9] and replace them with renewable resources and energy [11]. To achieve de-fossilization and emission reduction, it is crucial to use renewable electricity in the production process [10].

Two primary production pathways for renewable alternative fuels can be distinguished: e-fuels and biofuels. E-fuels or CO_2-based fuels, also known as electro-fuels or synthetic fuels, represent a category of renewable fuels produced by synthesizing hydrogen, typically generated via electrolysis using renewable electricity, with captured carbon dioxide (CO_2) [3,4]. This process results in the formation of hydrocarbons that can be utilized as substitutes for conventional fossil fuels. In contrast to biofuels, which are derived from organic biomass such as crops or waste [10], e-fuels do not rely on agricultural feedstocks. This characteristic avoids potential land-use conflicts and the debate surrounding the use of food versus fuel. Instead, e-fuels are produced through power-to-liquid (PtL) or power-to-gas (PtG) technologies, offering emission reduction if the production is powered by renewable energy and paired with sustainable CO_2 sources. The e-fuel family includes e-methane, e-methanol, e-diesel, e-gasoline, and e-kerosene, each with potential applications across sectors such as aviation, shipping, and road transport.

Recent studies, including those by the International Energy Agency [8] and the E-Fuel Alliance (e.g., [12]), underscore the potential of e-fuels as a complementary solution for sectors with significant de-carbonization challenges, particularly in scenarios where battery-electric alternatives encounter infrastructural or performance limitations. Consequently, e-fuels are garnering heightened consideration in policy deliberations concerning long-term climate-neutral mobility.

Considering the different characteristics of different alternative fuels, their advantages and disadvantages depend on the specific fuel type. Compared to electric vehicles, and apart from the potential reduction of CO_2 and pollutant emissions, some advantages of alternative fuels include increased energy density [13] and compatibility with conventional engines and existing infrastructure [14]. However, some alternative fuels may require vehicle conversion or be restricted to certain engines [15]. E-fuels can also be used to store excess renewable energy, helping to mitigate fluctuations in electricity supply and demand [13]. Despite their potential, large-scale adoption of CO_2-based fuels faces several barriers, including high production costs [9], energy inefficiencies [11], and limited industrial-scale deployment [3]. Furthermore, the introduction of alternative fuels that are not compatible with the existing infrastructure requires the construction of new supply infrastructure. Therefore, it is important to prioritize fuels that are highly compatible with current engines and infrastructure [9].

Beyond environmental and economic aspects, the health implications of alternative fuels are increasingly relevant to public perception and acceptance. Traditional fossil fuels such as gasoline and diesel are major sources of air pollutants, including e.g., particulate matter (PM), or nitrogen oxides (NO_x), which are associated with serious health issues such as respiratory and cardiovascular diseases, and even premature

mortality. In contrast, many alternative fuels – particularly e-fuels and advanced biofuels – have the potential to significantly reduce harmful emissions [16,17] when produced and used sustainably. For instance, studies have shown that synthetic fuels can lead to lower emissions of NO_x and PM under specific combustion conditions, contributing to improved urban air quality [18]. However, the health benefits depend heavily on the production process and fuel composition, as some biofuels may emit new or different pollutants if not properly regulated. Overall, while alternative fuels are not entirely emission-free, they generally pose fewer risks to human health than conventional fossil fuels, making them a promising component of both climate and public health strategies.

Nonetheless, alternative fuels are increasingly seen as a critical component of climate-neutral mobility strategies, with multiple pilot projects under development and policy interest growing across the EU and globally [19]. As these technologies move closer to commercialization, public awareness, trust, and willingness to adopt become essential – making it crucial to understand how different potential consumer groups receive and respond to information about such innovations.

Despite the growing technical literature on e-fuels and biofuels, few studies address how future users engage with these developments from an informational or perceptual standpoint. Understanding how individuals receive and prioritize communication around alternative fuels is thus essential – yet remains underexplored. This forms the basis of the present study.

1.2. Public perception of alternative fuels

In addition to the technical characteristics and the economic and environmental potential of alternative fuels, current social science research places increasing emphasis on the investigation of public perception and acceptance of these fuels, as public acceptance is a critical determinant for the market success of innovative and sustainable technologies. A lack of public acceptance can hinder the adoption of innovative technologies or products, leading to protests or rejection of economically and ecologically beneficial innovations, e.g., low-carbon energy projects [20] or renewable energy development, e.g., wind power systems [21]. Therefore, it is crucial to iteratively assess and consider technology perceptions and acceptance among all relevant stakeholders from the beginning of the development phase to identify and address perceived concerns and barriers as well as potential misconceptions or misinformation at an early stage. In this way, acceptance research aims to enable all stakeholders to make informed acceptance decisions based on verifiable information, and to incorporate stakeholder perspectives, concerns, and requirements into the technology development process.

In this context, there are different definitions of technology acceptance. Here, (public) acceptance is defined as the active or passive approval of a technology or product [22], which is assumed to exist when there is no active opposition to it [23]. Closely related to and shaping the acceptance of a technology or product, public perception refers to evaluations in terms of the public's understanding of technologies, which can be empirically measured by indicators such as perceptions of benefits, barriers, or risks [24].

In recent years, research has increasingly focused on the public perception and acceptance of alternative fuels, revealing positive acceptance ratings based on perceptions of their positive impact on the climate [25]. In addition to environmental benefits, economic benefits [26], technical benefits compared to electric vehicles, e.g., in terms of range or compatibility [27], and established factors such as efficiency and perceived usefulness [28] have been identified as relevant parameters for the acceptance of alternative fuels.

However, perceived risks and barriers persist. Examples include barriers related to the location, number, and size of fuel infrastructure [27], the need for new infrastructure [29], financial barriers, and lack of information [30]. Although research has shown that the risk perception of alternative fuels is lower than that of conventional fuels [31], alternative fuels are still associated with risks to the environment [32] and human health [33]. For example, concerns relate to the production process of alternative fuels, such as CO_2 leakage, which in turn are associated with threats to the environment and human health [34]. Furthermore, individual factors and perceptions have been identified as influencing parameters for the acceptance of alternative fuels. In this context, first results showed that the residential location of future customers of alternative fuels is relevant for acceptance [35], while other studies focused on the location type of the filling station and disproved direct effects of socio-demographic and spatial factors on acceptance [36]. Previous (low) knowledge of alternative fuels was another relevant factor in predicting the alternative fuel acceptance [37].

In addition to environmental and technical considerations, cost remains a critical factor shaping public perception and acceptance of alternative fuels. While many individuals express general support for climate-friendly innovations, they often perceive alternative fuels as more expensive and less economically viable than conventional options [38]. These price concerns can generate skepticism, especially in the absence of clear, transparent information regarding long-term cost benefits, subsidies, or infrastructure development. Studies have shown that perceived affordability directly influences willingness to adopt low-carbon technologies [39], with higher prices frequently cited as a barrier to acceptance. This underlines the importance of not only developing cost-effective solutions but also of communicating pricing structures and economic implications in ways that are accessible, trustworthy, and aligned with consumer expectations.

Despite this body of research, little is known about how potential users assess communication and information strategies concerning alternative fuels. This study addresses this gap by examining how future consumers evaluate, prioritize, and respond to different information and communication approaches, thereby offering new insights into the communicative dimensions of technology acceptance.

1.3. Impact of information and communication

Due to the limited public knowledge and technical complexity of alternative fuels, these technologies are often perceived as risky or unfamiliar innovations, even when concrete risks are not apparent [40]. For many potential consumers, there is little direct experience with such fuels, which contributes to uncertainty and caution.

In this context, previous research has highlighted the central role of trust – not only in the technology itself but, more importantly, in the stakeholders responsible for its development, implementation, and communication [41]. Trust refers to the expectation that information is accurate, reliable, and not misleading, making it a fundamental prerequisite for public credibility and acceptance. Empirical studies have shown that trust in organizations can significantly shape perceptions of risk and influence acceptance outcomes for new technologies [42].

Building on this, credible communication is essential for fostering acceptance. Studies have demonstrated that transparent, balanced information – emphasizing both benefits and potential risks – is more effective than promotional messaging alone [45]. When information is perceived as one-sided or incomplete, it can trigger skepticism, perceptions of greenwashing, or manipulation, ultimately reducing trust in the actors involved and decreasing technology acceptance [43].

From a marketing perspective, the credibility of information sources is particularly important when promoting sustainable or "green" innovations. Consumers tend to scrutinize such claims more carefully, and their decisions are often shaped by their trust in the communicators as much as by the content of the message itself [44].

In summary, empirical research on alternative fuels has begun to explore how public trust, communication strategies, and perceptions of credibility influence acceptance. However, there is limited insight into the preferences of future consumers regarding specific aspects of

communication—such as the type of information desired, the channels used, and the perceived trustworthiness of various sources. These gaps are especially relevant for informing effective communication strategies and ensuring the successful market introduction of alternative fuels.

1.4. Research aim and questions

Building on prior research into the acceptance of alternative fuels, this study investigates how future customers perceive and evaluate information and communication related to alternative fuels. Specifically, it explores which types of information are considered necessary, how information should be conveyed, which channels are preferred, and which actors are perceived as trustworthy sources. These aspects are critical for designing communication strategies that foster informed decision-making and public trust—two key prerequisites for the successful introduction of alternative fuels.

The research addresses both the general patterns across the full sample and potential differences between distinct customer segments. This two-step approach allows for a differentiated understanding of segment-specific communication needs, which can inform tailored outreach strategies and reduce the risk of rejection or misinformation.

- What are the preferences of future customers regarding information and communication about alternative fuels? (RQ1)
- Are there customer segments differing in their information and communication preferences, and how can they be characterized? (RQ2)
- To what extent do the identified customer segments differ in their information and communication preferences? (RQ3)

2. Methodological approach

In the following, this study's applied empirical approach is presented aiming at a quantification and segmentation of future customers' information and communication preferences related to alternative fuels. First, the concept and design of the online survey is described. Afterwards, the procedure of data analysis as well as the characteristics of the sample are introduced.

2.1. Concept and design of the online survey

The online survey consisted of different parts, which are described in this section. Appendix 1 shows an example of the survey's questions to illustrate the procedure.

Following an introduction to the topic of the survey, the first part asked for **demographic information** (i.e., age, gender, educational level). In addition, the participants indicated whether they live in a rather rural or rather urban area.

In a second part, the participants provided information about their **mobility behaviour** by indicating how often they drive by car or public transport. In this context, the participants also reported if they have a driver's license and if they own a car. On a six-point Likert scale, the participants assessed to what extent they need a car in their daily life (min=1; max = 6).

The third part of the online survey focused on the assessments of different **individual attitudes** of the participants. In this regard, the participants' general attitude towards technology was evaluated using 4 items (Cronbach's α=0.65, based on [46]). Further, the participants' environmental attitude was assessed using 7 items (Cronbach's α=0.87, based on [47]). The participants also evaluated their attitude towards car driving using 6 items (Cronbach's α=0.80).

In the next part of the survey, the participants were introduced to the **topic of alternative fuels** and explanations of bio- and e-fuels were provided as examples for alternative fuels distinguishing it from electric drives. Following the explanations, the participants evaluated their perception of feeling informed about alternative fuels. Then, *perceived advantages* (7 items, Cronbach's α=0.86), *perceived disadvantages* (6 items, Cronbach's α=0.76), *general acceptance* (5 items, Cronbach's α=0.91), and the *intention to use and buy* alternative fuels (4 items, Cronbach's α=0.85) were evaluated.

Starting the **information- and communication-related part** of the survey, the participants firstly assessed a statement asking for their information need regarding alternative fuels (min = 1; max = 6). Referring to the statement "The following topics are of interest to me when I think about alternative fuels", the participants evaluated their *interest in specific information topics* covering a broad range such as environmental aspects, i.e., "sustainability of energy and resource use" up to economic or technical aspects (using 17 items, Cronbach's α=0.88, see Table 1). Further, the participants evaluated 9 different *information channels* to the effect that they would use them to inform about alternative fuels, e.g., "print media" or "television" (Cronbach's α=0.61, see Fig. 1). For insights in how alternative fuels should be communicated, the participants evaluated for requirements of information and communication: "neutrality", "comprehensibility", "necessary expertise", and "balance" (Cronbach's α=0.61). As a last aspect, the participants assessed different sources (see Fig. 2) of information regarding their preferred *source of information* (using 9 items, Cronbach's α=0.80) and *trust in those sources* (using 9 items, Cronbach's α=0.74).

Six- point Likert scale assessments were used for measuring attitudes, perceptions of alternative fuels and information and communication preferences (min = 1; max = 6). Means ⟨ 3.5 represented rejection and means ⟩ 3.5 agreement of a statement. At the end of the survey, there was the opportunity to provide feedback and comments on the survey itself or the topic.

2.2. Data acquisition and analysis

Data was collected based on random sampling in Germany during the summer of 2022. The survey items were developed based on a literature review, qualitative pre-studies as well as on pretested item sets within alternative fuel measurements. Prior to data acquisition, the survey was checked on comprehensibility, wording, and length. On average, the respondents needed 15 min to complete the survey.

As only complete data sets can be used for further analyses, incomplete and inconsistent data sets were excluded.

The descriptive results are reported by means (M), standard deviations (SD) as well as percentages (%) and absolute frequencies (n) of the sample. Reliability analysis ensured the measurement quality of all constructs (Cronbach's α >0.6).

To identify distinct consumer segments based on their preferences

Table 1
Descriptive statistics for surveyed characteristics of the participants.

Sample (N = 215)		
Demographics		
Age	M(SD)	30.0 (8.90)
Gender	female	31.6 % (n = 68)
	Male	67.9 % (n = 146)
Educational level	University degree	42.3 % (n = 91)
	University entrance degree	27.0 % (n = 58)
	Lower degrees	30.7 % (n = 66)
Living Location	rural	24.2 % (n = 52)
	urban	75.8 % (n = 163)
Mobility Behaviour		
Car use	M(SD)	4.40
Public transport use	M(SD)	3.38
Car Owner	yes	57.7 % (n = 124)
	no	24.7 % (n = 53)
no, but access		17.7 % (n = 38)
Alternative Fuel Perception		
Advantages	M(SD)	4.72 (0.76)
Disadvantages	M(SD)	3.28 (0.75)
Acceptance	M(SD)	4.64 (1.01)
Intention to Use	M(SD)	4.62 (1.11)

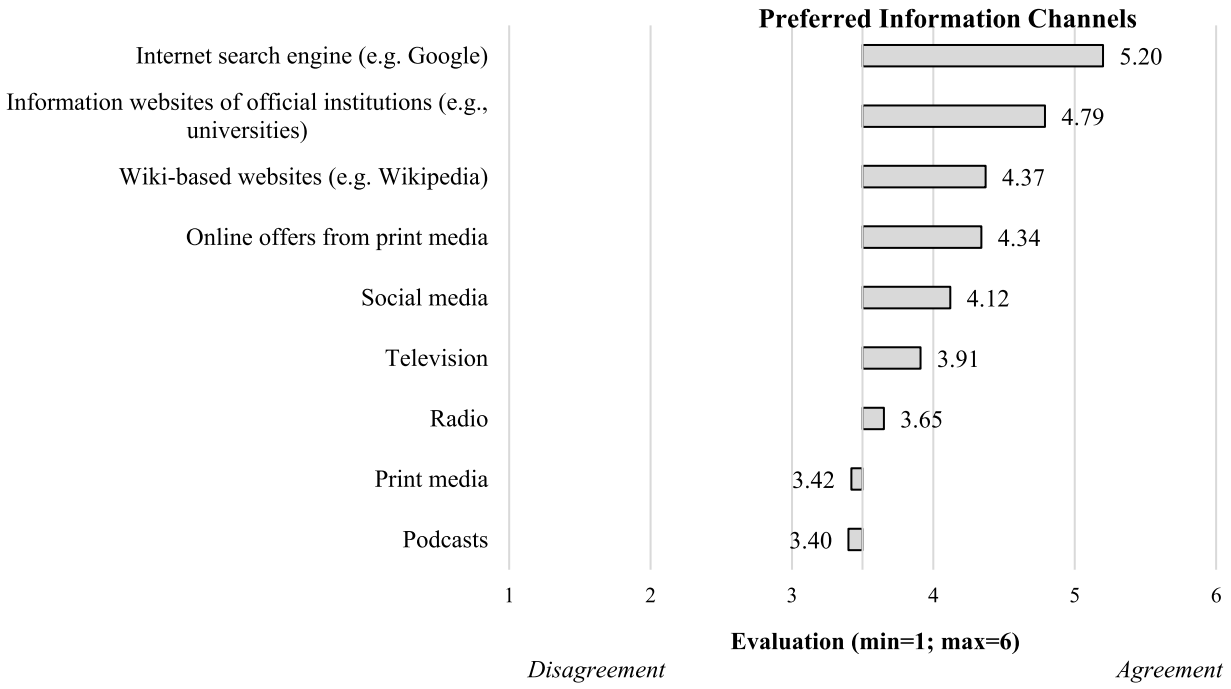

Fig. 1. Preferred information channels (whole sample).

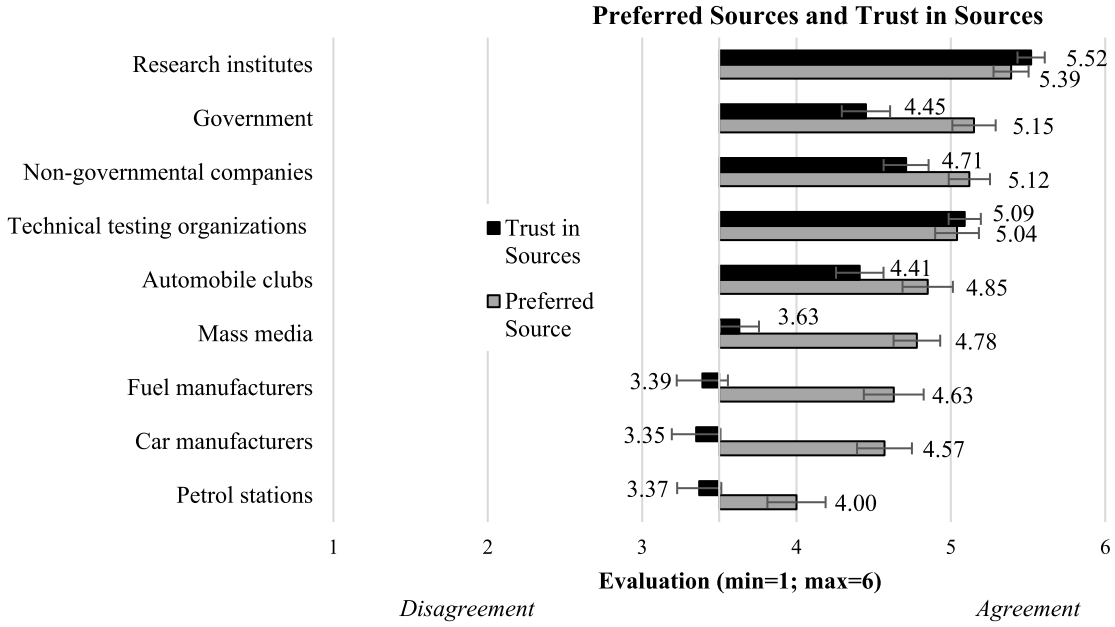

Fig. 2. Preferred sources and trust in sources of information (whole sample, error bars indicate 95 % confidence intervals).

for information and communication about alternative fuels, a two-step cluster analysis approach was employed [48]. First, a hierarchical cluster analysis was conducted to explore the optimal number of clusters by examining dendrograms and agglomeration coefficients, suggesting a two-cluster solution. This initial solution was then refined using k-means cluster analysis to assign participants more precisely to clusters based on their evaluations of information and communication preferences related to alternative fuels. The resulting two clusters represented groups of participants with distinctly different preference patterns. To validate the robustness of this segmentation, one-way ANOVAs were performed comparing the clusters on all relevant construct scores. The analyses revealed statistically significant differences between the two clusters across every measured preference dimension, confirming that the clusters captured meaningful and distinct consumer segments. This two-step approach, combining exploratory and confirmatory clustering with statistical validation, ensured both the reliability and interpretability of the identified consumer clusters.

The level of statistical significance (p) was set at the conventional level of 5 % (* = $p < .05$; ** = $p < .01$). Values above $p > .05$ were interpreted as not significant (n.s.).

2.3. Characteristics of the participants

Overall, $N = 324$ respondents participated in the online survey. As only complete data sets could be used for further statistical analysis, $N = 215$ data sets remained after data cleaning (exclusion of speeders,

incomplete and inconsistent answers) and the characteristics of the participants are presented in Table 1. The participants were on average rather young (min=18; max=64) and the sample consisted of a higher proportion of males compared to females. The educational level of the sample was rather high with the majority holding a university degree or a university entrance degree. When asked for their living location, most of the participants reported to live in an urban area, while a minority of 24.2 % ($n = 52$) indicated to live in a rural area.

Besides demographic information, the participants were also asked for their mobility behaviour. Most of the participants indicated to hold a driver's license (89.8 %, $n = 193$). Further, more than half of the sample reported to have their own car, while smaller proportions of the sample reported to have no car or to have access to a car (e.g., car sharing, company car). Asked for the frequency of use (min = 1: never; max = 6: daily), most of the participants reported to use a car daily or several times a week. Fewer proportions indicated to use the car only once a week once a month, less often, or never. On average and compared to that, the usage of public transport was on a lower level.

When asked for their perception and acceptance of alternative fuels (min = 1; max = 6), the participants showed a positive evaluation of perceived benefits ($M = 4.72$, SD=0.76) and a slight rejection of perceived barriers of alternatives fuels ($M = 3.28$; SD=0.75). These positive ratings and perceptions were accompanied by a positive acceptance assessment ($M = 4.64$; SD=1.01) as well as a positive intention to use alternative fuels ($M = 4.62$; SD=1.11).

3. Insights in general and group specific communication preferences

This section presents the results of the conducted study. In a first step, the results for the whole sample of participants are described (RQ1). In a second step, a segmentation of distinct clusters of future users of alternative fuels is introduced (RQ2), characterizing the clusters' preferences (RQ3) as well as their specific characteristics.

3.1. General information and communication preferences (RQ1)

When asked about *preferred topics for alternative fuel information*, all of the individual topics received a rating above the mean of the scale (3.5) indicating the relevance of these topics in general (Table 2). In more detail, the range of the evaluations allows to differentiate between more and less relevant information topics. In this regard, information about the "sustainability of energy and resource use", "environmental impacts due to use", "efficiency", "availability", and "usage costs for drivers" represented the five most relevant aspects. Compared to that, information related to "risks of use", "manufacturing costs", "user-friendliness/handling", "manufacturing process", and most clearly "technical details" received the lowest, still positive assessments.

Table 2
Preferred Topics of information (whole sample).

Preferred Topics	Evaluation ($N = 215$)	
	M	SD
Sustainability of energy and resource use	5.27	0.91
Environmental impacts due to use	5.24	0.94
Efficiency	5.24	0.77
Availability	5.18	0.86
Usage costs for drivers	5.18	0.95
Range of use	5.13	1.02
Environmental impact of the production process	5.03	0.98
Possible applications (passenger car, shipping, airplane)	5.03	0.98
Current state of research	4.90	0.99
Raw materials used	4.88	0.96
Compatibility with my vehicle	4.83	1.31
Economic impact	4.82	1.09
Risks of use	4.80	1.10
Manufacturing costs	4.77	1.05
User-friendliness/handling	4.71	1.12
Manufacturing process	4.37	1.26
Technical details (e.g., fuel composition)	3.87	1.43

Focusing on *preferred information channels,* the results (Fig. 1) show a clear distinction between the different options. "Internet search engines" represented the most desired information channel ($M = 5.20$; SD=0.84), followed by "information websites of official institutions" ($M = 4.79$; SD=1.31), wiki-based websites ($M = 4.37$; SD=1.37), and "online offers from print media" ($M = 4.34$; SD=1.37). In comparison, "social media" ($M = 4.12$; SD=1.59), "television" ($M = 3.91$; SD=1.61), and "radio" ($M = 3.65$; SD=1.58) were less preferred channels of information. "Print media" ($M = 3.42$; SD=1.61) and "podcasts" ($M = 3.40$; SD=1.63) received the lowest assessments at a neutral value level.

Further, the participants assessed four aspects being of importance as *requirements for alternative fuel information* and all of them received high confirming evaluations. In more detail, "neutrality" ($M = 5.61$; SD=0.68) of information was most important, followed by having "necessary expertise for adequate information" ($M = 5.53$; SD=0.63), "balance" ($M = 5.48$; SD=0.71), and "comprehensibility" ($M = 5.09$; SD=0.90) of information.

Finally, participants rated *their preferred source of information* (P) as well as *their trust* (T) in those same sources (Fig. 2). Overall, all considered sources of information received confirming evaluations, while the trust-related ratings were characterized by a higher dispersion. In more detail, "research institutions" represented the most preferred source of information (M_P=5.39; SD_P=0.85) and received the highest trust-related assessments (M_T=5.52; SD_T=0.66). In line with this, "technical testing organizations" received both, high preference (M_P=5.04; SD_P=1.06) and trust evaluations (M_T=5.09; SD_T=0.78). Further, "government" (M_P=5.15; SD_P=1.05, M_T=4.45; SD_T=1.17), "non-governmental companies" (M_P=5.12; SD_P=1.00, M_T=4.71; SD_T=1.09), and "automobile clubs" (M_P=4.85; SD_P=1.22, M_T=4.41; SD_T=1.11) were confirmed to be preferred sources of information, while they received lower, but still positive evaluations in terms of trust. The differences for "mass media" (M_P=4.78; SD_P=1.13, M_T=3.63; SD_T=0.95), "fuel manufacturers" (M_P=4.63; SD_P=1.45, M_T=3.39; SD_T=1.24), "car manufacturers" (M_P=4.57; SD_P=1.33, M_T=3.35; SD_T=1.18), and "petrol stations" (M_P=4.00; SD_P=1.41, M_T=3.37; SD_T=1.07) were even more striking: these four sources were confirmed as preferred sources of information, while the participants rated their trust in these sources significantly less positively (neutral values around the middle of the scale).

3.2. Segmenting future customers' preferences: A cluster analysis (RQ2 & RQ3)

In addition to analyzing the entire sample, a cluster analysis was performed to identify distinct groups of potential future customers with different preferences regarding information and communication about alternative fuels. A two-step, data-driven, hierarchical clustering procedure was applied. Initially, examination of dendrograms and changes in agglomeration coefficients suggested that a two-cluster solution was the most appropriate grouping. Next, a k-means cluster analysis was conducted to assign participants more precisely to these two clusters. The two resulting clusters displayed clearly differentiated preference and evaluation patterns regarding alternative fuel communication strategies. The distinctiveness of these clusters was confirmed through statistical testing; each cluster demonstrated significant differences across all relevant preference measures. Together, exploratory hierarchical clustering, confirmatory k-means classification, and subsequent validation confirm that the two-cluster solution robustly captures meaningful variation within the consumer base. Thereby, cluster 1 included $n = 131$ and cluster 2 $n = 84$ participants.

The Clusters' Characteristics (RQ2). ANOVA analyses did not reveal any cluster differences regarding demographic characteristics, i.e., age, gender, and educational level. In contrast, both clusters differed

significantly related to their living location, mobility behaviour, owning their own car, and attitude towards car driving. In addition, both clusters showed significant differences in their perception of alternative fuels. The detailed descriptive and inferential statistical results of the clusters' characteristics are presented in Table 3. Summarizing the main differences of the clusters, cluster 1 tends to live in rural areas, and has a higher tendency to use the car on a daily basis. Further, a higher proportion of cluster 1 owns their own car, and they expressed a comparably more inclined and enthusiastic attitude towards car driving. In addition, they showed a more positive evaluation of advantages, a lower evaluation of disadvantages, a higher acceptance, and a higher willingness to use and buy alternative fuels. Therefore, cluster 1 is simplified called "car lovers". Cluster 2 tends to live more in urban areas and is characterized by a more frequent use of public transport (PT) and a lower proportion of car owners. Beyond that, this segment expressed a more restrained attitude towards car driving and showed a less positive perception of alternative fuels. Therefore, this segment is simplified called "PT enthusiasts".

The Clusters' Preferences (RQ3). Fig. 3 shows the overall construct evaluations of both clusters referring to the information and communication preferences. All constructs confirmed the cluster segmentation by strong significant differences: *Preferred Information Topics* ($F(1,214)=82.06$; $p<.01$), *Preferred Information Channels* ($F(1,214)=55.88$; $p<.01$), *Information Requirements* ($F(1,214)=41.47$; $p<.01$), *Preferred Sources* ($F(1,214)=210.20$; $p<.01$), and *Trusted Sources* ($F(1,214)=126.21$; $p<.01$). Summarizing these differences, the "car lovers" showed higher evaluations of all constructs compared to the "PT enthusiasts", whereas the largest differences were identified for *Preferred Sources* and *Trust in Sources* of information.

Considering the single evaluations of *Preferred Topics of Information,* Fig. 4 shows that all topics were rated more positively by the cluster of "car lovers" indicating a higher interest in all topics compared to the "PT enthusiasts". In particular, vehicle-related information such as "range of use", "compatibility with my car", and "technical details" were of significantly higher interest for the "car lovers" than the "PT enthusiasts".

Fig. 5 shows the evaluations of all *Preferred Information Channels*. Here, the same pattern can be observed: the "car lovers" evaluated all channels significantly more positively compared to the "PT enthusiasts" except from the option of "podcasts" as information channel ($F(1,214)=1.10$; n.s.). In addition, some channels were slightly rejected by the "PT enthusiasts" representing unpreferred information channels, i.e., "radio", "television", and "print media". In contrast, these options still received positive evaluations by the cluster of "car lovers".

Although there were also significant differences for all single aspects referring to the *Information Requirements*, the differences were not that striking as both clusters strongly confirmed the four requirement options: "neutrality" ($F(1,214)=8.78$; $p<.01$), "balance" ($F(1,214)=17.11$; $p<.01$), "comprehensibility" ($F(1,214)=32.84$; $p<.01$), and "necessary expertise" ($F(1,214)=20.34$; $p<.01$). The pattern was in line with the previous evaluations revealing higher agreements and confirmations by the "car lovers" compared to the "PT enthusiasts". The largest difference was identified for the "comprehensibility" of information, which was more important for the cluster of "car lovers" ($M = 5.35$; SD=0.80) compared to the "PT enthusiasts" ($M = 4.68$; SD=0.89).

Considering the single options of the *Preferred Sources of Information* (Fig. 6), all single sources were evaluated significantly higher by the "car lovers" compared to the "PT enthusiasts". The comparably smallest, but still significant differences were identified for the options "research institutes" ($F(1,214)=28.57$; $p<.01$) and "mass media" ($F(1,214)=11.03$; $p<.01$). In contrast, highest evaluation differences were found for the sources "automobile clubs" ($F(1,214)=80.30$; $p<.01$), "car manufacturers" ($F(1,214)=90.63$; $p<.01$), and "fuel manufacturers" ($F(1,214)=95.82$; $p<.01$). In particular, the evaluation of "petrol stations" ($F(1,214)=50.16$) as information sources was striking, because it was preferred by the "car lovers" ($M = 4.50$); SD=1.16), while it was slightly rejected by the "PT enthusiasts" ($M = 3.24$; SD=1.43).

The evaluation of *Trust in Sources* of information (Fig. 7) showed a similar pattern. However, the evaluations were clearly less positive compared to the preferred sources of information. Again, all sources of information were evaluated higher by the "car lovers" compared to the "PT enthusiasts" indicating that both clusters differed in their trust in the sources: here, the "car lovers" showed higher trust evaluations than the "PT enthusiasts". Thereby, the comparably smallest difference was found for "mass media" ($F(1,214)=7.04$; $p<.01$). In contrast, highest differences were identified for "automobile clubs" ($F(1,214)=51.73$; $p<.01$), "car manufacturers" ($F(1,214)=45.40$; $p<.01$), "fuel manufacturers" ($F(1,214)=62.98$; $p<.01$), and "petrol stations" ($F(1,214)=55.10$). Referring to the last three sources, the "car lovers" still showed positive, confirming trust evaluations, while the "PT enthusiasts" slightly rejected these sources to be trustworthy. Most strikingly, the "PT enthusiasts" ($M = 2.65$; SD=1.14) clearly declined "fuel manufacturers" to be a trustworthy source of information, while the "car lovers" ($M = 3.86$; SD=1.06) showed slightly positive evaluations.

Table 3
Descriptive statistics for surveyed characteristics of the respondents of the identified clusters.

		Cluster 1 "car lovers" ($n = 131$)		Cluster 2 "PT ethusiasts" ($n = 84$)		Statistical Difference	Level of Signi-ficance
Demographics							
Age	M(SD)	30.1	(9.8)	29.9	(8.3)	$F(1,214)= 0.02$	n.s.
Gender	female	33.6 %	$n = 44$	26.2 %	$n = 22$	$\chi^2(2,215)= 1.30$	n.s.
	male	65.6 %	$n = 86$	71.4 %	$n = 60$		
Living Location	rural	30.5 %	$n = 40$	14.3 %	$n = 12$	$\chi^2(2,215)= 7.37$	$p<.01$
	urban	69.5 %	$n = 91$	85.7 %	$n = 72$		
Mobility Behaviour							
Car use	M(SD)	4.40	(1.55)	3.68	(1.68)	$F(1,214)=10.27$	$p<.05$
PT use	M(SD)	3.38	(1.52)	3.86	(1.42)	$F(1,214)= 5.30$	$p<.01$
Car Owner	yes	64.8 %	$n = 85$	45.2 %	$n = 38$	$\chi^2(2,215)= 9.87$	$p<.01$
	no	17.6 %	$n = 23$	22.9 %	$n = 30$		
no, but access		17.6 %	$n = 23$	17.9 %	$n = 15$		
Attitude Car driving	M(SD)	4.52	(1.57)	4.13	(1.58)	$F(1,214)= 9.96$	$p<.01$
Alternative Fuel Perception							
Advantages	M(SD)	4.88	(0.74)	4.46	(0.71)	$F(1,214)= 17.01$	$p<.01$
Disadvantages	M(SD)	3.20	(0.76)	3.42	(0.70)	$F(1,214)= 4.58$	$p<.05$
Acceptance	M(SD)	4.89	(0.84)	4.25	(1.14)	$F(1,214)= 22.11$	$p<.01$
Use Intention	M(SD)	4.87	(0.98)	4.22	(1.20)	$F(1,214)= 18.75$	$p<.01$

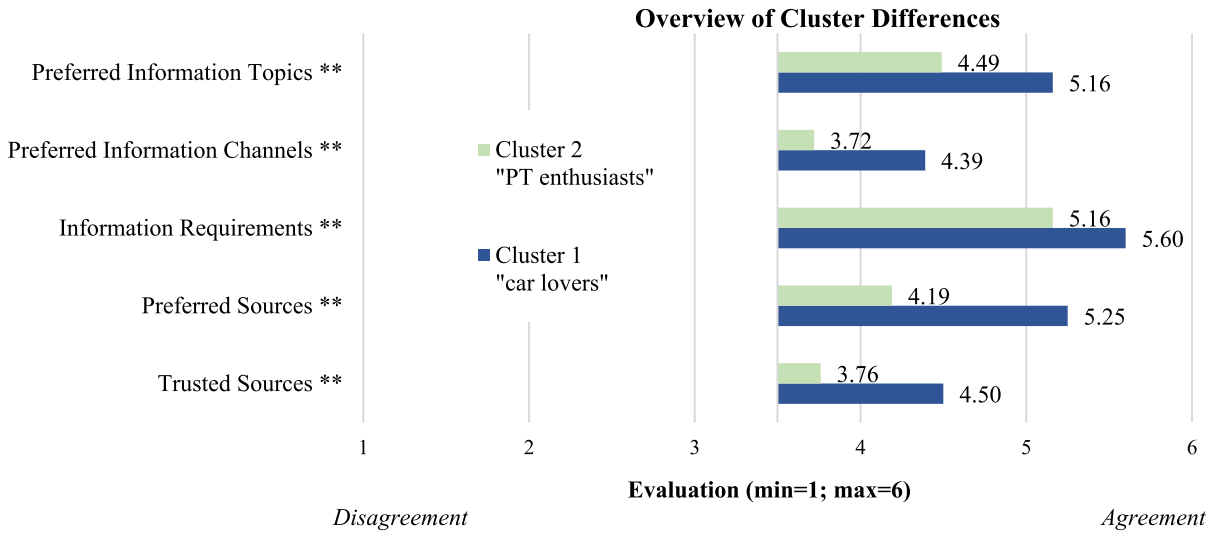

Fig. 3. Overview of cluster differences.

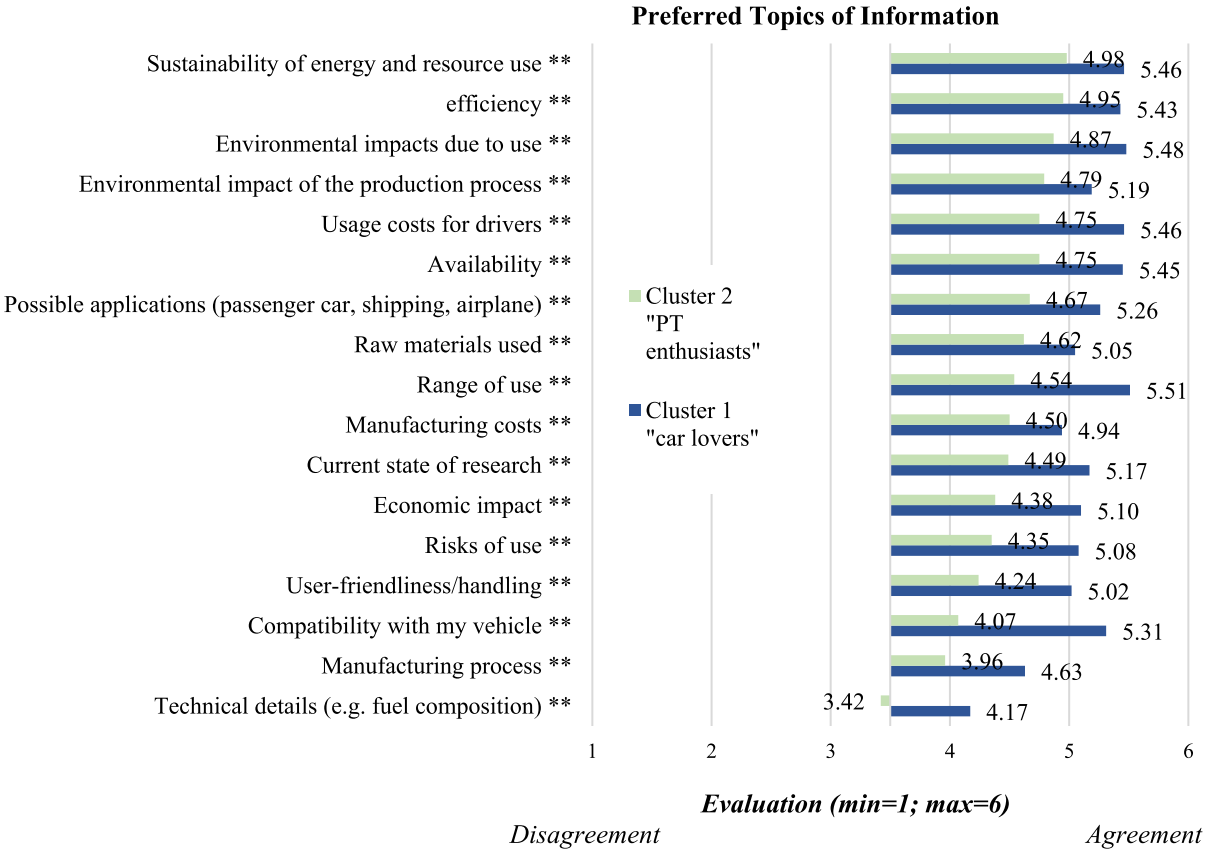

Fig. 4. Preferred information topic depending on the clusters.

4. Relevance and implications OF communication preferences

The conducted study provided insights into future customers' information and communication preferences related to alternative fuels. In the following, the key results are discussed and interpreted within the research landscape of alternative fuel acceptance. Afterwards, implications are derived based on the results, and limitations as well as potential for future research in the field are highlighted.

4.1. Key results on public communication and information preferences

In response to **RQ1** and focusing on *what type of information* is desired, participants expressed a high overall interest in information about alternative fuels, with topics such as sustainability, environmental impact, efficiency, availability, and cost of use ranked as most important. On the other hand, topics such as risks of use, manufacturing costs, ease of use, manufacturing process, and technical details were considered less important, but still received positive ratings. Participants preferred to obtain information about alternative fuels *through more*

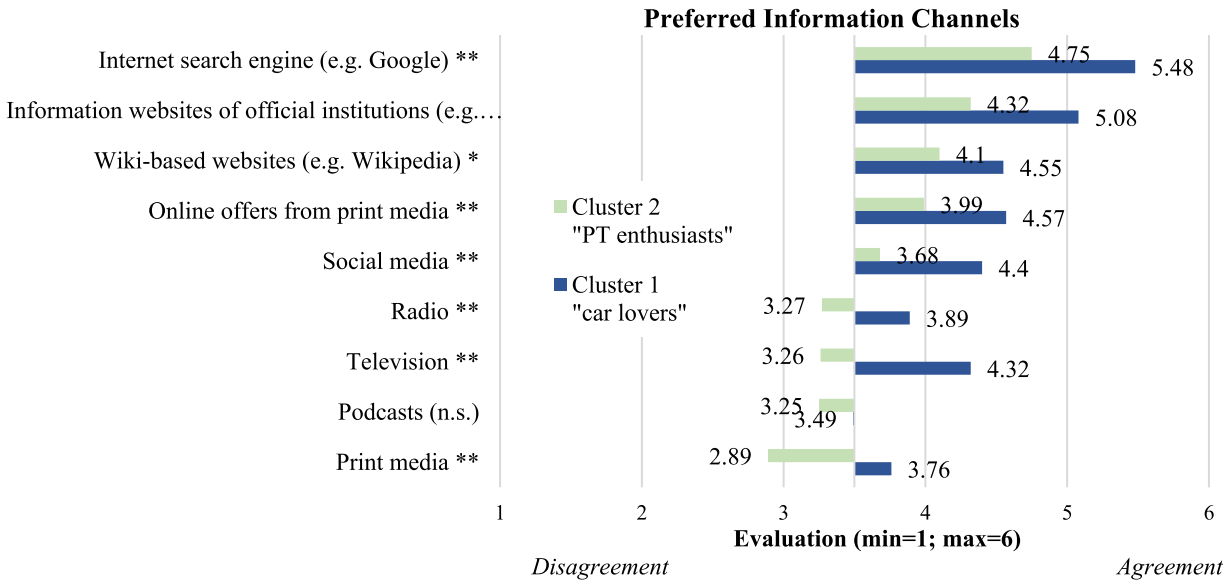

Fig. 5. Preferred information channels depending on the clusters.

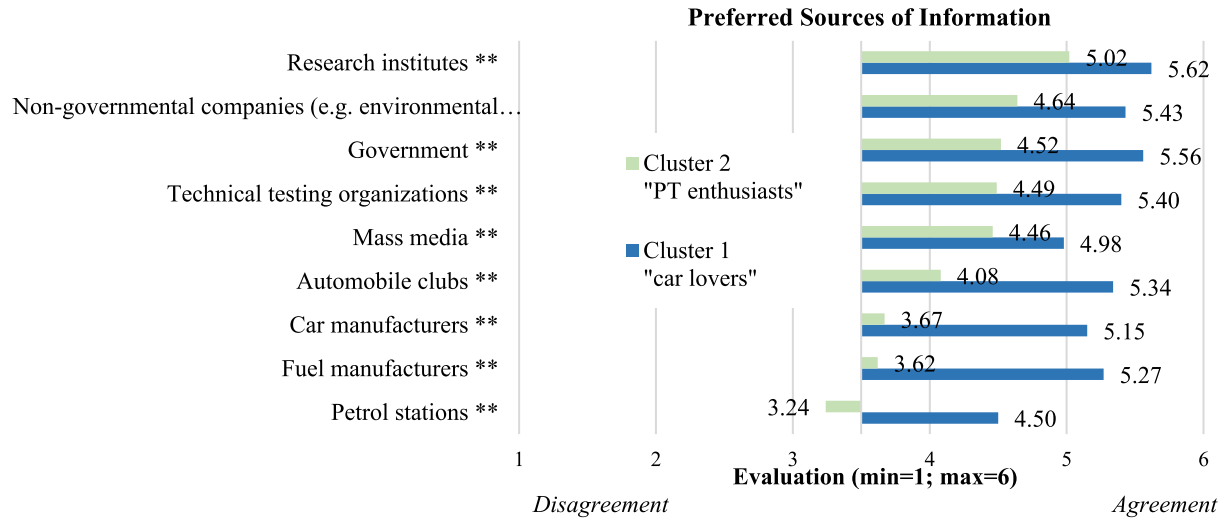

Fig. 6. Preferred information sources depending on the clusters.

independent channels, such as internet search engines, official institutional websites, and wiki-based sites. Less favoured channels included social media, podcasts, and more traditional information channels such as television, radio, print, and podcasts. Participants strongly emphasized the importance of four aspects of *how information about alternative fuels is communicated*: neutrality, expertise, balance, and understandability. Finally, participants rated their *preferred sources of information* and their level of *trust in those sources*. Independent sources in the form of research institutions emerged as the most preferred and trusted source, followed by technical testing organizations. Government, non-government companies and automobile clubs were confirmed as preferred sources with positive trust ratings. In contrast, mass media and business-oriented institutions such as fuel producers, car manufacturers, and petrol stations were preferred as sources of information, but received lower trust ratings, indicating a more neutral perception of trust.

The results show that the participants have a strong interest in information about alternative fuels and that they prefer independent information channels such as internet search engines and official institutions, while conventional channels such as social media and mass media are less favoured. Neutrality, expertise, and balance are identified as important communication requirements. Trust in independent sources such as research institutions is higher, while trust in mass media and business-oriented sources is lower. In line with previous research in this area, this highlights the role of trust [42] and the importance of credible and neutral information [44,45] for perceptions and preferences in the context of alternative fuels.

One potential reason for these findings could be the growing public awareness of misinformation and bias, particularly on social media and in commercially influenced media outlets. As alternative fuels are often presented within debates involving economic, political, and environmental interests, individuals may seek out sources they perceive as more objective and scientifically grounded to avoid the influence of vested interests [49]. Furthermore, the technical complexity and emerging nature of alternative fuel technologies likely drive participants toward sources that are seen as more authoritative and evidence-based [50]. The preference for official and research-based information may also reflect a broader societal trend toward valuing expert knowledge in areas that impact public health and environmental sustainability [51]. Together, these factors help explain why neutrality, credibility, and

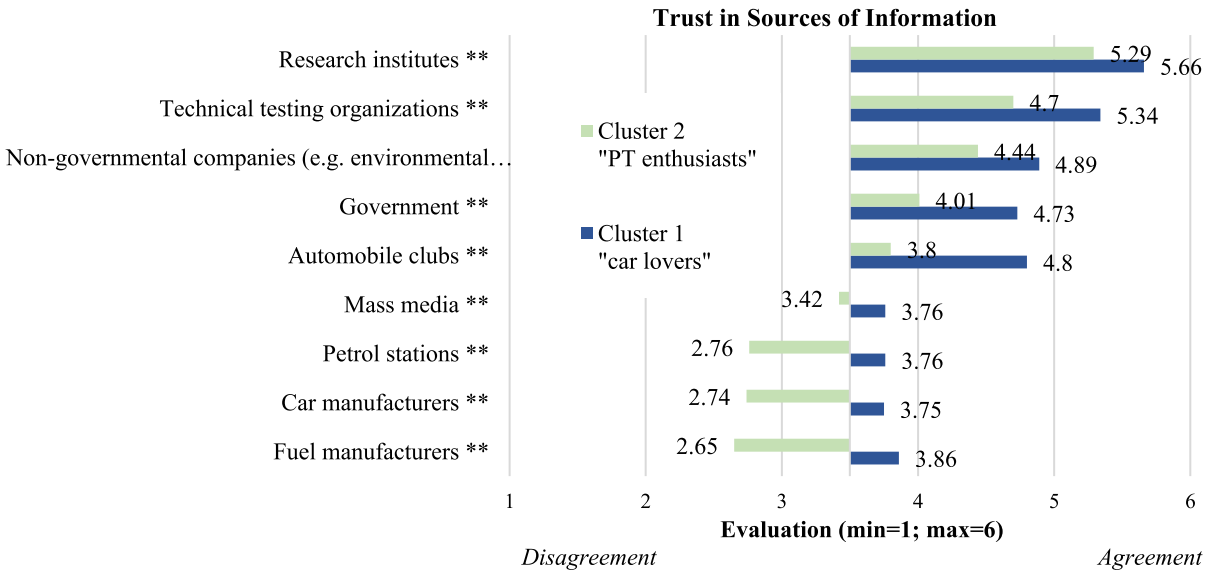

Fig. 7. Trusted information sources depending on the clusters.

expertise are seen as essential qualities in communication on this topic.

Focusing on **RQ2**, our study applied a two-step cluster analysis and identified *two distinct segments* of future customers who differed in their preferences for alternative fuel information and communication. Both segments shared similar demographic characteristics, but differed significantly in the variables of living location, mobility behaviour, car ownership, attitudes toward driving, and perceptions of alternative fuels. Specifically, cluster 1 "car lovers" resided more in rural areas, had a higher daily car use, a higher percentage of car owners, and expressed a positive attitude toward driving. This group also had a more favourable perception and acceptance of alternative fuels. In contrast, cluster 2 – "PT enthusiasts" – was more urban oriented, relied more on public transport, had a lower proportion of car owners, had a more reserved attitude towards driving and a less positive perception of alternative fuels.

These findings extend previous research [35] by confirming that the living location is a relevant factor for alternative fuel perceptions and preferences. As new insights for the context of alternative fuel information, mobility behaviour and attitudes towards driving were identified as influencing parameters.

One potential explanation for these differences lies in the accessibility and necessity of private car use in rural versus urban environments. In rural areas, where public transport options are often limited or inefficient, individuals may develop a stronger dependency on and affinity for private vehicles [52], making them potentially more attentive to innovations such as alternative fuels that promise to sustain car usage in a more sustainable way. This could partly explain why "car lovers" showed greater acceptance of alternative fuels. Conversely, urban residents may benefit from more diverse and convenient mobility options, reducing their reliance on personal vehicles and potentially leading to a more ambivalent or cautious stance toward car-centric innovations, including alternative fuels. Furthermore, attitudes toward driving may reflect lifestyle preferences and identity factors, which are shaped by one's everyday mobility routines and broader environmental values. These psychological and contextual differences likely influence how each group perceives and prioritizes information about alternative fuels and help explain the divergence in their communication preferences and levels of acceptance.

Considering **RQ3**, significant differences were observed for the identified customer segments across all investigated facets of information and communication. In summary, the "car lovers" cluster consistently rated all constructs higher compared to the "PT enthusiasts," with the most significant disparities seen in *preferred sources* and *trust in sources of information*. In more detail, the individual assessments *information topics* revealed that the "car lovers" cluster generally expressed a higher interest in all topics compared to the "PT enthusiasts." In particular, vehicle-related information, including range of use, compatibility, and technical details, stood out as significantly more appealing to the "car lovers." In line with this, the ratings of *preferred information channels* revealed a consistent pattern: "car lovers" rated all channels more positively than "PT enthusiasts," except for podcasts. Moreover, "PT enthusiasts" slightly rejected certain channels, such as radio, television, and print media, while these options still received positive assessments from the "car lovers" cluster. Beyond that, both clusters strongly affirmed the importance of key *information requirements*, including neutrality, balance, comprehensibility, and necessary expertise. Further, the "car lovers" consistently rated all *preferred sources of information* significantly higher than the "PT enthusiasts." Notable differences were found for automobile clubs, car manufacturers, fuel manufacturers, and petrol stations, with the latter being preferred by the "car lovers" and slightly rejected by the "PT enthusiasts. Finally, the evaluation of *trust in sources of information* revealed a similar pattern to preferred sources, although the overall assessments were less positive. All sources were rated higher by the "car lovers" than the "PT enthusiasts," indicating differing levels of trust between the clusters. In particular, the "PT enthusiasts" expressed clear scepticism toward fuel manufacturers as a trustworthy source, while the "car lovers" had more positive evaluations.

Summarizing these insights, analyzing customer segments ("car lovers" vs. "PT enthusiasts") regarding information and communication preferences revealed significant differences within the preference patterns: The "car lovers" consistently expressed higher interest and trust across various facets, especially in preferred sources and trust in information sources. Particularly, their strong preference for vehicle-related information and positive evaluations of channels and sources distinguished them from the "PT enthusiasts." These insights emphasize the need for tailored communication strategies based on distinct customer preferences in the alternative fuels' domain.

A likely explanation for these differences – going beyond previous research and insights – stems from the segments' underlying mobility mindsets and motivational engagement with vehicle use. "Car lovers," being more involved in daily car use and personally invested in driving, may naturally seek out more information related to vehicle technologies, including alternative fuels, as these directly impact their routines

and identity as drivers. Their higher trust in information sources could be tied to their familiarity with automotive topics and perhaps a greater sense of control or competence in evaluating such information. In contrast, "PT enthusiasts," who rely more on public transport and exhibit less personal identification with driving, may perceive alternative fuel information as less immediately relevant or impactful. This could lead to lower levels of engagement and trust, especially if the communication is heavily vehicle-centric. The contrast highlights how practical relevance, perceived usefulness, and self-identification with mobility modes influence how customer groups seek out, interpret, and trust information on alternative fuels.

4.2. Deriving information and communication implications

Based on the results, general key implications and recommendations for information and communication of alternative fuels can be derived in a first step. These implications can be used as information and communication tools for industry and policy likewise.

Focus on Key Information: Emphasize key topics such as sustainability, environmental impacts, efficiency, availability, and usage costs in alternative fuel information as these are of major relevance for future customers.

Utilize Independent Channels: Prioritize independent information channels like internet search engines, official institution websites, and wiki-based sites for disseminating alternative fuel information.

Addressing Communication Requirements: Take care that information is balanced and neutral and is communicated by experts in the field in a comprehensible manner so that laypeople are able to understand easily.

Trust-Building Initiatives: Rely on and collaborate with independent entities, e.g., research institutions and technical testing organizations, to enhance credibility in terms of possible information sources. Emphasize and realize transparency, reliability, and credibility in all communications to enhance trust levels across all potential customer segments.

Caution with Conventional Channels: Be cautious with using conventional channels for disseminating information such as mass media, fuel manufacturers, car manufacturers, and petrol stations, as they may be used as information sources, but it is not guaranteed that these sources will be trusted by future customers.

Continuous Monitoring and Adaptation: Establish mechanisms for ongoing monitoring of customer preferences and feedback from both segments. Adapt communication strategies dynamically based on evolving preferences, ensuring that campaigns remain effective and relevant over time.

Implementing these recommendations can enhance the effectiveness of alternative fuel communication strategies by aligning with customer preferences and promoting trust in the information provided.

In a second step, the results enabled the derivation of specific recommendations tailored to different consumer groups, which also can be used as information and communication tools by industry and policy.

Focusing on Key Information: To meet the needs of different customer groups, it is recommended to develop customized messaging strategies for different types of future customers, e.g., "car lovers" and "PT enthusiasts", to address their unique interests and preferences. For example, highlight vehicle-related information – such as engine performance, re-fueling time, and range of alternative fuel vehicles – prominently to address "car lovers," emphasizing benefits, technological advancements, and how these fuels align with driving enjoyment and performance expectations. For PT enthusiasts, place greater emphasis on environmental impact, societal benefits, and affordability, which may resonate more with their values and transportation habits.

Utilize Independent Channels: Keep in mind that there are diverse potential customer groups and address their specific needs: e.g., tailor content for "PT enthusiasts" by considering their reservations towards specific channels and exploring alternative platforms that align with their preferences. This could be realized by avoiding heavy reliance on commercial or industry-driven platforms, and instead disseminate information through government portals, environmental NGOs, or scientific institutions they may consider more credible. In contrast, "car lovers" may be also effectively reached through automotive blogs and forums, that align with their information consumption behavior.

Trust Building Initiatives: Implement initiatives to build trust, especially among potentially more critical customer groups (like the "PT enthusiasts"), acknowledging their skepticism. This could be realized by engaging independent experts, academics, or public sector representatives in communication efforts, offer transparent data on environmental impacts and long-term savings, and encourage two-way communication (e.g., by interactive webinars) to foster dialogue and address concerns.

Strategic Campaigns: Develop targeted campaigns that align with the positive evaluations and preferences of supporting customer groups (such as the "car lovers"), e.g., by focusing on innovation, performance, and convenience of alternative fuels. At the same time, any concerns or reservations expressed by the more restrained customers (such as the "PT enthusiasts") should be addressed, e.g., by educational initiatives that clarify misconceptions and show the broader benefits of alternative fuels. Utilize insights on living locations, mobility behaviors, and attitudes toward driving as impacting factors for the alternative fuel preferences to craft more impactful and resonant communication strategies. For example, a campaign in suburban areas might emphasize fuel availability and cost efficiency, whereas in cities, it might highlight integration with public transport and local emissions reductions.

5. Conclusion

This study emphasizes the importance of tailoring communication strategies for CO_2-based and bio-based alternative fuels to the diverse preferences and trust patterns of consumers. The findings emphasize the necessity of a tailored approach and highlight the inadequacy of a uniform strategy for garnering public acceptance. This assertion is substantiated by the identification of distinct consumer segments that have different expectations regarding the level of information detail, the credibility of the source, and the preferred communication channels. Therefore, effective outreach must be multifaceted, combining scientifically grounded content for knowledge-seeking audiences with more accessible, application-oriented messaging to encourage broader engagement. These insights provide a foundation for developing targeted communication initiatives that support the societal transition toward sustainable mobility. To adapt communication efforts according to technological progress and evolving regulatory landscapes, it will be crucial to continually evaluate public attitudes and preferences.

Besides the discussed key insights and derived implications, there are some sample- and study-related limitations of the conducted study that should be considered in future research.

As this study has revealed relevant information and communication preferences for alternative fuels among potential customers in a comparably small, rather young and highly educated sample, future research should assess information and communication needs in a larger and more representative sample (e.g., more balanced with regard to age, gender, and educational level close to the German population) in order to validate the results and evaluate the perspective of an entire population holistically. This way, it would also be possible to consider the perspectives of other stakeholder groups (besides laypeople as future customers), e.g., experts or companies.

A further study-related limitation refers to the fact that the study focused on a country-specific evaluation. Germany's extensive automotive history and deeply ingrained automotive culture [53] may impact the country's perspective on alternative fuels and drives [54]. It is important to consider how historical contributions to the industry can influence public attitudes and decision-making regarding the adoption of alternative fuels. Therefore, future research should be extended to the preferences in other countries to validate the findings and to enable cross-national comparisons of information and communication needs.

A second study-related limitation refers to the study-specific focus on

individual road transport which was reasonable in a first step as this scenario was easy to imagine for laypeople and evaluations of individual needs of information and communication have been realized. Future studies should expand the focus to different transport sectors and related information and communication needs enabling direct comparisons of different transport sectors such as public transport or shipping. This way, information and communication needs could be compared, and overarching strategies could be derived.

Beyond that, future research should capture the dynamic nature of consumer preferences regarding alternative fuels. As public discourse, technological innovation, and policy landscapes evolve, the communication needs and trust perceptions of different consumer groups may also evolve. Longitudinal studies or repeated cross-sectional designs could offer valuable insights into how individual or group preferences change over time. Incorporating contextual factors, such as shifts in fuel pricing, regulatory changes, or major life events (e.g., relocation or family expansion), may help explain the underlying drivers of these changes. These longitudinal perspectives would be instrumental in designing adaptive, future-oriented communication strategies that remain relevant as societal and technological contexts evolve.

In addition, future research should investigate how cultural, economic, and regional factors shape consumer communication preferences regarding alternative fuels. These contextual variables may influence not only trust in information sources but also the perceived relevance of specific messaging strategies. For instance, consumers in rural areas may prioritize different channels or content than those in urban centers, while cultural norms or economic constraints could affect openness to certain technologies or narratives. Accounting for such differences would enhance the precision and effectiveness of targeted communication strategies across diverse populations.

CRediT authorship contribution statement

Julia Offermann: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Linda Engelmann:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization. **Martina Ziefle:** Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

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

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jfueco.2025.100146.

Data availability

Data will be made available on request.

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