



Fresh air or a hard road? Exploring predictors of public acceptance of Carbon Capture and Utilization infrastructure

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ARTICLE INFO

Keywords:

Public perception
Acceptance
Carbon Capture and Utilization
Conjoint analysis
CO₂-based jet fuel

ABSTRACT

The urgency of mitigating global warming and the growing threat of natural disasters demand swift and decisive action. Carbon Capture and Utilization (CCU) technologies have emerged as a solution to this challenge, capturing and converting carbon dioxide (CO₂) into products, rather than allowing it to be released into the atmosphere. We explore public perception and acceptance of CCU-based products, with a focus on jet fuel as a case study. Using conjoint analysis within an online survey ($N = 1204$), we evaluated how contextual factors—transport options, energy sources, and production settings—affect consumer preferences. Participants rated both the acceptability of CO₂-based jet fuel and the infrastructure required for its local and general production. The results suggest that preferences for the production conditions of CCU plants were driven more by energy supply and transport than by the type of plant manufacturing the final product in both local and general contexts. The acceptance of CCU plants and the production of CO₂-based jet fuel in both contexts were the strongest predictors of overall acceptance. However, the final CCU product itself, regardless of context, was the least influential factor in shaping public perception. This study provides insights into public perceptions of the production of CO₂-based jet fuel and identifies key factors influencing local and general acceptance. Our findings contribute to a deeper understanding of the societal dimensions of CCU adoption and complement efforts in technology development and regulatory frameworks necessary for technology integration.

1. Introduction

Global climate change has emerged as one of the most pressing and complex challenges of our time, posing multifaceted risks to ecosystems, human health, and socio-economic structures worldwide [1–3]. Its impacts transcend geographical boundaries and generational divides, requiring urgent and coordinated action from all sectors of society. Scientists agree and have for years provided ample evidence that these climatic changes are caused by human activities: In particular, the burning of fossil fuels, deforestation, and industrial processes are driving the accumulation of greenhouse gases (GHGs) in the atmosphere, leading to significant warming of the Earth's climate system [4]. This temperature rise has triggered a range of impacts, including the melting of the polar ice caps, rising sea levels and an increase in the frequency and intensity of extreme weather events such as hurricanes, droughts, and heat waves. These changes pose immediate and long-term risks to the stability of natural systems, food and water security, human health, and economic resilience.

Among the major contributors to global emissions, the industrial and

mobility sectors—and the aviation industry in particular—play a prominent role [5]. Air transportation is essential to modern economies, facilitating global trade, tourism, and connectivity. It stimulates growth in various service sectors and has a strong link to long-term economic development [6]. However, despite these economic benefits, the environmental costs of aviation are significant [7,8]. As one of the fastest growing industries, aviation is responsible for a significant share of global carbon emissions and its impact on climate change is expected to increase as demand for air travel grows [9]. The need to reduce emissions from this and other emission-intensive sectors has therefore become a critical priority on the global climate agenda.

Several Carbon Capture and Utilization (CCU) technologies have emerged as promising tools to complement emission reduction efforts. CCU involves capturing carbon dioxide (CO₂) from industrial sources and converting it into usable products such as e-fuels, plastics, waxes and more, potentially reducing the environmental footprint of sectors in which emissions are difficult to reduce. The development of CCU technologies is particularly relevant for addressing emissions from aviation and other heavy industries, in which conventional decarbonization

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<https://doi.org/10.1016/j.jfueco.2025.100145>

Received 5 March 2025; Accepted 19 June 2025

Available online 21 June 2025

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strategies may not be sufficient. However, technological advances in CCU are still at an early stage and a complete transition to carbon-neutral or even carbon-negative industrial practices remains a distant goal.

Despite the great potential of CCU technologies, their success does not depend solely on technological feasibility. Public perception and acceptance play a critical role in determining the long-term viability of these innovations (e.g., [10–12]). Studies on supply chains and infrastructure implementation often focus primarily on techno-economic assessment [13,14], which is an essential analysis approach in terms of feasibility of technology implementation. However, new technologies and infrastructures are seldom introduced in isolation but are rather subject to public scrutiny and evolving perceptions over time. Thus, public acceptance or rejection of CCU plants and the products they generate—such as CO₂-based jet fuel—will influence their implementation and scalability. Understanding the factors that shape public perception, particularly in relation to the local and global acceptance of CCU infrastructure and resulting products, is therefore essential for their successful deployment (e.g., [15–17]).

This study aims to explore these dynamics, focusing on the general and local social perception and acceptance of CCU infrastructure and selected production conditions, as well as CCU-based products, using jet fuel as a case study. Through an empirical investigation, this research seeks to shed light on the aspects that influence public opinion to support or oppose the development of CCU technologies and associated infrastructures.

The structure of this article is as follows. The introduction is followed by a literature review, which provides the theoretical framework for CCU technologies and their acceptance implications from a social science perspective. This is followed by the methods section, in which, based on a multi-level empirical approach, acceptance-relevant criteria of selected production conditions of exemplary CCU-based products were identified, assessed, and weighted in a conjoint study. The results of the choice evaluations are then presented and aspects influencing the (general and local) acceptance of CCU facility site deployment for the production of CO₂-based jet fuel are identified. This is followed by a section discussing the results in relation to the research questions, and finally conclusions and future work.

2. Background

2.1. Carbon Capture and Utilization as a climate change mitigating technology

Carbon Capture and Utilization has emerged as a critical technological pathway for addressing the escalating levels of atmospheric carbon dioxide and mitigating climate change [18]. This innovative approach combines CO₂ capture with its subsequent conversion into valuable products, repositioning CO₂ as a resource rather than a waste product. As an integral part of the broader carbon management landscape, CCU technologies aim to reduce carbon emissions by preventing CO₂ from entering the atmosphere, with applications ranging across various industries [19,20].

At the core of the CCU approach is the ability to capture CO₂ from different emission sources. There is no single CCU technology that is applicable in all contexts, rather a range of carbon capture systems have been developed to address specific use cases [21]. CO₂ capture methods can be broadly classified into three categories: pre-combustion, post-combustion, and oxyfuel combustion systems [22]. Once captured, the CO₂ can be utilized in numerous applications, contributing to the creation of a circular carbon economy [23]. Carbon utilization is already progressing in areas such as agriculture (through soil improvement), concrete production (through mineralization processes), pharmaceuticals (through chemical synthesis) and refrigeration in the food industry [24]. In addition, CO₂ can be chemically converted into high-value products, including synthetic fuels, which are a particularly promising

way to decarbonize the transport sector [18]. By offering alternatives to conventional fossil fuels, synthetic fuels derived from CO₂ align with both energy demand and carbon reduction targets, demonstrating the potential of CCU in the transition to a sustainable and low-carbon future. Other product options include chemicals, plastics, fertilizers, waxes, carbonates and polycarbonates, and many more. However, while some CO₂-based products, such as CO₂-based plastics or building materials, are able to sequester carbon for decades [25–27], fuels – despite having a large deployment potential – cannot contribute as a negative emissions technology option because CO₂ is released during their use (e.g., combustion) [28].

Even if not all CO₂-based products achieve carbon-neutral status, widespread acceptance or rejection by the (potential) users may depend not only on the final product, but also on the manufacturing process and the existing infrastructure required for carbon conversion. The conditions under which the CCU approach is implemented and the internal processes, such as energy supply (e.g., electricity from specific nuclear power plants, via green certificates or from own renewable sources) and transport options (i.e., overground/underground pipelines, train, truck, ship) play an important role in the successful uptake of CO₂-based products. The question that remains is the weight, i.e., impact, of the respective production conditions on social perception and, ultimately, on the acceptance of the final product.

The utilization process transforms CO₂ into economically valuable products, promoting a shift in perception—from viewing carbon as a pollutant to recognizing its potential as a feedstock for various industrial processes. The convergence of CCU thus highlights the approach as a multifaceted solution to two pressing challenges: managing carbon emissions and promoting the development of sustainable industrial practices. Through technological diversification and innovative applications, CCU not only provides a mechanism for carbon mitigation, but also supports the broader goals of economic sustainability and circular resource use.

2.2. The role of social acceptance for a successful adoption of CCU-based products

Through technological diversification and innovative applications, CCU not only provides a mechanism for carbon mitigation, but also supports the broader goals of economic sustainability and circular resource use. Social acceptance of CCU technologies is a critical determinant of their successful adoption and market integration (e.g., [10,15,29]). As with other sustainable innovations, the success of CCU goes beyond technical and economic viability and requires public support and understanding of its potential benefits [30]. This necessity underscores the importance of raising awareness and knowledge of CCU technologies, as societal acceptance is critical to promoting widespread adoption. Without adequate public approval, even the most innovative and effective technologies may face significant barriers to adoption [31].

In addition, the complexity of CCU technologies, which represent a significant shift in existing socio-technical systems, amplifies the need for broader societal and stakeholder support. Similar to other transformative technologies, such as renewable energy systems, acceptance of CCU cannot be limited to the technology and products themselves. It also requires the endorsement of various actors—ranging from stakeholders and industry experts to organizations involved in its implementation [32]. Public perception of CCU infrastructure, production conditions, and processes is crucial, as these elements are integral to the production of CCU-based products. In this regard, the involvement of end users in the early stages of technology development and implementation is essential. Engaging the public allows for the identification of perceived benefits and potential drawbacks, thereby enabling a more user-centered approach to sustainable energy systems [33]. Furthermore, previous research shows that laypeople are interested in environmental aspects of consumer good production: Grunert et al. (2018)

found that people with higher interest in the conditions of the generation of livestock for consumption expressed higher environmental consciousness [34], while another study on life-cycle properties in the production of household appliances revealed an elevated interest of German laypeople in the amount of energy needed during the production of appliances [35]. It is therefore useful to consider not only the end product as a result of a production route, but also the whole process and the associated environmental impacts when studying public perception and acceptance of sustainable technologies and products.

In the broader context of technology adoption, technology acceptance is defined as both the active and passive support of a technology throughout its development, deployment, and use [36]. As an interdisciplinary field, technology acceptance draws on psychological, sociological, and innovation research frameworks to understand how new technologies are received by society.

The technology acceptance model proposed by Huijts et al. (2012) provides a useful framework for understanding public attitudes towards renewable energy technologies and can be applied to CCU [33]. This model emphasizes the role of perceived costs, risks, and benefits in shaping public support for or opposition to sustainable technologies. It also incorporates individual factors such as demographics, prior knowledge, and perceived fairness of the decision-making process, as well as sociological factors, such as adherence to social norms and trust in the implementing institutions. By integrating these dimensions, the model offers a comprehensive understanding of how public attitudes towards CCU might evolve and highlights the importance of addressing both individual and societal concerns to ensure broad acceptance of CCU technologies and products.

2.3. Acceptance of CCU infrastructure and CO₂-based products

The acceptance of CCU infrastructure and CO₂-based products is a critical factor in their successful implementation, as the deployment of CCU technologies faces numerous challenges. These include the identification of optimal technological pathways, economic viability, regulatory concerns, and public risk perceptions [37]. Empirical studies on CCU acceptance have shown that the public has a positive view of these technologies [38,39]. This favorable perception is pivotal for the broad adoption of CCU products, as public support can drive market success and pave the way for sustainable carbon management solutions.

Several studies have highlighted a strong willingness among consumers to purchase and use CCU-based products, although public perception varies depending on specific stages of the CCU process. Research by Arning et al. (2018) revealed that temporary CO₂ storage at production sites, CO₂ transport, and the disposal of CCU products are perceived as the riskiest phases of the CCU lifecycle [40]. In contrast, the actual capture of CO₂ and the use of CCU products are seen as relatively low-risk activities [17]. These findings underscore the importance of addressing specific public concerns related to the infrastructure and processes that support CCU technologies, particularly in relation to transportation and storage.

The acceptance of CO₂-based products varies greatly depending on their application. A study by Lutzke and Árvai (2021) found that participants were less accepting of carbonated beverages made using carbon captured from point sources compared to other products such as furniture or shatterproof glass. Nevertheless, two-thirds of their participants expressed openness to using or consuming CCU-based products, signaling that the public is increasingly willing to integrate these innovations into daily life [29]. Other examples of this accepting attitude can be found for insulation boards [41], foam mattresses [42], and everyday items such as clothing and cosmetics [43]. In addition, CCU is particularly promising for complementing renewable energy systems by converting captured CO₂ into synthetic fuels, which can serve as a sustainable alternative to conventional fossil fuels. These synthetic fuels, produced through approaches such as power-to-liquid and electrofuels, offer a viable solution for decarbonizing the transport sector,

particularly in sectors that face difficulties in transitioning to carbon-free alternatives, such as aviation [18,44]. Despite this potential, several barriers remain. The conversion of CO₂ and the associated infrastructure can be energy-intensive [45], and the reliance on low-carbon energy sources is crucial to maintain the environmental integrity of CCU technologies [46]. Moreover, the need for new or adapted infrastructure entails significant investment costs, which may affect both the economic feasibility and public acceptance of CO₂-based products [44]. Such findings therefore highlight both the opportunities and challenges in expanding the acceptance of CO₂-based products across different sectors.

With regard to infrastructure, public (risk) perception is a key factor influencing acceptance. While research on infrastructure perception in the context of renewable technologies such as CCU is still limited, initial studies suggest that public risk perception for CCU technologies is higher than for renewables such as solar and wind power, but lower than for conventional technologies such as nuclear and fossil fuels [31]. A study by Engelmann et al. (2024) found that CO₂ transport is perceived as less acceptable, less efficient, and less useful compared to its capture, purification, and conversion into hydrocarbons, while also being perceived as more costly and harmful to the environment and human health [47]. Furthermore, Lutzke and Árvai (2021) found that the public's willingness to accept CO₂-based products also varies depending on the source of the captured CO₂ [29]. This finding is also consistent with other research that has found significant differences in public perceptions of carbon capture and storage depending on the source of CO₂, transport option, and storage location [48]. These findings highlight the need for further research to understand public attitudes towards the infrastructure and production conditions required to support CCU technology and its products, such as factory plants, transport networks, and energy sources.

Another crucial aspect in terms of the CCU infrastructure and its acceptance is the potential difference between general perception and local acceptance when industrial facilities are located close to residential areas. For a successful deployment, the public must not only accept the overall concept of the technology and its resulting products, but also support, or at least tolerate, the necessary technical infrastructure and its impacts, such as land use, visibility, and emissions [12]. Empirical studies found that local acceptance of CCU facilities was lower than general acceptance, although a majority of respondents still supported the presence of such a site in their neighborhood [40,49]. This finding suggests that proximity to CCU infrastructure may influence public attitudes, highlighting the importance of addressing local concerns to ensure broader societal acceptance. Understanding the conditions under which local communities are more likely to accept CCU infrastructure will therefore be essential in guiding future deployment strategies.

3. Research questions

To complement previous research on the topic of CCU plant perception and acceptance of both industrial plants and products manufactured in associated processes, this paper focused on CO₂-based jet fuel as the primary object of acceptance analysis. To investigate how it is perceived in direct comparison with other potential end products, other alternatives were included (i.e., plastics and waxes). Therefore, we include the type of end product along with several low CO₂ energy sources and the transport of intermediate products to study laypeople's preferences for the CCU plant implementation in their country of residence and near their place of residence. The following research questions were formed:

RQ1: Does the perception of CCU plant production conditions differ between the local and general context?

Secondly, as previous research has found varying levels of acceptance depending on the CO₂ source (e.g., [40]), we pose the following question with regard to the plant types included in this study:

RQ2: Does the type of industrial CO₂ facility impact the local and general acceptance of CCU plants producing CO₂-based jet fuel?

Finally, we focus on CO₂-based jet fuel as the end product of CCU and complement previous research on fuel acceptance (e.g., [44,50]) by distinguishing predictors of acceptance for the implementation of plants producing CO₂-based jet fuel in the country of residence and near the place of residence.

RQ3: Which other factors influence the acceptance of local and general acceptance of CCU plants producing CO₂-based jet fuel?

4. Methods

The following section describes the survey instrument, including the conjoint tasks, the procedure of collecting and cleaning data as well as the inferential statistics used to aggregate (construct formation) and analyze the data. The chapter closes with a description of the sample.

4.1. Measurement instrument

Before beginning the survey, respondents answered screening questions about their age, gender, education, and region of residence. These were used to control the quotas that were set for data acquisition to meet the targeted representative sample. Next, respondents received a brief introduction and were informed about their data privacy rights (in line with the data privacy standards of the GDPR). After giving their consent, participants were asked about their location of residence, children, and monthly net income (voluntary information). Willingness to protest [51], environmental awareness [52,53], and knowledge of the greenhouse gas CO₂ [54] were surveyed (see Fig. 1).

The next part of the survey addressed the CCU approach and potential products in general. Participants were presented with a short text on CO₂-based products, including information on the total and per capita CO₂ emissions of Germany in the year 2019 [55] as well as a brief explanation of the CCU approach and the plant-internal processes suitable for CCU. In addition, the process described was shown in a simple illustration below the text to foster understanding (see Fig. 1). This was followed by three statements regarding the respondents' awareness of CO₂-based products [17].

4.1.1. Conjoint analysis – choice tasks

Then, participants performed conjoint choice tasks on their preferences for CCU infrastructure. In the case of the study conducted, the included attributes were the *transport modes of the intermediate hydrocarbons*, the *energy source*, and the *CO₂ product*. Table 1 lists the attributes included in the study and their respective levels.

First, respondents received a short informative text on the topic of the production infrastructure associated with CO₂-based products. At this point, the survey divided participants into four (equally quota representative) subgroups. Each of the resulting subsamples was presented with one of four industrial CO₂ sources as a context.¹ Accordingly, the surveyed CO₂ sources were 1) a cement plant, 2) a steel mill, 3) a refinery, and 4) a waste management facility. Depending on the subgroup and type of facility, the text contained information on refineries, steel mills, cement plants or waste management facilities. An example for this informative text is presented in the Appendix.

Subsequently, the attributes as well as the corresponding attribute levels (listed in Table 1) were explained to participants.

Participants were then asked to complete ten choice tasks during which they selected one of three combinations by indicating their preference for the infrastructure necessary to convert the CO₂ from the respective industrial CO₂ source. Subsequently, they were instructed to imagine the conversion using the CCU approach for a facility located in the vicinity of their own home. This was again followed by ten choice tasks (three sets of three attribute levels each) to elicit local

infrastructure preferences. An exemplary choice task is depicted in Fig. 2.

4.1.2. Evaluation of CO₂-based jet fuel (production)

In the final part of the survey, items assessing requirements for CCU plants – which were added to examine the industrial plant type cases and the effect of the information on the respective CO₂ quantity – and a battery of items on trust in stakeholders as sources of information were presented [38]. While the first part of the survey addressed the production of CO₂-based products in CCU plants, at this point, participants were instructed to focus specifically on the product CO₂-based *jet fuel* for the remainder of the survey. Following this, their acceptance of CO₂-based jet fuel production infrastructure in general [56–58] and in a local context [56,57,59] were surveyed. While the conjoint part of the survey allowed for the analysis of CCU production condition preferences in comparison to one another, this allows for a measurement of the acceptance of the CO₂-based jet fuel production infrastructure as a construct of itself. Following this, participants additionally indicated their acceptance of the CO₂-based fuel as the manufactured end product that is assessed in the second part of the survey [52]. The survey ended with a question about the proximity of their residence to various types of industrial facilities.

The final instrument was pretested with lay individuals, e.g., regarding understandability of the included informative texts and illustrations, and by technical experts for the correctness of the same and was reviewed and approved by the ethics committee of RWTH Aachen University.

4.2. Data collection

Data was collected by using the paid services of a market research company to spread the online questionnaire. We aimed to collect 300 responses per plant type, resulting in an overall sample size of $N = 1200$ German respondents. To ensure a representative dataset, we set quotas for age, gender, education, and region.

Most of the multi-item measurements (Likert scales and semantic differentials) were measured on a 6-point scale. The exception to this was the question on the respondents' knowledge of CO₂, for which a seventh option allowed them to indicate that they did not know the answer. Moreover, for all multi-item Likert scale measurements, the items were randomized within a block of questions.

Additionally, some quality checks were implemented in the questionnaire (i.e., speeders who completed the survey in less than a third of the median participation time, failed attentiveness checks, and incomplete data sets). After data cleaning, a sample of $N = 1204$ respondents was available for further analysis.

4.3. Statistical analysis

Data was analyzed using inferential statistics, i.e., ANOVAs and hierarchical regressions. For variables that were measured based on multiple items, we used the calculation on mean scores after ensuring sufficient internal consistency by calculating Cronbach's α . The level of significance was set at $p = .05$.

Furthermore, we gathered data using choice-based conjoint analysis. Conjoint analysis can be used to assess the decision-relevance of criteria that are taken into evaluation when choosing a product or scenario. Their decision relevance is determined by interpreting their relative importance scores. Based on the part-worth utilities determined by the conjoint analysis, the attractiveness of each individual level can be determined. Relative importance and part-worth utilities are linked by calculating the relative importance based on the range between the highest and lowest part-worth utility of the levels of an attribute for each participant of the study [60]. One-sample t -tests were used for post hoc testing of differences between attribute importances and part-worth utilities.

¹ The four studied industrial CO₂ sources represent CO₂ emitting sources studied in the eCOCO₂ project.

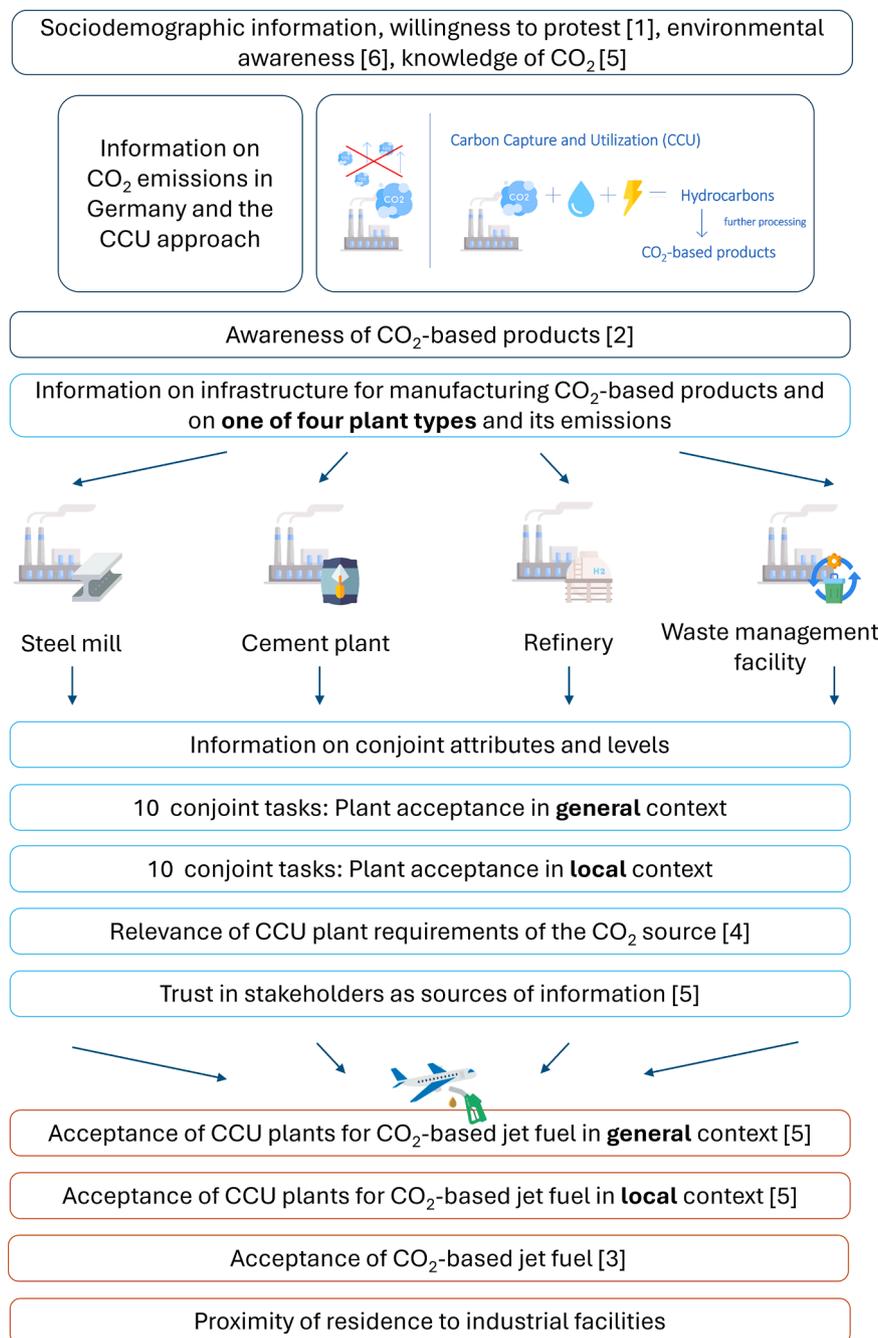


Fig. 1. Representation of survey flow of the study's instrument. Numbers in brackets indicate the number of items per construct.

4.4. Construct formation and data preparation

To use *education* as a variable in the analysis we divided the respondents into groups with a low, medium, or high level of education. To do so, we used the ISCED scale as a guideline [61]. Knowledge was measured on a 6-point Likert scale (from incorrect to correct) with an additional point indicating 'I don't know'. We re-ordered the scale so that 'I don't know' was in the midpoint of the scale. For this scale, as well as for the construct of *requirements for CCU plants*, we calculated the construct mean without regard to internal consistency in the sense of formative measurement (in contrast to the other constructs that can be defined as reflective measurements) [62]. For *knowledge of CO₂*, high values indicate high knowledge, medium values indicate lack of knowledge, and low values indicate that respondents are misinformed. Table 2 comprises the constructs formed for further analysis.

Furthermore, for inclusion in the hierarchical regression, nominal (e.g., *gender*) and ordinal variables (e.g., *education*) were dummy coded. In the case of *proximity of one's residence to various types of industrial facilities*, two groups were created. The first consisted of people knowing of a facility close to their home, the second group included those who did not know about or negated the existence of a facility type (see Table 3).

4.5. Sample

In the sample ($N = 1204$), 50.2 % of the respondents were female, 49.8 % were male, and 0.1 % were of another gender. The respondents' age ranged between 18 and 70 years, with an average age of 45.0 years ($SD = 14.6$). Most of the respondents had a medium (56.8 %) or high (28.2 %) level of education. A relatively small proportion of the respondents (15.0 %) completed a low level of education. 50.2 % indicated

Table 1

Attributes and attribute levels included in the conjoint part of the survey, including icons and translated explanations presented to participants.

Attribute	Level	Icon	Explanation
Transport	Overground pipeline		The produced hydrocarbons are transported primarily through one or more overground pipelines.
	Underground pipeline		The produced hydrocarbons are transported primarily through one or more underground pipelines.
	Truck		The produced hydrocarbons are transported primarily by tank trucks.
	Train		The produced hydrocarbons are transported primarily by freight trains.
	Ship		The produced hydrocarbons are transported primarily by ship.
	No transport		No transport of the produced hydrocarbons is necessary, as they are processed directly on site.
Energy source	Electricity using own renewable sources		The needed amount of additional energy is produced using renewable energy sources (e.g., solar or wind energy) built on-site for this use.
	Electricity via green certificates		The needed amount of additional energy is covered by external operators of renewable energy plants. It is contractually regulated that the required energy is generated specifically for this use.
	Electricity from specific nuclear power plants		The needed amount of additional energy is covered by energy from nuclear plants.
Manufactured end product	Jet fuel		The hydrocarbons can be used to produce jet fuel.
	Plastics		The hydrocarbons can be used to produce plastic goods.
	Waxes		The hydrocarbons can be used to produce waxes that can be used in the cosmetics industry, among other application contexts.

to have children. Regarding place of residence in Germany, 81.0 % lived in Western Germany, 19 % in Eastern Germany states, while 29.9 % inhabited a place in the city center, 40.5 % in the suburbs, and 29.6 % in a village or rural area. With 26.2 %, 1000 until below 2000 € of available monthly net income was the income category with the largest share. See [Table 3](#) for all income groups as well as share of people living in close proximity to existing infrastructure.

On average, respondents reported a rather high level of environmental awareness. On a scale of 1 to 6, the mean environmental awareness score was 4.3 ($SD = 1.0$). Participants answered 66.6 % of the

questions measuring knowledge of CO₂ correctly, 14.9 % incorrectly, and indicated that they did not know the answer to 18.5 % of the questions.

5. Results

To answer the study's research questions, in the result section we elaborate on the results of i) the conjoint analysis to check if there are differences between laypeople's perception of CCU plants in a local and general context, ii) a comparison of the four studied plant types

Imagine that the cases shown below are possible for the production of CO₂-based products based on CO₂ that was collected in cement plants. In this case, the plant where the CO₂ is captured and converted to hydrocarbons is located near your home. Please select the variant you would prefer from the three cases shown.

(1 of 10)

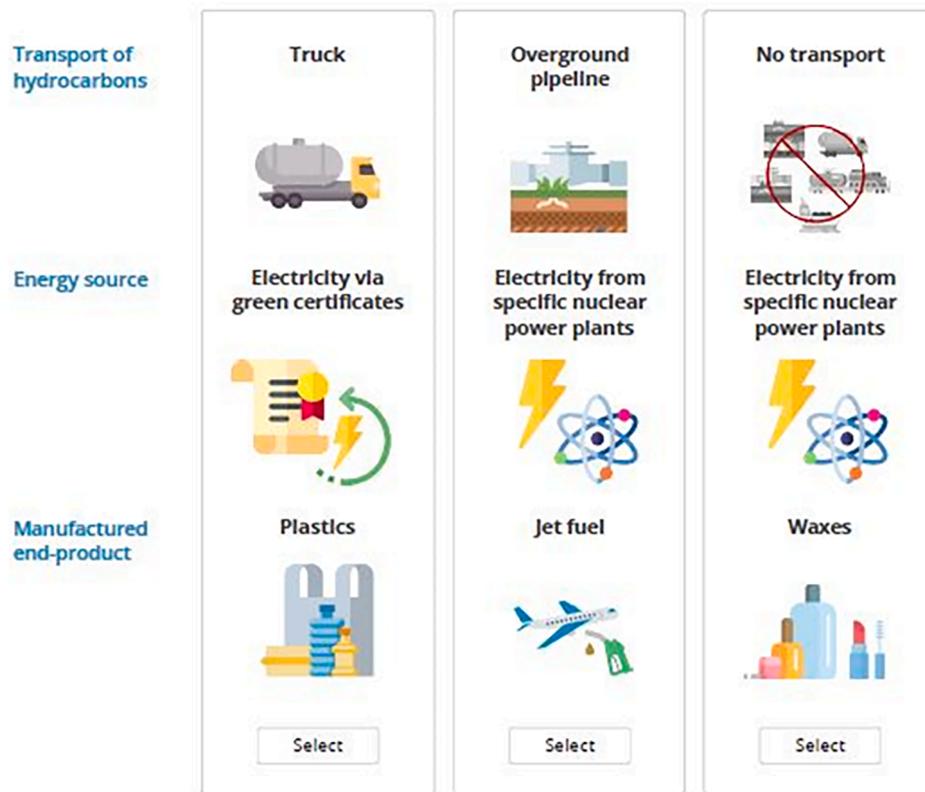


Fig. 2. A translated representation of an exemplary choice task presented to participants during the survey.

regarding local and general acceptance of CCU plants producing CO₂-based jet fuel, and iii) acceptance predicting factors for CCU plants that produce CO₂-based jet fuel, again for the local and general context.

5.1. Perception of production of CO₂-based products

The analysis of the respondents' selection of attribute levels during the conjoint tasks reveals that for the general acceptance of CCU infrastructure characteristics, energy source was identified as the most important characteristic ($M = 41.99$, $SD = 17.78$, see Fig. 3), closely followed by but statistically different from transport of hydrocarbons ($M = 39.65$, $SD = 15.07$, $t_{1,203} = -2.68$, $p = .007$, $d = -0.08$). Interpretation of the importance of the attributes furthermore shows that the manufactured end product was the least important in the case of general acceptance ($M = 18.35$, $SD = 13.04$). The same applies to the context of local acceptance, i.e., the part of the survey in which the participants were asked to imagine that the attributes to be assessed refer to a plant capturing CO₂ and converting it to hydrocarbons, which is located close to their own home. Manufactured end product is identified as the least important attribute ($M = 14.92$, $SD = 11.98$) in contrast to the transport of hydrocarbons ($M = 41.13$, $SD = 16.95$) and the energy source ($M = 43.95$, $SD = 19.33$). Although of similar importance, the mean value of energy source importance is significantly higher than the one of transport of hydrocarbons ($t_{1,203} = -2.85$, $p = .004$, $d = -0.08$).

Although the order of importance is the same between the two contexts of general and local acceptance, there are significant differences. Both the energy source ($t_{1,203} = -4.76$, $p < .001$, $d = -0.14$) and the transport of hydrocarbons ($t_{1,203} = -3.72$, $p < .001$, $d = -0.12$) are more important in the context of local acceptance, while the manufactured end product is more important in the case of general acceptance of the CCU infrastructure ($t_{1,203} = 10.71$, $p < .001$, $d = 0.31$).

The average utilities for the included attribute levels demonstrate which levels are preferred over others within the attribute borders. For the majority of the attribute levels of the manufactured end product, energy source, and transport of hydrocarbons, the average utilities are similar for the contexts of local and general acceptance (see Fig. 4).

Regarding *manufactured end products*, waxes ($M = 3.69$, $SD = 26.2$) are preferred over fuel ($M = 1.95$, $SD = 31.98$, $t_{1,203} = 1.17$, n.s.) and plastics ($M = -5.63$, $SD = 27.52$, $t_{1,203} = 7.49$, $p < .001$, $d = .22$) in terms of general acceptance. Based on the results, the latter can be considered a rejected product compared to waxes and fuels ($t_{1,203} = -4.91$, $p < .001$, $d = .20$). For the local context, again, waxes ($M = 3.94$, $SD = 23.45$) are the preferred option to plastics ($M = -4.77$, $SD = 20.74$, $t_{1,203} = 8.89$, $p < .001$, $d = .26$) and jet fuel ($M = 0.83$, $SD = 28.42$, $t_{1,203} = 2.26$, $p = .024$, $d = .07$). Average utilities are significantly different between jet fuel and plastics ($t_{1,203} = -4.42$, $p < .001$, $d = -0.13$). Paired samples *t*-tests revealed no significant differences between the general and local context (see Table 6 in the Appendix for test statistics).

Table 2

Item texts, Cronbach’s alpha, descriptive statistics, and references for computed constructs.

Construct and respective items	α	M	SD	Reference
Environmental awareness	.73	4.22	0.94	[52,53]
It worries me when I think about in what kind of environment future generations must most likely live.		4.67	1.31	
^R I do not think that one single person can do something against climate change.		3.56	1.65	
^R In the future we need more economic growth, even if it damages the environment.		4.18	1.28	
I think that CO ₂ emissions have a strong influence on climate change.		4.79	1.22	
Whenever possible, I avoid using my car and prefer to cycle, walk or use public transport.		4.21	1.51	
I feel guilty about using the plane for a short-haul flight.		3.97	1.74	
Knowledge of CO₂ **	0.53	0.85		[54]
^R CO ₂ is flammable. (n = 1204)		4.62	1.77	
CO ₂ is emitted when natural gas or coal is used to produce electricity. (n = 1012)		5.97	1.19	
^R Natural CO ₂ and industrially produced CO ₂ are different in their chemical composition. (n = 1204)		4.41	1.73	
CO ₂ affects the climate. (n = 1169)		6.07	1.33	
CO ₂ is toxic to humans in high concentrations. (n = 1082)		5.85	1.53	
Awareness CO₂-based jet fuel	.66	2.22	1.10	[50]
I have a very good knowledge on the topic the production of CO ₂ -based fuels.		1.98	1.11	
^R I have never dealt with the topic of the production of CO ₂ -based products before.		2.47	1.42	
Requirements for CCU plants	0.98	0.71		
In the case of plants that emit CO ₂ , it matters to me which product (e.g., cement) is produced there.		3.83	1.29	
It is important to me how much CO ₂ is produced by a plant.		4.24	1.19	
^R If the CO ₂ produced is captured in a plant and processed into products, the amount of CO ₂ produced is less important to me.		3.47	1.30	
If a plant captures the resulting CO ₂ and processes it into products, I think it’s good if it’s produced in plants that produce a lot of CO ₂ .		4.38	1.27	
General CCU plant acceptance	.89	3.98	1.03	[56,58, 59]
I support the construction of CO ₂ -based jet fuel production plants at manufacturing facilities in my country of residence.		3.93	1.23	
^R I find CO ₂ -based jet fuel production facilities unacceptable.		4.16	1.29	
^R I find CO ₂ -based jet fuel production facilities risky.		3.64	1.16	
^R I oppose the construction of CO ₂ -based jet fuel production facilities in the country where I live.		4.09	1.31	
I think plants for the production of CO ₂ -based jet fuels make sense.		4.11	1.20	
Local CCU plant acceptance	.82	3.55	1.2	[56,57, 59]
^R I would be against such a technical adaptation of the plant in my neighborhood.		3.69	1.43	
I would support of the technical adaptation of the plant in my neighborhood.		3.44	1.3	
I would accept the technical adaptation of the plant in my neighborhood.		3.6	1.34	
^R I would be concerned if a plant in my neighborhood was expanded in this way to produce jet fuel from CO ₂ .		3.47	1.38	
^{*R} I would protest against the adaptation.		3.53	1.38	
Acceptance of CO₂-based jet fuel	.83	4.53	1.06	[52]
^R I oppose the use of CO ₂ -based fuels in aviation.		4.72	1.25	
I would fly in an aircraft powered by CO ₂ -based fuel.		4.41	1.30	
I support the use of CO ₂ -based fuels in aviation.		4.45	1.14	

Table 2 (continued)

Construct and respective items	α	M	SD	Reference
Trust in stakeholders as information sources	.77	3.94	1.06	[38]
Research institutions		4.39	1.27	
Environmental organizations		4.12	1.38	
Governmental institutions		3.43	1.37	
Companies		3.04	1.21	
Non-Governmental-Organizations (NGOs)		3.81	1.37	

^R indicates that the item was inverted.
^{*} items not included in the construct.
^{**} 7-point scale.

Table 3

Shares of respondents for the variables *Monthly net income* and *Proximity of one’s residence to various types of industrial facilities*.

Monthly net income	Proximity of one’s residence to various types of industrial facilities		
		yes	no / don’t know
below 1000 €	14.6 %	Subsample industrial type* 10.1 %	89.9 %
1000 € to under 2000 €	26.2 %	Industrial infrastructure 38.5 %	61.5 %
2000 € to under 3000 €	24.3 %	Wind turbines 28.8 %	71.2 %
3000 € to under 4000 €	16.2 %	Nuclear power plants 3.7 %	96.3 %
4000 € to under 5000 €	8.5 %		
5000 € and more	6.8 %		
Missing	3.8 %		

* i.e., cement plant, refinery, steel mill, waste management facility.

For *energy source*, the differences between the attribute levels are more pronounced. For the general infrastructure context, electricity using resources built locally for this purpose is the only preferred option ($M = 50.80, SD = 39.48$), while electricity via green certificates ($M = -3.91, SD = 26.54, t_{1,203} = -46.05, p < .001, d = -1.33$) reached a negative average utility score. Electricity from specific nuclear power plants ($M = -46.90, SD = 53.16$) is the least preferred and differs significantly from electricity via green certificates ($t_{1,203} = -20.11, p < .001, d = -.58$). Similarly, electricity from own renewable source is clearly preferred for local acceptance ($M = 51.56, SD = 41.56$). The use of green certificates also reached a positive average utility ($M = 0.69, SD = 28.81$). However, this value is not significantly differing from the use of renewable source ($t_{1,203} = -3917, p < .001, d = -1.13$) and from the midpoint of the scale (0) ($t_{1,203} = 0.83, n.s.$). Apparently, this attribute level has little impact on the overall importance of the attribute energy source. Electricity from nuclear plants is the least preferred option ($M = -52.25, SD = 55.37$), significantly differing from green certificate use preference ($t_{1,203} = -23.58, p < .001, d = -.68$). Comparing results, it became apparent that there are significant differences between the general and the local context for electricity from nuclear power plants ($t_{1,203} = 4.99, p < .001, d = .14$), an option that is less preferred in the local context, and for electricity via green certificates ($t_{1,203} = -6.11, p < .001, d = -.18$), which is less preferred in a general context.

Finally, regarding *transport of hydrocarbons*, the results show diverging preferences between the investigated attribute levels. For general acceptance, the most preferred option is no transport ($M = 52.39, SD = 41.85$), followed by underground pipelines ($M = 21.63, SD = 26.49, t_{1,203} = 21.96, p < .001, d = .63$). Overground pipelines are significantly less preferred in direct comparison ($t_{1,203} = 25.25, p < .001, d = .73$), but with an average utility of $M = 6.96 (SD = 22.44)$ still preferred rather than not. Similarly, trains as a mode of transport for hydrocarbons ($M = 3.87, SD = 29.05$) differ significantly from their

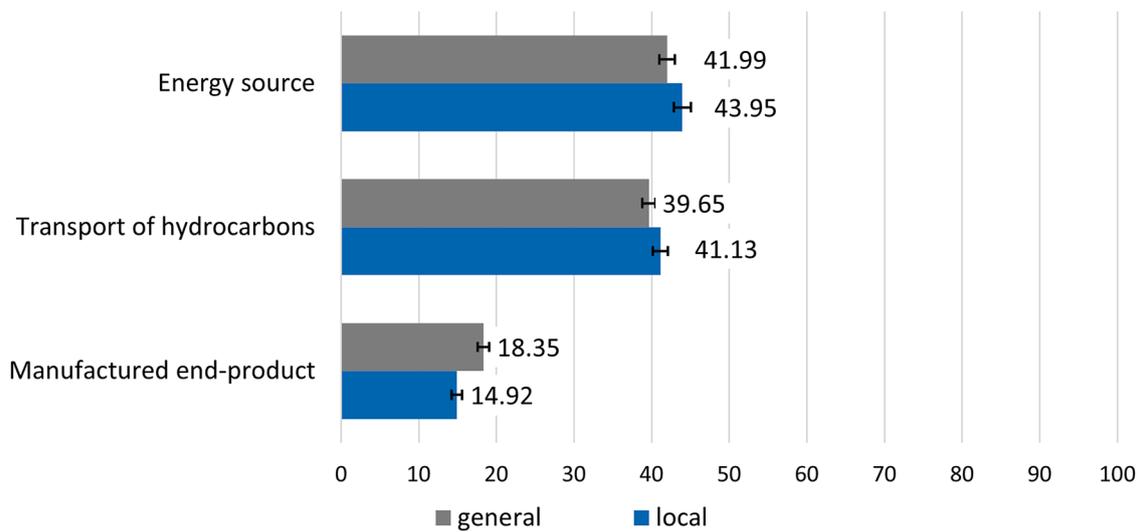


Fig. 3. Relative importances of study attributes for the general and local CCU plant context; error bars denote 95 % CI.

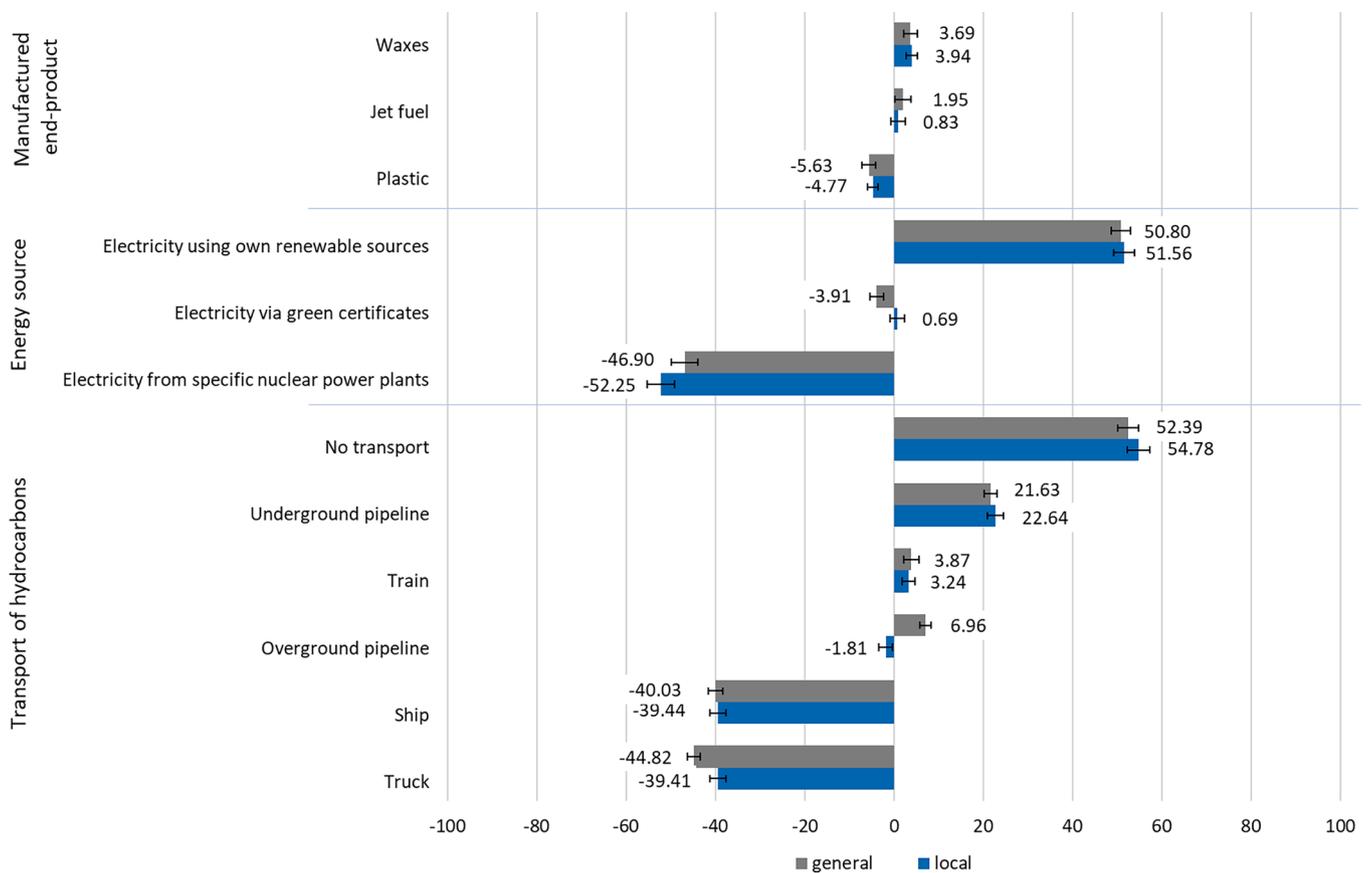


Fig. 4. Average part-worth utilities of attribute levels for the general and local CCU plant context; error bars denote 95 % CI.

predecessor ($t_{1,203} = 2.39, p = .017, d = .07$), as well as from the midpoint of the scale ($t_{1,203} = 4.62, p < .001, d = .13$). The two least preferred modes of transport are ship ($M = -40.03, SD = 28.50$) and truck ($M = -44.82, SD = 25.66$), the latter being significantly less preferred ($t_{1,203} = 6.94, p < 0.001, d = .20$). In the context of local acceptance, it is again no transport that is most preferred by participants ($M = 54.78, SD = 44.77$), followed by underground pipelines ($M = 22.64, SD = 31.82, t_{1,203} = 20.49, p < .001, d = .59$). This is followed by trains ($M = 3.24, SD = 24.82$) and overground pipelines ($M = -1.81, SD = 27.22$). In this case, trains are significantly more preferred in direct

comparison ($t_{1,203} = 3.95, p < .017, d = .11$). Additionally, although average utilities are significantly different from the midpoint of the scale in both cases – and therefore indicate an inclination of preference different from indifference – trains ($t_{1,203} = 4.53, p < .001, d = .13$) are rather preferred, while the negative average utility of the underground pipeline ($t_{1,203} = -2.31, p = .021, d = -.07$) demonstrates that it is not a preferred option in a local context. Ship ($M = -39.44, SD = 32.0$) and truck ($M = -39.41, SD = 31.76$) are the two least preferred modes of transport for hydrocarbons ($t_{1,203} = -0.3, n.s.$). When comparing the two studied plant contexts, it becomes evident, that no transport is preferred

slightly more in the local context ($t_{1,203} = -2.07, p = .039, d = -.06$), while overground pipelines are slightly preferred in a general and slightly not preferred in a local context ($t_{1,203} = 11.20, p < .001, d = .32$). Trucks were significantly less preferred in the general than in the local context ($t_{1,203} = -6.24, p < .001, d = -.18$; see Table 6 in the Appendix for all test statistics).

5.2. Origin of CO₂: acceptance of CO₂ emission sources as CCU plants for the production of CO₂-based jet fuel

The general and local acceptance of CCU plants producing CO₂-based jet fuel was measured using six-point Likert scales. Our results show that general CCU plant acceptance was rather high ($M = 4.12, SD = 1.05$), while local CCU plant acceptance was rather moderate ($M = 3.88, SD = 1.18$), but still significantly different from the midpoint of the scale ($t_{1,203} = 11.26, p < .001, d = .32$), indicating positive acceptance levels.

To check for differences in acceptance between the four plant types (cement plant, refinery, steel mill, and waste management facility) that were included in the survey, one-way analyses of variance were conducted with the constructs of general plant acceptance and local plant acceptance.

There were no significant differences between the four plant types regarding the acceptance of CCU plants producing CO₂-based jet fuel utilizing a plant's CO₂ emissions in a general ($F_{3, 1200} = 1.07, n.s.$) or local context ($F_{3, 1200} = 0.33, n.s.$, see Table 7 in the Appendix for test statistics).

5.3. Predictors of acceptance of production of CO₂-based jet fuel

Finally, to analyze which demographic, attitudinal, and contextual factors influence laypeople's acceptance of CCU plants that produce CO₂-based jet fuel, we conducted hierarchical regression analyses for the two contexts included in this study, using the constructs general plant acceptance and local plant acceptance as dependent variables.

5.3.1. Production of CO₂-based jet fuel in a general context

The results of model 1 indicate that 5.2 % of the variance of general CCU plant acceptance is explained by sociodemographic factors ($adj. R^2 = 0.052, F_{13, 1143} = 6.24, p < .001$). For gender, it was found that men were more accepting than women ($B = 0.29, p < .001$). Furthermore, respondents with a high level of education presented higher levels of acceptance when compared to respondents with a low educational level ($B = 0.44, p < .001$), while monthly net household income was identified as a small predictor ($\beta = 0.07, p = .032$). The remaining sociodemographic variables, as presented in Table 4, did not contribute significantly to the variance explanation.

With the inclusion of attitudes, model 2 explained 5.4 % of the variance ($adj. R^2 = 0.054, F_{15, 1141} = 5.43, p < .001$). While the previously reported significant impacts of gender ($B = 0.28, p < .001$), education (high vs. low) ($B = 0.45, p < .001$), and income ($\beta = 0.07, p = .037$) persisted, environmental awareness added a further significant impact on acceptance ($\beta = -0.07, p = .03$), interestingly indicating that lower levels of environmental awareness correlate with higher levels of acceptance (and vice versa).

Model 3 accounts for an explained variance of 11.7 % after the addition of knowledge related constructs ($adj. R^2 = 0.117, F_{17, 1139} = 10.04, p < .001$). While the influence of income becomes insignificant, differences in acceptance between groups of gender ($B = 0.14, p = .030$) and education (high vs. low) ($B = 0.34, p = .001$) remain. Compared to model 2, the impact of environmental awareness on acceptance is stronger ($\beta = -0.15, p < .001$). Knowledge of CO₂ ($\beta = 0.26, p < .001$) was found to increase general acceptance of CCU plant, while people's awareness of CO₂-based jet fuel ($\beta = -0.09, p = .002$) has a significant negative impact on acceptance.

The inclusion of CCU plant-specific attitudes resulted in a significant model 4 ($adj. R^2 = 0.137, F_{19, 1137} = 10.69, p < .001$). As before,

Table 4

Results of the hierarchical regression for the construct general CCU plant acceptance.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Step 1: Sociodemographic factors					
Age	.04	.04	.04	.05	.04*
Gender ^A	.29***	.28***	.14*	.15*	.01
Education_low vs. medium ^A	.17*	.18*	.12	.14	.03
Education_low vs. high ^A	.44***	.45***	.34***	.34***	.09
East/West Germany ^A	.04	.03	-0.01	.01	-0.04
Children ^A	.09	.09	.06	.03	-0.01
Monthly net income	.04*	.07*	.05	.04	.01
Residential location: rural vs. suburbs ^A	-0.03	-0.02	-0.001	-0.02	.03
Residential location: rural vs. city ^A	-0.02	-0.01	.05	.01	.00
Proximity to:					
Specific plant type ^A	-0.01	-0.02	.04	.04	.10
Other industrial plants ^A	.11	.11	.09	.08	.01
Wind turbines ^A	.05	.05	.07	.06	-0.02
Nuclear power plant ^A	-0.17	.14	.24	.22	-0.02
Step 2: Attitudes					
Willingness to protest		.03	.02	.02	.05*
Environmental awareness		-0.07*	-0.15***	-0.26***	-0.12***
Step 3: Knowledge					
Knowledge of CO ₂			.26***	.24***	.07*
Awareness of CO ₂ -based jet fuel			-0.09**	-0.09**	-0.03
Step 4: CCU plant-specific attitudes					
Trust in stakeholders as sources of information				.18***	-0.03
CCU requirements				.02	.004
Step 5: Acceptance					
Acceptance of CO ₂ -based jet fuel					.40***
Local CCU plant acceptance					.47***

(* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

^A = interpretation of unstandardized beta coefficients.

men presented higher levels of acceptance than women ($B = 0.15, p = .021$), as did highly educated respondents compared to less educated respondents ($B = 0.34, p = .001$). Environmental awareness continues to negatively influence acceptance in this model ($\beta = -0.26, p < .001$), as does knowledge of CO₂ ($\beta = 0.24, p < .001$) and awareness of CO₂-based jet fuel ($\beta = -0.09, p = .001$). Of the added plant-related factors, only increased trust in stakeholders in connection with information about CCU plant infrastructure was linked to increased levels of plant acceptance ($\beta = 0.18, p < .001$), while a higher level of requirement perceptions for implementation did not increase acceptance.

After the inclusion of the acceptance factors, the final model led to an increase of explained variance of 51.1 % ($adj. R^2 = 0.646, F_{21, 1135} = 101.32, p < .001$). In model 5, none of the sociodemographic factors influenced acceptance of CCU plants in general, with the exception of age, indicating that higher age is related to higher levels of acceptance ($\beta = 0.04, p = .041$). While awareness of CO₂-based jet fuel and trust in stakeholders were no longer identified as significant predictors, respondents' willingness to protest weakly influenced CCU plant acceptance ($\beta = 0.05, p = .015$). Furthermore, the higher people's knowledge of CO₂ ($\beta = 0.07, p = .002$) and the lower their environmental awareness ($\beta = -0.12, p < .001$), the higher their acceptance. The newly added factors of CO₂-based fuel acceptance ($\beta = 0.40, p < .001$) and local CCU plant acceptance ($\beta = 0.47, p < .001$) both added strong predictive

power to the model.

5.3.2. Production of CO₂-based jet fuel in a local context

The second hierarchical regression analysis, analyzing the predictive power of each model for local CCU plant acceptance by the stepwise inclusion of factor groups, included all **sociodemographic factors** in a first step. As a result, **model 1** accounts for 6.8 % of the explained variance (*adj. R*² = 0.068, *F*_{13, 1143} = 7.5, *p* < .001). Men were found to accept the local implementation of CCU plants significantly more than women (*B* = 0.38, *p* < .001), as did highly educated people in comparison to respondents with lower educational levels (*B* = 0.46, *p* < .001, see **Table 5**). A third significant difference was identified for the factor of residential closeness to existing industrial infrastructure: individuals living nearby to existing industrial plants accepted local CCU plant implementation more than those who do not (know) (*β* = 0.19, *p* = .009).

After the inclusion of constructs measuring **attitudes in model 2** (*adj. R*² = 0.068, *F*_{15, 1141} = 6.63, *p* < .001), 6.8 % of the variance was explained. Significant differences remained between genders (*B* = 0.39, *p* < .001) and people with higher and lower levels of education (*B* = 0.47, *p* < .001), as did proximity of one's place of residence to industrial plants (*B* = 0.19, *p* = .007). Of the added factors, willingness to protest and environmental awareness, none significantly predicted acceptance for local plants producing CO₂-based jet fuel.

In a next step, **model 3** accounted for an additional 3.9 % of explained variance compared to the previous model (*adj. R*² = 0.107, *F*_{17, 1139} = 9.14, *p* < .001) after the inclusion of the **knowledge** factors. The significant impacts of the factors gender (*B* = 0.25, *p* = .001), high

Table 5
Results of the hierarchical regression for the construct *local CCU plant acceptance*.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Step 1: Sociodemographic factors					
Age	.01	.00	-0.004	.01	-0.02
Gender ^A	.38***	.39***	.25***	.26***	.15**
Education_low vs. medium ^A	.16	.16	.10	.13	.001
Education_low vs. high ^A	.46***	.47***	.36***	.36***	.08
East/West Germany ^A	.14	.15	.11	.14	.14*
Children ^A	.12	.12	.10	.07	.05
Monthly net income	.04	.04	.03	.02	-0.02
Residential location: rural vs. suburbs ^A	-0.08	-0.07	-0.05	-0.08	-0.05
Residential location: rural vs. city ^A	.04	.05	.10	.05	.05
Proximity to:					
Specific plant type ^A	-0.09	-0.09	-0.04	-0.04	-0.05
Other industrial plants ^A	.19**	.19**	.17*	.16*	.10*
Wind turbines ^A	.13	.13	.15	.12	.07
Nuclear power plant ^A	.22	.24	.32	.30	.09
Step 2: Attitudes					
Willingness to protest		-0.04	-0.05	-0.05	-0.05**
Environmental awareness		.01	-0.06	-0.15***	.03
Step 3: Knowledge					
Knowledge of CO ₂			.22***	.20***	.02
Awareness of CO ₂ -based jet fuel			-0.04	-0.04	.04
Step 4: CCU plant-specific attitudes					
Trust in stakeholders as information sources				.21***	.05*
CCU requirements				-0.04	-0.07**
Step 5: Acceptance					
Acceptance of CO ₂ -based jet fuel					.20***
General CCU plant acceptance					.57***

(**p* < 0.05, ***p* < 0.01, ****p* < 0.001); ^A = interpretation of unstandardized beta coefficients.

education (in contrast to low levels of education) (*B* = 0.36, *p* = .002), and proximity to existing industrial infrastructure (*B* = 0.07, *p* = .015) could be identified in this model as well. Furthermore, the newly added factor of knowledge of CO₂ was found to significantly impact local acceptance (*β* = 0.22, *p* < .001), indicating that higher levels of knowledge are connected to higher levels of acceptance.

Subsequently, the inclusion of **CCU plant-specific attitudes in model 4** resulted in an explained variance of 13.3 % (i.e., an increase of 2.6 %; *adj. R*² = 0.133, *F*_{19, 1137} = 10.32, *p* < .001). In this model, men were again found to accept CCU plants locally to a higher degree than women (*B* = 0.26, *p* < .001). Respondents with a high level of education indicated to accept this local plant integration significantly more than those with a low level of education (*B* = 0.36, *p* = .002). Furthermore, the proximity to one's home was again found to be a significant predictor, meaning those who already live quite close (5 km) to preexisting industrial infrastructure are more likely to accept CCU in a local context than those who do not or do not know if they do (*B* = 0.16, *p* = .025). Contrary to previous models, after the inclusion of CCU plant-specific attitudes, a person's environmental awareness was revealed to have a negative impact on local acceptance (*β* = -0.15, *p* < .001), while knowledge of CO₂ was identified as a positive influencing factor, as was the case in model 3 (*β* = 0.20, *p* < .001). Of the two newly added factors, only one added significantly to the explained variance: The more someone trusts the stakeholders who act as sources of information about the CCU infrastructure, the higher their acceptance of a local CCU plant (*β* = 0.21, *p* < .001).

Finally, in **model 5, acceptance factors** were added, resulting in an explained variance of 57.3 % (*adj. R*² = 0.573, *F*_{21, 1135} = 74.98, *p* < .001). Of the sociodemographic factors, gender remained a significant predictor (*B* = 0.315, *p* = .003), while education could no longer be identified as a significant contributor to the model. However, people living in Eastern Germany were found to accept a local CCU plant more than residents from Western Germany (*B* = 0.14, *p* = .021). Residency in close proximity to existing industrial plants remained a significant predictor of local acceptance (*B* = 0.10, *p* = .034), while environmental awareness became insignificant. However, the other attitudinal variable included during step 2 now had a negative impact on local acceptance: respondents who confirmed to take part in demonstrations (in general, without reference to CCU plants) were less likely to accept a local CCU plant (and vice versa) (*β* = -0.06, *p* = .005). While knowledge of CO₂ was no longer included as a significant predictor, trust in stakeholders as a source of information remained as a small impact factor (*β* = 0.05, *p* = .032). In this final model, the higher the level of agreement with requirements regarding the way a CCU plant operates, the lower the level of a person's local acceptance of the CCU plant (*β* = -0.07, *p* = .002). Finally, the newly added acceptance factors, acceptance of CO₂-based jet fuel (*β* = 0.20, *p* < .001) and general CCU plant acceptance (*β* = 0.57, *p* < .001), both significantly predicted local plant acceptance.

6. Discussion

Flying is an integral part of today's society, offering opportunities in a wide range of areas, and will continue to be fundamental for passenger and transfer transport in the near to medium term. This makes it even more important to make a sector such as air transport as environmentally friendly as possible to minimize the associated CO₂ emissions and their impact on the climate as passenger numbers increase. As discussed in the theoretical background, the introduction of new technologies reaches into diverse societal domains potentially posing barriers to a successful integration. For public perception and acceptance, both production- and product-related aspects play a role when it comes to the introduction of innovations in the energy sector such as CO₂-based jet fuel. Therefore, our research focuses on i) the infrastructure and the preference for CCU production conditions, and ii) the predictors of acceptance of plants for the production of CO₂-based fuels in particular, in order to complement the existing literature on product-related

acceptance.

6.1. Preferences for production conditions of CCU plants – energy and transport over end product

The analysis of the data driven by the first research question—*Does the perception of CCU plant production conditions differ between the local and general context?*—revealed that there are significant differences in the importance of production conditions for laypeople's perception of CCU infrastructure. We found this to be the case for perceptions of infrastructure in Germany and in the context of local infrastructure close to one's place of residence. The manufactured end product in both the general and the local context was the least favored option, while energy supply and transport were more relevant to people's decision to accept CCU infrastructure. However, the comparison between contexts shows that the end product is significantly more important in general, national infrastructure implementation than it is in the local context, while the other two studied attributes are significantly more important in the local context. This result underlines that attributes which make a perceivable difference in their implementation in the plant (i.e., transport to the plant and local use of own renewable sources of energy production) are of more importance than the final consumer product manufactured there: For the layperson, it is not only what they can use at the end of a production route that matters, but that the infrastructure-specific conditions play a more important role for the plant infrastructure. This is true for the transport of intermediate hydrocarbons – a step in the life cycle that can be tangible due to its potential impact on a person's daily life considering transport options such as trucks or pipelines. But it also holds for the less directly perceivable energy source, indicating that also more abstract and less tangible production conditions as energy supply matter significantly to the lay public.

The evaluation of the utilities at the attribute level allows a more detailed analysis of the perception of the production conditions of the CCU: For the least decisive attribute, the production condition of the manufactured end product, the plastics option was most disliked, while waxes were slightly preferred and jet fuel was perceived as neutral. This outcome pattern showed no significant differences in the direct comparative analysis of a general vs. local implementation of CCU. It is an interesting finding that the product – the main subject in the second part of the analysis – is perceived as neutral in direct comparison with waxes and fuels. The part-worth utilities were in general not very high (as underlined by the importance of the attribute) but indicate a negative tendency for (more sustainably produced) plastics. A potential explanation for this could be a negative public perception of single-use plastic materials and goods, for which even a more sustainable production approach without the use of crude oil does not lead to positive preference values compared to other options.

Electricity for the conversion process of CCU is strongly preferred from own renewables on site and strongly disliked from nuclear power plants, while green certificates are disliked in the general context and assessed neutrally in the local context. Nuclear power has a negatively tainted background story in Germany, which could explain the strong aversion for this low emission option due to perceptions of potential risks. It is also noteworthy that green certificates (as an assurance that the necessary amount of green energy has been generated) are perceived neutrally in comparison to the strong nuclear aversion, while own renewables are a strong favorite. This points to favoritism of on-site solution for the energy intensive process and hints at a perceived accountability of emission producing plants to ensure the sustainability of the process in-house.

Finally, for the transport of the intermediate product of hydrocarbons, no transport at all would be preferred, followed by underground pipelines and transport by train, which is in line with previous research on CO₂ transport [63]. While overground pipelines are generally preferred, they are slightly disliked in the local context. Ship and truck transport is strongly disliked, also in the local context, while

hydrocarbon truck transport is the most strongly rejected option in the general context. The findings on transport underline two aspects: First, perceivability seems to play a pivotal role in public perception, as no transport and underground pipelines are preferred. The option of no transport is not only free of visual impacts, but also free of climatic impacts and other disturbances (e.g., noise pollution). Second, the difference we observed for overground pipelines between the perception of CCU plant production conditions for the local and the general context supports previous research that finds that residents are less comfortable with energy technologies [64] or pipelines transporting for example hydrogen [65] located near their homes.

6.2. Perception of CCU implementation in industrial plant type as CO₂-source for jet fuel production

During the survey, the investigated industrial plant types in each subsample were presented with plant-specific information (e.g., on the amount of CO₂ emitted per unit of produced or processed goods). As there were no significant differences in the acceptance of CCU implementation in a plant producing CO₂-based jet fuel between the four plant types, either in the general context or in the context of local plant implementation, one might conclude that the type of plant is less important. This is somewhat consistent with the results of the conjoint analysis, which implied a lower importance of the goods produced from hydrocarbons in a facility. It is also in line with the items formulated for the construct of *perceived requirements for CCU plants*, as there is no strong tendency observable for items such as "In the case of plants that emit CO₂, it matters to me which product (e.g., cement) is produced there." (see Table 1 for item means). In contrast, the statement "If a plant captures the resulting CO₂ and processes it into products, I think it's good if it's produced in plants that produce a lot of CO₂." received a higher agreement. Although respondents received information on how much CO₂ is emitted by the source in their subsample, this did not affect local and general acceptance of plants producing CO₂-based jet fuel., which might be possibly due to the low level of expert knowledge in laypeople.

6.3. Acceptance predictors for the production of CO₂-based jet fuel by industrial CCU implementation

When asked about possible factors influencing the acceptance of local and general implementation of CCU plants, we find positive values for both general and local acceptance of CCU plants producing CO₂-based jet fuel, although acceptance is significantly less positive in the case of the latter. This suggests that the public is open to plants that would use CO₂ emissions to produce fuel instead of emitting it.

For the *general acceptance of CCU plants*, we found that among the **sociodemographic factors**, gender and education influenced acceptance in all but the final model, i.e., men (compared to women) and highly educated people (compared to people with a low level of highest education) showed higher levels of acceptance of CCU plants. In the final model, however, the inclusion of additional acceptance factors made them insignificant, and age resulted in a weak influence on overall acceptance. For *local CCU plant acceptance*, men are more accepting of local plants than women. Regional effects were revealed as people living in East Germany are more accepting of local CCU plant integration more than West Germans. Perhaps the former socialist-communist ideology of the former GDR in East Germany, where social welfare was valued more than private preferences, still shapes public opinion in this case. People already living in close proximity (5 km) to industrial infrastructure also indicated higher levels of acceptance, hinting at habituation effects or the assumption that an existing local plant would separate CO₂ from its waste streams rather than emitting it in the local atmosphere. Interestingly, in terms of **attitudes**, the final model for general acceptance found a small but significant effect of protest, i.e., the more someone is willing to protest, the more they would accept the implementation of

CCU to produce CO₂-based jet fuel, while for the local context the opposite was found: the less someone accepts this implementation, the more they would be willing to protest (and vice versa). While environmental awareness was a predictor of acceptance in the case of general acceptance, we found that it had no impact on whether people would be in favor of a local plant converting its emissions into CO₂-based jet fuel. Interestingly, the impact in the general context was negative, indicating that people with higher environmental awareness are less positive about CCU plants in general. One possible explanation for this could be that people perceive the moral hazard of continued emissions – i.e., that removing CO₂ could lead to the moral hazard of continuing emissions rather than reducing emissions in the first place – which has been found to influence the support for carbon removal technologies in previous research [66].

People's **knowledge of CO₂** turned out to have a small positive effect on general acceptance, while it did not remain as a significant predictor in the final model for the local context. Awareness of CO₂-based jet fuel did not add to the final models of regression, indicating that the impact in earlier models (i.e., models 3 & 4) is not relevant after the inclusion of stronger predictors in the subsequent additions.

After the introduction of **CCU plant-specific attitudes** to the models, we find that trust in information sources and the level of plant requirements are not predictors of general plant acceptance, but turn out to predict local acceptance of CCU plants producing CO₂-based jet fuel: The more people trust stakeholders as sources of information on the implementation of CCU plants, and the less they agree with the requirements regarding, for example, the relevance of the amount of CO₂ emitted, the more they accept a CCU plant in the local context. It should be added that we interpreted *CCU plant requirements* as the degree to which a person has an increased awareness of production conditions, rather than in terms of agreement with the content of the requirements formulated in the items.

Finally, the addition of **acceptance-related factors** contributed strongly in both contexts. Acceptance of the produced end product of CO₂-based jet fuel and a person's local acceptance of a CCU plant added almost equally to acceptance of the use of CCU in industrial plants in the general context. For local acceptance, however, we examined a stronger prediction by a person's support for the concept of CCU plants in general than by acceptance of the manufactured end product, CO₂-based jet fuel. We conclude that there is a link between the conceptualization of acceptance in terms of general support for the implementation of CCU in industrial infrastructure and in terms of acceptance of CCU infrastructure close to one's place of living. At the same time, our results indicate that the influence of general support is of higher significance for a person's attitude towards local industrial developments than the outcome of the ongoing process, i.e., CO₂-based fuel as an end product, while for general support, local acceptance is an only slightly more relevant predictor than fuel acceptance.

7. Limitations and further research

There are a few methodological limitations to our study. The impact of some variables in our study should be tested with larger sample sizes, such as the *proximity of one's residence to different types of industrial facilities*, which was in some cases represented by rather unequal group sizes. Information on this characteristic was not collected with representative data or equal group sizes in mind, but this could have affected the results of the regression analysis.

When interpreting the results on the local acceptance of CCU infrastructure, it needs to be mentioned that we studied the case of a conversion that would take place in a plant that is close to one's home. The instructions did not explicitly specify the state of the facility where the CO₂ conversion would take place, which is why future studies should include the investigation of potential acceptance differences between existing plants that need to be modified for CCU and newly installed plants that incorporate the CCU approach from the beginning. Previous

findings observed interaction effects between the perception of carbon storage approaches and the type of CO₂ transport [67]. Further research on CCU (acceptance) should test the production conditions studied in this analysis for more complex relationships and interdependencies. Finally, the production characteristics studied here might be perceived differently in different countries. Germany for example with a history of a strong anti-nuclear movement might differ from other neighboring countries such as France, a country with a high number of reactors. National or cultural comparisons therefore should investigate differences in perception and acceptance of the public.

8. Conclusion

The remaining steps for widespread implementation of the CCU approach are diverse and reach, among others, into the economic, regulatory, and societal sphere. With regard to the latter, this study provided a deeper insight into the state of public perception of CCU infrastructure, in particular the acceptance of infrastructure for the production of CO₂-based jet fuel, as well as predictors of general and local acceptance. In this way, the study contributed to i) linking the introduction and production of CO₂-based fuel (and other products) and the necessary infrastructure with the societal perceptions, and ii) complementing other necessary areas of technology introduction (e.g., technological development, economic feasibility, and regulatory hurdles). In doing so, the results presented provide input for further research, technology development, and policy design by shedding light on the public perceptions of aspects of the necessary technology design and by allowing the identification of hot spots and potential hurdles of social acceptance of sustainable technologies such as CCU and resulting products.

Ethics approval and consent to participate

The instrument of the study was reviewed and approved by the ethics committee of the department "Empirical Humanities" of the Faculty of Arts and Humanities at the Rheinisch-Westfälische Technische Hochschule Aachen. The participants provided their written informed consent to participate in the study.

Funding

This work was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – Cluster of Excellence 2186. "The Fuel Science Center" ID: 390919832. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 838077. The funding sources were further not involved in conducting the study.

Use of Artificial Intelligence

During the preparation of this work the authors used DeepL.com in order to improve the written text grammatically and linguistically. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

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

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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jfueco.2025.100145](https://doi.org/10.1016/j.jfueco.2025.100145).

Data availability

Data will be made available on request.

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