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"Consumers' and Operators' Acceptance of GreenLNG"

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Content

1. Abstract

In two studies, we explored the acceptance of GreenLNG among operators and the general population. In study 1, 10 heavy transport operators were interviewed on their GreenLNG acceptance using a semi-structured interview approach. Operators expressed an interest in adopting and trying out GreenLNG, despite pointing out challenges such as accessibility, infrastructure, pricing, and environmental impact. They stressed the need for more information to fully shape their opinions. In study 2, the general population was surveyed on their GreenLNG acceptance via an online survey (*N* = 2005). Results indicated that attitude, safety, trust, usability, and usefulness all predict GreenLNG acceptance with trust in involved agents and perceived usefulness being the strongest predictors. Gender showed only minimal association with GreenLNG acceptance. The results from the two studies suggest that operators and the general population base their acceptance of GreenLNG on slightly different factors. Therefore, tailoring information seems to be important for successful implementation: operators require details on pricing, environmental impact, and accessibility, while the general population needs trust in involved agents and awareness of GreenLNG's (environmental) benefits.

2. Introduction

The transport sector is one of the most energy-intensive and emissions-producing sectors. Within the transport sector, road transport accounts for the largest proportion of overall transport emissions, contributing 76% of the total greenhouse gas emissions from transport (EEA, 2021). To counteract this situation, alternative fuel technologies must be emphasized. While there have been several developments in alternative fuel technologies in recent years, many of these innovations are not suitable for heavy-duty vehicles or long-distance transport (e.g., electric vehicles; Engerer & Horn, 2010). One promising alternative, however, is Liquified natural gas (LNG) which can also be used for long distances or as marine fuel (Arteconi & Polonara, 2013). LNG is converted from natural gas by cooling it down to -160°C, where it becomes liquid and reduces its volume by 600 times. All currently used LNG is derived from fossil fuels. However, the methane required for LNG can also be obtained from hydrogen and CO2. Hydrogen can in turn be produced using renewable energy sources. If both the hydrogen and the CO2 come from renewable or biogenic sources, we speak of GreenLNG, representing an environmentally friendly and sustainable fuel option. The CarbonNeutralLNG project aims to develop solutions for the production of this new type of GreenLNG.

Although new fuel technologies seem to be a promising approach to limit the greenhouse gas emissions in the transport sector, the implementation of these new technologies often hinges on public acceptance of those technologies (Moula, et.al 2013). For instance, the introduction of hydrogen fuel demonstrated that public opposition can lead to costly delays or even force changes to the implementation plans (Tchouvelev et al., 2019). Public support on the other hand can lead to increased political support and thus can accelerate implementation (Banister, 2008). For a smooth implementation, it is therefore crucial to understand the acceptance of GreenLNG. In this report we will focus on consumers' and operators' acceptance of GreenLNG and look at fears and attitudes that might prevent potential applicants to widely establish GreenLNG transportation but also motivations that will foster it.

Previous research focused on the acceptance of LNG proposed that the concepts of accessibility, attitude, safety, usability, and usefulness will all predict the individual acceptance of LNG (Pfoser et al., 2018). In this LNG acceptance model, accessibility pertains to the availability of technology and refueling stations. Studies have indicated that the availability of the technology and sufficient infrastructure influences an individual's acceptance of alternative fuels (Browne et al., 2012). Previous research has also demonstrated that the use of LNG is correlated with the proximity and efficiency of refueling stations (Arteconi & Polonara, 2013). Next, attitude towards the alternative fuel is supposed to determine an individuals' acceptance of LNG (Pfoser et al., 2018). Research has repeatedly shown that a positive attitude towards an alternative fuel is linked to its acceptance (e.g., Tarigan et al., 2012). Safety concerns represent another aspect linked to LNG acceptance. In the case of natural gas vehicles safety concerns often arise because natural gas is either stored at high pressure or, in the case of LNG, at very low temperatures (Bernatík et al., 2011). These safety concerns then negatively affect public acceptance of alternative fuel vehicles (Browne et al., 2012). Furthermore, LNG acceptance is supposed to be linked to the expected usability. Usability refers to the ease of use and applied to LNG it is given if similar or better functional attributes to existing fuels are evident. This enhances the likelihood of individuals accepting a new technology (Browne et al., 2012). Lastly, the likelihood of a technology being accepted depends on whether or not individuals believe it will lead to any improvements or improve performance (Davis, 1989). This aspect is referred to as expected usefulness.

In the context of GreenLNG, however, which is a new and yet-to-exist fuel, individuals may not yet fully comprehend what GreenLNG entails or what to expect from it. Consequently, their acceptance judgments may also be influenced by factors beyond factual understanding. One factor that might influence acceptance, particularly when individuals lack knowledge about a fuel technology, is trust in involved agents. Trust refers to the extent to which people believe they can rely on the parties in charge of making decisions and taking actions related to the implementation and management of the technology and the environment (Siegrist et al., 2000). Previous studies have found trust to have a positive influence on benefit perceptions and a negative influence on risk perception of a new technology (Siegrist et al., 2000) and have shown that individuals with high levels of trust tend to perceive new technologies as safer and more acceptable (Siegrist, 1999). Particularly in the absence of knowledge about a technology, trust often serves as an alternative basis for forming opinions about it (Siegrist & Cvetkovich, 2000; Huijts et al., 2012). Additionally, Liu et al. (2019) have shown that having high levels of trust in the responsible agents leads to greater project acceptability.

To adequately understand the acceptance of GreenLNG, we have therefore chosen to incorporate the concept of trust into the LNG Acceptance Model proposed by Pfoser et al. (2018; see Figure 1). In the following studies, we will investigate consumers' and operators' acceptance of GreenLNG based on this GreenLNG Acceptance Model. Initially, we will gain insight into operators' acceptance of GreenLNG through 10 semi-structured interviews, followed by a large-scale survey of the general population.

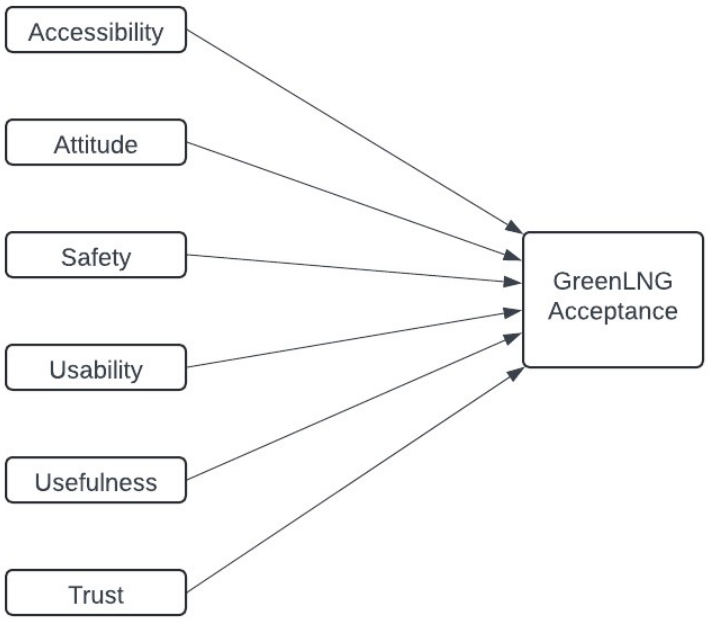

Fig. 1: GreenLNG Acceptance Model adapted from LNG Acceptance Model by Pfoser et al., 2018

3. Study 1 Operator Interviews

The purpose of Study 1 was to investigate the acceptance of GreenLNG for operators of LNG vessels and trucks in cargo and passenger transport. We conducted 10 interviews with different operators. The study was preregistered on the Open Science Framework (https://osf.io/rgtjy/?view_only=1d50640dfda341d297b6380d7cb3069a).

3.1 Methods

3.1.1. Sample and Design

To find operators to take part in our interviews, we approached acquaintances to inquire if they might have operator contacts and could facilitate an introduction for us. Subsequently, those were asked if they wanted to take part in the interviews. All of the, in total 10, participants were male, and their ages ranged from 24 to 62 (M = 40.40, SD = 12.82). One of them was recently retired, and one of them only worked during the summer while the rest were full-time employed. One of the interviewees was not a driver himself but was the CEO of a transport company already implementing LNG trucks. Another one's main occupation was a software developer, but he regularly worked and drove for the family's sawmill business. The rest of the operators were from the sections of forestry, waste disposal of sewage sludge, construction sites, standard truck drives, and one captain of smaller ships transporting passengers on a lake in a nature reserve.

According to participants preferences, interviews could be held online via the university's video conference tool UniMEET or in person. Five were held online, and five in person at different locations, such as a café outside normal business hours, one of the university's conference rooms, or at the participant's home. The

interviews duration ranged from 60 to 86 minutes (*M* = 71.20, *SD* = 13.29). All participants were compensated with 30 EUR for their participation in the interview.

3.1.2. Procedure

After reading and signing, or in the case of online interviews, verbally agreeing to the consent form, and providing their demographic as well as their banking data for compensation, participants were informed that the recording and the interview would now begin. At the beginning of the interview a short introduction about GreenLNG and the projects' goals were presented. The interview was sectioned into main- and follow up questions. To obtain comprehensive responses the main questions were formulated broadly and openly. Below are the main questions regarding the six variables of the GreenLNG acceptance Model (Figure 1):

- Attitude: "What do you think about/what is your (first) opinion about GreenLNG?"
- Safety: "What experience do you have with fuel safety in your professional environment?"
- Trust: "Who do you think is/will be involved at handling GreenLNG (in the implementation and dissemination)?"
- Usability: "How would you envision the transition to GreenLNG?"
- Accessibility: "How would you describe the accessibility of LNG- fuel/filling stations in your region/industry?"
- Usefulness: "In your opinion, what would be the general impact of switching to GreenLNG?"

Specific sub-questions were asked if the responses to the main questions did not address them. Below are examples of the follow-up questions for each variable (for entire interview guide see appendix).

- Attitude: "What role do you think GreenLNG will play in the future?"
- Safety: "What would you expect about the safety of using GreenLNG?"
- Trust: "How trustworthy are these actors?"
- Usability: "How would a switch to GreenLNG affect your working life?"
- Accessibility: "What do you think, how accessible will GreenLNG be in the future, compared to other fuels?"
- Usefulness: "How do you think a switch to GreenLNG would affect the environment?"

At the end of the interview, participants were questioned about their acceptance of and intention to use GreenLNG. They were also asked to summarize the most important aspects of the interview for them and provide their opinion on what could be the fuel of the future. Additionally, the opportunity to address topics regarding GreenLNG that were not discussed was provided.

3.1.3. Analysis

All interviews were professionally transcribed by the transcription service Transkribieren.at (UniChamp GmbH). We analyzed the transcripts using the program MAXQDA (version 24.1.0). Initially, we categorized each text segment of the transcript systematically into the six predefined variables (attitude, safety, trust, usability, accessibility and usefulness), along with an additional, already mentioned, category for acceptance/intention to use. Subsequently, we used an inductive approach to further analyze these categorized text segments to identify new underlying categories. Finally, the resulting categories and

corresponding text excerpts were read through again to ensure specificity and inclusivity of all relevant information.

3.2 Results

3.2.1. Attitude

The first question delved into participants' first thoughts and first attitude about GreenLNG after just shortly being introduced to it. The interviewees' first attitudes and opinions about GreenLNG were mixed. About half of the interviewees mentioned to have a positive first impression about GreenLNG, while the other half reported a negative first impression. Those with a positive first impression mostly referred to environmental benefits and CO2 reduction as the reason for their positive attitude. Additionally, factors such as interest in new technologies and local production of the fuel were highlighted as positive aspects. People with a negative first impression on the other hand voiced skepticism regarding GreenLNG actually being more energy efficient and climate friendly, its novelty and insufficient research, as well as challenges related to the transition such as high costs and limited availability of fueling stations.

However, despite reservations, many expressed openness to using GreenLNG once it becomes more established and widely available. While some people were very skeptical about the feasibility of the transition towards GreenLNG, most interviewees (7) acknowledged the necessity of shifting fuels, primarily due to environmental concerns and anticipated regulatory changes (such as the future prohibition of fossil fuels). Moreover, 9 people mentioned that new fuels and fuel alternatives are an important topic in their work and that they discuss this topic with their colleagues and superiors. Especially the prices of fuels seem to be an important discussion topic among the interviewees and their colleagues.

When asked about their employer's openness towards new fuels like GreenLNG, most people (7) said that they think their employers would be open to that. Some mentioned that their employers want to be more environmentally friendly and sustainable and are therefore already actively looking for alternatives, however, as of right now, electric vehicles are more present in that discussion and there seems to be less focus or discussions around other fuels like (Green)LNG. Nevertheless, financial considerations seemed to be the primary determinant, with most interviewees suggesting that their employers would only consider GreenLNG if it proved financially viable and profitable.

Overall, participants expressed a desire for more comprehensive information to form their attitudes and opinions about GreenLNG. They want to see facts about actual CO2 emissions, costs and feasibility of the implementation of GreenLNG.

3.2.2.Safety

The next discussed topic was safety concerning GreenLNG, particularly its transportation, handling, refueling processes, and the necessity of training for its use. A nearly equal number of participants expressed safety concerns compared to those who asserted there were none. Those without concerns stated that the safety of GreenLNG probably would not differ much from the safety of fossil fuels. It was also mentioned that safety is expected and must be ensured if GreenLNG is to be implemented widely. However, six participants highlighted the difficulty in assessing GreenLNG's safety due to a lack of prior knowledge and experience with the fuel. Almost all interviewees agreed that a short training or instructions for handling GreenLNG would be necessary and beneficial.

Concerns regarding the possibility of careless handling of GreenLNG and associated safety issues were raised by three interviewees. Refueling and the temperature of GreenLNG during that process emerged

as predominant concerns. Some participants mentioned potential issues arising from technology problems and the novelty of GreenLNG, highlighting the need for constant cooling and concerns about road accidents and transportation. Methane leakage and resulting environmental issues were noted as concerns by four of the operators.

Overall, the interviewees found it challenging to discuss the topic of GreenLNG's safety, mainly because they lacked previous familiarity and experience. Nonetheless, some expressed concerns regarding GreenLNG's safety, although they generally agreed that these concerns were comparable to those associated with fossil fuels and could be addressed to some extent with proper instructions and diligence.

3.2.3.Trust

The subsequent point of interest focused on participants trust in GreenLNG, the stakeholders involved, and the factors that could potentially influence it.

More than half of the interviewees expressed their wariness about GreenLNG, particularly regarding their trust in the involved actors. A significant concern raised was the perception that those actors might prioritize financial gain over environmental considerations. Nonetheless participants generally acknowledged that the actors needed to prioritize consumer rights and safety. Some questioned whether this consideration would then stem from moral principles or simply business and legal obligations. Additionally, two interviewees noted the impossibility of generalizing the intentions of all actors, recognizing that individuals vary in their intentions. Similarly, three others mentioned their inability to definitively assess their trust in the actors due to a lack of familiarity with them and their intentions. Furthermore, three participants emphasized the importance of personal contact with the actors in influencing trust.

Regarding other factors that could potentially influence trust, we asked the participants if a person's characteristics like their knowledge, abilities, and appearance, might impact their trust in them. Half of the interviewees believed that this will likely be the case. Sympathy and expertise, particularly the latter which they considered to be generally expected, were specifically mentioned. Lastly, the topic of campaigns was brought up, with four interviewees suggesting that campaigns and media presence could affect trust in the GreenLNG product itself.

3.2.4.Usability

In examining usability, we focused on comparing fossil fuel with GreenLNG and assessing the changes and implications resulting from a transition to GreenLNG.

Most of the interviewees expressed an expectation that the usage and usability of GreenLNG would resemble that of fossil fuels, not anticipating many changes resulting from the fuel switch. However, contrary to this, half of the participants anticipated a decline in usability, attributing it to the more cumbersome handling associated with GreenLNG usage. One of the major reasons mentioned for this is the expected difficulty in the fueling process due to the extremely cold temperature of GreenLNG. Additionally, concerns were raised about the potential difficulties in transporting the fuel, due to its temperature. Another potential issue, identified by half of the participants was the anticipation of more complex servicing due to the novelty of the technology, the necessity to maintain the fuel at low temperatures in pressurized tanks, and the possibility of higher service costs. The one factor where the positives seemed to outweigh the negatives was the environmental aspect, for which participants expected GreenLNG to be better in this regard.

Concerning participants expectations regarding the adoption and implementation of GreenLNG, nearly every interviewee (9) anticipated chances, primarily focusing on handling aspects such as the fueling

process, accessibility of GreenLNG, or a generally defined, more complex usage. Nonetheless, it was stated that these changes in handling would be relatively easy to learn, but a small introduction would still be important. Interviewees also noted that their previous job-related knowledge and experience would assist them in this regard. Hence, it could be presumed that while many participants anticipated changes in their job when GreenLNG would be implemented, these changes are generally perceived to be minor and not overly detrimental. When questioned about their job safety following a theoretical adaptation of GreenLNG, participants noted that this would be a challenging thing to predict but likely not a significant concern for the majority of drivers, except perhaps for older drivers who are reluctant to adapt or have trouble doing so.

The challenge of predicting usability also emerged during the discussions. Again, participants found it difficult to address this topic, as they lacked prior experience with GreenLNG, and in many cases, even with regular LNG. Consequently, discussing the usability of a newly introduced fuel based solely on the information provided posed a significant challenge for them. However, some participants highlighted the importance of refining the novel technology to ensure a satisfactory user experience. Additionally, points regarding the necessity of a well-developed infrastructure and the affordability of implementing these measures were stated during the discussion.

3.2.5.Accessibility

Next, the accessibility of GreenLNG and its infrastructure, were discussed.

One of the most frequently mentioned points in the interviews, highlighted by nine participants on numerous occasions, was the necessity and importance of a well-developed infrastructure. This need could generally be attributed to the two factors: money and time. Given the tight schedules of drivers, it would not be feasible for them to drive additional time and have higher costs resulting from the need to drive longer distances to refueling stations, due to an underdeveloped infrastructure compared to fossil fuels. Contrary to that, some few people still pointed out, that a developed infrastructure would not be of great importance at first. The stated reason was that there are many other factors crucial for a successful adaptation sometimes even more important than infrastructure, such as the price of GreenLNG, marketing, and consumer education.

Furthermore, eight interviewees anticipated that GreenLNG usage would increase with the availability of more refueling stations. This expectation stems from the considerations of time and cost, which naturally accompanies discussions about infrastructure plus an expected surge in market presence associated with an increased number of refueling stations.

When asked how developed the infrastructure needs to be to ensure usability, responses regarding the distance between refueling stations varied between 50 to 300 kilometers, with the majority falling within the 50 to 100 kilometer range. Other prevalent answers included the necessity for a station in proximity to every major city (in Austria), or at least a sufficient number of stations, just enough to not have concerns about availability.

Despite highlighting the need for a fully developed GreenLNG infrastructure for successful adaptation, some participants had doubts if such development would be possible. The dilemma, where the scarcity of refueling stations discourages GreenLNG adoption, while the lack of GreenLNG users hinders the expansion of refueling stations was mentioned in this context.

3.2.6.Usefulness

Delving into the usefulness of GreenLNG, our focus laid in discussing the implications of a potential adaptation and implementation of GreenLNG.

While some individuals expressed difficulties in assessing the environmental impact of GreenLNG, largely due to insufficient information, on for example on the production processes, the majority (9) stated on numerous occasions that they expect positive impacts on environmental aspects like air quality, ecological sustainability, and conservation of natural resources and ecosystems from GreenLNG. Similarly, they expect improvements in overall quality of living and health, particularly in terms of improved air quality. It was also noted that a higher quality of living, potentially achieved through lower-cost goods due to a reduction in fuel prices, could be a possibility. However, some also expressed uncertainty, suggesting that determining the extent of GreenLNG's contribution to these goals remains difficult. Four individuals also highlighted the assumption that companies would benefit from an image enhancement resulting from the adoption of GreenLNG and a more sustainable approach to operating their businesses. This suggests that there exists potential for gains in reputation and brand perception, which could further incentivize organizations to adapt environmentally friendlier practices like GreenLNG. Concerning the economic impact, participants also expressed difficulties in making predictions. The responses we received, as previously noted, primarily revolved around the potential for a subsequent reduction in the cost of living and a possible greater independence from oil-producing nations, which was viewed positively.

One of the most discussed topics regarding the usefulness of GreenLNG, reoccurring throughout the entirety of the interviews, was the price and the associated costs of GreenLNG. Again, people voiced difficulties in predicting the costs, largely due to the variety of influential factors and lack of information. The overall opinions regarding the potential price of GreenLNG compared to fossil fuels were mixed. However, the majority (8) expected the short-term costs to be higher, while many (7) also expected that in the long term, the costs could be lower than those for fossil fuels. The primary reason stated for the expected higher costs in the initial stages largely revolved around the expenses associated with large-scale adaptation and implementation. When asked whether the interviewees think GreenLNG would be affordable for all companies, they once again could not provide a clear answer. Lastly, half of the participants stated that they would, at most, be willing to pay the same price for GreenLNG as for fossil fuels, provided they offer similar range capabilities. The participants imagined the range capabilities of GreenLNG to be about the same as for fossil fuels.

As mentioned before, the overall cost of GreenLNG is crucial, not only for perceived usefulness but also for practicality, as it may not be feasible for individuals or companies to pay a lot more for alternative fuels, which was brought up by 9 interviewees on multiple occasions. A related topic is that of subsidies. Nine participants mentioned that subsidies could potentially influence motivation to adopt and utilize GreenLNG, and they expressed an expectation for such subsidies. The majority (6) also advocated for them. Nonetheless, six interviewees did not believe that the absence of subsidies would necessarily be demotivating for the adoption of GreenLNG.

3.2.7. Acceptance / Intention to Use

Lastly, we asked the operators about their acceptance of GreenLNG and their intention to use it. The primary focus of the interviews was on the factors that could influence the acceptance and intention to use GreenLNG. Therefore, we sought to understand what these factors might be and how participants perceive the possibility of GreenLNG adaptation and if they would support it.

Twelve potentially important factors for acceptance were raised by the interviewees, with three emerging as primary foci; price, accessibility, and the environmental impact of GreenLNG. The most frequently mentioned factor was the price and associated costs of using and adapting to GreenLNG. It was emphasized that additional expenses for fuel and vehicles were not feasible for companies, especially when their existing vehicles are still operational and a transition to newer LNG vehicles would be required. It was also mentioned, that a lower usage cost, for example stemming from lower fuel price or subsidies, would be a reason to adapt to GreenLNG. The point of accessibility and the need for a well-developed

infrastructure was already discussed in more detail previously. The final point among these three main factors is the potential positive environmental impact of GreenLNG. Particularly, the notion of contributing to environmental improvement appears to be significant for fostering an intention to use it. The other 9 discussed factors that contribute to the acceptance and intention to use GreenLNG (not listed in a particular order; see Figure 2 for number of people who mentioned each) are:

- Good performance of the fuel
- The prevalence of the topic in society
- Production of GreenLNG
- Education about GreenLNG
- Easy application
- The maturity of the technology
- Safety
- Marketing
- Firsthand knowledge

Most participants (8) agreed that a broad transition to GreenLNG, although challenging due to factors such as the seemingly high cost of adaptation and the previously mentioned issues (need for fully developed infrastructure, more complex fueling process), appears to be possible. Some also mentioned that the social acceptance (and the acceptance of their employer) of GreenLNG is likely to be high. Concluding their statements, the interviewees expressed to be at least interested in hearing more or testing out GreenLNG if possible.

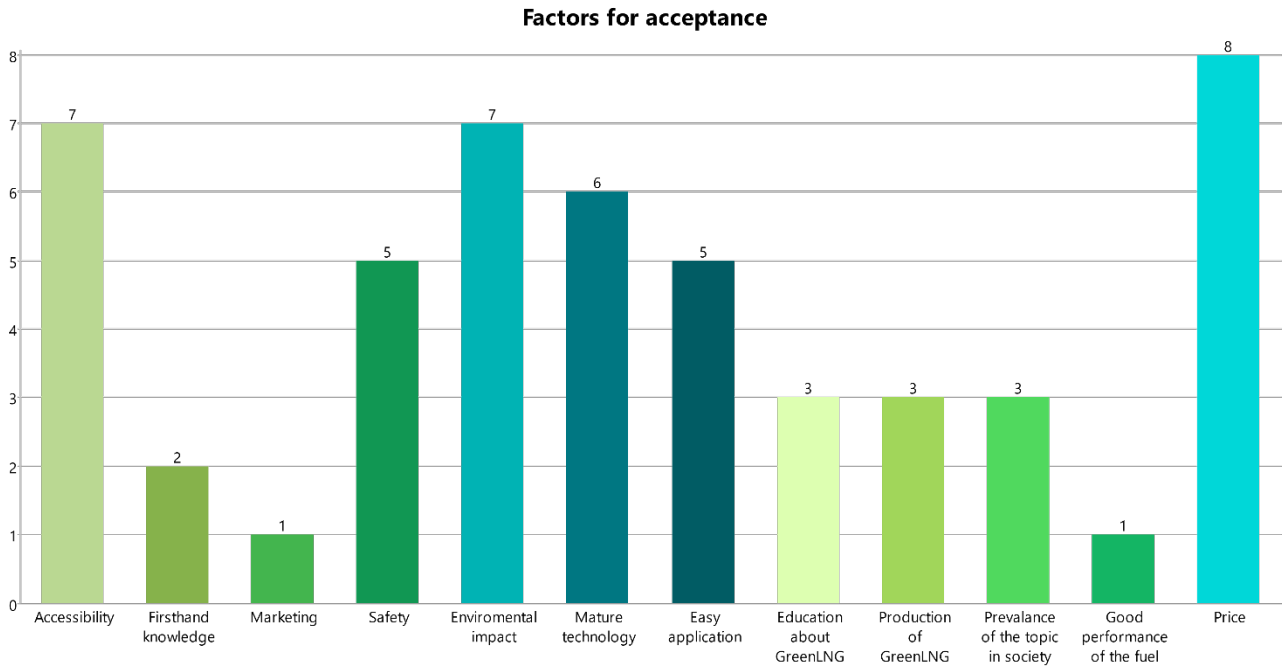

Fig. 2: Factors affecting GreenLNG acceptance and how many people have mentioned them (based on 10 interviews)

3.3 Conclusion Study 1

Overall, there seems to exist a general interest in exploring and potentially testing out GreenLNG among the operators, despite some expressed challenges. Accessibility issues emerged as a main point of worry

for the participants, centered on the necessity for a robust infrastructure, with emphasis on the proximity of refueling stations needed for widespread adoption. While positive environmental impacts were anticipated, pricing arose as a major theme. Participants highlighted the importance of affordability. Ultimately, acceptance and intention to use GreenLNG seemed to largely depend on factors such as price, accessibility, and environmental impact, with participants displaying openness to transitioning if these concerns were addressed. However, participants also repeatedly emphasized the need for more information to fully form their opinions.

4. Study 2 Survey General Population

Based on the insights form the operator interviews in Study 1, it became obvious that peoples' acceptability judgement also seems to depend on their values. Values can be defined as principles and goals which are stable across different situations and that people try to live by (Schwartz, 1992). There are several different values that can be categorized into four different value clusters namely, biospheric values, altruistic values, egoistic values, and hedonic values (Steg et al., 2014). Biospheric values include aspects such as respecting the earth, unity with nature, protecting the environment, and preventing pollution. Altruistic values encompass equality, peace in the world, social justice, and helpfulness. Egoistic values comprise an orientation toward social power, wealth, authority, influence and ambition. Finally, hedonic values focus on improving one's feelings and reducing effort.

Previous research indicated that values are an important predictor of acceptability of renewable energy sources and technologies (De Groot et al., 2013; Perlaviciute & Steg, 2015; Steg et al., 2005). Particularly important in the context of sustainable developments is the distinction between biospheric and egoistic values (Perlaviciute & Steg, 2015). This is also the impression we got from the interviews. People appeared to focus primarily on either financial implications of GreenLNG (egoistic values) or on environmental implications of GreenLNG (biospheric values) with these aspects recurring throughout the interviews and guiding their responses to most questions. Hence, we included a value measure in the Study 2 survey.

Furthermore, it is important to understand how individuals perceive new fuel alternatives like GreenLNG compared to established and currently used methods of CO2 reduction, such as carbon compensation. Carbon compensation, also known as carbon offsetting, involves activities that mitigate or balance out CO2 emissions generated from one source by reducing emissions elsewhere or by absorbing carbon dioxide from the atmosphere through activities such as tree planting or investing in renewable energy projects. It aims to counteract carbon emissions (Huber et al., 2024).

Moreover, there is a growing trend among consumers to prioritize environmental protection. While many acknowledge the potential negative impact of their consumption habits on the environment, they struggle to discern which products genuinely adhere to environmentally friendly standards. This uncertainty has led to a widespread skepticism towards companies' claims regarding their environmental practices, with consumers suspecting companies of engaging in "greenwashing." Greenwashing refers to the deliberate act of companies misleading consumers about the environmental quality of their products (Bottega et al., 2024). It is therefore crucial to determine if a new fuel like GreenLNG or a concept like carbon compensation will be perceived as a greenwashing attempt or if people will see it as a genuine environmentally friendly alternative. In study 2, we thus also looked at people's greenwashing perceptions.

Study 2 aimed to investigate the acceptance of GreenLNG within the general population. For that purpose, we conducted a large-scale survey with 2000 participants representative for the Austrian population. We assessed GreenLNG acceptance using the GreenLNG acceptance model (see Figure 1), measured values, evaluated participants' perceptions regarding the relevance of GreenLNG compared to carbon emission compensation, and explored whether individuals perceived GreenLNG as a form of greenwashing. Additionally, we investigated potential gender differences. The study was preregistered on the Open Science Framework (https://osf.io/cx2js/?view_only=05fad96e0ed1412da15d2512998f38c2).

4.1 Methods

4.1.1. Sample and Design

Data collection followed APA guidelines for the ethical conduct of research. Using the online panel "Talk", we gathered a representative sample of the Austrian population (based on age, gender, education, and federal state) and invited them to take part in the online survey in German programmed with Limesurvey. Participants were compensated for their participation by the panel. In total, 4102 people (partially) completed the survey out of which 2097 had to be excluded, most of them because they did not pass the attention checks. Out of the remaining 2005 participants, 50.5% were female and 49.3% male. Their ages ranged from 18 to 80 (M = 49.56, SD = 15.86). Sixty-four percent had completed at least lower-level education, and 59.5% were currently working full-time.

Regarding the power, a sensitivity analysis revealed that with a sample of 2000, a multiple linear regression analysis with six predictors, alpha = .00833 (Bonferroni corrected), and a power of .9 would be able to detect small effect sizes of f^2=.007.

4.1.2. Procedure

When clicking on the survey link, participants were initially provided with a brief overview of the study and prompted to provide their informed consent. Subsequently, they answered some questions regarding demographic variables. Following this, participants filled in the value measure. They were then presented with a concise introduction and description of GreenLNG, followed by a few questions on greenwashing related to GreenLNG. Next, participants completed the GreenLNG acceptance model, which encompassed questions regarding attitude, safety, usability, usefulness, and trust, ending with questions about their acceptance / intention to use or support GreenLNG. The aspect of accessibility was omitted because GreenLNG is not currently available, thus participants could not assess its accessibility. Then they read a short description of the concept of carbon compensation and were asked questions related to greenwashing concerning carbon compensation. Lastly, we also asked participants which option (GreenLNG or Carbon Compensation) they think is more effective in reducing or counteracting CO2 emissions.

4.1.3. Measures

First, demographic variables were measured. We measured age, gender (male, female, other), education and federal state.

Next, we measured values using an adapted version of Schwartz's value scale (1992) by De Groot and Steg (2008) with three added hedonic value items proposed by Schwartz (1992). The complete scale was tested in previous research by Steg et al. (2014). Participants rated the importance of the 16 values "as a guiding principle in their lives" on a 9-point scale ranging from –1 (*opposed to my values*) to 7 (*extremely important*).

An example item that participants had to rate was "Wealth: material possessions, money" (altruistic values α =.81, biospheric values α =.91, egoistic values α =.79, hedonic values α =.85).

All included aspects of the LNG Acceptance Model were measured with items by Pfoser et al. (2018). Additionally, three items for the concept of trust were added to the model. Each item was measured on a 7-point scale ranging from 1 (*do not agree at all*) to 7 (*completely agree*).

Attitude was measured with three items, one example being "Alternative fuels will play an important role for the future energy mix.". After deleting one item which did not correlate well to the other items, the reliability was acceptable (α = .76).

Safety was measured with five items such as "I think undesirable effects such as damages are improbable when using GreenLNG technology." (α =.68).

Usability was measured with three items including "The introduction of GreenLNG vehicles would keep a fleet operator's daily operations as they were before.". After deleting one item which did not correlate well to the other items, the reliability was acceptable (α = .62).

Usefulness was measured with three items with an example being "Compared with diesel, GreenLNG technology could help a company achieving its environmental and social sustainability goals." (α =.84).

Trust was measured with three items including "I trust the technical expertise of those involved in the GreenLNG sector." (α =.88).

Acceptance was measured with three items such as "I support GreenLNG as a favorable alternative transportation fuel for operating fleets." (α =.88).

We also assessed peoples' perceived greenwashing regarding GreenLNG and Carbon Compensation using four self-constructed items for each, respectively. An example item was "Companies or institutions only switch to GreenLNG to create an environmentally friendly image."(GeenLNG Greenwashing α =.64, Carbon Compensation Greenwashing α =.64).

4.2 Analysis and Results

We calculated bivariate Pearson correlations for GreenLNG acceptance, attitude, safety, usability, usefulness, trust and gender (see Table 1). Due to the large sample size, many of the results are statistically significant; however, we chose to focus on interpreting only results with effect sizes of at least r = +/-.15. Furthermore, since gender was coded as Male = 1, Female = 2 and Other = 3, we decided to exclude all "other" in the analysis concerning gender. This only affected 4 cases leaving us with a sample size of 2001 for all analysis including the variable gender. All variables within the GreenLNG acceptance model (attitude, safety, trust, usability, usefulness) show strong positive correlations with each other and with the acceptance of GreenLNG. Gender does not correlate to any of the variables to a meaningful degree.

Table 1: Bivariate correlations and confidence intervals

	Age	Education	Acceptance	Attitude	Safety	Trust	Usability	Usefulness
Gender	-.11 [-.15, -.06]	.01 [-.03, -.05]	-.05 [-.09, .00]	.02 [-.02, .06]	-.12 [-.16, -.08]	.00 [-.04, .05]	-.08 [-.12, -.04]	.01 [-.04, .05]
Age		.02 [-.02, .06]	.04 [.00, .08]	.17 [.13, .21]	.08 [.04, .12]	.02 [-.02, .06]	.02 [-.03, .05]	.08 [.04, .12]
Education			.06 [.02, .10]	.14 [.10, .18]	.06 [.01, .10]	-.01 [-.06, .03]	.01 [-.03, .05]	.06 [.02, .10]
Acceptance				.58 [.55, .61]	.58 [.54, .61]	.71 [.68, .74]	.61 [.58, .64]	.78 [.75, .80]
Attitude					.47 [.43, .50]	.48 [.45, .52]	.44 [.40, .48]	.69 [.67, .72]
Safety						.56 [.52, .60]	.51 [.47, .55]	.56 [.52, .59]
Trust							.64 [.60, .67]	.71 [.68, .74]
Usability								.59 [.55, .63]

Note. Values in square brackets indicate 95% confidence interval [lower limit, upper limit] for each correlation. Gender was coded as 1 = Male and 2 = Female

We hypothesized that attitude, safety, usability, usefulness, and trust will all predict acceptance of GreenLNG. To test the hypothesis, we conducted a two-stage hierarchical multiple regression analysis with acceptance as the dependent variable. The demographic variables gender, age, and education were entered at stage one of the regression. The variables of the GreenLNG acceptance model attitude, safety, usability, usefulness, and trust were entered at stage two. The hierarchical multiple regression revealed that at stage one, the demographic variables explained a significant amount of variation in GreenLNG acceptance ($F(3,1997) = 4.71$, $p = .003$). However, they only accounted for 0.6% of the variance in GreenLNG acceptance. Introducing attitude, safety, usability, usefulness, and trust at step two contributed

significantly to the regression model (R^2 change = .67, F(5,1992) = 833.89, p<.001). They accounted for 67.2% of the variation in GreenLNG acceptance. The results of the regression analysis are displayed in Table 2. The regression analysis revealed that the variables attitude, safety, usability, usefulness, and trust indeed all predict GreenLNG acceptance, with usefulness and trust being the strongest predictors. In total, the model was able to explain 67.8% of the variance in GreenLNG acceptance.

Table 2: Regression Table

Predictor	*B*	*B CI 95% [LL, UL]*	*SE B*	*β*	*t*	*p*
Step 1						
Gender	-.117	[-.23, -.01]	.056	-.047	-2.100	.036
Age	.003	[.00, .01]	.002	.035	1.549	.122
Education	.059	[-.01, .10]	.023	.057	2.545	.011
Step 2						
Gender	-.090	[-.15, -.02]	.032	-.036	-2.792	.005
Age	-.002	[.00, .00]	.001	-.025	-1.905	.057
Education	.017	[-.01, .04]	.013	.016	1.279	.201
Attitude	.071	[.03, .10]	.019	.070	3.826	<.001
Safety	.145	[.10, .19]	.022	.107	6.503	<.001
Trust	.246	[.21, .29]	.020	.244	12.141	<.001
Usability	.134	[.10, .18]	.020	.116	6.635	<.001
Usefulness	.455	[.41, .50]	.024	.426	18.993	<.001

Note. Gender was coded as 1 = Male and 2 = Female

Because trust is likely to play an important role in forming opinions and influencing acceptance of GreenLNG, considering that it is a relatively unfamiliar fuel, we wanted to assess the extent to which trust alone, after controlling for demographic variables in step 1, and the other variables of the GreenLNG acceptance model (attitude, safety, usability, usefulness) in step 2, could explain the acceptance of GreenLNG in the final step 3 of the model. To investigate this, we exploratively recalculated the hierarchical regression model, introducing trust in step 3 of the regression model, and retaining demographic variables in step 1 and the other variables of the GreenLNG acceptance model (attitude, safety, usability, usefulness) in step 2 (see Table 3). At step 1, the regression model stayed the same as before (see Table 2). Introducing attitude, safety, usability, usefulness at step 2 contributed significantly to the regression model (R^2 change = .65, F(4,1993) = 936.70, p<.001). Adding attitude, safety, usability, usefulness accounted for 64.8% of the variation in GreenLNG acceptance. Finally, the addition of trust to the regression model explained an additional 2.4% of the variation in GreenLNG acceptance and this change in explained variance was also significant (R^2 change = .02, F(1,1992) = 147.41, p<.001). Together, the whole regression model accounted for 67.8% of the variance in GreenLNG acceptance. Trust alone, however, was able to uniquely explain 2.4% of the variation in GreenLNG acceptance.

Table 3: Hierarchical Regression with Trust in Step 2

Predictor	*B*	*B CI 95% [LL, UL]*	*SE B*	*β*	*t*	*p*
Step 2						
Gender	-.065	[-.13, -.00]	.033	-.026	-1.943	.052
Age	-.002	[.00, .00]	.001	-.030	-2.230	.026
Education	.006	[-.02, .03]	.014	.005	.403	.687
Attitude	.059	[.01, .10]	.019	.058	3.091	.002
Safety	.204	[.15, .26]	.022	.151	9.056	<.001
Usability	.215	[.17, .26]	.020	.186	10.901	<.001
Usefulness	.579	[.51, .63]	.022	.542	25.761	<.001
Step 3						
Gender	-.090	[-.16, -.03]	.032	-.036	-2.792	.005
Age	-.002	[.00, .00]	.001	-.025	-1.905	.057
Education	.017	[-.01, .04]	.013	.016	1.279	.201
Attitude	.071	[.03, .11]	.019	.070	3.826	<.001
Safety	.145	[.10, .20]	.022	.107	6.503	<.001
Usability	.134	[.09, .18]	.020	.116	6.635	<.001
Usefulness	.455	[.39, .51]	.024	.426	18.993	<.001
Trust	.246	[.20, .30]	.020	.244	12.141	<.001

Note. Gender was coded as 1 = Male and 2 = Female; Step 1 of the regression is the same as in Table 2

Next, we exploratively looked if the regression model was moderated by gender. To do so, we used the same regression model as in Table 1, with the demographic variables gender, age and education in the first step of the regression, the variables of the GreenLNG acceptance model (attitude, safety, trust, usability, usefulness) in step 2 and with the interaction between gender and attitude, safety, trust usability, and usefulness, respectively, in step 3. The results for the first two steps of the regression stayed the same as displayed in Table 1, together explaining a total of 67.8% of the variance in GreenLNG acceptance. Adding the interaction between gender and attitude, safety, trust, usability and usefulness in step 3 did not significantly contribute to the regression model (R^2 change = .002, $F(5,1987) = 1.90$, $p = .090$). Adding the interactions with gender only explained an additional 0.2 % of the variation in GreenLNG acceptance and when looking at each of the effects, only the interaction between gender and useability was significant. For females, the relationship between usability and GreenLNG acceptance was slightly stronger than for males (see Table 4).

Table 4: Regression Table with Gender Moderation in Step 3

Predictor	*B*	*B CI 95% [LL, UL]*	*SE B*	*β*	*t*	*p*
Step 3						
Gender * Attitude	-.038	[-.13, .05]	.036	-.106	-1.056	.291
Gender * Safety	.004	[-.11, .11]	.045	.007	.079	.937
Gender * Trust	-.035	[-.13, .07]	.041	-.083	-.872	.383
Gender * Usability	.117	[.02, .21]	.041	.253	2.888	.004
Gender * Usefulness	-.011	[-.13, .11]	.048	-.027	-.221	.825

Note. Gender was coded as 1 = Male and 2 = Female; Step 1 and Step 2 of the regression are the same as in Table 2

Next, we computed bivariate Pearson correlations for GreenLNG acceptance, biospheric values, altruistic values, egoistic values, and hedonic values. The results indicate that only biospheric values and altruistic values both positively correlate moderately strongly with GreenLNG acceptance (see Table 5).

Table 5: Bivariate correlations of Values, Acceptance and Gender

	Acceptance		Gender	
	r	*CI 95% [LL, UL]*	*r*	*CI 95% [LL, UL]*
Biospheric values	.25	[.21, .30]	.12	[.07, .16]
Altruistic values	.25	[.21, .29]	.14	[.10, .18]
Egoistic values	.06	[.01, .10]	-.05	[-.10, -.01]
Hedonic values	.07	[.03, .12]	.03	[-.01, .07]

Note. Gender was coded as 1 = Male and 2 = Female

Additionally, we exploratively looked at what participants reported to perceive as more effective to reduce or counteract CO2 emissions, either GreenLNG or Carbon Compensation. The results are illustrated in Figure 3. Approximately half of the respondents (1027) reported perceiving carbon compensation as more effective, while the other half (978) reported perceiving GreenLNG as more effective.

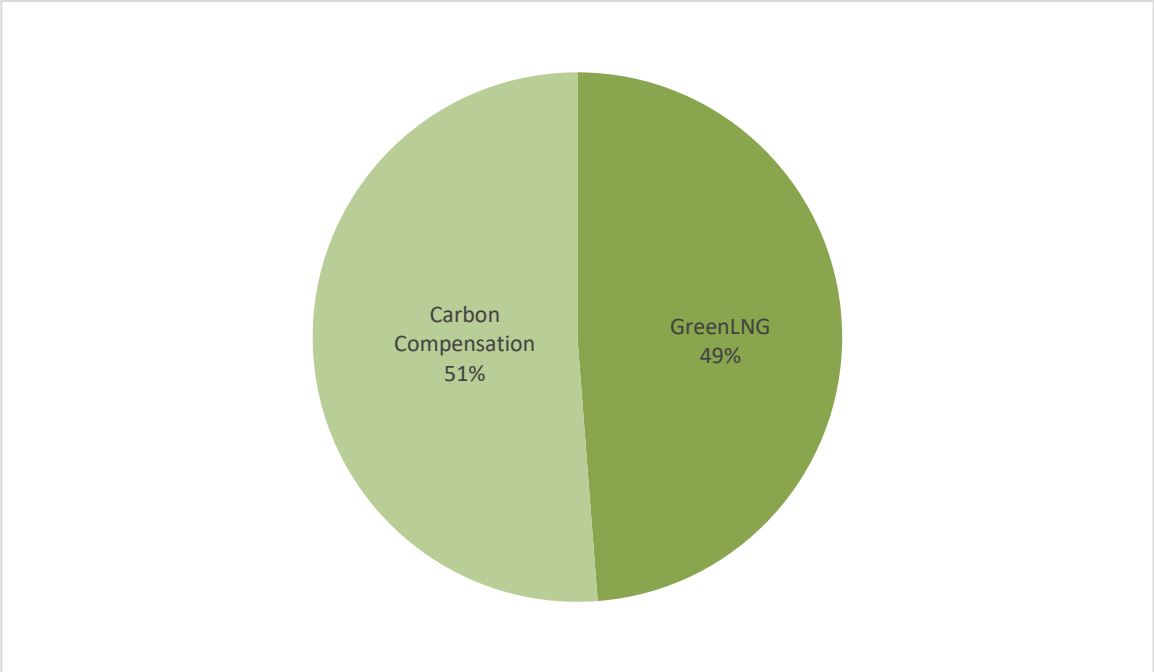

Fig. 3: Pie Chart of number of people who reported preferring GreenLNG vs Carbon Compensation *N* = 2005

Finally, we explored participants' perceptions of greenwashing associated with carbon compensation and GreenLNG. The findings suggest that individuals perceive carbon compensation as slightly more greenwashing than GreenLNG. However, both options are viewed as somewhat greenwashing, with mean scores slightly below the midpoint (M = 3.54 for GreenLNG and M = 3.87 for carbon compensation on a 7-point scale; see Figure 4). The difference in greenwashing perceptions between GreenLNG and carbon compensation was significant ($t(2000) = 15.54$, $p < .01$).

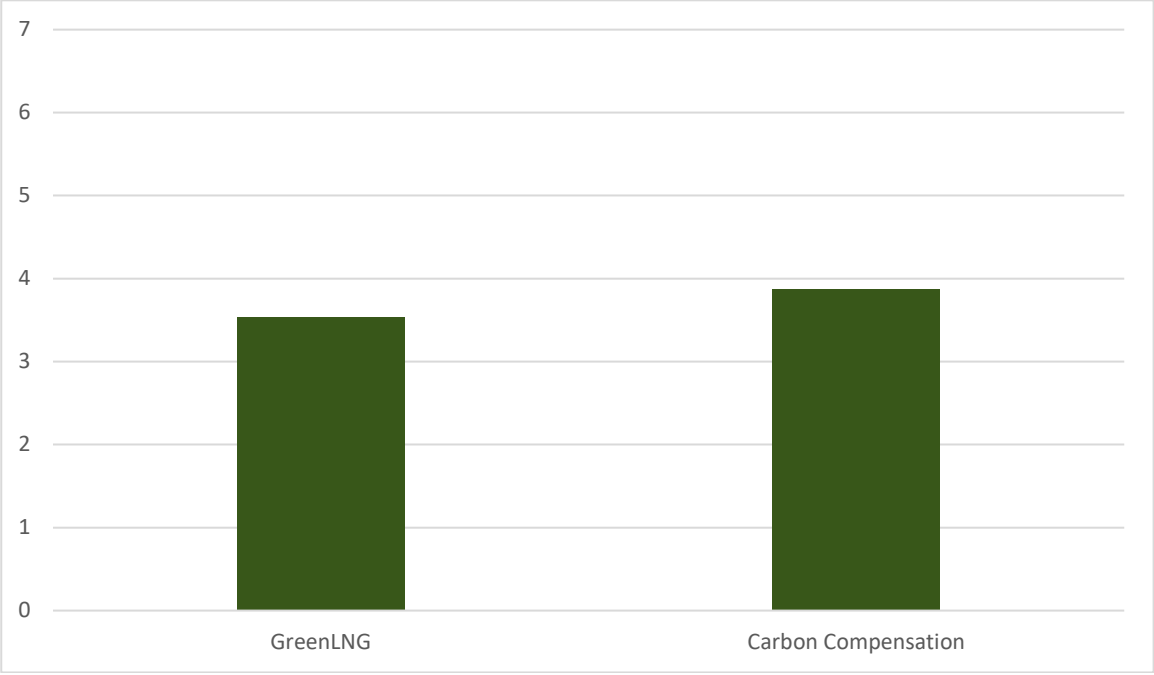

Fig. 4: Reported perceived Greenwashing of GreenLNG and Carbon Compensation (7-point Scale)

4.3 Conclusion Study 2

Study 2 investigated GreenLNG acceptance in the general population. Bivariate Pearson correlations revealed positive correlations among variables within the GreenLNG acceptance model—attitude, safety, usability, usefulness, and trust—all strongly linked with GreenLNG acceptance. Notably, gender was not substantially correlated with any variables.

Our hypothesis that attitude, safety, usability, usefulness, and trust would predict GreenLNG acceptance, was supported by our findings. A hierarchical multiple regression analysis demonstrated that these variables collectively explained a large portion (67.8%) of the variance in GreenLNG acceptance, with usefulness and trust emerging as the strongest predictors.

Given the important role of trust in shaping perceptions of unfamiliar technologies, we explored its unique impact on predicting GreenLNG acceptance. Our results suggested that trust alone after controlling for demographic variables and attitude, safety, usability, and usefulness, could still uniquely explain an additional 2.4 % of the variance in GreenLNG acceptance. This result highlights the importance of trust when it comes to new fuel-technologies. In the context of GreenLNG, which is a newly emerging and still-developing fuel, individuals might not fully grasp what it entails or its potential implications. Consequently, their acceptance judgments may also be influenced by factors beyond factual understanding. In such instances, trust in the involved stakeholders may serve as an important predictor of acceptance.

Furthermore, we found positive, moderately strong correlations between biospheric and altruistic values with GreenLNG acceptance, suggesting that individuals endorsing these values are more inclined to accept GreenLNG.

Additionally, our exploratory analysis showed how effective participants perceive GreenLNG and carbon compensation to be, alongside their perceptions of greenwashing. Approximately half of the respondents considered GreenLNG to be more effective, while the other half viewed carbon compensation as more effective, suggesting divided effectiveness perceptions among participants. Additionally, perceptions of greenwashing were slightly higher for carbon compensation than for GreenLNG. However, both alternatives showed scores slightly below the midpoint on the scale, indicating that while concerns regarding greenwashing exist for both GreenLNG and carbon compensation, they were not very pronounced.

Overall, our findings highlight the importance of trust in driving acceptance of unfamiliar technologies and fuels like GreenLNG, while also showing support for the GreenLNG acceptance model as well as values in shaping attitudes toward alternative fuel options.

5. Discussion

In two studies, we investigated the acceptance of GreenLNG, first among operators and then within the general population. Among operators, there appears to be a general interest in exploring and potentially adopting GreenLNG, despite some expressed challenges. The main points affecting operators' acceptance which emerged from the interviews were accessibility and infrastructure of the fuel, its price and affordability, and its environmental impact. However, the operators also emphasized the need for more information to fully form their opinions.

Conversely, a slightly different trend emerged among the general population. For the general population, which might not be very familiar with (new) fuel technologies and its consequences and implications, trust in involved agents emerged as an important predictor of acceptance. When people do not have many contact points with the fuel technology themselves, they seem to rely on trusting the parties handling the fuel in order to accept it. Additionally, the perceived usefulness of the new fuel was an important predictor of acceptance, also hinting to the importance of considerations of environmental impact and improvements the fuel will bring. This suggests that, in the general population, acceptance of a new fuel likely hinges on trusting the involved parties and perceiving the fuel as beneficial and useful, such as in reducing CO2 emissions.

A similar trend can be observed in the correlations between the values and GreenLNG acceptance. Here, biospheric and altruistic values, emphasizing protecting the environment and social justice, both positively correlated to GreenLNG acceptance. However, contrary to our expectations based on the interviews, egoistic values did not correlate to GreenLNG acceptance. This again suggests potential differences in GreenLNG acceptance patterns between operators and the general population.

To successfully implement GreenLNG, it might therefore make sense to specifically tailor information for different groups. For operators, emphasis should be placed on communicating details about pricing, environmental impact, fuel availability and refueling station accessibility. For the general population on the other hand, efforts should focus on fostering trust in the involved agents and highlighting the usefulness and environmental benefits of GreenLNG.

Lastly, when examining the relationship between gender and GreenLNG acceptance, no meaningful results could be found. Gender appears to only have minimal relation with GreenLNG acceptance or any of the variables within the GreenLNG acceptance model (attitude, safety, trust, usability, usefulness). We only observed a moderation effect of gender between GreenLNG acceptance and usability, yet this effect, while statistically significant, was notably small. The effect can likely be attributed to the large sample size and should thus not be over interpreted.

Overall, our findings suggest that people seem to be open towards new fuel alternatives like GreenLNG when their concerns are addressed adequately.

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