Examining the Social Acceptance of AWE Designs

with use of a Stated Choice Experiment

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Preface

Dear reader,

Little more than half a year ago, I embarked on this research journey at TU Delft with a profound curiosity about airborne wind energy systems. This research has allowed me to feel, even if only slightly, that I am contributing to the development of AWE technology, thereby advancing sustainability goals.

I would like to thank the members of my graduation committee. Firstly, thank you Gerdien de Vries for your guidance and wisdom, your mentorship ensured I stayed focused and on track, providing invaluable feedback that refined my approach. Secondly, thank you Eric Molin for your knowledge and feedback. Your insights into stated choice experiments have been instrumental in structuring and designing this research. Thirdly, thank you Helena Schmidt for your help and advice. Throughout the project, regular meetings with you enriched my understanding of airborne wind energy systems and helped steer the direction of my exploration.

Additionally, I would like to thank the AWE research group at TU Delft. They have been an invaluable support system, offering expert advice and constructive critiques. I extend my heartfelt thanks to all members, particularly Bart Zweers, who helped me immensely with visualizing all the different airborne wind energy designs.

I am deeply grateful to the wide range of participants—friends, colleagues, fellow students, and family—who generously participated in and facilitated the distribution of my survey. Their contributions have been essential in shaping the empirical foundation of this thesis.

This thesis marks a significant personal and academic milestone, contributing to the ongoing pursuit of sustainable energy solutions. I hope this work inspires further exploration and innovation in renewable energy, particularly in the field of airborne wind energy, paving the way for a cleaner and more sustainable future.

T. P. T. van Zweden
Delft, July 2024

Executive summary

The escalating global demand for sustainable energy solutions has spurred interest in pioneering technologies such as Airborne Wind Energy (AWE) systems. This thesis delves into the crucial aspect of public acceptance of various AWE designs, focusing on how different design attributes influence public perception and acceptance. Given that local opposition poses a significant threat to adopting emerging technologies, this study aims to shed light on strategies to enhance the social acceptance of AWE systems. By addressing these challenges, the research aims to pave the way for broader implementation of AWE technology. To achieve this objective, the study investigates the following research question:

- How do specific design attributes of airborne wind energy systems relate to the system's social acceptance?

To address this research question, this study employs a comprehensive research approach consisting of two parts. The first part includes a literature review serving two main purposes: conceptualizing the concept of social acceptance within the context of Airborne Wind Energy (AWE) systems and identifying an initial list of relevant design attributes currently used in the AWE field. Drawing from previous studies in psychology, sociology, microeconomics and technology acceptance, social acceptance is defined in this research as the behaviour exhibited by individuals, particularly local stakeholders, when confronted with the installation of specific AWE designs near their residences, managed or owned by external entities. Furthermore, the relationship between design attributes and acceptance is conceptualized, highlighting the roles of perceived safety and aesthetics as mediators that indirectly influence acceptance. Besides the effect of design attributes on acceptance, the literature study also pays attention to the role of different psychological variables which affect the acceptance of AWE systems. Moreover, through an examination of studies, articles, and literature in the airborne wind energy field, an initial list of design attributes is identified, including kite type, kite size, generation mode, operating height, kite colour, Air time, take-off mode and obstruction lights.

To find out more about the relation between these design attributes and the acceptance of AWE systems, two surveys have been conducted. Firstly, to validate and streamline the initial list of design attributes, a short survey has been distributed among developers and experts in the AWE field. The results of this preliminary survey are a final set of the most relevant design attributes which include: kite type, kite size, operating height, kite colour and obstruction lights. Secondly, a survey has been conducted to gain insights into the relation between design attributes and the social acceptance of an AWE design. The core of this survey consists of a stated choice experiment which uses the final set of attributes as a basis. A blocked foldover orthogonal design was used to create sixteen designs, which consist of a combination of the design attributes. The respondents are confronted with a block of eight designs, where each design is described by both a text and a visualization. In this confrontation, respondents had to rate the design on perceived safety and aesthetics and indicate if they would be in favour or against the particular design in a hypothetical local referendum about the implementation of the design close to their residence. Moreover, the survey contained a short questionnaire with questions concerning socio-demographic variables and personal attitudes and influences.

The results of the second survey were used to estimate two regression models, a logit model and a mediation model. The results of these models revealed several important findings:

- AWE designs were on average perceived as moderately safe and aesthetically pleasing.
- To increase the acceptance of an AWE design, the design should employ a soft wing kite, with a small size and white colour and operate at high altitudes.
- Obstruction lights did not significantly impact acceptance.
- Perceived safety and aesthetics strongly mediate the effect of design attributes on acceptance.

To show the value of the obtained results for real-world applications, the logit model has been used to predict the acceptance of AWE designs in four different plausible future scenarios. These scenarios each describe an AWE design which characterises the described trend in developing AWE systems typical for the scenario. The scenarios include designs focused on ultimate safety, making financial profit, off-shore application and urban application. Predicting the acceptance of these designs revealed that a profit-centred development focus generally results in designs with the highest levels of acceptance.

The research findings underscore several critical implications for stakeholders involved in advancing AWE systems. Firstly, understanding which design attributes enhance social acceptance is paramount, given that local opposition often obstructs the implementation of new energy technologies. Developers and policymakers should prioritize designs that are more likely to be embraced by the public, such as soft-wing kites, high operating heights, smaller kite sizes, and white kites. These attributes have been identified as promoting greater acceptance. Moreover, the study emphasizes that public attitudes significantly influence the feasibility of AWE projects, highlighting the need for developers and local governments to address community concerns early in the planning stages. Enhancing perceived safety and aesthetic appeal is crucial, as these factors mediate the influence of design attributes on acceptance. Effective communication about safety features is recommended to bridge the gap between perceived and actual safety.

Furthermore, this study acknowledges several limitations. Firstly, it utilized static images that failed to capture the dynamic movements of kites. In addition, the use of a single background in visualizations may introduce biases. Thirdly, the low explained variance suggests that respondents' choices have a high degree of heterogeneity. Finally, there is a possibility of hypothetical bias in the stated choice experiment.

To overcome this limitation in future research and guide further research this study gives several further research commendations. First of all, while this study focused on design attributes and their visual impacts, future research should broaden its scope to encompass additional influential factors such as planning processes, siting decisions, and community benefits. Secondly, there is a call to explore the broader impacts of design attributes beyond visual considerations, including ecological and acoustic dimensions. Addressing these research directions, along with incorporating dynamic visualizations and diverse environmental backgrounds, will refine our understanding of AWE technology's social acceptance factors. Ultimately, advancing this knowledge is vital for developing AWE systems that are not only technically efficient but also widely embraced, thereby enhancing their successful implementation as a renewable energy solution.

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1 Introduction

1.1. Problem statement

Airborne wind energy (AWE) is an emerging renewable energy technology that can contribute to decarbonizing the energy sector. AWE employs tethered flying devices, so-called kites, that harvest wind energy at altitudes between 200 and 500 meters. AWE thereby taps into the large wind resource potential at heights not accessed by conventional wind turbines (Marvel et al., 2013). Moreover, the new technology offers a variety of advantages over conventional wind turbines such as reduced material use, easy transport, and diverse applications (Heilmann, 2012 ;Fagiano and Milanese, 2012). Therefore AWE has the potential to significantly contribute to the decarbonizing of electricity production. In addition, AWE has a diverse range of applications, including disaster response, remote locations, offshore platforms, and floating wind systems (Cherubini et al., 2015; Ahrens et al., 2013) and also has an interesting economic potential (Chihaia et al., n.d.).

Nevertheless, only a handful of pilot projects have been started worldwide (Cherubini et al., 2015). In the past, social resistance has been a major hindrance to the implementation of new innovative energy technologies (Wüstenhagen et al., 2007; Batel et al., 2013 Hitzeroth and Megerle, 2013). Social resistance slows down the deployment and realisation of new renewable technologies that may appear to be indispensable for achieving sustainability goals. For instance, nuclear energy is still highly debated by policymakers as the technology is shrouded in social uncertainty (Yang et al., 2022). As a result, social acceptance is going to be indispensable for successfully implementing AWE as a beneficial and commercial technology.

Currently, AWE is still in the development phase, which means different designs and technological attributes are tested and analyzed. This means there is still room to not only research the technological side but also take into account what design attributes contribute to an increase in social acceptance. However, not much is known about how different design aspects of AWE affect the social acceptance of this technology (Schmidt et al., 2024; Schmidt et al., 2022). Hence, understanding and addressing the societal implications of AWE designs in the coming years is paramount for making the development phase more inclusive, which in turn will result in more accepted and efficient AWE designs. Therefore, this research recognizes that knowledge about how to increase the social acceptance of AWE designs is the key to a smoother and more successful implementation of AWE, facilitating the transition towards a more sustainable and decarbonized energy sector.

1.2. Connection to master program

This research deeply connects with the content of the Complex Systems Engineering and Management (CoSEM) master program of the Technology, Policy and Management (TPM) faculty of the TU Delft. The research ventures into an interdisciplinary realm, recognizing that the successful implementation of AWE not only involves technological design choices but also involves considering the effect of these systems in society. The intricate interplay between design attributes and the social acceptance of AWE systems form a complex sociotechnical system that demands a comprehensive investigation. Analyzing, designing and researching such complex sociotechnical systems lies at the heart of the CoSEM program. Furthermore, this study aspires to find crucial information which may shape the design and implementation of AWE, providing valuable insights for policymakers, developers, and the wider community. Giving recommendations to a variety of stakeholders is typical for the CoSEM program. All in all, This research exemplifies the interdisciplinary approach central to the CoSEM master's program at TU Delft, emphasizing the interplay between technological design and societal impact, and providing valuable insights and recommendations for the implementation of AWE systems to stakeholders.

1.3. Literature overview

Numerous studies have aimed to research the social acceptance of wind energy projects, yet the bulk of these investigations predominantly concentrate on conventional wind turbines (Enevoldsen and Sovacool, 2016; Ellis and Ferraro, 2017; Hübner et al., 2023; Fehrenbach, n.d.). However, to the best of my knowledge, only a handful of inquiries have ventured into exploring the social acceptance of AWE systems. Among these, a notable study by Schmidt et al., 2024 adopts a comprehensive approach, examining various influencing factors of AWE acceptance through a community acceptance study conducted near an AWE test site in Germany. Nonetheless, this study is delimited in its analysis, as it does not encompass the consideration of diverse AWE design variations, as the test site only includes one specific AWE design. This design, developed by SkySails, only employs a red/white striped soft-wing kite ("Skysails", 2024). Consequently, the study is not able to assess how different design attributes may influence the system's acceptance.

In light of this, there exists a critical gap in the literature concerning the relationship between the social acceptance of AWE designs and their particular design attributes. This gap is especially intriguing considering that AWE designs generally possess a higher visual appeal compared to traditional wind turbines (Schmidt et al., 2024). Their elevated altitude results in a reduced visual impact and a less obtrusive presence on the landscape (Archer et al., 2014; Diehl, 2013). Moreover, the visual impact of a wind turbine and its landscape disturbance are considered to be major factors influencing the turbine's social acceptance (Hübner et al., 2023; Jobert et al., 2007; Molnarova et al., 2012). Therefore, investigating the relation between design attributes and the system's social acceptance is particularly interesting. By addressing this knowledge gap, this research will be the first to gather insights on how different design attributes influence the social acceptance of airborne wind energy designs, paving the way for the integration of AWE systems into communities with greater ease and acceptance.

1.4. Research questions

This research aims to fill the identified knowledge gap by answering the following research question:

"How do specific design attributes of airborne wind energy systems relate to the system's social acceptance?"

To answer the main research question the following subquestions have been identified:

1. What is the effect of certain design attributes on the design's perceived safety?
2. What is the effect of certain design attributes on the design's perceived aesthetics?
3. What is the relationship between the design attributes of an airborne wind energy system and the choice for supporting the specific design?
4. To what extent do the landscape/environment, socio-demographic variables, environmental attitudes and social norms influence the acceptance of different airborne wind energy designs?
5. To what extent do perceived safety and aesthetics mediate the effect of design attributes on the social acceptance of an airborne wind energy system?

1.5. Societal relevance

As societies increasingly seek sustainable energy alternatives, the acceptance of renewable technologies, including AWE, is pivotal for achieving a transition to cleaner energy sources. However, while there is broad support for renewable energy at a macro level, local communities often exhibit reluctance or opposition to the implementation of renewable energy projects in their vicinity (Huijts et al., 2012; Scovell et al., 2024; Wüstenhagen et al., 2007). This discrepancy between sociopolitical acceptance and local acceptance poses a significant challenge to the widespread adoption of renewable technologies and is also called the national-local gap (Wüstenhagen et al., 2007).

The national-local gap describes the issue that general public acceptance is always higher than local acceptance and that, consequently, general acceptance does not translate into local acceptance (Sütterlin and Siegrist, 2017). As a result, while societies at large recognize the importance of transitioning to renewable energy sources to mitigate climate change and reduce reliance on fossil fuels, local communities may harbour concerns or reservations about the visual impact, noise pollution, land use, and perceived disruptions to their way of life associated with renewable energy systems(Huijts et al., 2012; Scovell et al., 2024; Wüstenhagen et al., 2007). Furthermore, the national-local gap only enhances itself. For example, when a certain renewable energy technology is generally accepted, policy-makers and developers may gain the incorrect belief that social concerns of the technology are limited and should not be addressed in much detail (Cohen and Schmidthaler, 2014). This causes the policy-makers and developers of new technologies to omit thinking about the social impact of the technology, which may only increase local opposition as new projects have not taken into account local social concerns. As a result, local acceptance should be carefully addressed when researching new technologies like AWE, as a lack of local acceptance can have severe consequences. For example prolonged permitting processes, legal battles, and ultimately, project delays or cancellations (Sütterlin and Siegrist, 2017; Cohen and Schmidthaler, 2014). These consequences hinder the widespread implementation of new technologies like AWE regardless of their technical performance and contribution to sustainability goals.

To prevent these undesirable consequences, policy-makers and AWE developers should aim to minimize local opposition by improving local acceptance. To help in this, this research provides valuable knowledge. By providing insights into the specific design attributes that influence social acceptance at the local level in a beneficial way, this study can inform the development of strategies to address community concerns and garner support for AWE projects. Moreover, by identifying which design features are most critical for local acceptance, developers can tailor their projects to minimize negative visual impact and maximize community integration.

By revealing these insights this research provides many societal benefits. Firstly, by uncovering knowledge on how to increase the acceptance of AWE projects, the implementation of AWE systems comes closer, which means society can accelerate its transition to renewable energy sources, reducing greenhouse gas emissions and mitigating the impacts of climate change. Additionally, increased acceptance of AWE designs allows for the implementation of more AWE systems, which could stimulate economic growth and job creation in the renewable energy sector, stimulating innovation and investment in clean energy technologies. Moreover, this research draws attention to addressing local acceptance in the development process, which may not only result in the stimulation of AWE designs with design attributes with a positive visual impact on social acceptance but also increase the attention to local concerns in the whole implementation process of AWE. This may lead to AWE designs and development which are more beneficial to communities.

In conclusion, studying the influence of the visual impact of AWE designs on social acceptance is paramount to the success of AWE technology. By providing insights and showing the importance of social acceptance, this research has the potential to, bring the widespread implementation of this technology closer and to guide the development of AWE designs in a way that they are most beneficial to policy-makers, developers and local residents.

1.6. Methods

1.6.1. Literature study

To be able to answer the main research question specific knowledge from the existing literature is required. Specifically, to contribute to answering the main research question and subquestions a literature study will be performed. Firstly, to answer the main research question. the concept of social acceptance must be defined in great detail in relevance to this research. Furthermore, the concept of social acceptance must be conceptualized, by analyzing the underlying perceptions through which design attributes affect a designs acceptance. A definition and conceptualization of social acceptance are required to be able to assess how the social acceptance of an AWE design is going to be measured accurately. In addition, the definition and conceptualization will help clarify what this research aims to measure. The literature study will use a combination of existing studies from the fields of psychology, technology, microeconomics and social sciences to illustrate a complete picture.

Secondly, to be able to answer subquestions 1, 2 and 3, knowledge is required on what design attributes of AWE systems play a role in influencing the design's acceptance. This knowledge will be obtained by first conducting a literature study which aims to map the most relevant AWE design attributes. The literature study dives deeper into what design attributes are currently used in existing AWE systems, or which attributes might become relevant in the future, by consulting existing academic research in the AWE and wind energy field as well as looking at current developers. This literary study aims to come up with a list of relevant attributes, which potentially will be used to measure the visual impact of the design attributes on the design's acceptance.

1.6.2. Developer survey

While the initial attribute list is based on academic and theoretical insights, it requires verification by practitioners, developers and experts in the AWE field to ensure its accuracy and relevance. Furthermore, only a limited number of attributes can be included in the final research to examine the relation between design attributes and acceptance. To make sure the list is validated and includes only the most important attributes, a survey will be created to gather feedback from AWE developers and scientific experts, asking them to validate and refine these attributes and their content based on current and future trends. This survey will be distributed among experts at the Airborne Wind Energy Conference (AWEC) in Madrid in 2024, leveraging their collective expertise. The iterative process of consultation and validation is crucial to ensure the final set of attributes is both academically robust and practically relevant. The results from the survey will be used to finalize the attribute selection, which will be used to conduct a stated choice experiment.

1.6.3. Stated choice experiment

Choice modelling is a statistical technique used to understand and predict decision-making behaviour by analyzing the choices individuals make among a set of alternatives (Louviere et al., 2000). A stated choice experiment is a fundamental part of choice modelling, a statistical method used to analyze and predict decision-making behaviour by presenting respondents with a set of hypothetical scenarios and asking them to choose their preferred option (Louviere et al., 2000).

To be able to answer the main research question, information about people's preferences for certain AWE systems must be uncovered. Additionally, the influence of the design attributes on these preferences must be explored. Given the need for these insights and the core principles of choice modelling, this research will employ a stated choice experiment. This approach will enable a detailed examination of preferences and attribute impacts, providing critical data for answering not only the main research question but also answering the subquestions.

Due to the lack of revealed preference data on airborne wind energy (AWE) designs, this research will utilize stated preference data obtained through a digital survey. This survey will present respondents with hypothetical AWE designs and collect additional data on socio-demographics, environmental attitudes and influences of social environments and the landscape. Aiming for at least 200 respondents to ensure robust results, a convenience sample is chosen due to time constraints. The collected data will be analyzed using various models, including linear regression, binary logit, and mediation models, to explore the relationships between design attributes and the system's perceived safety, perceived aesthetics, and social acceptance. These models will be used to answer all research subquestions.

1.6.4. Why choice modelling?

This research uses choice modelling for several reasons. Firstly, Choice modelling is effective in eliciting individuals' preferences in a structured and systematic manner(Hanley et al., 2001). By presenting respondents with a series of choices, researchers can capture nuanced information about the relative importance of different design attributes.

Moreover, choice experiments simulate decision-making scenarios that mirror the choices individuals encounter in the real world (Koppelman and Bhat, 2006; Hess and Daly, 2014; Hanley et al., 2001), making the results more applicable to actual choices individuals face in a certain context. Although, residents will rarely have a direct say in the decision-making regarding the realization of AWE projects, stated choice modelling will still help to give an indication of the attitude residents will have in the real world when confronted with the implementation of AWE design. This will have a positive effect on the external validity of the results.

Thirdly, in the realization of AWE on the market, a high level of human decision-making is involved (Schmidt et al., 2022). In other words, the realization of the technology is a complex process with plenty of stakeholders and policymakers involved. The predictive power of choice modelling helps policymakers understand the potential impacts of different designs and attributes(Motz, 2021). By incorporating individual preferences into the decision-making process, policymakers can design AWE designs which are more likely to be accepted.

Furthermore, Stated choice experiments are valuable tools for researching alternatives that do not yet exist. These experiments allow researchers to present hypothetical scenarios to respondents, enabling the evaluation of preferences and trade-offs for possible future options (van den Broek-Altenburg and Atherly, 2020; Louviere et al., 2000). Since only a handful of AWE systems have been realized in real life (Cherubini et al., 2015), this approach is especially useful for gathering information about preferences for AWE designs which do not yet exist but might become relevant in the future.

Finally, choice experiments can be more efficient and effective compared to other methods (Louviere et al., 2000). They allow for the gathering of a substantial amount of data on preferences and choices in a relatively short time frame (Hanley et al., 2001). Furthermore, choice modelling can also be seen as a statistically efficient approach. Using relatively small sample sizes, reliable estimates of preferences can be achieved (Abou-Zeid and Ben-Akiva, 2014).

1.7. Report outline

This research is structured as follows. First of all, chapter 2 describes the two literary reviews that have been conducted. Subsequently, chapter 3 describes the methodology, which describes in detail the research approach used to answer the research subquestions. This chapter explains the content, the construction of the final set of design attributes, the content of the survey and stated choice experiment and how the survey responses will be analyzed and used to answer the research questions. After this, chapter 4 presents the most important results revealed by this research approach. These models will be applied for simulating plausible future scenarios in chapter 5. Finally, in chapter 6 conclusions will be drawn from these results in light of the current literature and possible implications, recommendations and limitations of this research and its findings are discussed.

2

Literature study

This literature study consists of two parts. The first part aims to contribute to answering the main research question. By synthesizing various studies, a definition of social acceptance is given in light of this research. Moreover, this part consists of a conceptualization of social acceptance, which uncovers the underlying perceptions or mediators through which design attributes influence acceptance. Additionally, this part discusses additional psychological variables which may impact people their acceptance for different AWE designs.

Part 2 aims to contribute to answering the research subquestions. It investigates the current AWE field to create an initial list of relevant design attributes. Additionally, this part defines the concept of design attributes and examines the relation between design attributes and acceptance. Appendix A shows the search strategies used in both parts.

2.1. Social Acceptance

2.1.1. Defining social acceptance

In the introduction, it has been explained that while renewable technologies are socially accepted (Visschers and Siegrist, 2014), strong local opposition may arise when residents are faced with the implementation of renewable projects in their proximity (Huijts et al., 2012; Sütterlin and Siegrist, 2017; Cohen and Schmidthaler, 2014). To ensure a smoother implementation of a renewable technology like AWE, it is therefore important to specifically dive into the aspect of social acceptance concerning this strong local opposition. Hence, this section will present a definition of social acceptance in light of this research, with a focus on local acceptance. The definition is derived by combining several important and relevant theories from the field of technology acceptance, microeconomics and psychology.

Firstly, to come up with an encompassing definition of social acceptance this review dives into the different types and categories of social acceptance. The study by Wüstenhagen et al., 2007 presents three different categories of social acceptance of renewable innovation: Socio-political, community, and market acceptance. Socio-political acceptance involves the approval and endorsement of renewable energy technologies and policies by both society at large and key political stakeholders. Community acceptance refers to the specific approval of siting decisions and renewable energy projects by local stakeholders, including residents. Finally, market acceptance takes a more holistic market view of acceptance, regarding the acceptance of consumers and investors and looks into the introduction of renewable technologies on a market. From the three categories, the general public acceptance of renewable innovations by society at large is captured by the socio-political category, while the local opposition is resembled by community acceptance. As this research aims to measure how design attributes may influence this feeling of local opposition captured in community acceptance, it is of importance. This is in line with the work of Musall and Kuik, 2011, which reveals that actively involving communities is beneficial to the acceptance of local renewable energy projects and argues that this is crucial for the project's successful realization. As a result, this research will focus on community acceptance when talking about social acceptance.

In a similar style to Wüstenhagen et al., 2007, Huijts et al., 2012 distinguish two types of acceptance: consumer and citizen acceptance. Consumer acceptance reflects the social behavioural responses of the public to the purchase and use of products. Citizen acceptance entails a behavioural response to situations where the public is faced with products that are decided about, managed or owned by others. These products cannot be bought or consumed by the individual or a community, but they have to accept the product. For this research, the product is a certain AWE system. Since AWE systems have a high degree of complexity, and high costs and are still in development (Cherubini et al., 2015), open market introduction of AWE systems, or in other words the purchase and consumption of AWE systems by communities and individuals, are unlikely to happen in the near future. Nonetheless, public and private (pilot) projects are on the brink of realization (“Skysails”, 2024; “Enerkite”, 2024; Schmidt et al., 2024). Consequently, the perspective of citizen acceptance is more interesting for this research. This means this research will look at social acceptance through the perspective of community and citizen acceptance, both concerning local responses to the implementation of technology projects close to people’s residences.

Important to note is that citizen acceptance entails a behavioural response, while community acceptance refers to approval. Drawing on the work of Sauer et al., 2005, which presents the model of levels of acceptance shown in figure 2.1, the differences between these concepts can be understood more deeply. The model dives deeper into the transition phases of acceptance and presents eight stages of acceptance when going from acceptance to non-acceptance. In this way, the model argues that (non)acceptance is not an absolute value and that different individuals may have different levels of acceptance. These levels may be used to see whether a design is accepted or not when an individual has a certain attitude or behaviour towards the specific design. The model shows that levels 2-7 (rejection, ambivalence, indifference, tolerance, conditional acceptance, and approval) concern an attitude while levels 1 and 8 show active behaviour (resistance and engagement). Following this model, approval is shown the be an attitude as it is similar to level 7, while behavioural responses are related to levels 1 and 8 and are thus considered behaviour. Subsequently, this model and the different perspectives show that acceptance entails both behaviour and attitude. However, to be able to analyze and measure acceptance this research will recognize acceptance as a behaviour for two reasons.

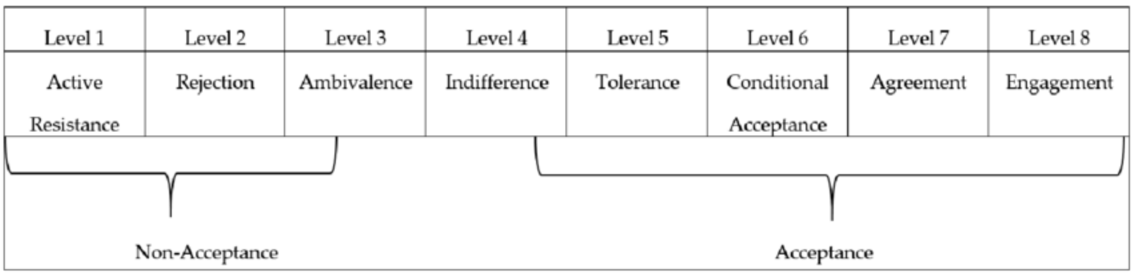

Figure 2.1: Levels of acceptance

Firstly, local opposition is so threatening to renewable energy projects like AWE, because of the associated behavioural responses by the local community in the form of protests or legal objections, significantly delaying projects or even leading to project abandonment (Rand and Hoen, 2017; Fast, 2014; Terwel et al., 2012; Brunsting et al., 2011). Moreover, studies like Wolsink, 2007c and Sütterlin and Siegrist, 2017 have documented instances where local communities expressed approval of renewable energy in principle but engaged in obstructive behaviours when specific projects were proposed near their homes. Furthermore, the study by Devine-Wright, 2005 shows that simply improving attitudes towards renewable energy is insufficient if the corresponding behaviours are not aligned. For instance, even if a community has a generally favourable attitude towards renewable energy, the actual implementation of projects can still face significant barriers if active resistant behaviour is prevalent (Sütterlin and Siegrist, 2017). This discrepancy between attitude and behaviour highlights the importance of focusing on acceptance as a behaviour to gauge true acceptance.

Furthermore, from the theory of planned behaviour (Ajzen, 1991), attitude, together with subjective norms and perceived behavioural control, determines one's intention and thus one's behaviour. This relation between attitude and behaviour shows that behaviour is highly influenced by one's attitude. As a result, behaviour can be seen as a proxy for one's attitude. In addition, looking at acceptance as a behaviour allows for a more relevant portrayal of acceptance for this research, as behaviour is also influenced by one's subjective norms and perceived behavioural control. For example, when someone disapproves of a specific AWE system but feels pressured by their subjective norms that others would disapprove of if they actively resist it, they might refrain from showing overt local opposition. Consequently, considering social acceptance as a behaviour allows for a precise capturing of the most threatening aspect of social acceptance namely active local opposition. Figure 2.2 shows the relation between attitude and behaviour in the model used for the theory of planned behaviour.

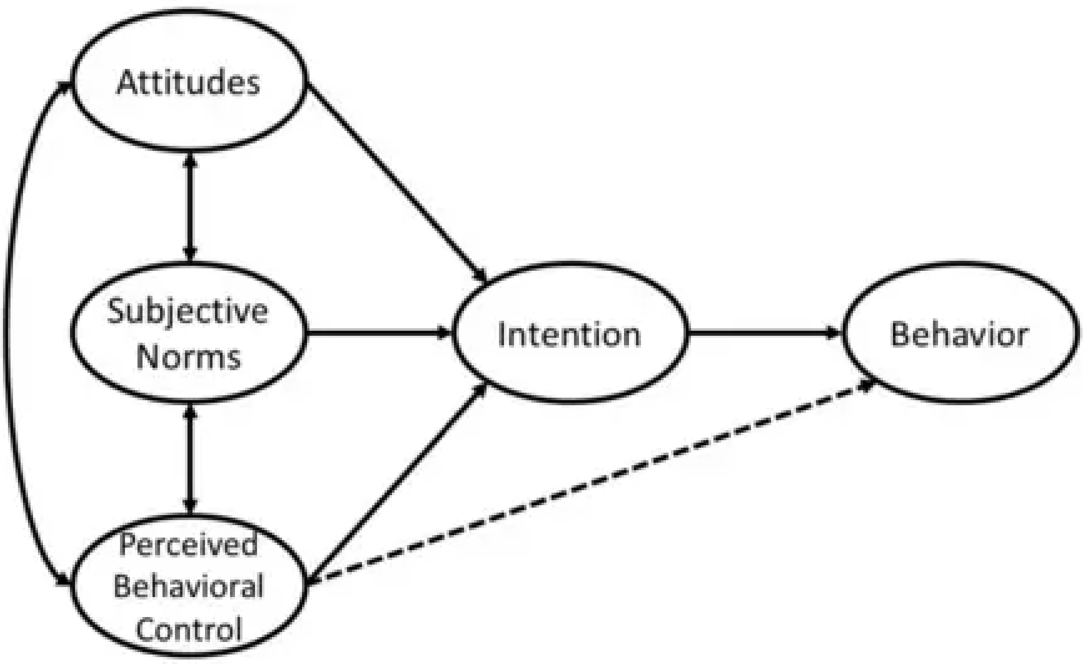

Figure 2.2: Theory of planned behaviour

In summary, for the purposes of this research, the social acceptance of AWE designs is defined as the behaviour exhibited by an individual, particularly local stakeholders, when confronted with the installation of a specific AWE design, in the vicinity of their residence, that is managed or owned by external entities. The next section explains what type of behaviour this entails by conceptualizing how design attributes of AWE systems influence the design's acceptance.

2.1.2. Conceptualization

To thoroughly explore the relationship between social acceptance and the design attributes of AWE, it is imperative to establish a clear method for measuring the dependent variable, social acceptance. To do this, social acceptance needs to be conceptualized. In this study, social acceptance is regarded as a behaviour. Investigating what this behaviour entails, is therefore crucial for conceptualizing social acceptance. The conceptual model by Molin and Kroesen, 2022 forms the basis for the conceptual model constructed in this research.

Support

The work of Huijts et al., 2012 explains that behaviour about acceptance entails both support and resistance of a technology. Support is expressed in proclaiming, endorsing, purchasing, or using the technology, while resistance can be expressed in taking protesting actions against the technology, or not purchasing or using the technology. Support conveys the desired optimal behaviour when people are confronted with the implementation of an AWE design (Sauer et al., 2005), while resistance is what makes local opposition able to jeopardize the implementation of new technological projects like AWE (Wolsink, 2007c; Devine-Wright, 2005). Avoiding resistance and promoting support are indispensable for the successful implementation of AWE systems. Therefore, it is paramount to gain insight into the local level of behavioural responses to the implementation of an AWE design close to one's residence.

To reveal the behaviour of people towards certain AWE designs, this research focuses on support. This choice is based on two reasons. Firstly, support is behaviour that is not complicated to measure. Secondly, because of the levels of acceptance model from the work of Sauer et al., 2005 (figure 2.1). In this model, the highest level of acceptance is engagement, which is described as active support and participation in the technology, policy, or project. From this model can be argued that support belongs to the highest level of acceptance, which means that when an individual supports a specific AWE design this is highly beneficial to the design's implementation. As such, if a project, or in this case an AWE design is supported this research assumes it is also accepted, as all other levels of acceptance are inferior to support. For these reasons, support has been chosen as the proxy behaviour for acceptance in this research.

Similarly as in other studies, like Molin and Kroesen, 2022 and Hensher, 2013 support is illustrated by voting behaviour. This works as follows: An AWE design is supported, and thus also accepted, when an individual would vote in favour for implementing the particular design close to their residence. When an individual does not vote in favour, this means that the design is not supported, and thus not accepted, as there is no active supportive behaviour exhibited. The mechanism behind this is further explained using the random utility maximization (RUM) theory, which explains that an individual will choose the option that maximizes their utility (Manski, 1977; Koppelman and Bhat, 2006). Utility is the level of satisfaction or benefit a decision-maker expects to receive from a specific option (Koppelman and Bhat, 2006). In other words, when an individual gains the highest utility of voting in favour this means it supports and thus accepts the AWE design. This is in line with the definition of social acceptance given by the work of Cohen and Schmidthaler, 2014, which argues that social acceptance of new infrastructure happens when the welfare-decreasing aspects of the project are balanced by welfare-increasing aspects of the project to leave an individual better off and supportive of the project. In conclusion, voting behaviour is observed to measure support, while support is an indicator of social acceptance. In this way, voting behaviour symbolizes whether an AWE design is accepted or not. This relation is illustrated in figure 2.3.

Having discussed the measurement of social acceptance for AWE designs, it is now time to explore how various design attributes of AWE systems influence support and, consequently, social acceptance. To do this, the underlying perceptions mediating the effect of design attributes on support must be determined. Conceptualizing these underlying perceptions is key as it allows for valuable knowledge of how design attributes influence the support for certain AWE designs. This research focuses on two important perceptions; aesthetics and safety. The following paragraphs argue why perceived aesthetics and safety are found to be most relevant.

Perceived aesthetics

In the field, research is lacking on the visual impact of AWE systems. However, the visual impact of traditional wind turbines has been studied extensively. Several studies have shown that the aesthetics of a wind farm play a large role in the social acceptance of the wind farm. Firstly, the study by Devlin, 2005 on the acceptance of wind turbines shows that visual impact is the factor influencing social acceptance the most. This is in line with the study by Wolsink, 2007b, which states that the strongest influence on an individual's attitudes towards wind farms comes from the perceived visual impact on the landscape, and the study by Strazzera et al., 2012, claiming aesthetics had a stronger effect on local perception than other concerns. Moreover, the study by Groth and Vogt, 2014 shows that aesthetics play a role in determining the success of wind turbine development. In short, studies on traditional wind turbines consistently demonstrate that the aesthetics of a wind energy project significantly affect the social acceptance of the system.

However, it should be noted that visual impacts are expected to be lower for an AWE system compared to a wind turbine due to the higher operational altitude, the absence of a tower, less shadow-casting, and the possibility of retrieving the kite in low wind (Schmidt et al., 2022). Furthermore, given that AWE is still in development, it offers a variety of potential designs, unlike traditional wind turbines which are largely standardized in their design. As a consequence, the influence of an AWE design on its social acceptance may differ from how traditional turbines influence their acceptance. Nevertheless, research from other renewable technologies also presents evidence for the importance of aesthetics in determining the local acceptance of projects. For example, Sütterlin and Siegrist, 2017 argue that visual components related to solar power seem to be particularly prevalent in people's mental imagery and that solar power installations with a larger visual impact on the landscape would probably be less favourably perceived. Moreover, Faiers and Neame, 2006 explain that aesthetic characteristics of solar panels limit adoption. Thirdly, Ferrario and Castiglioni, 2017 argue that visibility plays a primary role in the public acceptance of new energy plants and that landscape policies regarding renewable energy development are largely based on mitigating the visual impact of renewable energy plants. In conclusion, despite research lacking on the relation between aesthetics and social acceptance in the AWE field, it is assumed that design attributes influence the AWE design's acceptance because they have an effect on the design's perceived aesthetics. This assumption is based on research from other innovative renewable technologies.

Perceived safety

Another perception through which design attributes impact the social acceptance of an AWE design is by influencing the design's perceived safety. An example of this effect is given by the study by Paulig et al., 2013, which speculated that the perceived safety of soft-wing kites might be higher than fixed-wing or hybrid-wing kites due to lighter materials. Important to note here is that perceived safety may differ completely from actual safety concerns (Schmidt et al., 2022). For example, it has not been proven that soft-wing kites are indeed safer. Therefore, it is assumed that design attributes influence the perceived safety of the design and that the perceived safety affects the acceptance of the design. This latter assumption is supported by several scientific studies and claims. Cohen and Schmidthaler, 2014 explain that safety concerns play a role in the acceptance of both wind farm development and the development of pumped hydro storage. Secondly, Perlaviciute and Steg, 2014 argue that perceived safety can influence people on how they evaluate energy alternatives. Thirdly, Brunsting et al., 2011 show that safety concerns are important for people evaluating the implementation of a carbon capture storage project in a Dutch neighbourhood. Furthermore, it is likely to assume that safety plays an even greater role in the acceptance of AWE projects because of the novelty of AWE and people's unfamiliarity with the technology, as several studies have found that people perceive the unknown as less safe (Van der Pligt et al., 1986; Semati and Ghahremanpouri, 2020; Siegrist and Hartmann, 2020).

In other words, the effect of design attributes is mediated through the perceptions of aesthetics and safety, which indirectly influences the design's social acceptance. However, this does not mean that there are no other factors or perceptions influenced by design attributes which may affect acceptance. This unspecified effect may be caused by a wide variety of perceptions which are more difficult to capture distinctively; examples are the perceived ecological impact, of which the actual influence has a high level of uncertainty. These factors are taken into account as the direct effect of design attributes on social acceptance. This direct effect captures the effects of all ways in which design attributes influence social acceptance that are not related to aesthetics or safety. The separation of direct and indirect effects and the mediation effect of the two perceptions can be seen in the conceptualization of social acceptance in figure 2.3.

In conclusion, from this conceptualization can be derived how the dependent variable social acceptance is going to be measured, by looking at how design attributes affect voting behaviour for a certain AWE design. This effect can be direct or mediated through the perceptions of aesthetics and safety. To measure the total effect, the indirect effect of perceived aesthetics and safety are summed with the direct unspecified effect because the total effect of each design attribute on acceptance can be obtained by summing its indirect and direct effects.

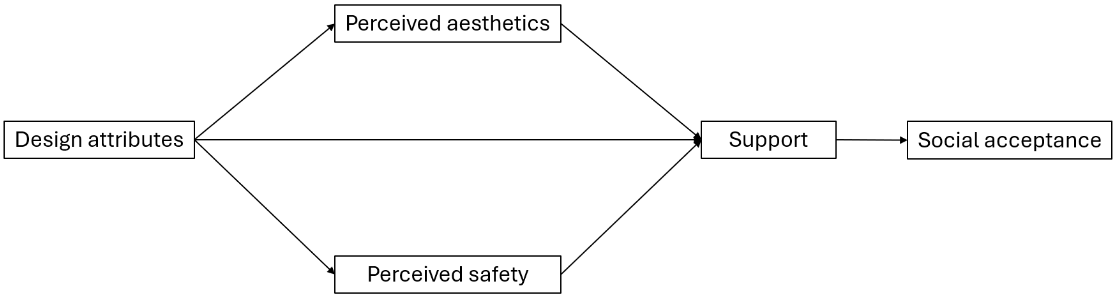

Figure 2.3: Conceptualization

2.1.3. Psychological variables

Besides design attributes, there might be other variables not related to the AWE system which may influence the support of an individual for a particular AWE design. Firstly, attitudes of the individual itself may impact their voting behaviour. For example, recent studies have shown that a positive attitude towards the energy transition is associated with a higher local acceptance of wind farms (Wolf, 2020;Renn and Marshall, 2020). Therefore, when aiming to analyze or measure the support of people, it is also useful to obtain insights in their environmental attitude.

Another attitudinal variable which research has shown to be important in people's decision-making is their social environment (Ciranka and Van den Bos, 2019; Cialdini and Goldstein, 2004). In addition, people use other people's opinions as information sources, which means that the perceived opinion of others can have an influence on the behaviour to act in favour or against sustainable energy technologies (Hübner et al., 2023; Devlin, 2005; Huijts et al., 2012). To gain insight into the effect of other people their opinions on an individual's decision-making, it might be valuable to reveal how much individuals perceive to be influenced by their social environment.

Thirdly, the personal importance or value of the subject, in this case AWE systems, may affect the individuals behaviour (Homer and Kahle, 1988). For example, when individuals do not care if an AWE systems is placed in their vicinity it is more likely to be acceptance than when people care a lot, because people who care a lot will be much more critical and eager to object (Chun et al., 2013).

In conclusion, these three psychological variables, may affect how different people evaluate different AWE designs and may influence their support for certain designs. As a result, knowledge of these psychological variables may be valuable when aiming to measure the social acceptance of an individual to a specific AWE designs.

2.2. Airborne wind energy systems

When looking at the social acceptance of different AWE systems, it is relevant to dive into how these systems work and what their specific characteristics are. Firstly, this chapter discusses the relationship between social acceptance and design attributes. Subsequently, the most prominent AWE designs and their key components are discussed.

2.2.1. Social acceptance and design attributes

Now that the concept of social acceptance has been defined, it is also necessary to explain the exact meaning of design attributes of AWE design for this research. Design attributes in the context of AWE systems refer to specific characteristics and features of the technology that can influence its acceptance by the public and stakeholders (Schmidt et al., 2022). These attributes include factors such as safety, visibility, acoustic emissions, ecological impacts, and the siting of the systems (Schmidt et al., 2022).

To explain the relation between these design attributes and social acceptance, this study makes two strong assumptions. Firstly, it is assumed that there exists a relation between different attributes of AWE design and the social acceptance of the technology. Since most psychological frameworks show that behaviour is the result of a combination of psychological processes and not a result of objects like design attributes (Bandura et al., 1986;Ajzen, 1991), this is a strong assumption. This assumption is based on the notion that differences in design attributes may influence the underlying perceptions of social acceptance. For example, different colours of kite design may influence the landscape fit of the AWE design, which may make the design more aesthetically pleasing, which in turn could increase social acceptance. Some studies support this assumption. For example, Schmidt et al., 2022 argue that the five major factors influencing the social acceptance of AWE based on the literature are: visual impacts, sound emissions, ecological impacts, safety, and geographical sites. However, it should be noted this has not been confirmed by empirical research. Furthermore, Hübner et al., 2023 present a framework for analysing the social acceptance of wind turbines which shows that the impact of the wind turbine on residents and nature is a key contributor to the social acceptance of a wind turbine. Technological design attributes are capable of influencing these underlying perceptions of social acceptance and thus are assumed to have an impact on residents and their acceptance level (Molnarova et al., 2012; Schmidt et al., 2024; Devine-Wright, 2008).

The second assumption is that this research solely focuses on how design attributes influence social acceptance through their static visual impact. This assumption is made because of the practical limit and core of the research approach. That is to say that a digital survey is in the first place not suitable to research, for example, sound effects or dynamic images, due to the lack of control on participants. Furthermore, these influences would increase the complexity of the research massively. This assumption allows for researching purely the visual impact which is interesting on its own and allows for estimating purely this visual impact. However, correlations between sound emission or the influence of dynamic images such as the flight path are neglected.

2.2.2. Airborne wind energy designs

As AWE is still in a development phase (Ahrens et al., 2013), a wide variety of different design concepts are in existence. Cherubini et al., 2015 and Fagiano and Milanese, 2012 present extensive overviews of a variety of different AWE designs and their technological specifications. Numerous combinations of different design attributes allow for a wide variety of AWE systems. The diversity of different AWE designs caused by small and large variations of different components, materials, and functionalities is indispensable to this research. For this research, design attributes are defined as the differences in components, materials, and functionalities in AWE designs that may change the operationality, functionality, and look of the design.

Researching all design attributes would be an excessive and overly complex task; therefore, this research will make a selection of the most relevant attributes. To do this, first, an overview is presented which identifies the attributes most discussed in the literature. An attribute is only included in the overview if it satisfies the following two criteria:

- The attribute must embody a key characteristic of an airborne wind energy system.
- The attribute is likely to have an impact on citizens.

Kite

When designing an AWE system, the choice of a certain type of kite is very important for the engineers as the kite affects the performance and operation of the system drastically (Cherubini et al., 2015; Ahrens et al., 2013). Thus, the kite presents a key design choice for an AWE system. In addition, the design of the kite will impact the appearance of the kite enormously. As explained earlier, aesthetics play an important role in the acceptance of an AWE design (Wolsink, 2007c; Strazzera et al., 2012). Therefore, it is assumed that citizens will base their choice for support on the type of kite installed on the AWE system.

A variety of kites are being used in the AWE field. These kites can be classified into two main categories: soft-wing kites and fixed-wing kites (Watson et al., 2019; Cherubini et al., 2015). soft-wing kite wings can be made extremely lightweight and can be best compared to very large surf kites. They keep

Figure 2.4: Soft-wing kite ("Skysails", 2024)

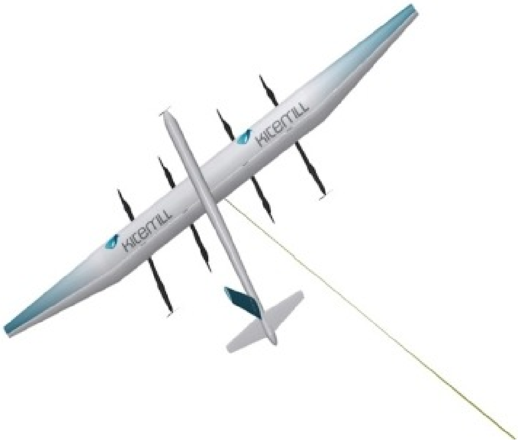

Figure 2.5: Fixed-wing kite ("Kitemill", 2024)

Figure 2.6: Hybrid-wing kite("Enerkite", 2024)

their shape due to the aerodynamic load distribution generated by the airflow (Diehl, 2013). They fly at moderate speeds and can easily be controlled by a human pilot (Diehl, 2013). Moreover, soft-wing kites are considered safer as in case of a crash, they usually do not cause major damage, due to their lightweight and flexibility absorbing the shock (Ahrens et al., 2013; Diehl, 2013). An example of a soft-wing kite can be seen in figure 2.4. Fixed-wing kites are heavier and can be better compared to small planes; they are more durable and have better aerodynamic efficiency and keep their shape independent of ambient wind conditions (Cherubini et al., 2015; Ahrens et al., 2013; Diehl, 2013). Due to this, they can reach higher velocities and thus a higher power potential (Cherubini et al., 2015; Diehl, 2013). However, these higher velocities and heavier designs make fixed-wing kites more dangerous (Ahrens et al., 2013; Diehl, 2013). Figure 2.4 shows an example of a fixed-wing kite. A mix between the two categories is the hybrid-wing kite. These types of kites have both fixed and flexible wing components. An example of a hybrid-wing kite can be seen in figure 2.4.

Kite size

The size of the kite determines the amount of wind energy an AWE system can convert and thus highly affects the amount of power an AWE system can generate (Ahrens et al., 2013; J. Weber et al., 2021; Khan and Rehan, 2016). As a result, the size of the kite is important for determining the economic benefits of the kite. However, the kite size has a large visual impact as well. Kite sizes can already reach enormous sizes of 180 m^2 and are thus not comparable to people's normal expectations of surf kites or recreational kites ("Skysails", 2024). Because of this unfamiliarity with the kite size and the sheer size of the kites, the size of the kite will likely impact citizens.

A wide variety of kites with diverse sizes are employed by different research groups and companies (Cherubini et al., 2015). For soft-wing kites, the kite size is often presented in the surface area of the kite, while fixed-wing kite sizes are presented by the wingspan (Cherubini et al., 2015). For soft-wing kites, the range of sizes goes from 20 m^2 to 180 m^2, while for fixed-wing the wingspan ranges from 5m to 40m (Schmehl, 2018; Ahrens et al., 2013; "Skysails", 2024; Cherubini et al., 2015). In the future, it might be possible for designs to reach a wingspan of 50m to 100m, however, this is still only speculation (Cherubini et al., 2015).

Generation mode

AWE systems can convert wind energy to electrical energy in two different ways. The different ways of energy conversion have a great effect on the performance, operation, and visuals of the AWE system (Cherubini et al., 2015).

Firstly, systems can employ energy conversion on the ground, this is called a ground-gen system. Ground-gen systems vary in operation but are generally based on using the strong tether tension to unroll the tether from a drum, and the rotating drum drives an electric generator (Diehl, 2013; Cherubini et al., 2015; Schmehl, 2018). Both the drum and the generator are located on the ground, thus the name ground-gen. A wide variety of ground-gen designs exist, but mostly they employ a flexible lightweight kite (Diehl, 2013). Ground-gen systems are preferred if the kite is less durable and needs to be replaced often (Trevisi et al., 2021).

On the contrary, a fly-gen system has the generator on board. This type of system is usually designed to have a rigid wing, as the generators and motors are quite heavy and require a heavy kite (Cherubini et al., 2015; Diehl, 2013). This heavy kite makes the fly-gen system more dangerous compared to ground-gen systems (Ahrens et al., 2013). Fly-gen systems can produce a higher amount of energy for a longer period because the kite is usually not brought back down to the ground (Fagiano and Milanese, 2012). However, fly-gen systems are still lagging in development and require more research before their commercialization (Trevisi et al., 2021).

Operating height

The height at which an AWE system operates influences the performance of the system but also has an impact on the appearance of the system (Archer et al., 2014). In the current field, AWE systems operate between 200-500 meters altitude (Cherubini et al., 2015 ;Schmehl, 2018). At these heights, they capture high wind speeds to increase the power output of the system (J. Weber et al., 2021). In the future it might be possible to subtract wind energy from higher altitudes, resulting in AWE design with a higher operating height (Watson et al., 2019). This is interesting as Archer and Caldeira, 2009 have shown that the global wind power densities are highest at altitudes above 6 km and optimal height is above 500m. However, research by Miller et al., 2011 argues that harvesting wind energy from jet streams at above 6 km altitude will not contribute as a significant source of renewable energy, due to the environmental impact and the actual energy conversion from jet streams will be much lower than theoretically anticipated. Furthermore, above 500m wind speeds become increasingly dependent on the weather conditions (Archer and Caldeira, 2009), creating unpredictable strong winds not ideal for AWE systems for which good control systems are still in development. AWE systems currently in the field operate at 200 to 500 meters altitude. For example, systems from Enerkite operate at 100-300 meters (“Enerkite”, 2024) and systems from Kitepower operate at 200-500 meters (“Kitepower”, 2024).

Kite colour

The kite colour of the AWE system does not influence the operation or performance of the system. However, colour design may impact flight safety. Variations in colour impact human attitude and behaviour in various ways (Jalil et al., 2012). Furthermore, from research on traditional wind turbines can be concluded that colour has a significant influence on the visual evaluation of the system (Maffei et al., 2013). Therefore, it is plausible to assume that colour impacts social support for a certain AWE system. An example that supports this assumption, is the colouring of the base of wind turbines in green, to limit visual disturbance.

Different colours are currently used in the field of AWE. Kitepower uses white kites (“Kitepower”, 2024), while Enerkite and Skysails use a combination of white and red coloured kites (“Enerkite”, 2024;“Skysails”, 2024).

Obstruction lights

Obstruction lights may be included in the AWE design, because of airspace regulation. From research on off-shore wind turbines, the obstruction lights may attract avifauna but also have a large visual impact (Orr et al., 2016). As a result, it is assumed that obstruction lights may play a significant role in determining the acceptance of an AWE design (Schmidt et al., 2024).

The International Civil Aviation Organization (ICAO) has published international regulations which contain standards and recommendations regarding the marking and lighting of obstacles at more than 150 meters altitude, including specific recommendations for wind turbines. These standards recommend medium-intensity lights either flashing white, flashing red or steady red (NLR, 2018). These recommendations are not directly applicable to airborne wind energy, but up to this day, no legislation for obstruction lights on AWE systems has been published.

Air time

The operating time, or the amount of time the AWE system is airborne, not only depends on siting, weather conditions and regulations but also varies per design. Some designs aim to operate multiple days continuously while others may only operate a few hours a day. Since the system only generates electricity when it is airborne, the air time of the design heavily influences the system’s performance. While the influence of air time on the social acceptance of AWE systems has not been researched yet, the study by Windemer, 2023 has shown that there exists a relation between the operating time of on-shore wind farms and their corresponding social acceptance. The shorter the operating time of the wind turbines, the higher the acceptance of the wind farm.

Take-off mode

Lastly, AWE designs have three different take-off modes: Vertical, horizontal and rotational (Watson et al., 2019; Fagiano and Schnez, 2017). While some designs may not take off that often the impact of the different modes seems limited. However, the different modes also require different base and kite features. Therefore, the take-off mode heavily influences the design attributes.

The vertical take-off mode is often used for fixed-wing kites. The kite is propelled upwards and often guided by a support tower (Cherubini et al., 2015; Bevirt, 2010). The best example of vertical take-off mode is the design developed by Makani. Makani was a developer who invested in researching large fixed-wing kites with vertical take-off, unfortunately, the company discontinued in 2021 (“Makani”, 2021). Another example of vertical take-off is the helicopter-like designs with autonomous landing and take-off of the ground (Bevirt, 2010; Khan and Rehan, 2016).

Horizontal take-off is a bit more diverse and several (conceptual) forms have been developed. Examples include take-off by a catapult and an arresting line, using the tether for (de)acceleration or using a launch pad and propellers (Kruijff and Ruiterkamp, 2018; Fagiano and Schnez, 2017).

Thirdly, rotational take-off entails attaching the kite to the tip of a rotating arm. When the tangential speed of the arm is large enough, the aircraft takes off exploiting its aerodynamic lift and the tether is gradually extended out of the rotating arm until a certain height is reached. Then, the rotating arm is gradually stopped while the aircraft transitions into a power-generating mode (Fagiano and Schnez, 2017). In the current field, only Enerkite is researching rotational take-off modes (“Enerkite”, 2024; Fagiano and Schnez, 2017).

Different take-off modes are still highly in development, as autonomous take-off in a safe and space-efficient way is one of the largest challenges of AWE systems (Fagiano and Schnez, 2017; Kruijff and Ruiterkamp, 2018).

2.3. Conclusion

In the first part, we have carefully defined social acceptance of AWE designs as the behaviour exhibited by an individual, particularly local stakeholders, when confronted with the installation of a specific AWE design, in the vicinity of their residence, that is managed or owned by external entities. In addition, social acceptance has been conceptualized. By highlighting the role of perceived safety and perceived aesthetics the (in)direct influence of these factors on social acceptance became clear. This definition and conceptualization can be used to answer subquestion 1. The design attributes influence the systems’ acceptance in the following way: Design attributes of a specific AWE design installed in the vicinity of an individual, influence the behaviour the individual exhibit towards the design. This influence is predominantly exerted through individual’s perceptions of safety and aesthetics of the design, but of course, unaccounted factors may also play a role to a certain extent. The behaviour, exhibited as support, determines to what extent a design is accepted.

The second part of the literary review aimed to design an initial list of relevant attributes and what forms the attributes might take. This initial list is not able to answer the associated research questions directly but will be used to determine, what attributes will be used to answer the research questions and present the first draft version of the dependent variable design attributes. Important to note is that this initial list will be streamlined and validated further on in the research.

3 Methodology

To gain a better understanding of how design attributes of airborne wind energy systems influence the social acceptance of the European public, a comprehensive research approach has been crafted. The main focus of this research approach is a modelling approach that involves choice modelling. This approach aims to explore the diverse dimensions of social acceptance. In this way, this research aims to map how design attributes influence the acceptance of AWE systems.

3.1. Survey

The choice modelling involves a survey which will be distributed digitally. In this section, it is explained how the survey and stated choice experiment have been designed. The structure of the digital survey will be as follows:

- Introduction
- Choice experiment
- Questionnaire

3.1.1. Introduction

In the introduction, respondents are invited to join the research on the acceptance of AWE. Firstly, The technology is briefly introduced, as most individuals will be unfamiliar with AWE. Subsequently, it explains the set-up of the choice experiment, the aim of the research and what a referendum entails. This section aims to emulate the real-world context of an AWE referendum. After that, the respondent is asked to imagine they are living in a certain environment, this is explained in further detail in section 3.1.8. Following that, the respondents are introduced to the different design attributes that are varied in the variety of AWE designs. This is done by a visualization which highlights the location of the specific attribute. Finally, an explanation is given regarding the consent of data use and privacy, time duration and contact details of the responsible researcher. The aim of the introduction is to be as concise and neutral as possible to limit the influence the researcher has on the respondents.

3.1.2. Choice experiment

Referendum experiment

Social acceptance is about citizen's choices and not about consumer choices. However, since stated choice experiments are meant to measure a consumer choice for a product or service a traditional stated choice experiment is not very suitable. Therefore, the stated choice experiment will involve a referendum style of questioning, which has been demonstrated before in several other studies for example by Molin and Kroesen, 2022 and Hensher, 2013. In this type of experiment, respondents are confronted with one design which contains certain attributes. This design symbolizes the choice or option for the respondent and can therefore be seen as the alternative of this choice experiment. As a consequence, the words design and alternative may be used interchangeably in the rest of this research.

Design 1

Design	
Kite type	Fixed wing
Kite size	30m
Operating height	Medium altitude
Kite colour	White
Obstruction lights	No

I perceive this airborne wind energy design as safe.

- Stronly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

I perceive this design to be aesthetically pleasing.

- Stronly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Suppose that in a local referendum, you were asked to vote in favour or against implementing this design close to your residence. How would you vote?

- In favour
- Against

Figure 3.1: Choice task

In the referendum experiment, respondents are placed in a hypothetical situation where a local referendum will be held which will decide if an alternative will be realized. Respondents have to assume that they are going to vote and are asked if they would vote in favour or against a certain alternative in a referendum, basing their choice on the attributes of that specific alternative. For this research, this means that respondents will be confronted with an AWE design with certain design attributes, for which respondents have to vote against or in favour. A vote in favour would theoretically mean that the particular design would be realised in proximity to the residence of the respondent. This vote entails the direct effect of design attributes on the acceptance of the design.

However, before the actual vote, to capture the indirect effects of design attributes on the design's acceptance, respondents have to rate the design on the two underlying perceptions: Safety and aesthetics. To rate the design respondents have to let know to what extent they agree with a statement in the form of: 'I perceive this airborne wind energy design as safe'. Where the answers are posed on a Likert scale: Strongly agree, agree, neither agree nor disagree, disagree and strongly disagree. First, the respondents rate the safety aspect and second the aesthetics. After they have rated the design, they have to vote in the referendum. When a respondent gets confronted with a certain AWE design and has to evaluate the design by answering the three questions, this is called a choice task. An example of a choice task can be seen in figure 3.1.

Finally, after judging all eight AWE designs, the respondents are confronted with a question asking them if they would participate in a real-world referendum concerning the implementation of an AWE design in their vicinity. This question aims to indicate how much the respondent values the content of the referendum.

3.1.3. Attribute selection

In the literature study, eight design characteristics of AWE systems have been identified based on two criteria: The attribute must embody a key characteristic of an airborne wind energy system and the attribute is likely to have an impact on citizens. To streamline these eight characteristics into the most essential attributes, the next step involves consultation with experts from the AWE research group. A presentation and discussion session has been planned with these experts to refine the selection. Two additional requirements for the essential attributes have been established:

- Citizens must find the attribute relevant to their decision-making.
- Collectively, the attributes should create a comprehensive and cohesive visual representation of the AWE system.

Following this selection process, the attributes finalized are type of kite, kite size, operating height, kite colour, and obstruction lights. The reasoning for this final selection will be explained in section 3.1.4.

This section also explains what attribute levels are chosen for the final set of attributes. In choice modelling an attribute level refers to the specific values or categories that an attribute can take (Hess and Daly, 2014). As the alternatives are unlabelled the attribute levels must be diverse and distinctive, so that the respondent can differentiate different designs. Moreover, the levels must not be too numerous to make comparison between attribute levels simple. As a result, the attribute levels have been chosen based on their distinctiveness and importance, to limit the number of attribute levels. The selection of attribute levels has also been part of the discussion in the AWE research group. The selection of attributes and their corresponding attribute levels as a result of the discussion are shown in table 3.1.

3.1.4. Attributes and levels

Kite type

The type of kite has been included in the final set of attributes due to its visual impact on the design as a whole. Furthermore, many different types of kites are used in the field and opinions are divided on what type of kite performs best. For the attribute levels, two of the three main classifications of kites are taken into account: Soft-wing and Fixed-wing. These categories encompass the most prominent kite designs but still are very different (Watson et al., 2019). Hybrid-wing has been excluded as the AWE group pointed out that only one developer is currently researching this kite type. The two levels are simple but still portray the diversity of designs used in the field.

Kite size

The size of the kite has been included as an attribute because it is expected that because of the visual impact of the size, due to the enormous size and unfamiliarity with such kites, the size will influence respondent decision-making. Furthermore, the size of the kite is an important aspect of the visual impression of the design as a whole. The discussion with the research group also uncovered that the size of the kite may be interesting to include as it also highly influences the power the systems can deliver. Before defining the attribute levels of this attribute first a unit must be defined as the different categories of kites are measured differently, either in wingspan or surface area. As wingspan is a simpler and more intuitive measure for citizens the wingspan has been chosen as the measuring unit. In the field, kites are being employed in a wide variety of sizes. Kite sizes range from a 5m wingspan to a 50m wingspan, as explained in chapter 2. However, following the advice of the AWE research group and to keep the levels simple, only the three most common sizes are used as attribute levels: 10m, 20m and 30m.

Operating height

The operating height is assumed to influence citizen decision-making as it influences the visual perceptions of the design. The AWE research group also revealed that the operating height will influence the feeling of safety and will determine in what detail the kite will be seen. Furthermore, the group confirmed the common range of operational height of 200-500m which is in line with what has been defined in the literary study. To keep the attribute levels distinctive and simple, the minimum and max of this range have been chosen as attribute levels: 200m and 500m.

Kite colour

The literature study uncovered that the kite colour is a key part of the visual impression of the design and that colour has a significant influence on the visual evaluation of the system (Maffei et al., 2013).

Table 3.1: Design attributes

Attributes	Levels			
Kite type	Soft wing	Fixed wing		
Kite size	10m	20m	30m	
Operating height	200m	500m		
Kite colour	White	Red	Black	Green
Obstruction lights	No obstruction light	Red obstruction light	White obstruction lights	

However, The importance of the kite colour has also been stressed by the research group as it plays a large role in flight safety. Several relevant colours have been identified in the discussion which will form the attribute levels of the design: White, red, black and green.

Obstruction lights
Obstruction lights are included as an attribute for their proven role in influencing the acceptance of AWE designs (Schmidt et al., 2024). The research group pointed out that obstruction light regulation for AWE systems is still vague and differs per country. However, consensus was reached that white and red lights are most commonly used in the field. Therefore the attribute levels are: No obstruction light, white obstructing light or red obstruction light.

Excluded attributes
Firstly, the generation mode has been excluded from the final selection of the attributes. From the discussion with the research group followed that fly-gen systems are losing interest in the field. Furthermore, the group highlighted the difficulties that may arise when combining different attributes with fly-gen as fly-gen designs are bound to a few limited kite types. For example, a soft-wing fly-gen system is not really compatible. Therefore, the attribute has been excluded because of its limited relevance in the field and the fact that it complicates the construction of realistic and cohesive AWE designs.

The second attribute that has been excluded is the take-off mode. The research group pointed out that AWE systems are supposed to stay in the air most of the time and that actual take-off moments are not only brief but also rare. Therefore the influence on citizen decision-making is questioned leading to the exclusion of the design.

The final attribute that was excluded is the air time of the design. Although air time may influence citizen decision-making, the discussion brought up that air time is more location and weather-dependent than it is actually a design characteristic. It was explained that the air time is more a dependent variable rather than a design attribute. Furthermore, it was argued that the air time would be difficult to convey in a survey to respondents.

3.1.5. Developer survey

With the assistance of experienced researchers from the TU Delft AWE research group, a preliminary set of relevant attributes and their corresponding levels has been constructed to characterize airborne wind energy (AWE) systems. While this initial set provides a solid foundation based on academic insight and theoretical considerations, it has yet to undergo verification by practitioners and developers actively engaged in the AWE field. Ensuring that these attributes and levels accurately reflect the current state and future trends of AWE technology is crucial for the validity and applicability of the research findings.

To address this need for verification, a targeted survey has been developed, aimed at gathering feedback from developers and scientific experts in AWE. This survey will present respondents with the constructed set of attributes and ask them to identify which attributes they consider most relevant in the context of current AWE developments. For the attributes deemed most pertinent, respondents will be prompted with follow-up questions to specify the levels that are currently utilized or expected to be adopted in the future within the industry.

Additionally, the survey will ask for any remarks or feedback from participants regarding the attribute set and will collect information on their organizational affiliation and field of expertise. The complete survey is presented in appendix B.

The survey will be distributed among experts attending the Airborne Wind Energy Conference (AWEC) in Madrid in 2024 and via E-mail by Airborne Wind Europe to IEA Task 48 and the wider AWE network. By targeting this specific audience, the survey aims to leverage the collective expertise of leading professionals in the field. This iterative process of consultation and validation is critical to ensure that the final set of attributes and levels is not only academically robust but also practically relevant and reflective of real-world AWE applications. The survey was distributed among 46 respondents. However, after excluding incomplete responses, 33 valid responses were used for further analysis. Most respondents (91%) indicated to be academics as well as AWE developers.

To construct a final set of attributes used for creating the alternatives of the choice experiment, the results of the developer survey will be used. Appendix B presents a full overview of the results of the survey. However, in this section 3.1.6, the conclusions which are drawn from these results, have been described.

3.1.6. Final attribute selection

Several adjustments are made to the initial attribute selection of table 3.1 following the results of the developer survey. No attributes are excluded or added, however some of the attribute levels have to change to increase reliability and validity. Firstly, for the kite colour, the colour green is replaced by red/white striped kite colour, as the survey has shown that green is a colour barely in use, while red/white striped is quite popular. Furthermore, the option of white obstruction lights has been removed as this option is not used as much in the field as the red light.

After the final selection of attributes has been determined, the next step involves constructing a design for choice sets. A choice set is a collection of the options presented to respondents in a choice experiment, each described by different levels of the specified attributes (Louviere et al., 2000).

To ensure the reliability of the experiment, the choice sets must have attribute level balance. This means that each level of every attribute should appear an equal number of times across all choice sets. This ensures that every attribute level is measured an equal number of times. Attribute level balance is essential for several reasons. Firstly, it enhances statistical efficiency by providing more precise and reliable estimates of the effects of each attribute level on choice behaviour. Without balance, some levels might be underrepresented, leading to some estimates being measured more reliably than others. Secondly, it contributes to a better model fit, as balanced data allow for a more accurate representation of respondents' preferences and trade-offs, resulting in more robust and generalizable conclusions (Hanley et al., 2001).

In this study, each attribute has between 2 to 4 levels, except the attribute kite size, which originally had 3 levels. Maintaining attribute level balance with varying numbers of levels across attributes can significantly increase the number of choice sets needed, making the design longer and more complex. To simplify the design and preserve balance, the levels of kite size have been reduced to two by removing the middle choice of 20m. This adjustment helps streamline the choice set design, making it more manageable for respondents while maintaining the integrity of the experiment.

This concludes all adjustments to the initial choice set and the final attribute selection is presented in table 3.3. Now that the attribute selection process is complete, the attribute levels are coded so that the constructions of alternatives/choice sets can take place in the following section.

3.1.7. Alternative construction

The selected attributes and their levels are combined into a variety of alternatives that will form the different AWE designs. The alternatives are constructed by using an orthogonal fractional design. An

Table 3.3: Final attributes selection and coding

Attributes	Levels	Coding
Kite type	Soft wing	0
	Fixed wing	1
Kite size	10m	0
	30m	1
Operating height	Medium altitude	0
	High altitude	1
Kite colour	White	0
	Red	1
	Black	2
	Red/white striped	3
Obstruction lights	No obstruction light	0
	Red obstruction light	1

orthogonal design is a type of design where the attributes are varied in such a way that their effects can be independently estimated without confounding, making it possible to analyze the influence of each factor on the response variable independently. This is advantageous because it maximizes statistical efficiency and reduces collinearity, leading to more accurate and reliable results (Louviere et al., 2000). Moreover, to be able to estimate the interaction effects, which are the effects between the different attributes, a foldover design has been added. This means that the main effects of the models will be unbiased as the effects of all design attributes will be uncorrelated with each other and with all two-way interactions. This design has been constructed by using the coding from table 3.3 and using Ngene software. The Ngene syntax used for creating this design can be seen in Appendix D. This resulted in a design with 16 alternatives or 16 different AWE designs. This design is shown in table 3.2. For the choice experiment, every choice task will include one AWE design. To reduce the length of the survey and make the survey not too tiresome, the design is blocked in two blocks: The original block and the foldover block. Each block contains 8 designs, which means a respondent will be confronted with 8 different AWE designs. Each block preserves attribute level balance. To illustrate how an alternative will look table 3.4 gives an example of the first design.

Table 3.2: Foldover orthognal design

Design	Kite type	Kite size	Operating height	Kite colour	Obstruction lights	Foldover block
1	1	1	0	0	0	1
2	0	0	0	1	1	1
3	1	0	0	3	0	1
4	0	1	0	2	1	1
5	0	1	1	1	0	1
6	1	0	1	0	1	1
7	0	0	1	2	0	1
8	1	1	1	3	1	1
9	0	0	1	3	1	2
10	1	1	1	2	0	2
11	0	1	1	0	1	2
12	1	0	1	1	0	2
13	1	0	0	2	1	2
14	0	1	1	3	0	2
15	1	1	1	0	1	2
16	0	0	0	0	0	2

Table 3.4: Design 1

Attributes	Level
Kite type	Fixed wing
Kite size	30m
Operating height	200m
Kite colour	White
Obstruction lights	No obstruction light

Figure 3.2: Visualization of design 8

3.1.8. Visualization

As the focus of this research is on the effect of visual aspects of AWE designs, respondents must get the correct image in their mind that resembles the real design, to ensure representativeness. To ensure this, wording will not be enough. Therefore the choice experiment will use visuals to make sure respondents will visualize the described AWE design as accurately as possible. The visuals are not required to be very detailed as the attribute (levels) often describe a general design choice or category which embodies a group of similar designs. As a result, the visuals will include self-made graphical images which display the design and its attributes in a relatable environment for the respondents. As the survey will use static images, this research will not include any dynamic visual impacts of an AWE design. As a result, the influence of, for example, the flight path of the kite and tether movement are not taken into account. An example of a visualization can be seen in figure 3.2.

Landscape

The landscape or environment where a design is located can highly influence the visual evaluation of a wind energy project (Wolsink, 2007b). Subsequently, the choice of the background is important as it may play a role in the decision-making of respondents. To research the local component of acceptance respondents have to imagine that the design will be implemented close to their residence. However, people live in a wide variety of places. This gives complication to the reliability and generalisability of the results as the visual evaluation of the design may be influenced by a wide variety of unknown environments. To counter this, the survey will ask respondents to imagine that they are living in a set environment comparable to the background of the visualizations. To accommodate this, the background has been chosen to resemble an environment outside a major city with well-known elements like buildings, nature and a road, to stimulate familiarity for a vast majority of the respondents. A car has been included so that the respondents get a grasp of the scale of an AWE design. A consequence of including a car and the skyscraper is that the background may not reflect a realistic environment for an AWE design, as it is unlikely AWE will be deployed in proximity to a large city.

3.1.9. Questionnaire

After the choice experiment, a short questionnaire will ask respondents whether their decision-making has been influenced by other factors than design attributes, nine questions are asked based on the three psychological variables identified in the literary study and three questions are asked about socio-demographic variables.

To be able to measure a respondent's environmental attitude, six questions are asked. These questions are based on the short version of the New Ecological Paradigm (NEP) defined by Dunlap and Van Liere, 1978. The NEP is an established way to determine one's environmental friendliness. However, the original NEP is fifteen questions long, while this short version only included six questions. Unfortunately, there is no information available concerning the reliability and validity of this short version, still, it has been used in a variety of scientific studies (Hawcroft and Milfont, 2010; Zelezny et al., 2000). These six questions will involve a few statements on which the respondent will have to answer on a five-point Likert scale (1 = strongly agree, 5 = strongly disagree) (Likert, 1932). Measuring the environmental attitude of respondents is important as it is likely that individuals with a higher environmental attitude have a higher acceptance of renewable technology projects (Perlaviciute and Steg, 2014;Hübner et al., 2023).

The 7th question aims to determine the influence of the social environment on decision-making. Similarly, as with the NEP this question involves a statement followed by the Likert scale. The eight question aims to measure the influence of the background and landscape of the visualization on decision-making. The ninth question ties into this as it presents a manipulation check and asks the respondents if they still remember what elements were present in the background of the visualization. If respondents indicated precisely knowing the correct elements that were present, they were more aware of the elements and it is more likely their decision-making has been influenced.

Lastly, the three demographic questions involve questions regarding gender, age and education level. The results of this may be used to check the representativeness of the sample. The full questions can be seen in appendix F which displays all survey questions.

3.1.10. Pilot

A pilot survey will be conducted to assess the accuracy and suitability of the questions before the main survey begins. This preliminary survey aims to identify any potential issues with the survey instrument, such as unclear or ambiguous questions, and to ensure that the survey is neither too lengthy nor burdensome for participants. This survey is the final check before conducting the final survey and is distributed only to a minimum number of respondents, to avoid wasting too much valuable respondents for the final survey. By gathering feedback from a small sample of respondents through the pilot survey, adjustments can be made to improve the clarity, relevance, and efficiency of the questionnaire, thereby enhancing the quality of data collected in the subsequent main survey. The small sample involved two small groups. One group was unfamiliar with the concept of AWE, while the second group comprised students from the AWE research group. Both groups were targeted by non-random means, but were representative of members from the target sample for the final survey. This dual approach ensured that the survey was comprehensible to novices and accurately represented AWE technology to experts.

The pilot study yielded several findings. Firstly, the introduction was excessively lengthy, causing respondents to lose interest and focus. Additionally, non-fluent English-speaking participants found the term 'aesthetically pleasing' challenging to understand. Moreover, The expert group identified a discrepancy between the described "operating height" and the visualizations, as the images did not accurately depict the 200m and 500m heights mentioned. In addition, the experts argued that the environment of the visualizations used in the survey does not depict a realistic environment for an AWE project. Finally, both groups agreed that the survey was too long, with non-fluent English speakers experiencing additional difficulty due to the effort required to understand the content adequately.

To improve the survey and the data-collection process, the identified challenges of the pilot survey are being tackled. The introduction was significantly shortened to retain respondents' interest and attention. Furthermore, to reduce the survey's length and complexity, the six questions related to environmental attitude were condensed into a single, comprehensive question. The term aesthetically pleasing is clarified with a more detailed explanation. Additionally, the levels of operating height were redefined as medium altitude and high altitude to align more intuitively with the visualizations provided. Lastly, a disclaimer has been included at the end of the survey, which tells respondents that the visualizations may not present a fully realistic and accurate environment of an AWE system. The choice for the disclaimer instead of changing the visualization has been grounded in the constraints of the time limit of this research and the difficulty of changing the visualizations, this late in the process. These modifications aimed to enhance the survey's clarity and accuracy, ensuring it was both engaging and comprehensible for all participants.

3.1.11. Data collection

For the choice experiment, a decision needs to be made between using stated preference data and revealed preference data. Stated preference data concerns choices that people make from a set of hypothetical alternatives that are presented to them in a survey setting. Revealed preference data concerns choices made by people that are observed in the real world (Abdullah et al., 2011). However, since only a handful of pilot projects have started worldwide with a limited variety of AWE designs, there is no or very little revealed preference data available. Moreover, because the technology is still in the development phase the research also does not want to leave out experimental design attributes which might become relevant in the near future. In short, this means that because of the lack of revealed preference data, this research will use stated preference data.

Besides stated preference data, the survey will also involve collecting data on socio-demographics, the influence of social norms, environmental attitudes and the influence of the landscape. The data of this questionnaire will be used to answer subquestion 4 in combination with the data from the stated choice experiment.

3.1.12. Sample

To collect all this data, a stated choice experiment has been set up. The experiment entails a digital survey which will confront respondents with different AWE designs as alternatives. In a stated choice experiment, ensuring a sufficient sample size is imperative to obtain robust and reliable results. The aim of this research is to achieve a sample size of at least 200 respondents, this has two reasons. Firstly, a larger sample provides greater statistical power, allowing for a more precise estimation of model parameters and increased generalisability of findings to the broader population. Secondly, a sizable sample helps mitigate the risk of type II errors, ensuring that meaningful patterns and effects are not overlooked due to insufficient data. To achieve this, a snowball sampling method will be used in which participants are initially recruited through non-random means, such as through existing contacts or social networks. In other words, the survey invitations will be distributed in two ways: physically or digitally. Physical distribution will take place by letting contacts scan a QR code. Digitally will include sending a link via WhatsApp groups, email, LinkedIn, Facebook or Instagram. After completing the survey or participating in the study, these initial participants are then asked to refer or recruit additional participants from their own networks, and the process continues iteratively, resembling the way a snowball grows in size as it rolls downhill(Becker Howard, 1963).

Table 3.5: Dummy coded kite colour

Kite colour	r	b	rw
White	0	0	0
Red	1	0	0
Black	0	1	0
Red/white striped	0	0	1

The advantages of snowball sampling are that in a relatively short time, a large amount of respondents can be questioned. Moreover, it allows for reaching individuals who are considered hard-to-reach(Parker et al., 2019). Nevertheless, the method also poses some challenges. Firstly, the initial respondent selection is dependent on the selection bias of the researcher. Secondly, it is not producing samples that meet the criteria of random samples in the statistical sense. As a result, the representativeness and external validity are sometimes questioned as the respondent group may not prove to be an accurate representation of society. Questions about demographics in the first part of the survey will give insight into the representativeness of the sample.

A consequence of snowball sampling is that the sample will be a convenience sample, which is a type of non-probability sampling technique where the subjects are selected based on their accessibility and proximity to the researcher (Farrokhi and Mahmoudi-Hamidabad, 2012). This method relies on the ease of reaching the participants rather than using random selection. The advantages of a convenience sample are that data can be quickly collected, a disadvantage is that because participants are not randomly selected, the sample may not represent the broader population, leading to biased results (Etikan et al., 2016). However, due to the time constraints and the scope of this research, a convenience sample has been chosen to collect data.

3.1.13. Human Research Ethics Committee

Conducting human research at TU Delft requires adherence to strict ethical guidelines and regulations to ensure the safety and privacy of participants. To make sure, this research is in compliance with these ethical guidelines and reflations, a checklist, informed consent form and data management plan were constructed and verified by the Human Research Ethics Committee (HREC). The primary goal of the HREC checklist is to evaluate potential risks participants may encounter, including physical, emotional, and privacy-related risks, and to specify mitigation strategies. Researchers must prepare detailed informed consent materials, ensuring participants are fully aware of the nature of the research, the data being collected, and how it will be used. This informed consent is included in the survey, so all respondents have given their consent for the data collection process. The data management plan outlines careful handling procedures to ensure that all collected data is treated with the highest level of care and remains completely anonymous. Only data from individuals above the age of 15 will be stored and used in the analysis, further safeguarding participant privacy and compliance with ethical standards. The committee found this research to be in compliance with human research ethical guidelines and legislation and gave their permission and approval for conducting the survey.

3.2. Model estimation

3.2.1. Attribute coding

To be able to estimate models from the choice experiment the attributes still need to be coded. Four out of the five attributes have only two attribute levels. Therefore, these attributes can simply be coded in binary. However, kite colour is an attribute with four levels, therefore this attribute will be dummy coded, which is presented in table 3.5.

3.2.2. Decision rule

From the stated choice experiment a range of models can be estimated, based on an assumed decision rule. A widely adopted decision rule is Random Utility Maximization (Ben-Akiva, 1985). In this decision rule, it is assumed that individuals choose the alternative that maximizes their utility. Utility is defined as an indicator of value (Koppelman and Bhat, 2006). However, since this choice experiment employs the referendum style of questioning, utility is not the dependent variable, but acceptance is. When a design is accepted enough, a respondent will vote in favour. Therefore this experiment will not use the utility function but an acceptance function. The acceptance function is made up of the different components which define the acceptance of a certain design. These components are derived from the conceptual model defined section 2.1.2.

Firstly, the designs are rated on their safety and aesthetics. To measure how each attribute influences the perceived safety or aesthetics this part of the model is estimated as a linear regression model, with the following functions for perceived safety and perceived aesthetics respectively:

$$PS_j = C^{PS} + \sum \beta_i^{PS} * X_{ij}$$

$$PA_j = C^{PA} + \sum \beta_i^{PA} * X_{ij}$$

In these functions C is the regression constant, portraying the base value of the perceived safety or aesthetics. The beta is the estimated regression coefficient for each attribute level, or in other words the effect of each design attribute of a particular design on the perceived safety or aesthetics. The $X_i j$ portrays the coded (binary or dummy) value of the respective attribute level i.

The third component of the acceptance function pertains to the referendum vote outcome, which is represented by a binary dependent variable (in favour, or against). Therefore this component is specified by a binary logit model. A design is accepted if there is a higher probability individuals vote in favour than against. Therefore the acceptance of a design is determined by the natural logarithm of the probability of voting in favor over the probability of voting against an AWE design(P_A and P_F).

$$Support = logit = \ln(\frac{P_F}{P_A}) = \beta_0 + \sum \beta_i^V * X_{ij}$$

In this equation, X_i denotes the attribute level of the alternative, which means that parameters beta s and beta a denote the contribution of each design attribute i to the safety and aesthetics of the design respectively. The variable Vote resembles the vote in favour or against the implementation of a certain design and is thus a binary variable. Beta v is the contribution of the choice to vote to the total acceptance determining the support.

3.2.3. Models

Now that the decision rule has been specified, the models which will be estimated shall be presented. First of all, two linear regression models are estimated to discern the influence of design attributes on the perceived safety and the perceived aesthetics of the design. These two models will be used to test the significance of the estimated parameters of the design attributes, according to the 95 percent confidence when the absolute t-value is above 1.96. The results of this estimation will be used to answer research subquestions 1 and 2 respectively.

To measure the influence of design attributes on the referendum vote a binary logit model is estimated. The logit model is used to estimate parameters for the effect of specific design attributes on the voting behaviour of respondents. The results of this will be used to answer subquestion 3.

Additional variables that were measured will be added step by step to these initial models. Variables which are not statistically significant will then be removed. In this way, a final model is constructed by first adding socio-demographic variables then the attitude variables and finally possible interaction effects, which are explained in section 3.2.5.

Finally, a mediation model will be estimated to be able to answer the fifth research subquestion: "To what extent do perceived safety and aesthetics mediate the effect of design attributes on the social acceptance of an airborne wind energy system?". A mediation model examines how independent variables influence a dependent variable indirectly through one or more mediator variables. The model decomposes the total effect of the independent variables on the dependent variable into a direct effect (the effect of the independent variable on the dependent variable not through the mediator) and an indirect effect (the effect of the independent variable on the dependent variable through the mediator). This helps in understanding the process or mechanism through which the independent variable affects the dependent variable (Baron and Kenny, 1986). In this model, the referendum vote is the dependent variable symbolizing the local acceptance, independent variables are the design attributes. The mediators are the perceived safety and aesthetics. In this way, the estimated mediation model allows for controlling if the effect of the design attributes on voting behaviour is mediated through the identified perceptions, or that there may be other unidentified perceptions which may play a role.

3.2.4. Multiple linear regression assumptions

The regression models employed in this study satisfy several key assumptions essential for reliable analysis. Firstly, linearity assumes that the relationship between the predictor variables (design attributes) and the response variable (social acceptance) is linear. This assumption is upheld through careful model specification and testing of linear relationships between variables. Independence, although not entirely guaranteed due to potential taste heterogeneity among respondents, has been managed effectively. Measures such as blocking the designs and limiting survey length were implemented to minimize respondent fatigue and mitigate the effects of taste heterogeneity on the independence assumption. Homoscedasticity, which requires the variance of the residuals to be constant across all levels of the predictor variables, is supported through residual analysis and model diagnostics. Lastly, multicollinearity is avoided by employing an orthogonal design, ensuring that the predictor variables are not highly correlated with each other. These practices collectively ensure that the regression models used in this study adhere to the fundamental assumptions necessary for valid interpretation and inference.

3.2.5. Interaction effects

”Interaction effects occur when the effects of two or more independent variables on the dependent variable are not simply additive, but rather depend on the combination of values of the independent variables. Interaction effects indicate that the impact of one independent variable on the dependent variable varies depending on the level of another independent variable, and vice versa.”(Louviere et al., 2000, p. 105). It is reasonable to assume that interaction effects play a role in this choice experiment. Individuals’ perceptions and preferences for AWE designs could be influenced by a combination of attributes rather than single attributes in isolation. In other words, different combinations of attribute levels may result in different effects. Three interaction effects, which appeared to be most likely are included in the model estimation. Firstly, it could be that the effects of kite type and the kite size are affected by the value of the other attribute. For example, it is assumed that for fixed kites, the kite size will impact the design’s support less than the kite size does for soft wings(Pereira and Sousa, 2022). Secondly, different kite types may be preferred at different altitudes, and the same could be said about kite sizes and altitudes. As a result, the interaction effects of kite type and operating height and kite size and operating height are included as well.

3.2.6. Model fit

Before the results of the model estimations are discussed this section will present the model fit of the different models. The model fit is analyzed to measure how well the different models suit the data. Furthermore, the model performance of the different estimated models is analyzed by comparing the model fit between models, but also comparing the fit to guidelines from the field.

Model fit linear regression models

Firstly, the model fit of the estimated linear regression models is evaluated. A commonly used metric for assessing the goodness of fit of t linear regression models is the rho-squared value (ρ^2), which ranges between 0 and 1 (Ben-Akiva, 1985). This value indicates the proportion of initial uncertainty that the model explains. A ρ^2 value of 1 indicates a perfect fit, implying that every choice is accurately predicted. The adjusted R-squared value is a statistical measure that indicates the proportion of variance in the dependent variable that is predictable from the independent variables, adjusted for the number of dependent variables in the model. It is a modified version of the R-squared value that accounts for the number of predictors, preventing overestimation of the model’s explanatory power when more predictors are added (Menard, 2002). Table3.6 presents the adjusted R-squared values of two sets of linear regression models, denoted as MS and Ma, which were iteratively refined by adding and removing statistically significant variables. The final models in each set are labelled as MSF and MAF, respectively.

Table 3.6: Adjusted R-squared Values

Model	Adjusted R-squared
MS	0.06027
MSS	0.07674
MSSA	0.08037
MSSAI	0.08102
MSF	0.08086
Ma	0.04084
MAS	0.05118
MASA	0.05633
MASAI	0.05634
MAF	0.0579

The adjusted R-squared values for both sets of models are relatively low, with the final models, MSF and MAF, explaining approximately 8.09 percent and 5.79 percent of the variance, respectively. This indicates that the models, while statistically significant, do not account for a large portion of the variability in the dependent variable. The low adjusted R-squared values suggest the answers of different respondents are significantly different. In other words, low rho squared is an indicator of a high degree of heterogeneity in the sample. While normally, R-squared values beneath 0.1 are considered a very poor model fit in social sciences it is always more challenging to grasp all the relevant predictors. Social science studies often deal with complex human behaviours and social phenomena, which are influenced by a myriad of factors. As a result, it is not uncommon for social science models to exhibit relatively low R-squared values, particularly when compared to models in the natural sciences or engineering, where phenomena can often be more precisely quantified. For instance, studies in psychology, sociology, and education frequently report R-squared values ranging from 0.1 to 0.2 as acceptable, and values below 0.1 are not unusual. This reflects the inherent complexity and variability in human behaviour and social interactions, which are challenging to capture fully with a limited set of predictors. According to Cohen, 1988, in the context of behavioural sciences, an R-squared value of around 0.26 is considered a medium effect size, and 0.02 is considered small.

Given this context, the adjusted R-squared values of 0.08086 for the MSF model and 0.0579 for the MAF model, while low, are not atypical for social science research. These values indicate that the models capture a modest portion of the variability in the dependent variable, which is consistent with the complexity of the social phenomena being studied. Therefore, while these models might have limited predictive power, their fit is within a reasonable range for exploratory social science studies. It is also a reminder of the value of using a range of complementary approaches and data sources to understand complex social issues more comprehensively. In conclusion, the adjusted R-squared values of the final models are acceptable in the field of social science, when researching complex behaviour like support. However, the low model fit also highlights the need for further research to increase the explained variance of the dependent variables. With this in mind, both models are considered good enough to be used to explain how design attributes influence an AWE design's perceived safety and perceived aesthetics. Nonetheless, it should be stressed that the low Rho-squared values indicate a high degree of heterogeneity between respondent choices and it could be that the choices are correlated with other personal characteristics that were not measured in this experiment.

Model fit logit models

By estimating the loglikelihoods and McFadden's pseudo rho-squared values the model fit of the logit model can be analyzed. The log-likelihood is a measure of the goodness of fit of a statistical model to a sample of data (Ben-Akiva, 1985). It is derived from the likelihood function, which represents the probability of the observed data under the model. Higher log-likelihood values indicate better model fit. McFadden's pseudo rho squared is an analogue to the rho squared value used in ordinary least squares regression (Menard, 2002). It is calculated as:

$$\text{McFadden's } R^2 = 1 - \frac{\ln(L_{\text{full model}})}{\ln(L_{\text{intercept model}})}$$

McFadden's pseudo-rho-squared values typically range from 0 to just under 1, with higher values indicating better model fit. While not directly comparable to the rho squared in linear regression, it provides a useful measure of the explanatory power of the logit model.

Table 3.7: Model fit statistics logistic models

Model	llh	llhNull	Difference in Log-Likelihood	McFadden	r2ML
MV	-1110.766	-1141.601	30.835	0.027	0.038
MVS	-1100.095	-1140.148	40.053	0.035	0.050
MVSA	-1080.459	-1123.654	43.195	0.038	0.054
MVSAI	-1089.722	-1134.825	45.103	0.040	0.056
MVF	-1093.455	-1134.825	41.370	0.037	0.051

The model fit of the referendum vote model is measured to gain insight into the performance of the model which aims to reveal how design attributes affect people's voting behaviour. First of all, The log-likelihood is a measure of the goodness of fit of a statistical model to a sample of data (Ben-Akiva, 1985). It is derived from the likelihood function, which represents the probability of the observed data under the model. Higher log-likelihood values indicate better model fit. McFadden's pseudo rho squared is an analogue to the rho squared value used in ordinary least squares regression (Menard, 2002). It is calculated as:

$$\text{McFadden's } R^2 = 1 - \frac{\ln(L_{\text{full model}})}{\ln(L_{\text{intercept model}})}$$

McFadden's pseudo-rho-squared values typically range from 0 to just under 1, with higher values indicating better model fit. While not directly comparable to the rho squared in linear regression, it provides a useful measure of the explanatory power of the logit model. The difference between llh and llhNull provides a measure of how much better the model performs compared to a baseline model with no predictors. Finally, the Cox-Snell Pseudo R-squared (r2ML) is another measure of the proportion of variance explained by the model, which adjusts for the number of parameters in the model, giving a more realistic estimate of the model's explanatory powerLouviere et al., 2000.

The work by Train, 2009 argues that McFadden's pseudo-rho-squared values between 0.2 and 0.4 are typical for discrete choice models and are considered excellent fit, while values below 0.05 have a poor model fit. As a result, the model fit of the final logit model can be considered poor, because it has a large part of unexplained variance which indicates a high degree of heterogeneity in voting behaviour. Despite, the poor fit this model will still be used for explanatory purposes. However, the presence of heterogeneity will be kept in mind.

Model fit mediation model

Table 3.8: Mediation model fit indexes

Fit index	Value
Comparative Fit Index (CFI)	0.715
Root Mean Square Error of Approximation (RMSEA)	0.559
Standardized Root Mean Square Residual (SRMR)	0.079

To assess the model fit of the mediation model a combination of indices is used. Firstly the Comparative Fit Index (CFI): This index compares the specified model to a null model where no relationships are specified. A CFI value closer to 1 indicates a better fit, with values above 0.90 often considered acceptable (Hu and Bentler, 1999). Secondly, the Root Mean Square Error of Approximation (RMSEA) measures the discrepancy between the observed data and the model. Smaller values of RMSEA indicate better fit, with values below 0.05 considered good fit and values between 0.05 and 0.08 indicating reasonable fit Hu and Bentler, 1999. Thirdly, the Standardized Root Mean Square Residual (SRMR) measures the average discrepancy between the observed correlations and those implied by the model. Values closer to 0 indicate a better fit, with values below 0.08 typically considered acceptable.

The mediation model performs poorly on the CFI which means that the model does not adequately explain the relationships among the observed variables in the dataset. This could indicate that the model is missing important paths, has incorrect specifications, or does not capture the underlying structure of the data well. Similarly, to the low adjusted R-squares, this implies that the model misses additional relevant predictor variables. While the CFI is low the model does score decent on the RMSEA and the SRMR, which suggests that the model performs well in terms of both the average residual and the overall discrepancy between the observed data and the model's prediction. In other words, the model has a decent fit to the data, symbolizing the model's ability to reproduce observed data patterns accurately within the expected margins of error. In conclusion, while the mediation model does not offer a complete picture of all relevant predictors it is still acceptable to use the model to explain to what extent the influence of design attributes on the support of an AWE design is mediated through perceived safety and aesthetics.

3.2.7. Model application

After all models have been estimated, the best version of the logit model will be applied to predict the acceptance levels of a diverse selection of designs. These designs are specified in four scenarios, which aim to emulated plausible future trends in the AWE field. These scenarios are compared and ranked based on their respective expected acceptance. In this way, the value of the logit model for real-world application is shown to policymakers and AWE developers, Furthermore, this scenario analysis makes it easier for people unfamiliar with choice models to understand the findings of these models in a practical setting.

4 Results

This chapter presents the results derived from the digital survey. These results aim to answer the main research question as well as answering all subquestions. In section 4.1 the data is prepared to allow for estimating models and deriving results. Furthermore, section 4.2 includes the results of the questionnaire, while section 4.3.1 presents the results from the stated choice experiment and model estimation. Finally, the results are summarised in section 4.4.

4.1. Data preparation

The data has been collected between May 24th and June 2nd. The survey was distributed among a convenient sample in the Netherlands. As a result, the majority of respondents are Dutch. However, since it is a digital survey, the survey was also sent internationally by sending it to family, friends and fellow students and posting the survey on social media and online forums. The exact origin of all responses is unknown due to privacy reasons and the requirement of the HREC to ensure the responses are completely anonymous and no sensitive data is recorded. Nevertheless, the majority of the sample is Dutch which means this sample can be seen as a fraction of the Dutch population. Convenient sampling is susceptible to representativeness issues because the survey is distributed through non-random means(Etikan et al., 2016). Therefore, section 4.2.1 aims to compare the descriptive statistics of the sample with the statistics of the Dutch population and addresses a possible mismatch.

The survey distribution resulted in 311 respondents opening the survey. However, 240 complete responses were registered. This means 78% of the respondents clicked through to the whole survey. A dropout of 22% can generally be seen as pretty low, which means the survey length and complexity did not exhaust a majority of the respondents.

To further analyze these 240 responses, the data has been exported to SPSS. In SPSS the data has been cleaned and restructured before it was used for further analysis.

4.1.1. Data cleaning

For cleaning the data responses have been evaluated on several criteria. As the sample group only had to meet the requirements of the HREC, the criteria have only been used to filter incomplete or double data and to filter out responses of people under 16. Data cleansing has been aimed to be as minimal as possible because unnecessary data deletion is undesirable. The data had to meet the following criteria:

- Respondents must be 16 years or older.
- 70 % of the questions must have been answered.
- Responses must not have a similar response ID.

In this way, all duplicate and severely incomplete data have been omitted. After cleaning the data on the above criteria 200 valid responses remained. As every respondent was confronted with eight choices this led to a total of 1656 observations.

4.1.2. Data structuring

To make analysis of a stated choice experiment possible the 200 valid responses have been restructured. Firstly, the choices of respondents were transposed from variables to cases to make sure every choice task is one observation. Consequently, the rating of all designs has been combined into three variables: Perceived safety, perceived aesthetics and referendum vote.

Additionally, the design attributes were included as new variables. In this way, every observation also shows information on the design and what attributes were being judged. Kite type, kite size, operating height and obstruction lights are binary variables, kite colour has four levels so dummy coding has been applied as shown in table 3.5.

Finally, the multiple choice questions have been translated into one variable called: BG check. In this question, respondents could fill in all elements they thought were visible in the background of the visualizations. The variable is a summation of all correct checked options. This question also contained an open answer the respondents could fill in. After manually checking all open responses, it can be concluded that no open responses contained any objects which were not present in the background of the visualization. Therefore the other responses have been included in the correct options. This means the range of this variable is between zero and four. The correct responses are tree, car, skyscrapers, and other. The wrong responses are animal, billboard and truck.

4.2. Questionnaire results

Now that the data has been prepared, results can be estimated from the data. Firstly, this section presents the results of the questionnaire. Sample characteristics are derived via SPSS to get insights into the sample's socio-demographic representation as well as what attitudes and external influences may influence respondents' decision-making.

4.2.1. Socio-demographic

Table 4.1: Age descriptives

Statistic	Value
Mean	31.25
Minimum	16
Maximum	79
Standard deviation	15.275

Table 4.2: Sample gender and education characteristics

Variable	Category	Percentage
Gender	Female	39.6
	Male	56.5
	Other	1.4
	Prefer not to say	2.4
Education level	Primary school	2.5
	High school	28.4
	MBO	13.7
	HBO	26.0
	Bachelor	16.2
	Master	12.3
	Doctoral degree	1.0

The sample population exhibits a diverse range of demographic characteristics (table 4.2). Regarding age distribution, the largest group falls within the 18-24 age range, accounting for 42.6 % of the participants. This is followed by individuals aged 40 and above, who comprise 31.4 % of the sample. The 24-40 age group represents 15.9 %, while the youngest cohort, aged 16-18, comprises 10.1 % of the participants. The mean age is 31.25 %. The mean, minimum, maximum and standard deviation of the sample age can be seen in table 4.1. The distribution of gender and education in the sample can be seen in table 4.2.

Population comparison
To assess the representativeness of our sample, we compare it with the Dutch population based on the three measured socio-demographic variables: age, gender, and education level.

The Dutch population's age distribution can be summarized using data from Statistics Netherlands ("CBS StatLine", 2024). According to recent statistics, the mean age of the Dutch population is approximately 42.7 years. The standard deviation for the Dutch population's age is around 20 years. The sample's mean age is significantly lower than the Dutch population's, indicating that our sample is younger. Furthermore, the standard deviation in our sample is slightly lower than that of the Dutch population, suggesting less age variability within our sample. This younger age distribution in our sample could influence the results and limit the generalizability to the entire Dutch population, which is older on average.

According to CBS, the Dutch population's gender distribution is as follows: 50.5% is female and 49.5% is male ("CBS StatLine", 2024). This shows, that in the sample male respondents are over-represented. Additionally, while the inclusion of non-binary and those who prefer not to say is progressive, these categories represent a small portion of the sample and are not compared directly with the national statistics due to their omission in the broader census data.

The Dutch population's educational distribution (for individuals aged 15-75) is approximate: primary education: 27%, secondary education (VMBO, HAVO, VWO): 39%, MBO: 22%, HBO and University (Bachelor and Master): 12% and PhD: 0.5% ("OECD", 2024). Our sample has a higher representation of individuals with higher education (HBO, Bachelor, and Master degrees) compared to the Dutch population. The percentage of individuals with primary education is significantly lower in our sample compared to the general population. This discrepancy indicates that our sample is more educated than the general Dutch population.

In conclusion, the comparison reveals that our sample is younger, more male-dominated, and better educated than the overall Dutch population. These differences suggest potential biases in our sample that could affect the representativeness and generalizability of our findings. Therefore, caution should be exercised when extrapolating the results of this study to the broader Dutch population. Possible causes and implications of these findings are further discussed in section 6.4.

4.2.2. Descriptive statistics of psychological variables

Table 4.3: Descriptive statistics of attitudes and influences

Variable	Mean	Std. Deviation
Background influence	3.02	1.229
Social environment influence	2.14	1.168
Personal importance of protecting the environment	3.43	0.967

The descriptive statistics of the psychological variables provide valuable insights into respondents' perceptions (table 4.3 and appendix C). These results may show if and how these variables influence the support of different AWE designs. All three variables were measured on a scale from 1 to 5, where 5 is the most influence and 1 is the least influence. Firstly, the influence of background and surroundings depicted in the images on decision-making suggests a "somewhat" level of influence, with responses varying widely among participants (table 4.3). In addition, interesting to note is that environmental attitude is positively correlated with age and education, meaning elderly and people with a higher education were more concerned with protecting the environment.

Regarding the influence of the social environment on support, the mean indicates a lower level of perceived influence more in the ”slightly” level of influence. Thirdly, participants’ personal importance of protecting the environment yielded a mean score suggesting a relatively high level of importance placed on environmental protection among the respondents, with responses showing less variability compared to the other two variables.

Table 4.4: Percentage distribution of background manipulation check

Element	Percentage
Tree	46.1
Animal*	2.0
Truck*	4.9
Billboard*	4.4
Car	67.1
Skyscraper	82.8
Other	10.2

* items which were not present on the background

Table 4.5: Descriptive statistics of background check scores

Variable	Mean	Minimum	Maximum	Std. Deviation
Background check score	1.89	0	4	1.18

The significance of the influence of the background is further strengthened by the results of the background manipulation check. In which respondents had to guess the correct elements from the background. Table 4.4 shows that the incorrect elements were almost not being chosen. Furthermore, the background check score shows that on average most respondents got two elements correct. As a result, the background of the visualizations likely affected the acceptance of the AWE designs. Implications of this are further discussed in section 6.4.

In conclusion, the descriptive results of the psychological variables indicate that they might have affected the support for different designs. Inclusion in the model estimation process might confirm these findings and show how these variables impacted the acceptance in general.

4.3. Stated choice experiment results

This section presents the results of the stated choice experiment. The following sections describe the results of the model estimation process.

4.3.1. Model estimation

To dive into the relationship of design attributes and an AWE design’s acceptance several models have been estimated. All models have been estimated using R. For estimating the mediation model the package ’Lavaan’ has been used (Rosseel, 2012). Lavaan does not support full maximum likelihood model estimation for categorical data; it only supports weighted least squares estimation. As a result, these estimated results are suboptimal. Firstly, section 4.3.1 presents the results of the linear regression model estimated to delineate the influence of the design attributes on a design’s perceived safety. Subsequently, section 4.3.1 contains the results of the model estimation of the linear regression model concerning a design’s perceived aesthetics. Then, section 4.4 shows the results for the two logit models concerning the referendum vote. Finally, a mediation model is estimated to discern the indirect and direct effects on the referendum vote through safety and aesthetics.

An initial model is estimated by using the five design attributes and the relevant dependent variable. This model is iteratively improved by adding additional variables like socio-demographic and attitude variables and interaction effects. These added variables will remain in the model if they are statistically significant and excluded otherwise. These iterative models are extensively presented in appendix E, while the following sections only describe the final models.

Perceived safety linear regression model
To find out what the effect is of design attributes on the perceived safety of an AWE system, a regression model has been estimated. Perceived safety is the dependent variable of this model while the independent variables initially include the five design attributes that make up an alternative, where kite colour is dummy-coded in red, black and red/white striped. In addition, the model also includes the intercept which is the base value of the alternative (perceived safety when all variables are zero). This leads to a base model with a total of eight variables. This base model is expanded incrementally by adding socio-demographic variables, attitude variables and interaction effects as independent variables. If the effects of these variables are significant they are kept in the model. In this way, a final model is derived which will be used to analyze the influence of design attributes on perceived safety. The results of this final model can be seen in table 4.6. The incremental model steps can be seen in Appendix E.

The table shows the estimated parameters to show the size of the effect and shows the statistical significance of this effect. Analyzing the results shows that four of the initial variables are not statistically significant. Firstly, this means that there appears to be no significant relation between obstruction lights and perceived safety. Furthermore, the kite colours red and red/white striped also do not appear to make a difference in the feeling of safety compared to a white kite.

Table 4.6: Final regression model perceived safety

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.332	0.151	22.016	0.000	***
Kite type	-0.334	0.055	-6.104	0.000	***
Kite size	-0.165	0.055	-3.008	0.003	**
Operating height	0.401	0.055	7.334	0.000	***
Obstruction lights	0.022	0.055	0.396	0.692	
Red	-0.094	0.077	-1.213	0.225	
Black	-0.242	0.077	-3.126	0.002	**
Red/white striped	-0.096	0.077	-1.246	0.213	
Education	-0.073	0.019	-3.729	0.000	***
Gender	0.168	0.046	3.654	0.000	***
Social influence	0.057	0.025	2.321	0.020	*
Background influence	-0.052	0.023	-2.239	0.025	*

Significance levels: *** < 0.001, ** < 0.01, * < 0.05, . < 0.1

The other variables in the model do have a statistically significant effect on the design's perceived safety. The statistically significant estimated parameters can be used to explain the relation of the variables on the dependent variable perceived safety. A higher perceived safety means that a design is perceived as safer where 1 is the most unsafe and 5 is the most safe. For kite type this means that the soft kite (coded as 0) leads to a higher safety score as a change to a fixed kite averagely leads to a decrease to the perceived safety score. Similarly, a smaller kite size leads to a safer perceived design. A change from medium altitude to high altitude results in a substantial increase in safety score. In other words, people perceive a design at a higher altitude as more safe. A white kite is preferred over a black kite as a black kite leads to a decrease in safety score. Subsequently, the intercept shows that when all variables are assumed to be zero the design will have a perceived safety score of 3.33 which is slightly above the middle value of 3.

Considering the socio-demographic variables, there appears to be no statistically significant relation between age and perceived safety. However, respondents with a higher education are more likely to perceive a design as unsafe. Moreover, male respondents perceive designs as safer than female respondents.

Regarding the attitudes, there is no statistically significant relation between the environmental attitude and perceived safety. However, respondents who claimed to be influenced by their social environment marginally perceive a design as more safe. Moreover, respondents who were more influenced by the background of the visualizations perceived the designs as less safe.

Finally, the interaction effects that have been specified in section 3.2.5 have been added to the model. None of the interaction effects proved to be statistically significant. This suggests that the relationship between the kite type, kite size and operating height with perceived safety does not depend on the combined influence of those variables. In other words, the effect of a fixed-wing kite does not change significantly when it is a larger fixed-wing kite.

Perceived aesthetics linear regression model
To analyze the relationship between design attributes and perceived aesthetics a regression model is estimated in similar style to the perceived safety regression model. In this section, the final model which describes this relationship is presented and analyzed. The incremental models are described in appendix E.

Table 4.7: Final regression model perceived aesthetics

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.498	0.120	29.243	0.000	***
Kite type	-0.098	0.054	-1.795	0.073	.
Kite size	-0.082	0.054	-1.504	0.133	
Operating height	0.287	0.054	5.285	0.000	***
Obstruction lights	-0.038	0.054	-0.707	0.480	
Red	-0.341	0.077	-4.425	0.000	***
Black	-0.445	0.077	-5.793	0.000	***
Red/white striped	-0.387	0.077	-5.030	0.000	***
Education	-0.071	0.019	-3.735	0.000	***
Soc influence	0.085	0.023	3.630	0.000	***

Firstly, three attributes do not have a statistically significant effect. There appears to be no relationship between the kite type, kite size and obstruction lights and the perceived aesthetics of a certain AWE design. However, the operating height and the kite colours do have a statistically significant effect on the perceived aesthetics of an AWE design. A higher operating height results in a more aesthetically pleasing design. Additionally, a kite colour of white results in a significantly more aesthetically pleasing design than kite colours of red, black and red/white striped, of which black is the worst perceived colour. Similarly as with perceived safety, people with a higher education perceive AWE designs as less aesthetically pleasing. Furthermore, people who are influenced by their social environment perceive design as more aesthetically pleasing. The interaction effects were not found to be statistically significant.

Referendum vote logit model
The third model contains the logit model where the referendum vote is the dependent variable. In this model, the log odds of the probability of the dependent variable being 1 are estimated. The model is similar to the linear regression model however, the t-value is now the z-value, which is used for logit models but embodies the same: The test statistic for the null hypothesis that the coefficient is equal to zero. This is calculated by the parameter estimate divided by the standard error. The results of the final model are presented in table 4.8.

Several interesting results need to be pointed out. Firstly, the coefficient for Obstruction lights is not statistically significant on the log odds of voting in favour. The other variables do have a statistically significant effect. A negative coefficient for kite type indicates that a fixed-wing kite results in an AWE design with a lower acceptance. Subsequently, the coefficient for kite type indicates that a design with a larger kite has a lower level of support. Similarly, a higher operating height results in higher log odds of a design being voted for in favour. The negative significant estimated coefficient for red, black and

Table 4.8: Final logit model referendum vote

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	0.612	0.049	12.496	0.000	***
Kite type	-0.117	0.025	-4.743	0.000	***
Kite size	-0.068	0.025	-2.769	0.006	**
Operating height	0.113	0.025	4.587	0.000	***
Obstruction lights	0.016	0.025	0.642	0.521	
Red	-0.076	0.035	-2.174	0.030	*
Black	-0.114	0.035	-3.260	0.001	**
Red/white striped	-0.083	0.035	-2.382	0.017 *	
Age	-0.003	0.001	-3.711	0.000	***
Social influence	0.029	0.011	2.702	0.007	**

red/white striped means that an AWE design with a white kite is better accepted. Of these three colours, the kite colour black has the most negative impact. Finally, the intercept is 0.612, which represents the log odds of voting in favour of the design when all predictors are at their reference levels or zero. This reference design has a soft-wing kite, a small kite size, medium operating height, white kite colour and no obstruction lights. This result is highly significant, indicating a baseline tendency towards voting in favour.

The coefficient for age shows that older individuals are slightly more associated with lower log odds of voting in favour. Furthermore, the coefficient for social influence is positive, indicating that higher social influence is associated with higher log odds of voting in favour. Interaction effects were not found to be statistically significant which means that the main effects of kite type, kite size and operating height are not affected or enhanced by the value or level of the other attribute.

Mediation model

A mediation model has been estimated to assess the extent to which perceived safety and aesthetics mediate the effect of design attributes on the social acceptance of an airborne wind energy system. In this model, social acceptance is represented by the dependent variable vote, indicating the likelihood of respondents voting in favour of the design in a referendum. The model aims to elucidate the pathways through which design attributes influence social acceptance, by examining the intermediate roles of perceived safety and aesthetics. In the following section, the results of this mediation model will be described, detailing the direct and indirect effects of the design attributes on social acceptance.

First of all, table **??** shows that the estimated coefficient for perceived safety is 0.198, which is significant at the $p < 0.001$ level. This suggests that an increase in perceived safety is associated with an increase in the log odds of Vote, holding other factors constant. In other words, a higher perceived safety results in a better accepted AWE design. The standardized coefficient of 0.483 indicates a strong positive relationship between perceived safety and Vote. This means that perceived safety is a strong predictor of support, and changes in perceived safety have a substantial impact on vote. In other words, a safer perceived AWE design also has a higher chance of being supported by votes in favour.

The estimated coefficient for perceived aesthetics is a touch lower and is also significant at the $p < 0.001$ level. This indicates that holding all other variables constant, an AWE design with higher visual appeal has a higher level of support, and thus a higher level of acceptance. The standardized coefficient of 0.386 shows a strong positive relationship between perceived aesthetics and Vote, suggesting that perceived aesthetics is also a strong predictor of support.

Now that the independent effect of the mediators on the referendum vote has been determined, the indirect and direct effects of the design attributes on the dependent variables can be delineated.

Firstly, kite type has a statistically significant indirect effect on perceived safety but not on perceived aesthetics. Additionally, it has a near-significant negative direct effect on the vote, suggesting a ten-

Table 4.9: Mediation model (in)direct effect of mediators and design attributes

Mediator	Est. effect on vote	Std.Err	Std.all	P-value
Perceived Safety	0.198	0.008	0.483	0.000
Perceived Aesthetics	0.161	0.008	0.386	0.000
Independent variables	**Est. perceived safety**	**P-value**	**Est. perceived aesthetics**	**P-value**
Kite type	-0.320	0.000	-0.089	0.096
Kite size	-0.160	0.003	-0.079	0.141
Operating height	0.391	0.000	0.282	0.000
Obstruction lights	0.041	0.441	-0.035	0.509
Red	-0.099	0.194	-0.344	0.000
Black	-0.256	0.001	-0.460	0.000
Red/white striped	-0.094	0.216	-0.398	0.000
Independent variables	**Est. direct effect on vote**	**P-value**	**Est. total effect on vote**	**P-value**
Kite type	-0.034	0.057	-0.111	0.000
Kite size	-0.018	0.299	-0.063	0.005
Operating height	-0.012	0.504	0.111	0.000
Obstruction lights	0.018	0.302	0.021	0.354
Red	-0.003	0.913	-0.078	0.014
Black	-0.003	0.915	-0.127	0.000
Red/white striped	0.001	0.984	-0.082	0.009

dency for fixed-wing kites to be less favourable when perceived safety and aesthetics are controlled. The total effect of Kite Type on the vote was significantly negative, suggesting that the overall perception of fixed-wing kites, considering both direct and mediated effects, is less favourable.

The estimated coefficients for kite size for perceived safety and aesthetics are similar to the estimates from the regression models. However, in the mediation model kite size did not show a significant direct effect on the vote, while a significant negative total effect on the vote is present (Est. = -0.063, p = 0.005). This not only indicates that larger kites are generally less accepted, but also that the kite size influences a design's acceptance mainly through the design's perceived safety.

Similarly, operating height estimates are comparable to the regression models, implying that higher operating heights are perceived as safer and more aesthetically pleasing. Operating Height also did not have a significant direct effect on the vote. The total effect of operating height on the vote shows that designs operating at high altitudes are generally more accepted because they are perceived as safer and more aesthetically pleasing.

Obstruction Lights did not have a significant impact on the direct or indirect effects, which is in line with the regression models. For this study, it appears that there is no relation between the inclusion of obstruction lights and a design's acceptance.

The effect of kite colours is highly mediated through the perceived aesthetics. The direct effect on perceived aesthetics is substantial and highly significant, while direct effects are not statistically significant and only the colour black has a significant impact on safety. A white kite colour enhances an AWE design's acceptance by increasing the visual appeal of the design.

In summary, the effect of design attributes on a design's acceptance is highly mediated through perceived safety and aesthetics, where perceived aesthetics have the highest contribution to the total mediation effect. These findings highlight the importance of perceived safety and aesthetics in influencing social acceptance of airborne wind energy system designs. Additionally, the mediation model underscores the complexity of public acceptance of new technologies and the necessity of considering multiple pathways through which design attributes can impact perceptions and ultimately, acceptance.

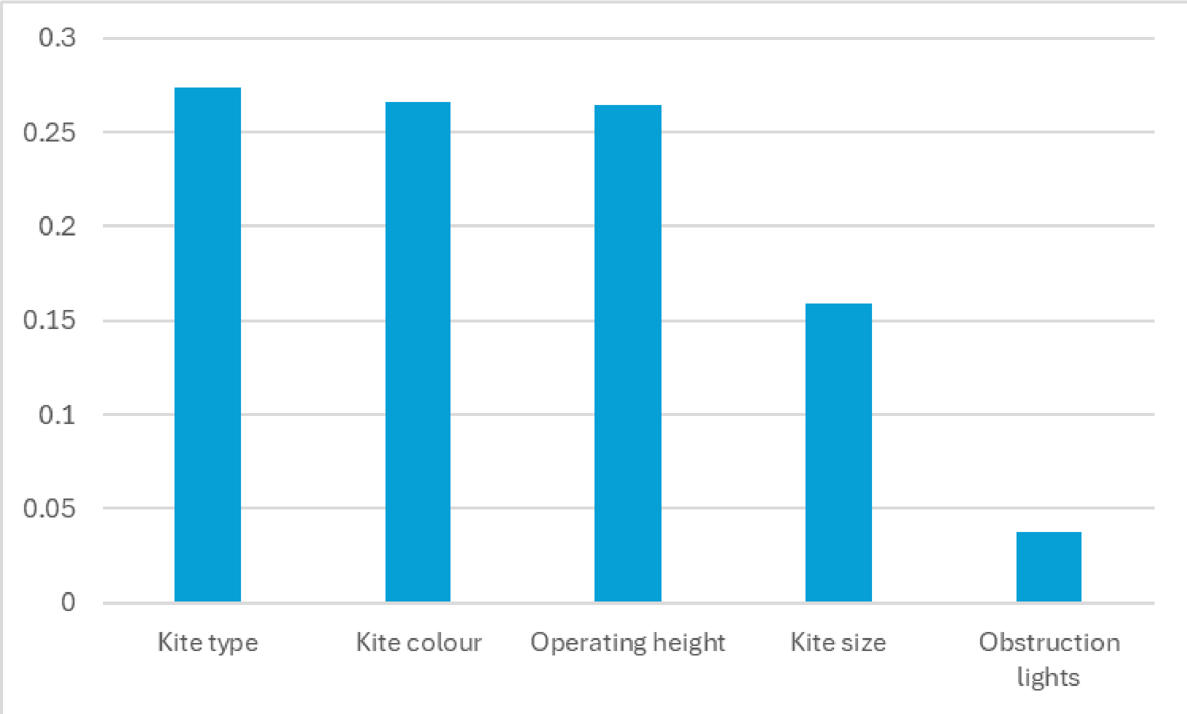

Figure 4.1: Relative importance attributes

The results of this mediation analysis provide valuable insights for designers and policymakers aiming to enhance the social acceptance of airborne wind energy systems by focusing on improving both perceived safety and aesthetics.

4.3.2. Ranking attributes

Table 4.10: Attribute importance based on utility ranges

Attribute	Min. Est.	Max. Est.	Utility Range	Relative importance
Kite type	-0.117	0	0.117	0.273
Kite size	-0.068	0	0.068	0.159
Operating height	0	0.113	0.113	0.264
Obstruction lights	0	0.016	0.016	0.037
Kite colour	-0.114	0	0.114	0.266
Sum utility range			0.428	

Determining the importance of each design attribute based on utility ranges is a useful method in understanding voter preferences. Utility ranges provide a clear, quantifiable measure of how changes in each attribute influence the overall utility, which in turn affects the acceptance of an AWE design. By assessing the utility ranges, the attributes can be ranked according to their impact, allowing for targeted improvements of AWE designs. To determine a ranking, the estimated effects of the individual design attributes on the referendum vote are used. These effects can be derived from the estimated logit model (table 4.8). The importance of each attribute is determined based on their respective utility ranges, calculated from their estimated coefficients. The utility of the reference level for all variables (dummy coded as zero) is 0, which means that the coefficient already present the utility range of the attributes. For kite colour, a white kite colour has the maximum utility while a black kite colour has the minimum utility. Table 4.10 present the utility ranges for the five attributes and the sum of all utility ranges. The relative importance of the attributes is presented by the utility range of the attribute divided by the total sum of utility ranges. This fraction is used to analyze the relative importance of the attributes. The relative importance is graphically shown in figure 4.1.

1. Kite type has the highest utility range, indicating that it has the most significant impact on the referendum vote. This suggests that the type of kite is a critical factor in influencing voter decisions.
2. Kite colour follows closely, making it a significant determinant in the voting behavior, almost as important as the type of kite.
3. Operating height plays a vital role in shaping the preferences of the voters, comparable to the impact of kite type and color.
4. Kite size have a less influential effect than the previous attributes.
5. Obstruction lights have the smallest utility range, indicating they contribute the least to the overall utility compared to other attributes.

By understanding the relative importance of each attribute, we can make informed decisions about which factors to prioritize in order to maximize support.The three most important attributes are kite type, kite colour and operating height, their importance is close with a significant gap to the fourth attribute kite size. Therefore, these attributes stand at the core of designing AWE designs with a high level of support.

4.4. Summary main results

4.4.1. Socio-demographic characteristics

- Higher-educated people have generally a lower perceived safety, while male respondents have generally a higher perceived safety.
- People with a higher education perceive AWE designs as less aesthetically pleasing.
- Older people generally have a lower acceptance of AWE designs.
- The sample is not fully representative of the Dutch population. The age distribution, gender distribution and education level distribution are different which is likely caused by the non-random way the survey has been distributed.

4.4.2. Psychological variables

- Respondents felt their voting behaviour was on average ”slightly” influenced by their social environment. If respondents are more influenced in their voting behaviour by others they are more likely to perceive a design as safer and more aesthetically pleasing and have a generally higher support level for the AWE designs. As a consequence, people being influenced by their social environment appears to be beneficial for the acceptance of AWE designs.
- Protecting the environment appears to be moderate to very important for respondents. However, The environmental attitude of an individual does not have a statistically significant effect on the support or perceived safety or aesthetics for a specific AWE design. In other words, environmental attitude does not affect the acceptance of AWE designs.
- Respondents perceived a ”somewhat” influence from the background and surroundings in the images on their voting behaviour and perceptions. This was strengthened by the results of the background check, indicating that it is likely the background of the visualization has an effect on the design’s acceptance. This effect is centred around the perceived safety of designs. Respondents who indicated to be significantly influenced by the background of the visualization are more likely to perceive a design as less safe.

4.4.3. AWE designs

- To have a better-supported design, a soft wing kite with a small kite size, high altitude operating height and a white kite colour is preferred.

- To get a safer perceived design, a soft wing kite, with a small size, high operating height and white colour is desired.
- To increase the perceived aesthetics of an AWE design, a white kite colour and high altitude operating height are preferred. A kite colour of black is the least desired and there is no significant relation between kite type and kite size and aesthetics.
- Obstruction lights were not found to have a statistically significant effect in any of the estimated models.
- Kite type has the largest effect on the design's acceptance, followed closely by kite colour and operating height. Kite size still has respectively smaller effect on acceptance, while the effect of obstruction lights is by far the smallest.
- Perceived safety and aesthetics strongly mediate the effect of design attributes on support for a specific AWE design. The mediated effect of perceived aesthetics is the largest of the two. The direct effect of design attributes on support is not statistically significant. As a result, the effect of design attributes on acceptance is dominated by their effect on perceived safety and perceived aesthetics and other perceptions (which may have been overlooked in this research) appear to not play a role in effecting the design's acceptance.
- The three identified interaction effects were not found to be statistically significant in any of the models, which means that the main effects of kite type, kite size and operating height are not affected by the value or level of the other attribute.

4.4.4. Model fit

- The model fit for the regression model is portrayed by the adjusted R-squared values of 0.08086 for the MSF model and 0.0579 for the MAF model, though relatively low, they are not atypical in social science research. The low R-squared values indicate that there exists a high degree of heterogeneity among the choices of respondents in the sample.
- Despite its limitations in fully capturing all relevant predictors, the mediation model demonstrates adequate fit as indicated by acceptable RMSEA and SRMR values. Therefore, it remains suitable for examining how the influence of design attributes on support for an AWE design is mediated through perceived safety and aesthetics.

5

Model application

In this chapter, the results from chapter 4 will be used and analyzed further to come up with four different realistic scenarios. These scenarios aim to show the value of the obtained results for real-world applications and are constructed to make the results from the model estimation process more practical and easier to understand. Every scenario consists of a different AWE design based on the five design attributes, for which the level of support will be calculated. Based on this the acceptance of different AWE designs in realistic scenarios can be determined. This can form the basis of valuable knowledge and recommendations for policy-makers and AWE developers. Firstly, section 5.1 discusses the model that is used to predict the acceptance levels. Subsequently, section 5.2 shows how acceptance is predicted for the AWE design in each scenario. Finally, In section 5.3 the different scenarios are described. In the next chapter (section 6.3) the results of the model application and possible policy recommendations are discussed.

5.1. Model for predicting acceptance

Table 5.1: Logistic regression model referendum vote

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	0.581	0.035	16.591	0.000	***
Kite type	-0.118	0.025	-4.774	0.000	***
Kite size	-0.067	0.025	-2.723	0.007	**
Operating height	0.112	0.025	4.528	0.000	***
Obstruction lights	0.016	0.025	0.657	0.511	
Red	-0.076	0.035	-2.171	0.030	*
Black	-0.115	0.035	-3.279	0.001	**
Red/white striped	-0.083	0.035	-2.362	0.018	*

For predicting acceptance in the scenarios the first iteration of the logit model is used (tableE.9). This model exclusively contains the five design attributes used to construct the alternatives. It differs from the final referendum vote logit model in that the effects of age and social influence are neglected. These effects are removed because policymakers and developers typically do not have access to data involving the social influence or age of their target group. Therefore, incorporating age and social influence into the model would limit its practical applicability for policymakers, except in situations where they could continuously gather updated attitudinal data. Furthermore, excluding the age and social influence from the model results in a simpler model which is easier to understand. This better serves the purpose of this model application, which is to make the results understandable for policy-makers and AWE developers, who may not be familiar with the different models. Thus, to predict the support levels for various AWE designs, it was decided to use a model that focuses solely on the design attributes. This approach ensures that the model remains usable and relevant for policymakers, providing clear insights based on the attributes of the choice alternatives alone.

5.2. Predicting acceptance

To analyze the level of support for various scenarios in the logit model, four scenarios are defined with different combinations of the attributes: Kite type, Kite size, Operating height, Kite colour, and Obstruction lights. For each scenario, the utility (log odds) is calculated to determine the probability of acceptance (percentage of people voting in favour of the design) using the logit function:

$$\text{Probability} = \frac{e^{\text{Utility}}}{1 + e^{\text{Utility}}}$$

The utility for each scenario is calculated by summing the intercept and the products of each coefficient with its corresponding attribute value according to the below formula:

$$\text{Utility} = \beta_0 + \beta_1 \cdot \text{KT} + \beta_2 \cdot \text{KS} + \beta_3 \cdot \text{OH} + \beta_4 \cdot \text{OL} + \beta_5 \cdot \text{R} + \beta_6 \cdot \text{B} + \beta_7 \cdot \text{RW}$$

Where:

- KT is kite type
- KS is kite size
- OH is the operating height
- OL is obstruction lights
- R is kite colour red
- B is kite colour black
- RW is kite colour red/white striped

After calculating the probabilities for all scenarios, a ranking may be determined from the scenarios with the highest to lowest level of acceptance. This ranking will provide insights into which scenario is most favoured based on the estimated model parameters.

5.3. scenarios

5.3.1. Scenario 1: ultimate safety

In the first future scenario, the developing process of AWE systems is dominated by the search for a design with high safety. Various realistic reasons could be underlying this scenario. Firstly, this study has shown the importance of perceived safety for better-accepted designs in section 2.1.2 and in table 4.9. Secondly, Salma et al., 2020 and Watson et al., 2019 argue that the industry consensus is that safe operation with a sufficient degree of autonomy is a prerequisite for the successful market introduction of AWE systems.

Table 5.2: Scenario 1: ultimate safety

Attribute	Level	Utility
Intercept	-	0.581
Kite type	Fixed-wing	-0.118
Kite size	10m	0
Operating height	Medium altitude	0
Obstruction lights	Pulsing red light	0.016
Kite colour	Red/white striped	-0.083
Log odds		**0.396**
Acceptance probability		**59.8%**

In search for the safest design developers would likely focus on the design that experts consider as the safest, while this may not necessarily be the safest perceived design by society (Schmidt et al., 2022). As a result, in this scenario, a design prioritizes safety by choosing attributes that enhance visibility and operational control. As such, a fixed-wing kite is selected for its stability and control, reducing risks during operation (Pereira and Sousa, 2022). Furthermore, a smaller kite size of 10m wingspan minimizes potential hazards and damage in crashes. Operating at a medium altitude reduces the risk of collision with aircraft. The red/white striped kite colour enhances visibility, and the red pulsing lights ensure the kite is easily seen, which is also in line with safety regulationsNLR, 2018.

Using this design, the formulas from section 5.2 and the logit model we can calculate the acceptance log odds and the acceptance probability. The results of this can be seen in table 5.2.

5.3.2. Scenario 2: profit-centred

Table 5.3: Scenario 2: profit-centred

Attribute	**Level**	**Utility**
Intercept	-	0.581
Kite type	Soft wing	0
Kite size	30m	-0.067
Operating height	High altitude	0.112
Obstruction lights	None	0
Kite colour	White	0
Log odds		**0.626**
Acceptance probability		**65.2%**

The economic potential of the technology is also important for the successful market introduction of AWE designs (Chihaia et al., n.d.). A plausible future scenario could therefore be that the development process of AWE designs is focused on creating economically advantageous designs. As a result, cost-effective design attributes would be preferred. Hence, a soft wing kite would be the dominant design choice as these have reduced manufacturing costs (Pereira and Sousa, 2022;Chihaia et al., n.d.). Additionally, designs would employ a large kite size of 30m wingspan and operate at high altitudes to maximize energy production and thus economic gains (Ahrens et al., 2013;Archer et al., 2014;Watson et al., 2019). Moreover, The white kite colour is simple and cost-effective, and the absence of obstruction lights cuts down on additional equipment expenses. Using this model and similar calculations of scenario 1 the acceptance probability can be seen in table 5.3.

5.3.3. Scenario 3: off-shore

Table 5.4: Scenario 3: off-shore

Attribute	**Level**	**Utility**
Intercept	-	0.581
Kite type	Fixed-wing	-0.118
Kite size	30m	-0.067
Operating height	High altitude	0.112
Obstruction lights	None	0
Kite colour	Red	-0.076
log odds		**0.432**
Acceptance probability		**60.6%**

Offshore deployment of AWE systems offers advantages such as stronger and more reliable wind resources (Pereira and Sousa, 2022;Archer and Caldeira, 2009), more free space and remote locations. Therefore, it could be plausible for future AWE development to focus on the development of off-shore designs. This scenario aims to emulate what the dominant AWE designs with such a future trend would look like and to gain insight into their expected acceptance.

While off-shore designs have some advantages they also require to be robust and resilient to withstand harsh marine conditions (Pereira and Sousa, 2022). Furthermore, while remote locations offer advantages in that it has a smaller impact on society it also results in logistic challenges.

Fixed-wing kites require less maintenance, which is desired for remote locations, due to them being made up of more durable material than soft-wing kites (Pereira and Sousa, 2022). Moreover, the material is also stronger and fixed-wing kites are better able to withstand the great aerodynamic loads at sea (Pereira and Sousa, 2022). For these reasons, it is assumed the development of AWE systems will focus on fixed-wing kites in this scenario. Additionally, since this scenario is tailored for offshore operations, where space and visibility are less constrained, a focus on larger kite sizes (30m) and a high operating height will optimize energy capture over the open sea (Ahrens et al., 2013;J. Weber et al., 2021;Khan and Rehan, 2016;Archer and Caldeira, 2009;Watson et al., 2019). The absence of obstruction lights is feasible due to the lower risk of collision with aircraft or other obstacles above the sea, while the red kite colour is used so it stands out in the sky. The acceptance probability of these off-shore designs is presented in table 5.4.

5.3.4. Scenario 4: urban

Table 5.5: Scenario 4: urban

Attribute	**Level**	**Utility**
Intercept	-	0.581
Kite type	soft-wing	0
Kite size	10m	0
Operating height	medium altitude	0
Obstruction lights	Pulsing red light	0.016
Kite colour	Red/white striped	-0.083
log odds		**0.514**
Acceptance probability		**62.6%**

Studies byIshugah et al., 2014 and Celik et al., 2007 have shown that there exists a substantial potential for wind energy to be employed in urban areas. Based on this, AWE development could concentrate on developing AWE systems suitable for being employed in urban areas. Urban energy projects require careful consideration of safety and visibility to ensure public acceptance and successful implementation (Khan and Rehan, 2016;Schmidt et al., 2022). A focus on designs employing soft-wing kites is likely as they are much safer to use in populous areas because they cause less harm in case of a crash due to their lightweight (Diehl, 2013;Pereira and Sousa, 2022;Pereira and Sousa, 2023). Subsequently, smaller kite sizes seem plausible to make the designs fit within urban constraints. To avoid air traffic, which is more crowded in urban areas, a focus on designs operating at medium altitudes seems likely. Furthermore, to increase safety high visibility colours, so red/white striped kites and red pulsing lights will be employed. The expected acceptance probability of such compact urban designs is shown in table 5.5.

Important to note is that based on current trends within the AWE field the urban scenario seems the least likely to happen as several studies have pointed out the significant challenges associated with implementing AWE designs in an urban setting (Khan and Rehan, 2016; Schmidt et al., 2022).

5.4. Scenario ranking

Using the acceptance probability of the four different scenarios, the scenarios can be ranked according to their levels of acceptance.

1. Scenario 2: profit-centred provided AWE designs with the highest level of acceptance with a probability of 65.2 %. This means designs focused on being economically advantageous also are the most supported.

2. Scenario 4: urban, which focuses on AWE designs in a compact urban setting, has the second highest level of acceptance with a probability of 62.6 %. This means designs focused on safety and visual appeal generally are supported by a majority of the people (more than 50%), which is in line with the literature as described in section 2.1.2.
3. Scenario 3: off-shore AWE designs result in a level of acceptance with a probability of 60.6%. This means that designs, which pay much attention to the impact on citizens and focus on durability and performance are marginally less accepted than scenarios 2 and 3.
4. Scenario 1: ultimate safety, AWE systems aimed at providing very safe designs result in the least accepted designs with an acceptance probability of 59.8%. Although, counter-intuitive this shows that designs focused on ensuring actual safety are not the most accepted designs.

In conclusion, this ranking shows that all scenarios result generally in designs which are accepted by the majority of the people. Furthermore, differences in acceptance are minor as the difference between the best and worst accepted scenario is just a little bit more than five percent. The implications of these results are described in the next chapter.

6 Conclusion & Discussion

In this chapter, conclusions are drawn from the research findings. Furthermore, these findings and conclusions are evaluated in light of the existing literature. After this, the implications of the findings are discussed and recommendations are given to relevant actors to deal with these identified implications. Finally, the study's limitations are discussed and further research commendations are given.

6.1. Conclusion

6.1.1. Overview of the research

Airborne Wind Energy (AWE) holds significant promise for addressing climate challenges due to its potential to harness high-altitude wind resources more efficiently than traditional wind turbines. This innovative technology can contribute substantially to the energy transition by providing a renewable, low-carbon energy source. However, the commercial introduction and widespread adoption of AWE heavily depend on the technology's social acceptance. Public perception and support are crucial for ensuring successful implementation, making it essential to understand and address the factors influencing social acceptance of AWE systems. This research aims to investigate how specific AWE designs impact their acceptance, thereby providing insights necessary for fostering public support and facilitating the technology's integration. By particularly focusing on the visual impact of specific design attributes this research aims to uncover what the effect of certain design attributes is on how an AWE design is supported. At the heart of this inquiry lies the central research question: "To what extent do the design attributes of airborne wind energy systems influence their social acceptance?" To address this overarching question, it is essential to first explore the associated research subquestions.

To provide crucial knowledge for answering some of these subquestions, a literature study has been performed. This resulted in a definition of social acceptance for this research and a conceptualization of the relationship between design attributes and the social acceptance of an AWE design. Social acceptance is defined as the behaviour exhibited by an individual, particularly local stakeholders, when confronted with the installation of a specific AWE design, in the vicinity of their residence, that is managed or owned by external entities. With this definition in mind, how design attributes influence social acceptance has been conceptualized by showing the importance of perceived safety and perceived aesthetics as mediators and by showing the role of three psychological variables. This conceptualization showed that design attributes influence an AWE system's social acceptance in two ways: directly and indirectly by affecting the system's perceived safety and perceived aesthetics. The literature study showed that to understand how design attributes affect social acceptance it is important to understand their effect on perceived safety and perceived aesthetics as well.

The second purpose of the literature study is to contribute to answering research subquestions by mapping the relevant AWE design attributes commonly used in the field. An initial list of relevant design attributes was established through an investigation of the existing literature. Given the necessity to focus on a manageable and pertinent set of attributes, a concise list was required to ensure the research's feasibility and relevance. This list was further validated and streamlined by conducting a survey among developers at the Airborne Wind Energy Conference. This led to the following list of relevant design attributes: kite type, kite size, operating height, kite colour, and obstruction lights. The influence of these design attributes was deemed most interesting to explore. Therefore, these five design attributes formed the basis for answering the research subquestions.

To answer the research subquestions, a digital survey consisting of a stated choice experiment and a questionnaire was conducted. The stated choice experiment method was chosen due to its effectiveness in capturing respondents' preferences and trade-offs among different design attributes in a controlled manner. This method allowed for the evaluation of hypothetical scenarios, providing insights into how specific design attributes influence perceived safety, aesthetics, and voting behaviour. In the experiment, respondents were presented with eight different AWE designs and asked to rate each design on its perceived safety and aesthetics. Additionally, they had to indicate whether they would vote in favour of implementing the design in a hypothetical local referendum. The survey was distributed to a convenience sample, resulting in 200 valid responses. The results of the stated choice experiment were then used to estimate several models, which are now used to answer the research subquestions.

6.1.2. SQ1. What is the effect of certain design attributes on the design's perceived safety?

To determine to what extent design attributes affect an AWE system's social acceptance, it is crucial to understand how they influence the perceived safety of an AWE design. This is because the indirect effect of design attributes through perceived safety significantly impacts support for the design, making it essential to answer the first research subquestion.

The estimated regression model for perceived safety shows that specific attributes may increase the perceived safety of an AWE design. To create a design with the highest perceived safety a soft-wing kite is preferred above a fixed-wing kite. This is in line with the existing literature, as the studies by Paulig et al., 2013 and literary review by Schmidt et al., 2022 hypothesize that people might perceive soft-wing kites as safer than fixed-wing kites due to their lighter materials. This statement is inspired by the assumption that lighter, more flexible materials pose less risk in the event of a failure compared to heavier, rigid structures (Pereira and Sousa, 2023; Diehl, 2013). However, it should be noted that these studies talk about perceived safety as some studies consider fixed-wing kites to be actually safer due to their higher controllability than soft-wing kites (Pereira and Sousa, 2022; Cherubini et al., 2015).

Secondly, designs with a small kite size are perceived as safer. This finding seems logical as smaller kites will cause less damage when they crash (Pereira and Sousa, 2022). However, literature argues that a preference for small kites is often rooted in a reduced visual impact and not necessarily in safety reasons, the implications of this will be discussed further in subsection 6.1.4.

Furthermore, the stated choice experiment revealed that a higher operating height is perceived as safer. This might be caused by the fact that the systems seem farther away from residents, infrastructure or the landscape, which means that the distance between a collision or a crash is larger. This feeling may have been enhanced by the choice of background for the visualizations used in the survey, this will also be discussed later in section 6.4. Interestingly, the fact that a higher altitude may also result in a more severe crash as landing speeds would be achieved did not seem to have a substantial effect. Moreover, safety concerns appear to be centred around people their own safety concerns on the ground instead of air space safety. This may seem remarkable as a crash with a plane would cause considerately more harm, however, research in psychology shows that people tend to prioritize their immediate environment and personal safety over more abstract or less immediate concerns, such as airspace safety (Slovic, 1987;Hsee et al., 2001).

Additionally, a black kite is significantly less safe perceived than a white, red or red/white striped kite. Reasons for this might be rooted in the fact that darker colours are less contrasting than lighter colours like red and white, especially in dark skies. However, a white kite colour also does not have a high contrast in cloudy skies. As a consequence, it is more likely the safety concerns for black kites are rooted in negative safety sentiments about dark colours. For example, Adams and Osgood, 1973 and Frank and Gilovich, 1988 show that the colour black is associated with evil and aggressiveness. Remarkable in these findings is that there is no significant difference in safety perception between red or red/white striped kites and white kites, while red and red/white striped kites are considered the safest options for kites by developers “Skysails”, 2024;**<empty citation>**). This highlights again that perceived safety and actual safety are not equal. This last effect is also apparent in the fact that the inclusion of obstruction lights does not affect the perceived safety of a design, while obstruction lights are key to flight safety NLR, 2018;Salma et al., 2020.

In summary, a soft-wing, small kite, high altitude operating height, and white, red or red/white striped kite positively affect the AWE design’s perceived safety. Operating height and the type of kite have the largest and second-largest effects on the design’s perceived safety, respectively.

6.1.3. SQ2. What is the effect of certain design attributes on the design’s perceived aesthetics?

Similarly, understanding the relation between design attributes and perceived aesthetics is indispensable for understanding how design attributes influence acceptance. This knowledge is acquired by answering the second research subquestion, which is answered by using the results of the estimated regression model for perceived aesthetics. These results gave insight into how the design attributes relate to the AWE design’s visual appeal.

Firstly, the results showed that a design operating at high altitudes has a higher visual appeal than a design operating at medium altitudes. This effect is likely caused by the fact that AWE systems, operating at even greater altitudes, have a significantly reduced visual impact and are less obtrusive on the landscape compared to traditional wind turbines (Diehl, 2013;Archer et al., 2014).

Furthermore, the kite colour also affects the design’s visual appeal. Similar findings are found in research on traditional wind turbines which claim that colour has a significant influence on the visual evaluation of the wind energy system (Maffei et al., 2013). AWE designs which employ a white kite are perceived as more aesthetically pleasing than designs which employ a red, black or red/white striped kite. These findings seem logical as white is often associated with cleanliness, safety, and neutrality, whereas darker colours can be perceived as more threatening or less visually appealing. While no studies in the AWE field show what kite colours are better perceived, studies from other renewable energy technologies show the same result. For instance, a study on wind turbine acceptability found that lighter colours are less likely to be perceived negatively compared to darker colours (Wolsink, 2007b). In addition, Jalil et al., 2012 that variations in colour may impact human behaviour like support.

Interestingly, The kite type, kite size and the inclusion of obstruction lights did not affect the design’s perceived aesthetics. While these design attributes still form distinctive visual features of an AWE system.

In conclusion, to ensure that an AWE design is perceived as aesthetically pleasing it should operate at high altitudes and employ a white kite.

6.1.4. SQ3. What is the relationship between the design attributes of an airborne wind energy system and the choice for supporting the specific design?

If a design is supported the social acceptance of the design will be higher. Insight into what determines the support for an AWE design is therefore crucial for getting to understand how design attributes may influence the acceptance of an AWE design. The voting behaviour of respondents based on the different AWE designs gives valuable comprehension of how the different design attributes relate to the choice for supporting a particular AWE design. This voting behaviour can be observed in the results of the logit model for the referendum vote. These results are used to answer the third subquestion.

The model shows that all design attributes have an influence on the choice to vote in favour or against a specific design, except for the inclusion of obstruction lights. Designs which include a soft-wing kite have a higher chance of being voted for in favour. The reason behind this is that soft-wing kites are perceived as safer. Moreover, the utility range for kite type is the largest, signalling that the type of kite is the most important design choice for determining the design's support. A possible explanation for kite type to be the most dominant design attribute for affecting the support of an AWE design is that the two types of kites are very distinctive and different. Additionally, the design attribute kite type can be seen as the most eye-catching characteristic of an AWE system (Cherubini et al., 2015; Diehl, 2013).

Moreover, AWE designs with smaller kites have a higher chance of being supported. Several other studies confirm this finding. For instance, Warren et al., 2005 claim that smaller wind turbines are often preferred due to their reduced visual and physical impact, which translates to a perception of lower risk and greater safety among local populations. Furthermore, smaller structures are often seen as less imposing and less dangerous. For example, this research by Wolsink, 2007b indicates that the acceptance of renewable energy technologies, including wind turbines, is higher when the structures are perceived as less visually intrusive, emphasizing the importance of scale in public acceptance. Thus, the preference for smaller kites in AWE systems is a logical extension of this general trend. However, the positive effect of a small kite on support is in our research mediated by perceived safety while both sources only talk about the visual impact of energy systems and about how smaller structures are perceived as safer. This is not in line with the findings of the regression models as the kite size did not have a significant effect on perceived aesthetics. This means that it is to the best of my knowledge that this study has a new finding that smaller AWE systems are more likely to be accepted due to higher perceived safety.

A design operating at a higher altitude has a higher chance of being voted for in favour. This effect is marginally smaller than kite type, but still substantially larger than kite size. In wind energy literature, it is well-documented that wind turbines operating at higher altitudes tend to have a higher social acceptance. This is because their elevated placement reduces their visual and noise impacts on surrounding areas(Wolsink, 2007b).

Finally, the kite colour is the second most important variable which affects the support for an AWE design. Employing a white kite results in the most supported designs, while employing a black kite results in the largest decline in support. Red and red/white striped kite designs have higher support levels than black kite designs but marginally lower support levels than designs with a white kite. This preference for white kites stems from their visual appeal and the high perceived safety.

Contrary to what's found in the literature, this research did not reveal a relation between obstruction light and an AWE design's voting behaviour. For example, the study by Pohl et al., 2021 showed that people experience annoyance from obstruction lights on wind turbines. Based on this, Schmidt et al., 2022 argue that obstruction lights likely also play a role in the acceptance of AWE systems. This means this finding is not in line with the current literature. As a result, no apparent relation was probably found due to the limitations of this research, which will be discussed in section 6.4.

In summary, To have a better-supported design, a soft-wing kite with a small kite size, high altitude operating height and a white kite colour is preferred. A large black fixed-wing kite, operating at lower altitudes should be avoided when aiming to design AWE systems with a high support.

6.1.5. SQ4. To what extent do the landscape/environment, socio-demographic variables, environmental attitudes and social norms influence the acceptance of different airborne wind energy designs?

Now that the effects of design attributes on the acceptance of various AWE designs have been elucidated, it is imperative to broaden the scope to include other influential variables. Beyond design characteristics, factors such as socio-demographic variables (age, gender, education) and psychological variables (environmental attitude, background influence, social influence) may play a role. This ties into answering subquestion four which is answered by exploring to what extent these variables influence how people perceive and accept AWE designs by analyzing the results of the two regression models and the logit model.

Firstly, regarding the effect of age, it was found that older people have a slightly lower tendency to vote in favour of a design. Various reasons can induce this effect. For example, studies show that as people age, they become more conservative in their decision-making and are less likely to support new, unproven technologies due to perceived risks and uncertainties (E. U. Weber and Hsee, 1998;Czaja and Lee, 2007). Another reason could be that While younger people may prioritize the environmental benefits of renewable energy, older individuals might be more concerned about the immediate impact on their surroundings, such as changes in landscape aesthetics (Laroche et al., 2001). However, contrary to the study by Laroche et al., 2001, this research found a positive correlation between age and environmental attitude, so for this research, this is not a valid explanation.

Concerning the effect of gender, the stated choice experiment found that men have a tendency to rate AWE designs safer than women. This finding is in line with research by Sjoberg and Drottz-Sjoberg, 2009 which indicates that men and women differ in their risk perception for energy technologies like nuclear waste, with men typically exhibiting lower perceived risks and higher acceptance levels for emerging technologies.

Subsequently, people with a higher education rate AWE as less safe and less aesthetically pleasing. In other words, people with a higher education pose a more critical attitude when evaluating the design. Several reasons could be the cause of this. For instance,Siegrist and Cvetkovich, 2000 claim that highly educated people are better informed about the risks involved in new energy technologies and therefore pose a more critical attitude towards the implementation of new technologies. However, this is contradicted by the work of Koundouri et al., 2009, which argue that a higher education leads to a higher willingness to pay for renewable energy systems. Both these sources are supported by the fact that this study found a positive effect between education and environmental attitude.

Interestingly, there appears to be no relation between the environmental attitude of individuals and their acceptance of AWE designs. This is curious as typically, individuals with higher environmental awareness tend to have a higher acceptance of renewable technologies. For example, Devine-Wright, 2008 highlight that people who are more environmentally conscious are generally more supportive of renewable energy projects due to their perceived environmental benefits. A reason for this could be that in a survey about a new renewable energy systems people would feel obliged to indicate that they are environmentally friendlier than they are in real-life. In other words, Social desirability bias may have influenced respondents. This bias occurs when respondents answer questions in a manner that will be viewed favorably by others. This can lead to over-reporting of desired behaviour or under-reporting of undesirable behaviour (Fisher, 1993).

People who are more influenced by the landscape of the visualization used in the survey in general perceive AWE designs as less safe. This in combination with the fact that the survey results revealed that respondents were significantly influenced by the background means that the background affected the safety evaluation of the AWE designs. The negative effect on perceived safety makes sense as taken in the background more consciously may make a design feel more threatening as it appears to be closer to infrastructure and nature than in reality. This observation aligns with existing literature on the importance of visual impact on the landscape in the acceptance of renewable technologies. For instance, research by Devine-Wright, 2005 underscores the significant role that landscape aesthetics play in public acceptance of renewable energy installations, where intrusive or visually disruptive designs often face greater opposition. Furthermore, Wolsink, 2007b states that the strongest influence on an individual's attitudes towards wind farms comes from the perceived visual impact on the landscape. The implication of the substantial influence of the background on safety evaluation is discussed in section 6.4.

Finally, people who are influenced more by their social environment have in general a higher support for AWE designs. Furthermore, the finding that social influence was low in the sample is not reflected in the research of Wolsink, 2007a. The study argues that social networks influence decision-making and perception regarding wind farms. However, the neglected influence of social norms may be typical for the Dutch context of the sample, as Dutch individuals often emphasize personal independence and may be reluctant to admit being influenced by others. This cultural trait can affect the perceived impact of social influence in surveys and studies.

6.1.6. SQ5. To what extent do perceived safety and aesthetics mediate the effect of design attributes on the social acceptance of an airborne wind energy system?

To comprehensively explore how design attributes of AWE systems influence their social acceptance, this study first conceptualized the underlying perceptions through which these attributes exert their influence. Analyzing the role of perceived safety and aesthetics as mediators in this relationship, as hypothesized in the conceptualization, is crucial. By estimating a mediation model which is used to answer the fifth research subquestion, the role of perceived safety and aesthetics is delineated. The results of this mediation model underscore the pivotal role of perceived safety and aesthetics as significant mediators of acceptance. Interestingly, the analysis revealed no direct effect of design attributes on the referendum vote, highlighting that the effect of design attributes on perceived safety is fully mediated through perceived safety and aesthetics. This also means that no other perceptions, which may have been overlooked by this research, significantly mediate the effect of design attributes on acceptance. Notably, perceived aesthetics emerged as the most influential mediator, significantly shaping public support for AWE designs. This emphasizes the profound impact of visual appeal on the social acceptance of AWE systems.

6.1.7. RQ. To what extent do the design attributes of airborne wind energy systems influence their social acceptance?

In conclusion, now that the research subquestions have been answered it is time to answer the main research question and describe how the five key design attributes: kite type, kite size, operating height, kite colour, and obstruction lights, affect the social acceptance of specific AWE designs. Firstly, when an AWE system uses a soft-wing kite it is more easily accepted than when a design has a fixed-wing kite. The difference is moderate and originates from the fact that soft-wing kites are perceived as safer. Secondly, when an AWE design contains a kite with a smaller wingspan it is more likely to be accepted than a design with a significantly larger kite. Subsequently, AWE designs operating at higher altitudes are more easily accepted than designs operating at medium altitudes. Not only are they perceived as safer but higher operating AWE systems also have a better visual appeal. The operating height is the design attribute with a moderate contribution to the design's acceptance similar to the type of kite. Designs which employ a white kite colour have a higher acceptance as they are perceived as safer and more aesthetically pleasing than designs employing a red, black or red/white striped kite. Of all kite colours black clearly performed the worst. Kite designs with a black colour had a notable decrease in acceptance as they are perceived as less safe and have a low visual appeal. Finally, obstruction lights do not appear to influence the acceptance of AWE designs.

Notably, the impact of these design attributes on the design's acceptance is all mediated through perceived safety and perceived aesthetics. Interestingly, perceived aesthetics emerged as the most influential mediator, underscoring the significant role of visual appeal in public acceptance. Furthermore, the estimated models also show that the main effects of operating height, kite size, and kite type are not dependent on each other, as there is no interaction effect between these variables. Based on this, we can conclude that the design attributes of AWE systems, particularly kite type, operating height and kite colour, significantly influence their social acceptance through their impact on perceived safety and aesthetics. These findings provide critical insights for the design and deployment of AWE systems, emphasizing the importance of optimizing these key attributes to enhance public support and facilitate the technology's integration into the energy landscape. Overall, these findings contribute to our understanding of the factors shaping the social acceptance of AWE systems, affirming many established principles while also highlighting areas where further investigation or contextual consideration may be warranted.

6.2. Scientific contribution

This study makes significant contributions to the literature on airborne wind energy (AWE) systems through three main avenues.

Firstly, previous research on the social acceptance of wind energy has predominantly focused on traditional wind turbines, overlooking AWE. While some studies have explored AWE, they often examine limited design variations, because of the scarcity of realised systems and the focus on pilot projects. For instance, Schmidt et al., 2024 conducted a community acceptance study near an AWE test site which only concerned a specific AWE design. By investigating how various AWE design attributes influence the system's acceptance, this research is to the best of my knowledge, the first study to dive into how the technological elements of an AWE system affect the system's acceptance.

In addition, this study employs a stated choice experiment with a referendum-style questioning approach, as demonstrated by Molin and Kroesen, 2022, which to the best of current knowledge, has not been applied to research about the social acceptance of emerging renewable energy technologies like AWE systems.

Thirdly, unlike previous studies that often sample individuals familiar with AWE through local pilot projects, this research extends its scope to include participants who may be unfamiliar with the technology. This approach broadens the understanding of societal perceptions and acceptance thresholds towards AWE designs among diverse demographic and geographic backgrounds. Moreover, this is the first research to use hypothetical visualizations of different AWE designs.

In conclusion, this study breaks new ground in the field of AWE by systematically exploring the impact of various design attributes on social acceptance of the technology. Through its novel application of a referendum-style stated choice experiment and inclusion of diverse participant backgrounds, it not only enhances our understanding of public attitudes towards emerging renewable technologies but also sets a precedent for methodological innovation in studying technology acceptance. These contributions help to inform future research and policy-making efforts aimed at stimulating a wider realization of AWE systems.

6.3. Implications and recommendations

The findings of this research have significant implications for various stakeholders involved in the development and deployment of AWE systems. In this section, these implications are identified and recommendations on how to deal with these implications are given.

To start off, this research gives insights into what design attributes increase the acceptance of AWE systems. As local opposition is a major hindrance to the widespread implementation of emerging energy technologies, social acceptance of the technology is indispensable for the technology's success. As a result, to increase the chance of widespread successful introduction of AWE systems, developers might consider focusing on developing systems which are more easily accepted. As a result, this research provides valuable knowledge about the development process of AWE systems, which means this research may shape the development of AWE systems. To guide this search for better-accepted designs this research recommends taking into account that soft-wing kites, high operating height, small kite size and white kites increase the acceptance of the design.

Secondly, this research highlights that a majority of people (75%) values the contents of a referendum concerning the implementation of an AWE system in proximity of their residence. This indicates that local concern for the realization and introduction of an AWE system is apparent. As a consequence, AWE developers and policy-makers like local governments should take into account the attitude of local residents, when planning to construct an AWE system in populous areas. To foster positive attitudes is crucial for mitigating feelings of local opposition and avoiding project cancellation or delays. However, stakeholders should also take into account that only fostering positive attitudes and communicating the advantages of AWE systems may result in so-called 'greenwashing' (de Vries, 2017). Perceptions of greenwashing can lead to a backlash effect on sustainable behaviour, causing individuals to engage in the opposite behaviour that stakeholders aim to avoid, local opposition. Therefore, transparency about possible disadvantages and simplicity in fostering this positive behaviour is required to increase the credibility of policy-makers in charge(De Vries, 2020). In this way, the social acceptance of local AWE projects may be significantly improved.

Furthermore, the study offers critical insights into the design attributes that enhance public acceptance of AWE systems. Given that local opposition can significantly impede the implementation of emerging energy technologies, understanding and improving social acceptance is essential for the success of AWE systems. Therefore, developers should prioritize creating designs that are more likely to be accepted by the public. This research provides valuable guidance for the development process, potentially shaping the future design of AWE systems to ensure higher acceptance rates. Specifically, the study recommends focusing on soft-wing kites, high operating heights, smaller kite sizes, and white kites, as these attributes have been found to increase acceptance. Based on this research, it is recommended to focus on using the design attributes the type of kite, the colour of the kite and the operating height to increase the design's acceptance as these attributes were found to be the most influential in affecting the support for AWE designs. By incorporating these findings into the design and development phases, developers can enhance the likelihood of successful and widespread adoption of AWE technology.

Additionally, this study revealed that the influence of design attributes on the acceptance of AWE systems is fully mediated by perceived safety and aesthetics. Consequently, the perceived safety and visual appeal of an AWE system are vital for its successful implementation. Therefore, we recommend that developers and policymakers prioritize enhancing these aspects before starting AWE projects to increase local acceptance. This can be achieved not only through designs with favourable visual impacts but also by effectively communicating the actual safety features of AWE systems to residents, thereby aligning perceived safety with actual safety. This is particularly important because perceived safety often differs from actual safety, as was shown by the fact that obstruction lights do not influence a design's perceived safety. Again, it is recommended that stakeholders hold the greenwashing effect in mind in their communication, as it can lead to behavioural effects opposite to their intentions (de Vries, 2017;De Vries, 2020).

Finally, it is important to note that while design attributes play an important role in determining the acceptance of AWE systems, there are of course also other factors to take into account, for example, ecological aspects, acoustic aspects, siting and planning and management process. This directly links to the limitations of this research which will be further explained in the section 6.4.

6.3.1. Implication of model application

The results of the model application revealed several important implications for the development and acceptance of AWE systems. Describing and tackling these implications is crucial for successful implementation and provides actionable recommendations for a variety of stakeholders.

Firstly, Although prioritizing safety seems crucial, scenario 1 showed that a development process solely focused on creating the safest designs resulted in AWE designs with the lowest acceptance probability. This suggests that while safety is significant, it alone may not drive public support if other factors like cost and visual appeal are not addressed. This result may be rooted in the discrepancy between perceived safety and actual safety, which is portrayed by the perceived safety regression model. Hence, policymakers and developers need to not only consider actual safety but also mind the perceived safety of their designs in the development process to enhance public acceptance. In addition, this scenario reinforces the recommendation of the previous section, to communicate actual safety concerns to the public to increase the alignment between actual safety and perceived safety.

Secondly, scenario 2 revealed that designs focused on economic benefits (profit-centred) have the highest acceptance probability, indicating that cost-effective design attributes are also well supported by the public. While this relation could be coincidental it is also possible that people subconsciously take into account economic aspects of design attributes in the evaluation of the AWE system. This means that AWE developers should not be afraid to take a profit-centred approach in choosing their design attributes, when considering that this still has no drawbacks in creating well-supported designs.

Scenario 3 revealed that when AWE development would focus on creating offshore designs, these designs would be slightly more accepted than the designs from the ultimate safety scenario. However, it should be noted when looking to implement AWE designs offshore the concern for local opposition and well-accepted designs changes drastically due to the remoteness of these projects. Moreover, it is questionable if the same findings for acceptance of these design attributes were found in a similar stated choice experiment when these designs were shown in a visualization with an off-shore landscape. The concern for landscape diversity is elaborated on in section 6.4. As a result, logistical challenges and the need for robust designs would in this scenario be more appropriate challenges than overcoming local opposition. It is recommended for policymakers and AWE experts to further research the application of AWE designs in an off-shore environment before analyzing and comparing the support levels of these designs.

Lastly, despite significant challenges identified in scenario 4, urban AWE designs received a relatively high level of support, just marginally worse than designs from the profit-centred approach. These findings highlight the potential for integrating AWE systems into urban environments in the future when these challenges are overcome. Therefore, it is recommended for policymakers and AWE developers to not neglect the future possibility of implementing AWE designs in more urban environments based on a low expected public acceptance in urban areas, even if the current trends may tell otherwise.

By addressing these implications and incorporating the recommendations directly into the respective scenario analyses, stakeholders can better navigate the complexities of AWE system development and implementation of which the future is still shrouded in uncertainty. These recommendations may help to enhance the acceptance of AWE systems in a variety of possible future applications.

6.4. Limitations

Despite the significant insights gained from this research, several limitations must be acknowledged, and their consequences considered.

First of all, a major limitation is the use of static images to assess the visual impact of design attributes. This approach does not account for the flight path and dynamic movements of the kites, which are crucial aspects of real-life AWE systems. Consequently, the static representation may not accurately reflect the true visual experience. Studies on visual impact assessments in renewable energy suggest that how technologies are presented in visual surveys can affect public perception (Phillips et al., 2009). As a consequence, the visualizations used in this survey may have potentially biased respondents' perceptions. Specifically, the insignificance of obstruction lights in this study could be attributed to the lack of dynamic effects, especially in low-light conditions where pulsing red lights might have a more outstanding visual impact.

Subsequently, the convenience sampling method used to gain survey responses, may not fully reflect the broader population's views, as students and people in their twenties appeared to be overrepresented. This skewed sample can limit the generalizability of the findings, especially as the inclusion of socio-demographic variables in the estimated models revealed the effects of age, gender and education on the acceptance of AWE designs. As a result, the conclusions drawn might not accurately represent the attitudes of the wider public as the population contains generally older and less educated individuals than in the sample.

Another limitation arises from the context in which this research was conducted, a Western, densely populated country, which may influence the generalizability of the findings. In such regions, concerns about safety, and aesthetics are amplified due to the proximity of residential areas, infrastructure, and dense populations. Consequently, public perceptions and acceptance of AWE systems are shaped by these local contexts. However, if AWE systems were to be deployed in remote or sparsely populated areas, such as isolated islands or rural regions far from urban centres, public perceptions might differ significantly. In these locations, the primary concerns could shift from safety and visual impact to factors such as economic benefits and transparency in the project's planning and implementation (Schmidt et al., 2024).

Furthermore, a notable limitation of this study is the low explained variance observed in the results, which can largely be attributed to the heterogeneity within the sample. The diversity of the sample population introduces significant variability in responses. Such heterogeneity makes it challenging to capture a high proportion of variance with a single model, as individual differences may lead to distinct patterns of acceptance and perception of AWE systems. This inherent diversity among respondents means that some factors affecting acceptance may remain unaccounted for or are underrepresented. This heterogeneity dilutes the explanatory power of the different models used to predict acceptance.

The potential bias introduced by the specific background used in the visualizations is another limitation. Since only one background was studied, the findings may not capture the influence of different environmental contexts on the acceptance of AWE systems. This limitation is critical because the visual impact of AWE designs can vary significantly depending on the surrounding landscape. For example, the models used in this research may not be accurate in predicting the acceptance of off-shore AWE designs. Moreover, the background and landscape used in the visualization do not accurately represent the real-world application of an AWE system. For example, siting, perspective, distances and sizes may not reflect real-world situations or correct scales. As a result, the background may bias the results found in this study, which means the study findings are not fully representative of how people would perceive AWE designs in a real-world setting. This limitation was confirmed by the fact that on average respondents indicated to be moderately influenced by the background of the visualization. Unfortunately, because of time constraints and the scope of this research, it was not possible to make the visualizations used in this research more realistically reflect real-world applications of AWE designs.

Finally, individuals may not only base their choice on a technology's observed attributes but also infer other attributes from a label or visualization. This can invoke thoughts and feelings that do not necessarily match the observed attributes of a technology or alternative (van Rijnsoever et al., 2015). Therefore, as with any stated choice experiment, hypothetical bias could influence the results. In other words, respondents might state preferences that differ from their actual choices in real-life situations. Another example of this is that social desirability bias may have influenced respondents. This bias occurs when respondents answer questions in a manner that will be viewed favourably by others instead of what they actually feel. This discrepancy can lead to overestimation or underestimation of certain attributes' importance.

In conclusion, these limitations highlight the need for a cautious interpretation of the results. While the study provides valuable insights into the factors influencing the acceptance of AWE systems, the findings should be viewed as preliminary. The static nature of the images, the non-representative sample, the Western context, potential visualization biases, unexplained variance, and hypothetical bias collectively suggest that further research is essential to confirm and extend these results. Addressing these limitations in future studies will enhance the reliability and applicability of the findings, ultimately contributing to more effective design and deployment strategies for AWE systems that are broadly accepted by the public.

6.5. Further research commendations

This study is a significant step towards understanding the factors influencing the social acceptance of AWE systems, particularly focusing on design attributes and their visual impacts. However, to build a more comprehensive understanding and improve the acceptance of AWE technology, further research is needed in several key areas.

Firstly, recommendations are given for exploring broader influences beyond visual and technological attributes. While this study highlighted the importance of design attributes and their visual impacts, future research should expand the scope to include other crucial factors that could influence acceptance. This broader perspective is essential given that little knowledge still exists on the social acceptance of AWE projects. Future research could focus on a variety of directions to paint a more comprehensive picture of a system's acceptance. Examples of directions are that research could consider investigating how different approaches to planning and stakeholder engagement affect acceptance or examining the impact of location-specific factors, such as proximity to residential areas and local landscape characteristics. or asses how the distribution of benefits to local communities (e.g., economic incentives, job creation) influences support for AWE projects. Future research in these directions will give insight into the acceptance of AWE systems beyond the effect of their design attributes, which will help to create a more holistic understanding of the factors driving the social acceptance of AWE systems.

Secondly, further research should focus on investigating other impacts of design attributes beyond static visual impact. For instance, design attributes may also influence other environmental and social dimensions. Research could for instance explore how different AWE designs affect local ecosystems and wildlife or investigate the relation between design attributes and their economic potential. The latter is particularly interesting because the model application revealed that profit-centred designs have the highest level of acceptance of the scenarios. Additionally, it would be valuable to study the noise levels associated with various AWE designs and their potential effects on nearby communities as understanding acoustic impacts will be crucial for designing socially accepted AWE systems (Schmidt et al., 2022). These research directions will contribute to painting a comprehensive picture of how design attributes affect the social acceptance and perceptions of AWE designs.

To enhance the accuracy and relevance of studies on the visual impact of AWE designs, future research could build further upon the result of this study. The current study's sample was not fully representative of the Dutch population in terms of age, gender, and education. Future research should aim to use more representative sampling methods to ensure findings have a higher generalizability across the population. Additionally, studies in different cultural and geographical contexts are needed to validate the findings and understand global perceptions of AWE technology.

Secondly, the finding that higher-educated individuals generally perceive AWE designs as less safe and less aesthetically pleasing suggests a need for targeted educational campaigns. Future research should explore the underlying reasons for these perceptions and develop strategies to effectively communicate the benefits and safety of AWE technology to this demographic.

Moreover, the positive influence of the social environment on the perceived safety, aesthetics, and support for AWE designs highlights the importance of social dynamics in technology acceptance. Future studies should investigate how social networks and community discussions can be leveraged to enhance public acceptance of AWE systems.

Furthermore, this study found a preference for soft-wing kites, small kite sizes, high operating heights, and white kite colours to enhance safety, aesthetics, and overall acceptance. These findings provide a clear direction for future AWE design optimization. Research should continue to explore and validate these design preferences in various operational contexts.

Another interesting result that can form the basis for future research is the strong mediation effects of perceived safety and aesthetics on the support for AWE designs. Future studies should investigate in greater detail the role of perceived safety and perceived aesthetics and should look for additional factors that might influence these perceptions and develop comprehensive models to predict and enhance public acceptance of AWE technology.

Lastly, future research should address the limitations identified in this study. First of all, future research could work with dynamic Visualizations. By incorporating animations and simulations that depict the kites in motion, including their flight paths and movements, this approach will provide a more realistic assessment of their visual impact than static images. Moreover, research could investigate the use of multiple backgrounds. By exploring the influence of different environmental settings on public acceptance and using a variety of backgrounds, this research will help gain insights into how AWE designs are perceived in diverse landscapes. Lastly, future studies must consider the varying contexts in which AWE systems might be implemented. This research contains a strong Western context which may heavily influence results. Research in diverse geographical settings, including remote and less densely populated areas, can provide a more comprehensive understanding of public perceptions and acceptance. This broader perspective can help tailor AWE designs and implementation strategies to meet the specific needs and concerns of different communities, ensuring more effective and widespread adoption of this sustainable energy technology.

By addressing these recommendations, future research can build on the findings of this study and contribute to a more nuanced and comprehensive understanding of the factors influencing the acceptance of AWE technology. This knowledge will be crucial for designing and deploying AWE systems that are not only technically efficient but also socially accepted which will increase the chances of AWE becoming a successfully widely implemented renewable technology.

6.6. Reflection on use of artificial intelligence

Throughout the course of this research, I have leveraged artificial intelligence (AI) tools to enhance various aspects of the study. Specifically, I utilized OpenAI's ChatGPT and Grammarly to aid in programming, formatting, writing, and ensuring the overall quality of the thesis.

ChatGPT was instrumental in assisting with programming-related tasks. For instance, while working on complex data analyses and model estimation, I used ChatGPT to help debug and optimize codes which I used in R. Moreover, ChatGPT was utilized to make it easier to quickly translate model estimation results and other data from R to clear and clean formatted LaTeX tables which could be incorporated in the report which has been written in Overleaf. Not only did this improve the look and layout of the thesis, but it also significantly reduced the time and effort required to achieve the desired formatting.

In terms of writing, ChatGPT served as a critical tool for improving clarity and overall readability. AI has been used to rephrase sentences and paragraphs or to suggest more precise vocabulary. This iterative process of drafting and revising with AI support helped to elevate the quality of the thesis, ensuring that the findings and arguments were communicated effectively.

Grammarly played a crucial role in refining the grammatical correctness and language quality of the thesis. By running each chapter through Grammarly, I was able to identify and correct errors in grammar and punctuation. This tool also provided stylistic suggestions that improved the overall readability and professionalism of the document.

As it is known AI tools can make mistakes, it is important to validate and check the results derived from these AI tools. Therefore, to ensure the accuracy and reliability of the outputs generated by these AI tools, I conducted thorough manual checks on all critical sections of the thesis. For example, I validated that translating data from R to LaTeX did not result in changes to the actual data. Furthermore, the process of using AI tools was iterative. I continuously refined the outputs by integrating feedback and re-evaluating the suggestions provided by ChatGPT and Grammarly. This iterative process ensured that the final content was accurate and reliable.

In conclusion, the integration of AI tools like ChatGPT and Grammarly significantly enhanced the efficiency and quality of this research. These tools provided invaluable support in programming, formatting, and writing, allowing me to focus more on the substantive aspects of the research. The rigorous validation process ensured that the AI-assisted outputs were accurate and reliable, ultimately contributing to a well-crafted and robust thesis.

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A

Search strategy literary review

To thoroughly explore the factors influencing the social acceptance of airborne wind energy (AWE) systems, two comprehensive literature reviews were conducted. The first review aimed to define and conceptualize social acceptance specifically in the context of AWE, drawing from a diverse array of academic fields including sociology, psychology, and technology. The second review focused on identifying and listing relevant design attributes, primarily utilizing technological studies. Both reviews employed rigorous selection criteria to ensure the inclusion of high-quality and pertinent papers. These criteria included peer-reviewed status, relevance to Wind energy systems and related renewable energy technologies.

To conduct these reviews, extensive searches were performed using Google Scholar and Scopus databases. Some of the search entries utilized included ”social acceptance AND renewable energy ,” ”community acceptance AND wind energy,” ”visual impact AND wind energy ,” ”design attributes AND airborne wind energy,” and ”perceived safety AND renewable energy technologies.” Additionally, the snowballing technique was employed to enhance the comprehensiveness of the reviews. Forward snowballing involved reviewing the citations of the initially identified papers, while backward snowballing entailed examining the references within these papers to uncover additional relevant studies.

B Developer survey

B.1. Survey

Developer Survey

Q11
Dear respondents,

We are conducting a study to explore the visual impact of specific Airborne Wind Energy (AWE) designs on the social acceptance of AWE. The study is a master thesis project conducted by Tim van Zweden under the supervision of Helena Schmidt, Gerdien de Vries, and Eric Molin at Delft University of Technology. The study consists of a survey that exposes respondents to visualizations of different AWE systems, each with a different combination of design attributes. Survey participants will have to state their preference for a specific design. The research will offer valuable recommendations for AWE developers about which AWE designs are the most supported by the public.

As developers and experts in the field, your insights are invaluable in understanding the key design attributes that might influence how communities and other stakeholders perceive AWE systems. Your participation in this survey (about 5 minutes) will **help us identify and prioritize the design attributes that should be included in the research**, considering the current state/direction of AWE development. All responses are confidential and will be used solely for research purposes.

Thank you for your participation!

Q1 In your opinion, which (design) attributes of AWE systems are the most relevant regarding the visual impact? [Select all that apply]

- ☐ Kite type (e.g., soft-wing, fixed-wing) (1)
- ☐ Kite colour (2)
- ☐ Kite size (3)
- ☐ Operating height (4)
- ☐ Obstruction lights (5)
- ☐ Other: (7) ____

Q4 Which wingspans are currently being used, or will likely be used in the near future?

- ☐ 5m (1)

Q2 Which kite types should be included in the research? [Select all that apply]

- ☐ Fixed-wing (1)
- ☐ Soft-wing (2)
- ☐ Hybrid-wing (3)

Q3 Which kite colours are currently used for prototypes or will likely be used in the near future? [Select all that apply]

- ☐ Red (1)
- ☐ Blue (2)
- ☐ Green (3)
- ☐ Yellow (4)
- ☐ White (5)
- ☐ Grey (6)
- ☐ Black (7)
- ☐ Other: (8) ____

Figure B.1: Developer survey

Q8 Do you have any other suggestions or feedback for the research?

____

Q12 Which type of organization/field are you from?

- ○ AWE developer (1)
- ○ Governmental agency/body (2)
- ○ Academia/research (3)
- ○ Consultancy (4)
- ○ Other (5) ____
- ○ Click to write Choice 6 (6)

B.2. Results

First and foremost, in total 46 respondents filled in the developer survey. However, after subtracting incomplete or invalid responses, 33 responses remained. An organizational distribution showed academia/researchers or developers.

The main results can be seen in figure B.2. The attributes which were found to be most relevant are the size of the kite and the operating height, 73 percent of the responses included these attributes in their selection. With 42 and 39 percent respectively the type of kite and kite colour were also found to be relatively important. Obstruction lights received 30 percent of the votes. The option to include other suggestion has been used but did not turn up any new attributes that should have been included as no other suggestion was mentioned more than three times.

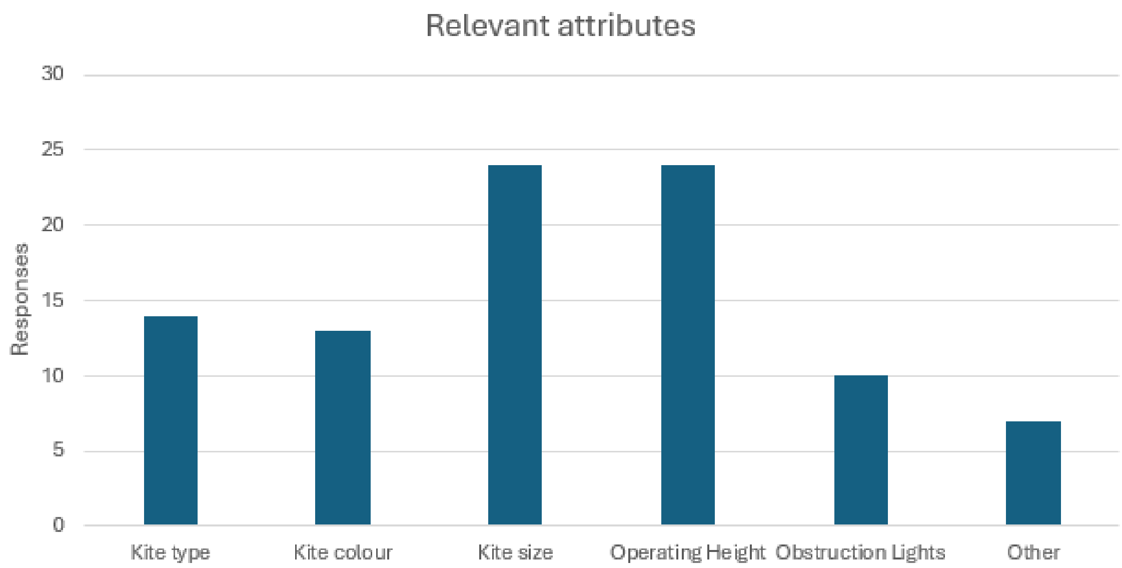
For the type of kite, fixed wing and soft wing were found to be most important, while hybrid wing the least important. This is in line with the discussion from the research group, which suggested the removal of the hybrid wing from the attribute levels.

For the size of the kite a 5m wingspan and 50m were found to be the least important by a large margin. 30m and 20m were found to be the most important while 10m came close after that. The range of 10-30m could therefore be seen as quit accurate.

The question concerning the operating height found that 200 and 500m were by far the most used operating heights with 1000m receiving half the responses of the other two. This is also in line with the 200-500 range found in the AWE research group discussion.

The responses on kite colour posed some interesting results. White was significantly stated as most used in the field followed by red and black. However, the other option, which gave room to suggestions also showed that a red/white striped kite is a popular design. This is a different result from the AWE research group and the levels will be changed in the final selection accordingly.

Finally, regarding the obstruction lights, the responses showed that red lights are the most commonly used in the field. White lights are used but less.



$Attributes_relevant Frequencies

		Responses N	Responses Percent	Percent of Cases
Attributes_relevant[a]	Kite type	14	15,2%	42,4%
	Kite colour	13	14,1%	39,4%
	Kite size	24	26,1%	72,7%
	Operating Height	24	26,1%	72,7%
	Obstruction Lights	10	10,9%	30,3%
	Other	7	7,6%	21,2%
Total		92	100,0%	278,8%

a. Dichotomy group tabulated at value 1.

Figure B.2: Results

C

Results of attitudes and influences

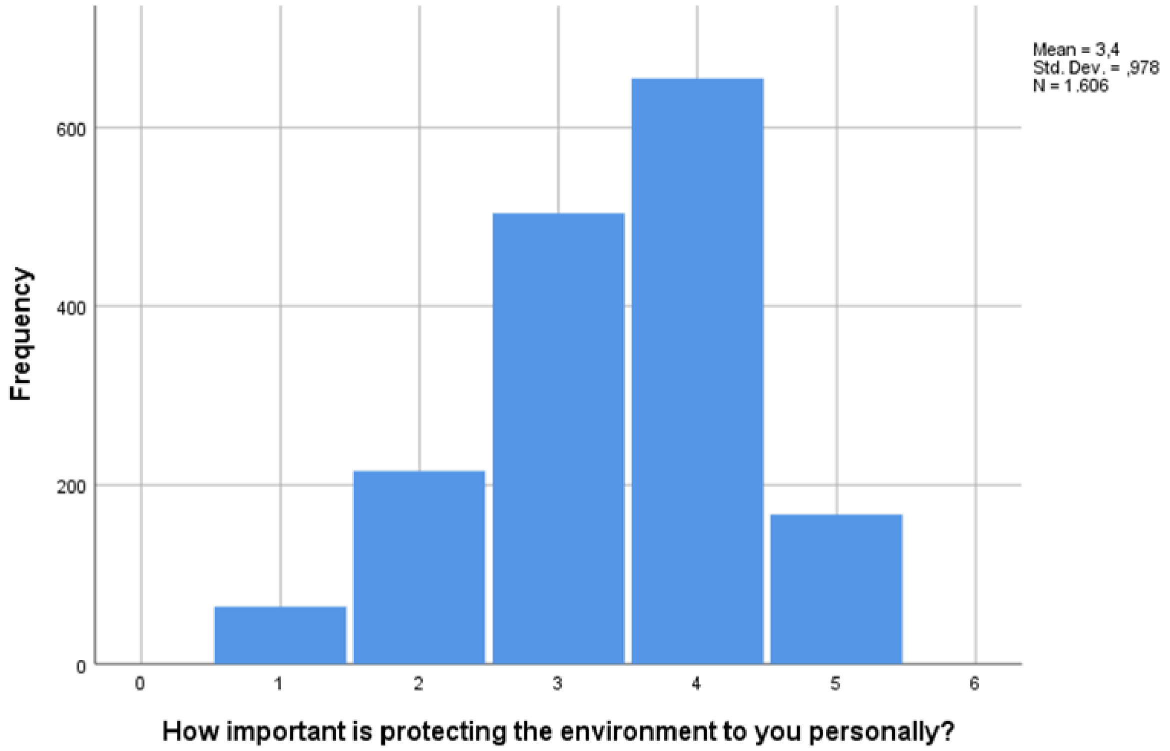


Figure C.1: Influence of the Landscape

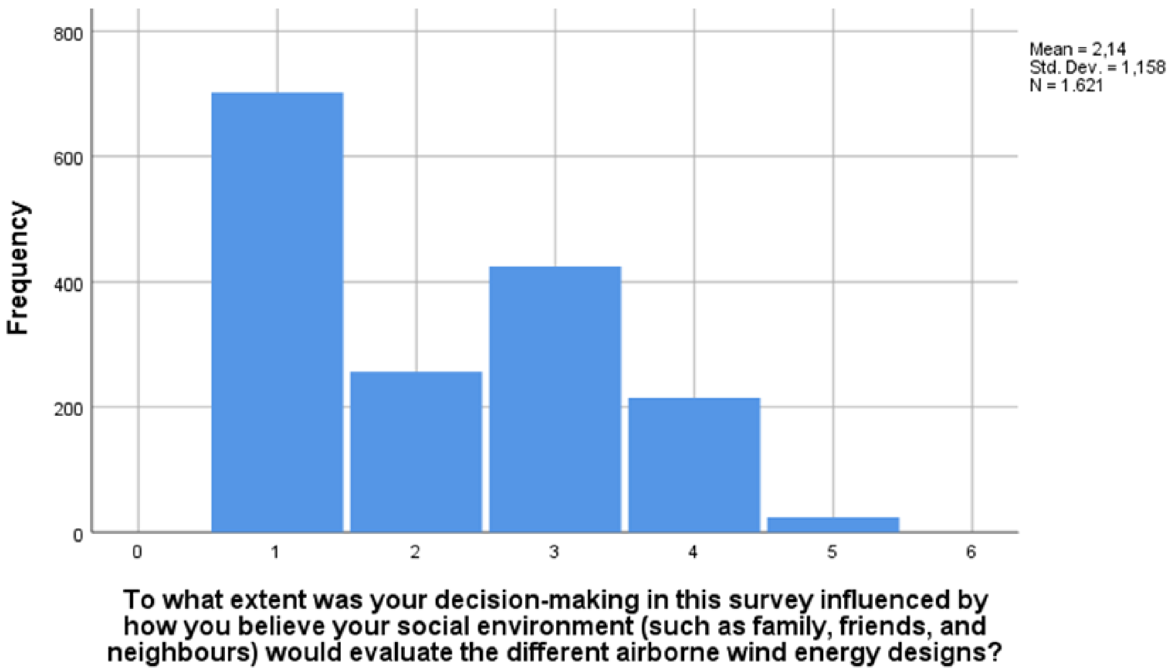


Figure C.2: Influence of social environment

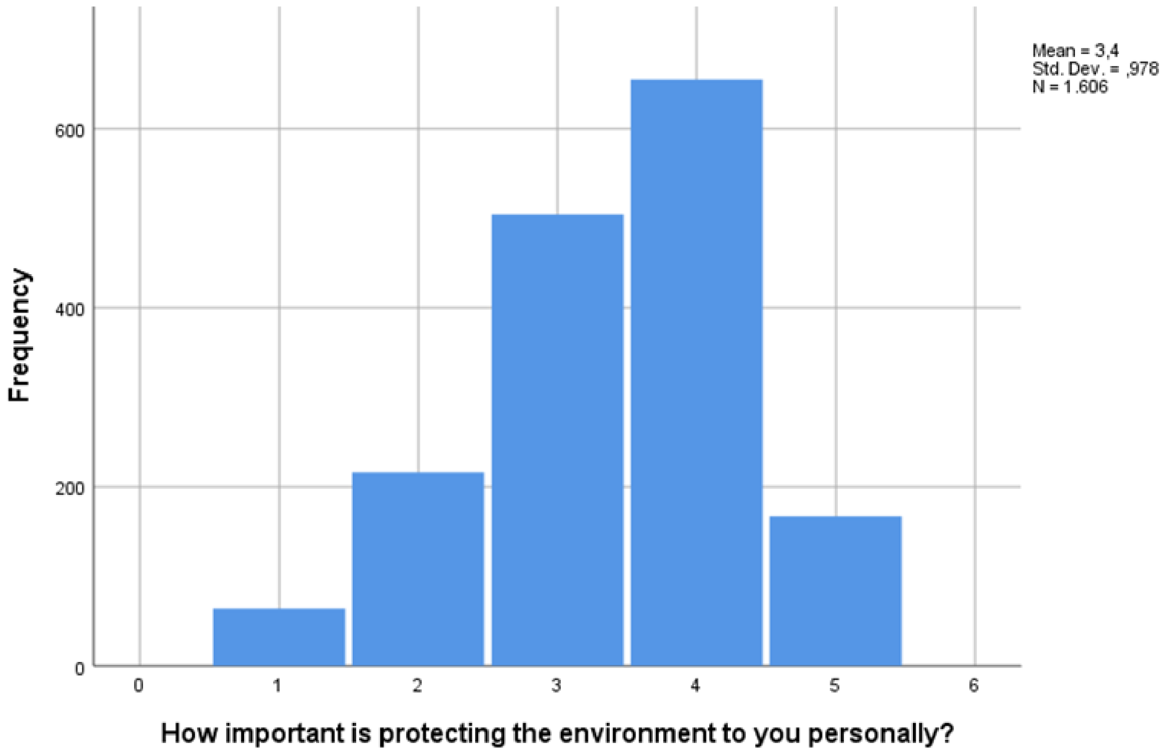


Figure C.3: Environmental attitude

D

Ngene syntax

```
? AWE designs
Design
; alts = alt1,base
; orth = seq
; rows = 8
; model:
U(alt1) = b1*Kite_type[0,1] + b2*Kite_size[0,1] + b3*Operating_height[0,1] +
b4*Kite_colour[0,1,2,3] + b5*Obstruction_light[0,1]
$
```

Figure D.1: Ngene syntax

E Estimated Models

Table E.1: Regression model perceived safety

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.301	0.078	42.295	0.000	***
Kite type	-0.333	0.055	-6.026	0.000	***
Kite size	-0.169	0.055	-3.056	0.002	**
Operating height	0.397	0.055	7.197	0.000	***
Obstruction lights	0.028	0.055	0.501	0.616	
Red	-0.099	0.078	-1.269	0.205	
Black	-0.249	0.078	-3.189	0.001	**
Red/white striped	-0.100	0.078	-1.281	0.200	

Table E.2: Regression model perceived safety socio-demographic

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.317	0.131	25.356	0.000	***
Kite type	-0.331	0.055	-6.049	0.000	***
Kite size	-0.168	0.055	-3.065	0.002	**
Operating height	0.398	0.055	7.274	0.000	***
Obstruction lights	0.026	0.055	0.474	0.636	
Red	-0.098	0.078	-1.270	0.204	
Black	-0.246	0.077	-3.172	0.002	**
Red/white striped	-0.099	0.077	-1.282	0.200	
Age	0.002	0.002	0.834	0.404	
Education	-0.090	0.020	-4.552	0.000	***
Gender	0.163	0.046	3.565	0.000	***

Table E.3: Regression model perceived safety psychological variables

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.267	0.170	19.208	0.000	***
Kite type	-0.333	0.055	-6.062	0.000	***
Kite size	-0.153	0.055	-2.781	0.005	**
Operating height	0.402	0.055	7.324	0.000	***
Obstruction lights	0.025	0.055	0.457	0.648	
Red	-0.097	0.078	-1.253	0.210	
Black	-0.238	0.078	-3.058	0.002	**
Red/white striped	-0.098	0.078	-1.255	0.210	
Education	-0.076	0.020	-3.840	0.000	***
Gender	0.169	0.046	3.668	0.000	***
Social influence	0.057	0.025	2.268	0.023	*
Environmental attitude	0.022	0.029	0.735	0.462	
Background influence	-0.055	0.023	-2.341	0.019	*

Table E.4: Regression model perceived safety interactions

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.363	0.159	21.202	0.000	***
Kite type	-0.301	0.095	-3.183	0.001	**
Kite size	-0.220	0.095	-2.321	0.020	*
Operating height	0.306	0.095	3.229	0.001	**
Obstruction lights	0.022	0.055	0.397	0.692	
Red	-0.094	0.077	-1.219	0.223	
Black	-0.242	0.077	-3.129	0.002	**
Red/white striped	-0.097	0.077	-1.248	0.212	
Education	-0.073	0.019	-3.732	0.000	***
Gender	0.168	0.046	3.653	0.000	***
Social influence	0.057	0.025	2.321	0.020	*
Background influence	-0.052	0.023	-2.242	0.025	*
Kite type:Kite size	-0.073	0.109	-0.669	0.504	
Kite type:Operating height	0.008	0.109	0.069	0.945	
Kite size:Operating height	0.184	0.109	1.679	0.093	.

Table E.5: Regression model perceived aesthetics

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.414	0.077	44.083	0.000	***
Kite type	-0.092	0.055	-1.673	0.094	.
Kite size	-0.077	0.055	-1.415	0.157	
Operating height	0.285	0.055	5.212	0.000	***
Obstruction lights	-0.038	0.055	-0.690	0.491	
Red	-0.349	0.078	-4.505	0.000	***
Black	-0.454	0.077	-5.865	0.000	***
Red/white striped	-0.395	0.077	-5.099	0.000	***

Table E.6: Regression model perceived aesthetics socio-demographics

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.668	0.130	28.153	0.000	***
Kite type	-0.093	0.055	-1.701	0.089	.
Kite size	-0.079	0.055	-1.448	0.148	
Operating height	0.284	0.055	5.207	0.000	***
Obstruction lights	-0.037	0.055	-0.680	0.497	
Red	-0.349	0.077	-4.518	0.000	***
Black	-0.455	0.077	-5.907	0.000	***
Red/white striped	-0.394	0.077	-5.111	0.000	***
Age	-0.001	0.002	-0.692	0.489	
Education	-0.080	0.020	-4.067	0.000	***
Gender	0.053	0.046	1.152	0.249	

Table E.7: Regression model perceived aesthetics psychological variables

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.483	0.148	23.533	0.000	***
Kite type	-0.092	0.055	-1.689	0.091	.
Kite size	-0.077	0.055	-1.411	0.159	
Operating height	0.285	0.055	5.207	0.000	***
Obstruction lights	-0.041	0.055	-0.751	0.453	
Red	-0.336	0.077	-4.346	0.000	***
Black	-0.435	0.077	-5.629	0.000	***
Red/white striped	-0.383	0.077	-4.950	0.000	***
Education	-0.073	0.020	-3.685	0.000	***
Social influence	0.083	0.025	3.365	0.001	***
Environmental attitude	-0.013	0.029	-0.449	0.653	
Background influence	0.020	0.023	0.858	0.391	

Table E.8: Regression model perceived aesthetics interactions

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	3.471	0.129	26.986	0.000	***
Kite type	-0.030	0.094	-0.315	0.753	
Kite size	-0.081	0.094	-0.857	0.392	
Operating height	0.327	0.094	3.476	0.001	***
Obstruction lights	-0.038	0.054	-0.704	0.481	
Red	-0.341	0.077	-4.424	0.000	***
Black	-0.446	0.077	-5.791	0.000	***
Red/white striped	-0.387	0.077	-5.028	0.000	***
Education	-0.071	0.019	-3.734	0.000	***
Social influence	0.085	0.023	3.625	0.000	***
Kite type:Kite size	-0.029	0.109	-0.266	0.790	
Kite type:Operating height	-0.107	0.109	-0.983	0.326	
Kite size:Operating height	0.027	0.109	0.248	0.804	

Table E.9: Logit model referendum vote

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	0.581	0.035	16.591	0.000	***
Kite type	-0.118	0.025	-4.774	0.000	***
Kite size	-0.067	0.025	-2.723	0.007	**
Operating height	0.112	0.025	4.528	0.000	***
Obstruction lights	0.016	0.025	0.657	0.511	
Red	-0.076	0.035	-2.171	0.030	*
Black	-0.115	0.035	-3.279	0.001	**
Red/white striped	-0.083	0.035	-2.362	0.018	*

Table E.10: Logit model referendum vote socio-demographic

Variable	Estimate	Std. Error	t value	p-value	Significance
(Intercept)	0.7035428	0.0589394	11.937	< 2e-16	***
Kite type	-0.1173747	0.0246618	-4.759	2.12e-06	***
Kite size	-0.0673031	0.0246612	-2.729	0.00642	**
Operating height	0.1121285	0.0246613	4.547	5.87e-06	***
Obstruction lights	0.0154267	0.0246613	0.626	0.53171	
r	-0.0753913	0.0349212	-2.159	0.03101	*
b	-0.1129226	0.0348766	-3.238	0.00123	**
rw	-0.0818699	0.0348764	-2.347	0.01903	*
Age	-0.0027115	0.0008354	-3.246	0.00120	**
Education	-0.0178688	0.0089128	-2.005	0.04515	*
Gender	0.0181063	0.0206111	0.878	0.37982	

Table E.11: Logit model referendum vote attitude

Variable	Estimate	Std. Error	t value	p-value	Significance
(Intercept)	0.6347339	0.0689434	9.207	< 2e-16	***
Kite_type	-0.1154512	0.0247869	-4.658	3.47e-06	***
Kite_size	-0.0654939	0.0247852	-2.642	0.00831	**
Operating_height	0.1110188	0.0247851	4.479	8.04e-06	***
Obstruction_lights	0.0169803	0.0247852	0.685	0.49339	
r	-0.0738106	0.0350758	-2.104	0.03551	*
b	-0.1111480	0.0350527	-3.171	0.00155	**
rw	-0.0816073	0.0350516	-2.328	0.02003	*
Age	-0.0026327	0.0008433	-3.122	0.00183	**
Education	-0.0190247	0.0092235	-2.063	0.03931	*
Soc_influence	0.0285496	0.0112243	2.544	0.01107	*
Env_attitude	0.0169918	0.0133276	1.275	0.20253	
Backg_influence	-0.0090248	0.0105471	-0.856	0.39232	

Table E.12: Logit model referendum vote interactions

Variable	Estimate	Std. Error	t value	p-value	Significance
(Intercept)	0.6692903	0.0608652	10.996	< 2e-16	***
Kite_type	-0.1027912	0.0427127	-2.407	0.01622	*
Kite_size	-0.0925871	0.0427127	-2.168	0.03034	*
Operating_height	0.1114945	0.0427127	2.610	0.00913	**
Obstruction_lights	0.0159169	0.0246761	0.645	0.51900	
r	-0.0761923	0.0349310	-2.181	0.02932	*
b	-0.1138764	0.0348860	-3.264	0.00112	**
rw	-0.0832641	0.0348860	-2.387	0.01712	*
Age	-0.0025805	0.0008336	-3.096	0.00200	**
Education	-0.0165755	0.0089710	-1.848	0.06484	.
Soc_influence	0.0261575	0.0106498	2.456	0.01415	*
Kite_type:Kite_size	0.0081627	0.0493521	0.165	0.86865	
Kite_type:Operating_height	-0.0369358	0.0493522	-0.748	0.45432	
Kite_size:Operating_height	0.0404780	0.0493522	0.820	0.41224	

F Survey

AWE designs survey

Sky High Sentiments: Assessing Acceptance of Airborne Wind Energy Designs

You are invited to participate in this research study that seeks to better understand people's preferences for different designs of airborne wind energy systems. Airborne wind energy is an innovative renewable energy technology that harnesses the power of wind using airborne devices such as kites or drones. These systems operate at high altitudes where winds are stronger and more consistent.

In part 1 of this survey, you will be asked to judge 8 specific designs according to your preferences and rate them on how safe and aesthetically pleasing you perceive them. Furthermore, you are asked to imagine that a local referendum will be held to determine if a design should be implemented close to your residence. A referendum is a vote in which everyone in an area is asked to give their opinion about an important political or social question. To ensure that participants' survey responses are comparable, please envision yourself living in a rural environment, where the airborne wind energy design will be located in a flat, open area about 200 meters from your home.

The designs will be varied based on 5 key visual characteristics. An example of an airborne wind energy system and the 5 characteristics can be seen below.

Participation in this study is voluntary, and you can withdraw at any time without any disadvantage to you. You are free to skip any questions. Your data will be completely anonymous. The survey will take you between 5-10 minutes.

For any questions, please contact Tim van Zweden at T.P.T.vanZweden@student.tudelft.nl. You agree with this opening statement by clicking next to continue to the survey.

Design X

I perceive this airborne wind energy design as safe.

- Strongly agree (1)
- Agree (2)
- Neither agree nor disagree (3)
- Disagree (4)
- Strongly disagree (5)

I perceive this airborne wind energy design as aesthetically pleasing. (I like the looks of this design)

- Strongly agree (1)
- Agree (2)
- Neither agree nor disagree (3)
- Disagree (4)
- Strongly disagree (5)

Suppose that in a local referendum, you were asked to vote in favour or against implementing this design close to your residence. How would you vote?

- In favour (1)
- Against (2)

Suppose that in a local referendum, you were asked to vote in favour or against implementing this design close to your residence. Would you vote in this referendum?

- Yes (1)
- No (2)

You have concluded part 1 of the survey. Part 2 is much shorter and will involve a quick questionnaire.

How important is protecting the environment to you personally?

- Not at all important (1)
- Slightly important (2)
- Moderately important (3)
- Very important (4)
- Extremely important (5)

To what extent was your decision-making in this survey influenced by how you believe your social environment (such as family, friends, and neighbours) would evaluate the different airborne wind energy designs?

- Not at all (1)
- Slightly (2)
- Somewhat (3)
- Moderately (4)
- Extremely (5)

To what extent did the background and surroundings depicted in the images influence your decision-making in the survey?

- ○ Not at all (1)
- ○ Slightly (2)
- ○ Somewhat (3)
- ○ Moderately (4)
- ○ Extremely (5)

Which of the following elements do you remember seeing in the background of the image presented to you? (Select all that apply)

- ☐ Tree/bush (1)
- ☐ Car (2)
- ☐ Billboard (3)
- ☐ Animal (4)
- ☐ Skyscraper (5)
- ☐ Truck (6)
- ☐ Other (7) ____

How old are you?

	0 10 20 30 40 50 60 70 80 90 100
Age ()	

What is the highest level of education you have completed?

○ Primary school (1)

○ High school (2)

○ MBO or intermediate vocational education (3)

○ HBO or associate degree (4)

○ University bachelor (5)

○ University master (6)

○ Doctoral degree (7)

What is your gender?

○ Female (1)

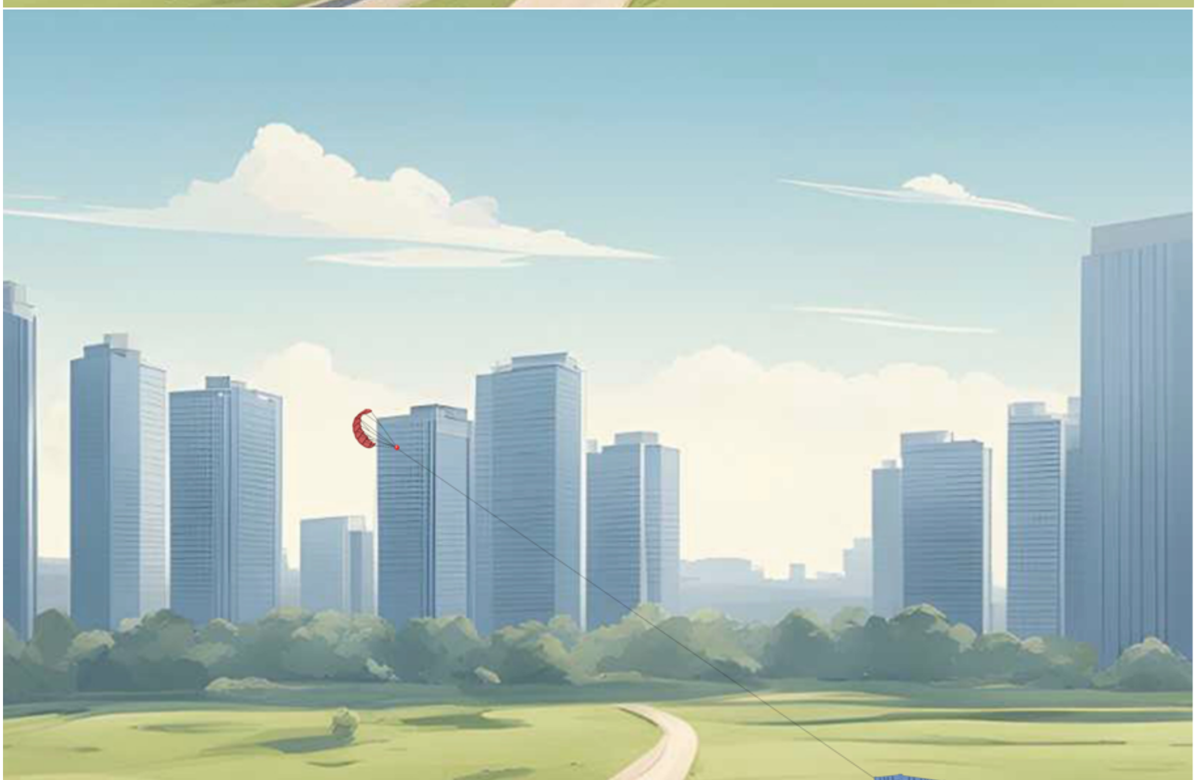
○ Male (2)

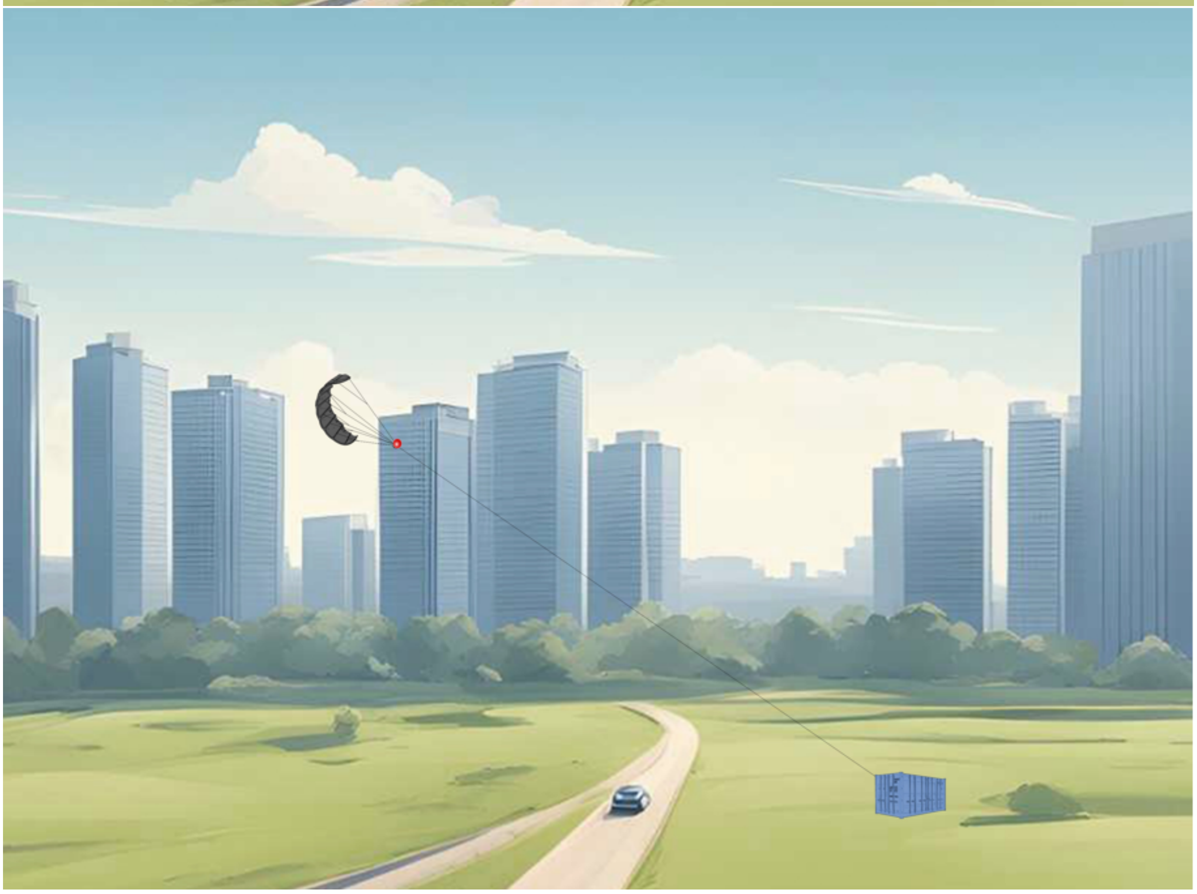
○ Other (3) ____

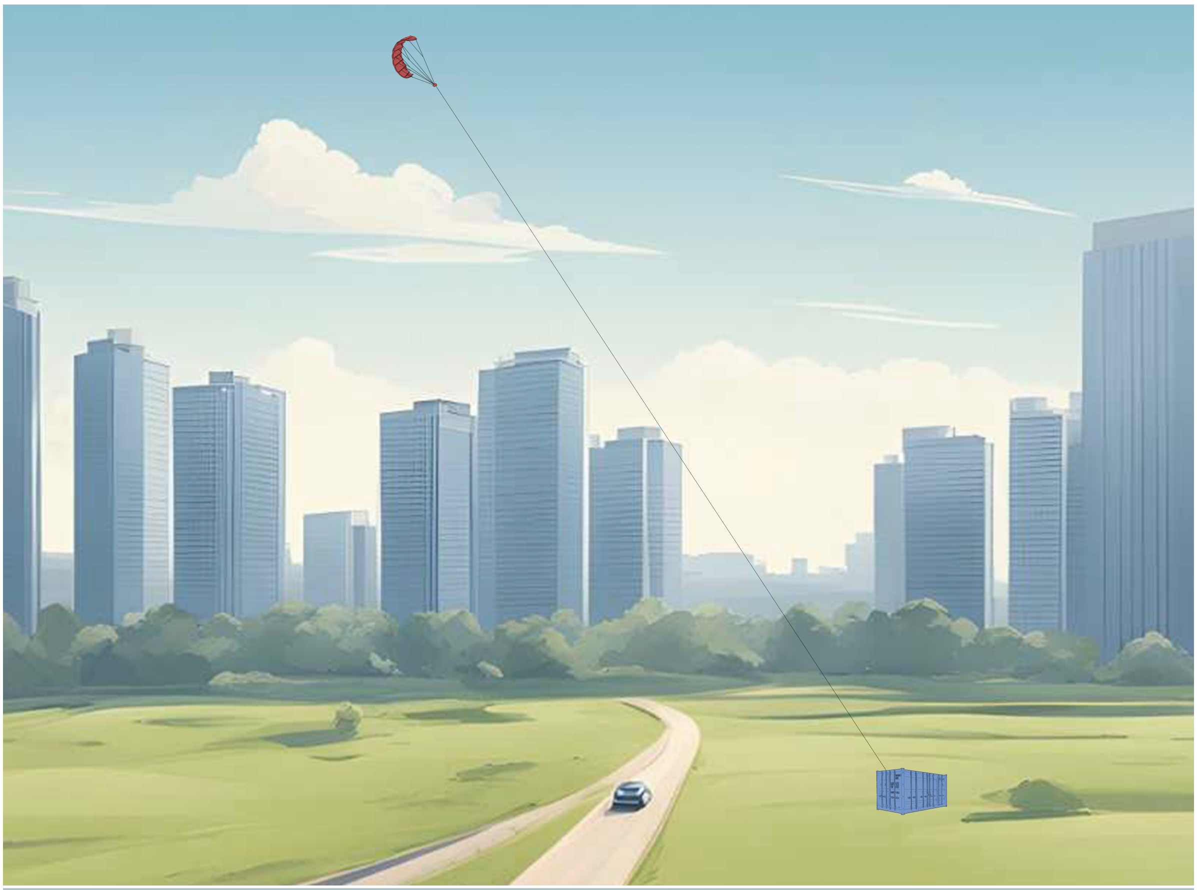
○ Prefer not to say (4)

G

Visualization of all designs







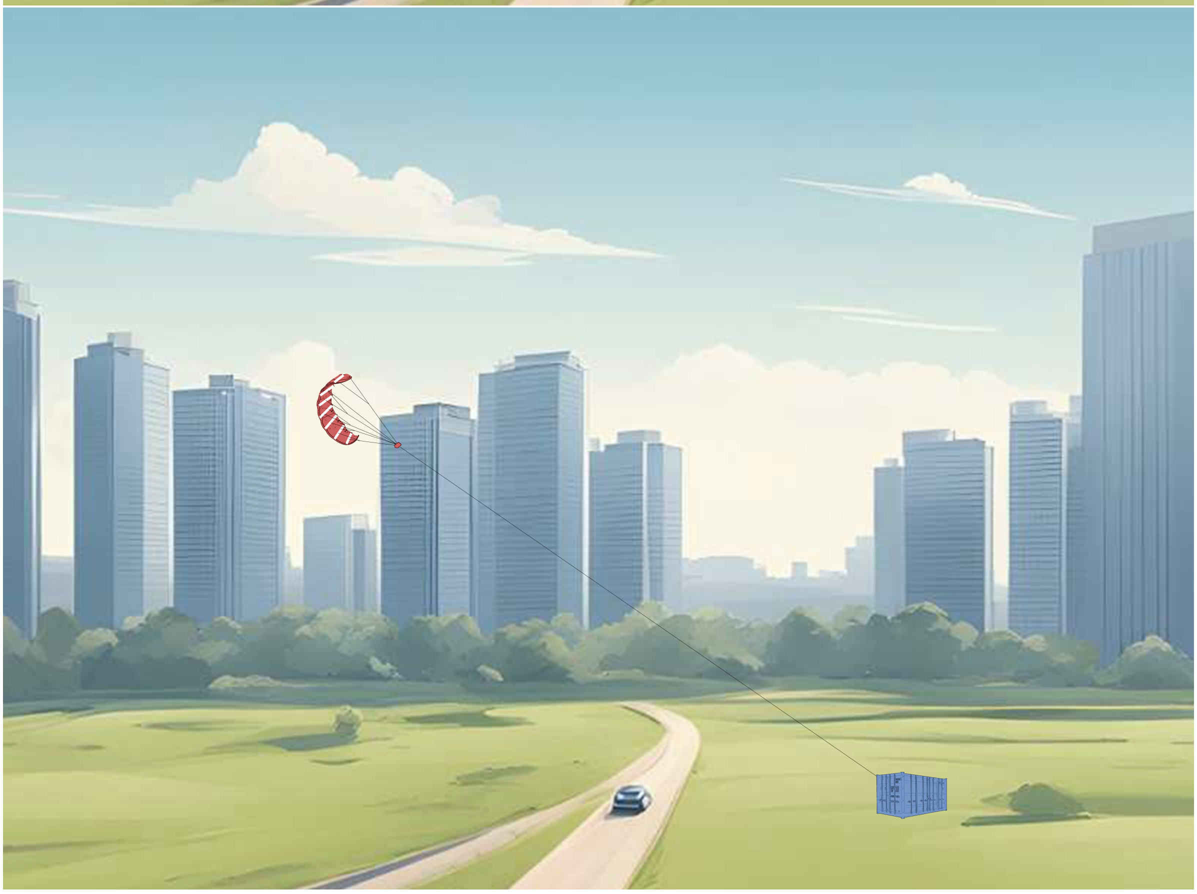


Figure G.1: Visualizations of All designs (1-16 in order)