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Acceptance of electrically powered gliders as a sustainable alternative to conventional gliders. An exploration study based on a survey of gliding pilots.

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Executive Summary

The exploration of sustainable alternatives in aviation has become increasingly significant due to environmental challenges. Among these alternatives, the concept of gliders with electric propulsion emerges as a potential game-changer. Traditional gliders rely on thermals and air currents, while electric propulsion offers a consistent and controlled flight experience. From a behavioral economics perspective, understanding pilots is crucial in adopting new technologies. Furthermore, behavioral economics can offer insights into how pilots perceive the risks and benefits of transitioning to electric propulsion. By examining technical feasibility, economic incentives, and ecological benefits, this study aims to assess whether electric propulsion can redefine the future of gliding. These systems promise lower operational costs due to reduced fuel expenses and maintenance requirements, appealing to hobbyists and commercial operators. To identify potential for gliders with electric propulsion, glider pilots are surveyed on their opinion on using this new technology and on factors influencing the capabilities of this market.

Keywords: Electric Vehicles, Electric Ships & Airplanes, Consumer Behavior, Environmental Impact, Climate Change

1 Introduction

The exploration of sustainable alternatives in aviation has become increasingly significant due to environmental challenges. Among these alternatives, the concept of gliders with electric propulsion emerges as a potential game-changer. Traditional gliders rely on thermals and air currents, while electric propulsion offers a consistent and controlled flight experience. From a behavioral economics perspective, understanding pilots is crucial in adopting new technologies. By examining technical feasibility, economic incentives, and ecological benefits, this study aims to assess whether electric propulsion can redefine the future of gliding. These systems promise lower operational costs due to reduced fuel expenses and maintenance requirements, appealing to hobbyists and commercial operators. To identify potential for gliders with electric propulsion, glider pilots are surveyed on their opinion on using this new technology and on factors influencing the capabilities of this market. Nevertheless, there are several challenges and issues that electric propulsion brings and that must be investigated nearer regarding the potential for the technology. Therefore, the purpose of this study is to examine the critical factors that influence the development and adoption of electric gliders. By examining advances in battery technology, electric motor systems, and integrated airframe and propulsion design (Adu-Gyamfi & Good, 2022), the research will assess the technical feasibility and environmental benefits of electric gliders, such as achieving near net-zero carbon dioxide (CO2) emissions and requiring fewer resources to operate (Baumeister, Simić, & Ganić, 2023). In addition, the study explores economic considerations and consumer perceptions within an explorative study, including the role of sustainable behavior in influencing the adoption of green technologies, to provide an integral understanding of the challenges and opportunities for integrating electric aviation into the glider industry.

2 Literature Review

2.1 Focus and Methods of the Literature Review

A comprehensive literature search was carried out, which formed the foundation for this exploratory study. By reviewing and analyzing the literature, an overview of the current state of research is provided (Snyder 2019). When conducting this literature review, it was crucial to follow a systematic and targeted approach to identify relevant and up-to-date sources (Pandey et al., 2024). Therefore, this study attempted to use sources that are not older than five years. Another important aspect was the quality assessment of the sources found. The impact factor of the journal and the reputation of the journal were considered to ensure that only high- quality and relevant studies are included in the analysis (Chen & Song, 2019). This was done by using either the Resurchify information portal (www.resurchify.com) or the VHB Jourqual 3 collection (https://vhbonline.org/en/vhb4you/vhb-jourqual/vhb-jourqual-3). To identify possible knowledge gaps and to define the relevant information in the literature, the sources in this study were divided into defined scientific fields. This approach allows for a clearly structured overview of the collected sources. Each source was assigned to a specific scientific field, and the associated journal and publication date were also noted. This systematic categorization makes it possible to quickly access the most important information and ensures that no relevant studies are overlooked (Brandt et al., 2013). Innovation/Technology & Aviation accounts for nine references, reflecting the recent surge in research in this area. Sustainability emerges as a significant focus with eight references, mostly concentrated between 2021 and 2023. Lastly, Behavioral Economics is represented with seven references, showcasing its relevance in studies from 2022 onwards. This distribution highlights the interdisciplinary nature of research and the evolving focus on sustainability and innovation in aviation technology.

2.2 Innovation, Technology and Aviation

The development of electrical engines can be seen in many industries no matter if the vehicle is a truck, plane, ship, car or motor bike. The aviation industry itself has been dealing for many years with the issue of too high weight batteries, that make the use of electrical energy combined to engines running with fuel that has a high energy density inefficient (Wojnar, Kozuba, & Mrozik, 2020). Nowhere in the aviation industry is the weight of a plane as important as for a sailplane that tries to be in the air as long as possible without using an engine. Manufacturers like *Lange Innovation* are offering sailplanes with electrical propulsion within their *"Antares"* series (Lange Aviation, 2024, online). This series of sailplanes should regarding the manufacturer's offer with the help of electric propulsion, high climbing speeds with low noise pollution and powerful battery systems (https://www.lange-aviation.com/).

Electric aviation's development hinges on advancements in three key technological areas: battery technology, electric motor technology, and efficient integrated airframe/propulsion design. These components are crucial for enhancing the performance and feasibility of electric aircraft. Currently, the aviation industry faces several challenges in replacing conventional drives with electric drives. These challenging areas are power conversion, distribution, low power generators, and power management persist (Adu-Gyamfi & Good, 2022). The design of electric aircraft often requires innovative solutions, such as the installation "of a retractable pylon for the engine and propeller behind the pilot's cockpit"; this modification is necessary due to the high density of devices within the fuselage, impacting aerodynamic efficiency. Unfortunately, many manufacturers overlook the increased aerodynamic drag ranging from 11% to 23% during flight caused by an extended power unit (Wojnar, Kozuba, & Mrozik, 2020, p. 5). Advancements in power electronic converters, particularly those based on silicon carbide (SiC) devices, offer significant benefits. These include regarding electronic components "reducing the loss, reducing the volume and weight, simplifying heat dissipation" (Xun et al., 2015, p. 1341). Weight estimation is still a critical step of aircraft design, influencing decisions in the conceptual phase (Ma & Elham, 2023). Battery reliability is crucial, and studies have shown that long-term storage does not have degradation in quality or reliability. This implies that batteries keep charge capacity and as well voltage stability, which ensures a reliable lifespan (Valiˇs, et al., 2023). Motor drives are integral to the More-Electric Aircraft (MEA) concept, supporting systems like compressors, pumps, and actuation (Gao, et al., 2022). Neural networks are utilized to estimate key engine parameters engine speed, leftover torque, and exhaust temperature using hierarchical organization (Li et al., 2021). Additionally, hybrid electric propulsion systems, combining turbine engines and lithium-ion batteries, offer potential improvement. Intelligent energy management strategies, such as deep reinforcement learning (DRL) optimize these systems (He et al., 2023). Despite these advancements, jet fuel's high energy density compared to current batteries presents challenges. There needs to be much more storage capacity for electricity than fuel tanks in a conventional plane. Hybrid electric propulsion remains a promising solution, enhancing fuel efficiency by using "electric power to reduce the power demands from the combustion engine" (Reid, Perez, & Jansen, 2024, p. 1). These developments signify a transformative shift towards sustainable aviation, necessitating continued innovation and interdisciplinary collaboration.

2.3 Sustainability

Electric aviation offers significant environmental and efficiency benefits over conventional engines. Achieving higher efficiency, these systems approach almost net-zero CO2 emissions and require fewer resources to operate (Baumeister, Simić, & Ganić, 2023). This transition to electric propulsion systems not only reduces greenhouse gas emissions but also addresses other critical environmental concerns. One of the key advantages of electric aircraft is that there could be a reduction from 82 % to 88 % of reduction if batteries are charged by renewable energy, with some systems demonstrating improvements (Eaton, Naraghi, & Boyd, 2022). This enhances the longevity and reliability of electric propulsion systems, making them more viable for widespread adoption in aviation. Electric propulsion has as well potential to significantly lower emissions of water vapor and nitrogen oxides (NOx), which are concentrated during takeoff and climb (Avogadro & Redondi, 2023). By minimizing these emissions, electric aircraft can mitigate their impact on climate change and improve air quality especially since sailplanes most of the time only use electric propulsion during take-off. While General Aviation accounts for only 1 % of CO2 emissions within the entire aviation industry, the shift to electric propulsion can reduce CO2 emissions but represents just a very small proportion in the total emission balance of the aviation industry (Adu-Gyamfi & Good, 2022). However, electric aviation also contributes to other environmental issues, including "land use, ionizing radiation, ozone depletion and terrestrial ecotoxicity" (Thonemann, et al., 2023, p. 380). Addressing these challenges requires a comprehensive approach to sustainability considering not only the burning of resources but also the use of rare metals to build the plane and its batteries. The "well-to-wake analysis" of electric aircraft indicates a decrease in "environmental and socio-economic impacts, particularly if the electricity used is sourced from renewables" (Barke, et al., 2022, p.469). This highlights the importance of integrating renewable energy into the aviation sector to maximize sustainability benefits. Hybrid-electric powertrains emerge as a promising technology for reducing emissions and promoting decarbonization, especially in segments with lower energy demands like sailplanes with limited flight energy requirements (Figueroa, Cavallaro, & Cini, 2023). By combining electric and conventional propulsion, these systems can optimize fuel efficiency and reduce harmful emissions. In conclusion, electric and hybrid-electric aviation technologies offer transformative potential for reducing the environmental impact of air travel. With advancements in battery efficiency and propulsion technology, coupled with renewable energy integration, the aviation industry can move towards a more sustainable future. This shift not only addresses CO2 emissions but also tackles broader environmental challenges like the reuse and recycling of materials and the extension of the lifespan for products.

2.4 Behavioral Economics

Electric aviation is poised for transformative advancements, particularly with the development of four key battery technologies: lithium-metal (Li-Metal), lithium-sulphur (Li-S), zinc-air (ZN- Air), and lithium-air (Li-Air) (Eaton, Naraghi, & Boyd, 2022). These innovations promise to enhance the market capabilities of electric aircraft, offering significant improvements in energy density and performance. One of the primary advantages of electric aviation is the anticipated reduction in fuel and maintenance costs, which are expected to be significantly lower compared to conventional aircraft through decreased maintenance requirements. However, this is offset by higher purchasing/leasing costs, posing a challenge for widespread adoption. Yet, as these technologies consolidate, reductions in aircraft prices, battery replacement costs, and maintenance costs could drastically improve the cost-effectiveness of electric aircraft. Noise reduction is another critical benefit of electric propulsion, particularly for passengers, where noise levels are notably high. Reducing noise within the plane can increase an occupant´s overall comfort onboard. This aspect is crucial for improving customer satisfaction and competitiveness in the aviation market. Airfields must adapt their infrastructure to accommodate electric aircraft. This includes updating stands and charging facilities to support the new technology. Such adaptations are essential for the seamless integration of electric aviation into existing airfield operations. Pilots buying sailplanes with electric propulsion may see this as a prerequisite for making this purchasing decision (Avogadro & Redondi, 2023). Interestingly, parallels can be drawn with e-motorcycles, where many travelers express - regarding findings from *Doward* (2018) and *Pardo-Ferreira et al.* (2020) - concerns about their silent operation, lighter weight, and perceived weaker build compared to conventional motorcycles (Nguyen et al., 2023; Ludin et al., 2023). These perceptions highlight the importance of addressing safety and reliability concerns in the adoption of new technologies. Studies show that there is "no significant direct association between electric vehicle (EV) satisfaction and continuance intention". This suggests that factors like green self-identity functions are “as a moderate in other environmentally friendly technologies” (Cruz-Jesus, et al., 2020, p. 13). Test drive experiences have shown that early adopters reinforce their technology identity, with enhanced private symbolic meanings leading to "influence adoption intentions” (Herziger & Sintov, 2022, p. 8). Statistical analyses reveal that perceived ownership is highest among individuals aged 31-35, followed by those aged 2630 and 36-41. Additionally, higher income levels are an influencing factor for buying an electric vehicle (Le, Jabeen, & Santoro, 2023). In summary, the future of electric aviation is shaped by technological advancements, economic considerations, and consumer perceptions. Addressing these facets will be crucial for the successful integration and acceptance of electric aircraft in the aviation industry.

2.5 Research Gap and Research Questions

There are already several studies existing investigating how good battery systems are working in planes, where the issues are explicitly laying in compact glider that need to be light and ergonomic and sustainability aspects related to electrical engines. Important insights of these studies miss the importance of sustainability aspects like CO^2 reduction for pilots especially flying gliders. There are so far no studies investigating the purchasing decision of pilots for sailplanes and the important preferences that play a role within their hobby of flying sailplanes. Eventually glider pilots take other factors like maintenance efforts or cost aspects as more serious when thinking of purchasing a new glider, while these factors lay more near to their day-to-day living compared to future changes and threats regarding the climate. This includes as well if pilots see other drive types as more potential for future changes in the mobility sector towards climate change and resource conservation. Based on the stated research gaps the following three research questions (RQ) lead through the exploration study:

RQ 1: How is the acceptance of electric propulsion among pilots shaping up in the context of the growing importance of sustainable mobility?
This is the guiding question for scientific field sustainability. It should lead to answers given by pilots regarding their opinion on electric mobility in its potential for reducing CO2 emissions and the importance compared to other factors like technological fascination.

RQ 2: What are the barriers to the spread of electrically powered gliders in comparison to conventional propulsion systems?
Research question two belongs to the scientific field innovation, technology and aviation. The purpose of this question is to get more information on how electrical propulsion for gliders is seen by pilots compared to engines running on fuel. Pilots should comment on the efficiency of this technology and the issues that currently exist.

RQ 3: What factors influence the decision of glider pilots to switch to electric gliders?
The last research question three should bring more clarity to the intention of glider pilots to count on this technology for future purchasing decisions regarding owning sailplanes with electric propulsion. By identifying the interest in gliders with electric propulsion it is possible to draw the market potential for this glider nowadays and with further development soon.

3 Methods

This study explores the perspectives and attitudes of glider pilots towards a wider spread of electric propulsion in gliding. To collect reliable and relevant data, an online survey was designed. The survey aimed to capture a broad range of opinions and was sent by mail to pilots of the gliding club “Verein für Segelflug (VFS) Krefeld” in Krefeld, North Rhine-Westphalia (NRW), Germany. In total there are 60 active sailplane pilots members of the gliding club. The survey was conducted on Microsoft Forms and made available to all active members of the gliding club via personalized email invitations. The survey was published to all members of the VFS Krefeld via mail on 17th of November 2024 at 15:03 MET. Until the 20th of November 2024 25 pilots filled in the survey. To increase the response rate, a reminder email was sent on 30th November 2024 nearly two weeks after the first publishment via mail. In the end a total of 27 participants filled in the survey. The resulting participation degree of the main target group is 45 %. To ensure that if someone did not read the email with the general information, but clicked directly on the link, an explanatory letter on the Microsoft Forms platform was also provided, including an acknowledgement. Participants had to read this text before they could see the first question in the questionnaire.

The survey was not compulsory for any member of the gliding club. Each member was free to decide whether to participate in the survey and complete the questionnaire. A pretest was essential to check comprehensive and technical functionality. It was conducted in a small personal circle before the questionnaire was distributed to the target group. Ensuring data quality was important as well. Certain safeguards were in place, such as IP address checks and the blocking of multiple entries. For this reason, respondents in this survey could only answer with one response option and, if necessary, formulate an opinion regarding a specific question, for which a free text field is provided (Torrejón-Guirado et al., 2023).

The structure of the survey follows a logical and user-friendly approach, like the design of the *Alaska Aviation Operator Questionnaire* (Schroeder et al., 2024). The questions are grouped into the following categories:
1. Demographic data: Age, gender, marital status (question 1 - 4).
2. Attitudes towards sustainability and electronic vehicles: general opinions and experience with electric drivers (question 5 - 9).
3. Glider specific issues: Glider ownership, interest in future purchase and key factors influencing purchase decision (question 10 - 19).
The questionnaire consists of 19 questions designed to take an average of eight to ten minutes to complete. The number and focus of the questions were carefully crafted to address the research objectives and fill existing knowledge gaps, while maintaining a reasonable length for participants. The questions were intentionally concise and specific to ensure clarity and ease of understanding while facilitating focused and accurate responses (Torrejón-Guirado et al., 2023).

Firstly, the data collected was structured to directly answer the research questions. Data from the survey was analyzed using mixed-methods approach that combines quantitative and qualitative analyses. Closed-ended questions are analyzed descriptively to identify key trends, such as means, frequencies, and rankings. These metrics allow for a systematic examination of responses and facilitate the identification of trends and patterns across the sample (Torrejón- Guirado et al., 2023). For instance, responses to ranking questions, such as prioritizing factors for purchasing a glider, will provide clear insights into participants' preferences and support quantitative conclusions. Data from closed-ended questions are processed using tools such as pivot tables in Microsoft Excel to ensure precision and efficiency in identifying correlations and key findings. Statistical methods will be used for a systematic analysis to gain an overview of the results, to detect patterns or relationships and to answer the research questions (George & Mallery, 2018). Open-ended questions, on the other hand, are analyzed thematically. This qualitative approach is used to capture the nuances of participants' opinions, undercover specific concerns and explore innovative ideas related to electric propulsion in gliding (Schroeder et al., 2024).

4 Results

4.1 Results "Innovation, Technology and Aviation"

For the first scientific field of this study RQ2 *"What are the barriers to the spread of electrically powered gliders in comparison to conventional propulsion systems?"* must be answered. In general, 78 % of the glider pilots said that they are interested in vehicles with electric engines. 11 % of the participants are not interested in technology and a further 11 % think this depends on the implication. Within a comparison of the drive types of biofuels, electric energy, hydrogen and Liquefied Natural Gas (LNG), the surveyed pilots see electric and hydrogen-based engines as the leading technologies for the upcoming years to address the climate change, whereby 56 % of the participants ranked electric energy as the top technology used for engines in the mobility sector. Less potential is seen in biofuels and further less potential in LNG.

The potential for gliders with electric propulsion is seen by 63 % of the pilots asked for in the survey. 37 % refer to issues regarding this technology. Out of the 37 % have 60 % concerns regarding the additional weight of the battery and fear a too low range for the plane to fly without an engine under the conditions of a lack of thermals. These findings are aligned with the importance of weight in the construction planning of the plane mentioned by *Ma and Elham* (Ma & Elham, 2023). 30 % of critics regarding the electric propulsion see too many question marks regarding the future development involving the lifespan of batteries, the research on lighter materials for batteries, as well as safety concerns in connection with burning batteries and engine failure during take-off. This shows that current sailplane models with electric propulsion are not yet 100 % convincing and require continuous improvement regarding battery safety, weight and capacity as well as durability, what at the same time requires efficient onboard systems and engine technology. In this regard it must be taken into consideration that all surveyed pilots with a motorized glider in possession are only familiar with combustion engines, what limits their expertise to market observations, test flights or knowledge from information exchanges with other glider pilots.

Aligned with this finding is the statement from a survey participant that a motorized glider from type *Ventus* is supported by a combustion engine that is built for 40 years until today and therefore electric propulsion doesn't mean automatically a suitable or better alternative to gliders with combustion engines. If the same counts for gliders with electric propulsion is questioned within the survey. Nevertheless, there is no pilot from the survey who has a glider with a combustion engine fully rejecting electric propulsions for gliders. Noteworthy in this context is that biofuels are more important for the future of a more sustainable mobility for pilots whose glider has a combustion engine than the average pilot from the survey. The overall opinion of all pilots surveyed gave hydrogen the same importance as electric energy, what could imply that pilots in possession of a fuel burning glider are looking forward in solving sustainability issues with biofuels while sticking to proven combustion engines, when not buying a new glider with electric propulsion.

4.2 Results "Sustainability"

RQ1 *"How is the acceptance of electric propulsion among pilots shaping up in the context of the growing importance of sustainable mobility?"* is becoming increasingly relevant. The survey results provide valuable insights into the motivations and attitudes of pilots, particularly regarding sustainability and new technologies. The most important factor that makes gliding attractive is the community with other glider pilots, which 24 % of people find attractive. This means for many, the social experience and connection with other glider pilots is a big part of why they enjoy gliding. Next, the challenge of finding thermals and the competitive aspect is important to 23 % of respondents. For these people, the thrill of finding rising air currents and the excitement of sport and competition are the main reasons for gliding. A further 19% are attracted by physics of flight, appreciating the science and mechanics behind how gliders work and how they stay in the air without an engine. The lack of engine also appeals to 19 % of the responds. Less pilots enjoy the quiet, peaceful experience of gliding without the noise of an engine, which makes the flight feel more comfortable. Finally, the environmental aspect of gliding, with decreased CO2 emissions, is important to 15 % of respondents. These people appreciate that gliding is an environmentally friendly sport that doesn't contribute much to pollution. Overall, the reason why glider pilots enjoy flying gliders as a sport so much is not because it is more environmentally friendly. According to the survey results, this is the least significant factor. Building upon the insights from the factors that make gliding attractive, a further analysis of responses to question 4, "Do you have children? – Yes/No" and question 15, "In your opinion, is electric propulsion a suitable solution for motorized sailplanes?" reveals important connections between sustainability, age, and parental status in shaping attitudes toward electric propulsion.

Younger individuals, particularly in the 14 to 30 age range, tend to be more supportive of electric propulsion. This could be due to their generally more open stance toward sustainability. The 18 to 30 age group is particularly strong in its support, with seven respondents in this group voting in favor of electric propulsion. On the other hand, older age groups, especially those between 41 and 70 years old, exhibit more mixed opinions, with a higher proportion of "No" answers. When considering the connection between having children and supporting electric propulsion, there seems to be a notable trend. People with children are generally more in favor of electric propulsion, with a significant number of parents expressing support, particularly in the younger age groups, like 18 to 30 years old. This could be because parents may feel stronger responsible for ensuring a better future for their children, which aligns with the environmental benefits of electric propulsion.

In conclusion, younger respondents and parents are particularly supportive of electric propulsion. While sustainability is not the primary reason people are drawn to gliding, it plays an important role in the discussion of new technologies such as electric propulsion. The findings suggest that acceptance of electric propulsion in the gliding community can be encouraged by emphasizing its environmental benefits, its appeal to families, and its potential to modernize and enhance sport. This analysis provides valuable insights into the role of sustainability in glider pilots decision making, particularly regarding the adoption of more environmentally friendly technologies.

4.3 Results "Behavioral Economics"

The last and third field of this study sustainability deals with the third research question RQ 3 *"What factors influence the decision of glider pilots to switch to electric gliders?"*. In general, 63 % of the participants in the survey are currently not in possession of an electrically powered or assisted vehicle. Around 19 % of participants have an e-bike, 7 % possess electric cars and a further 9 % rely on an electric hybrid or an E-

Vespa. 26 % of the survey respondents are not in possession of a vehicle with an electric motor but using one from friends or family members whereby the distribution over electric cars and e-bikes or E-Vespa is half a half. This means that in total around 60% of all glider pilots from the survey are familiar with the use of electrically powered vehicles. Reasons why the pilots surveyed are using these vehicles are the interest in the degree of efficiency that an electric engine has compared to conventional combustion engines, cost savings, the conservation of resources and the reduction of CO2 emissions as well as a few other reasons. Currently 26 % of the glider pilots are in possession of their own glider. 86 % of these gliders have their own propulsion whereby 100 % of these rely on combustion engines. Within the future 38 % of the survey participants are interested in buying a glider, 31 % are not sure if they want to buy one and another 31 % is not interested in a glider purchase. The reason why 31% say that they are not interested is that they already have a glider, the investment is too high or that they don´t need one because of the expected low occupation of the glider. 50 % of the pilots who have already their own glider are not interested in a future glider acquisition where at the same time only 25 % of pilots who have not their own glider are not interested in a purchase, what could imply that possessing a glider reduces the interest in looking for future alternatives. Looking at the factors for buying a glider, the most important factor is the purchase price with an importance of 23 % in the overall purchasing decision. The acquisition price is followed by the operating costs as well as the customer service with a weight of 16 % each. These three factors are then followed by the maintenance effort (14 %), motorization (12 %) as well as the overall aircraft performance (11 %). The least important point within the decision-making process of a glider is the delivery time with 8 %.

Regarding gliders with electric propulsion, 63 % of the glider pilots surveyed say, as already mentioned, that electric propulsion is a good option for gliders that are taking off without external energy supply by a towing motor plane or a cable winch. A further 22 % of the participants are not sure about this technology for the glider application and 15 % are not convinced by this propulsion alternative. Within the group of participants with an age from 31 to 50 years 100 % are convinced by electric propulsions for gliders. Within the group of younger pilots from the age of 18 to 30 years 64 % believe in a future for gliders for electric propulsion where at the same time 18% are not convinced and another 18 % are not sure. The largest incisiveness can be recognized in the group of pilots from the age of 61 to 70 where 40 % affirm the technology, 40 % are undecided and 20 % are not seeing a future in electric propulsion for glider. Out of the group of glider pilots that are unsure or not convinced by the electric propulsion for a glider 70 % are not in possession of a vehicle with electric engine or assistance. Additionally, 40 % have nearly no experience with electric mobility at all. Pilots that are convinced by developing electric propulsions for gliders count on the reliability and simplicity of the technology, noise reduction and the alignment of the sustainability aspect of gliders as planes which fly without a motor for most of the flight using only thermal winds. Pilots that are not or are not totally convinced point to poor battery capacities, high purchasing costs as well as too high weight of the plane caused by the float of the batteries. From their perspective the price-performance ratio is the decisive factor for buying an electric plane.

5 Conclusion

5.1 Summary

Within this study the perspective of glider pilots on electric propulsions for sailplanes was investigated. Regarding RQ2 within the scientific field innovation, technology and aviation can be stated that most glider pilots see the largest potential in electric drives next to hydrogen for tackling climate change and most pilots with 63 % believe that this technology is a suitable alternative for gliders with combustion engines. What pilots see as barriers for a wide spread of this technology are concerns regarding the weight of the batteries influencing the performance of the gliders in the air resulting in insufficient ranges as well as uncertain safety conditions regarding inflammability of batteries and engine failures. At the same time gliders with electric propulsion are regarding investigations of the surveyed pilots significantly more expensive than conventional gliders with combustion engines what might be the main barrier since this is the most important decision factor for glider pilots when making a purchasing decision for a sailplane. In terms of sustainability and RQ 3 it can be said that sustainability is the least important factor to glider pilots within their reason why they have chosen this hobby. More convincing is for them the lower maintenance efforts an electric engine needs, the higher energy conversion within the engine as well as noise reduction. The sustainability factor itself has greater importance for younger pilots at the age of 14 to 30 years as well as pilots that have children. Explanations of the surveyed pilots regarding their opinion on sustainability in connection to electric drives for gliders complain that sustainability is associated in a to high regard with direct CO^2 emissions, while lifetime of batteries as well as cyclability of battery materials are neglected too fast. Factors that are influencing the decision of glider pilots within their decision-making process for a new glider are in the first place the acquisition costs followed by operating costs as well as the customer support offered by the manufacturer. Motorization itself is rank five behind the maintenance efforts of the seven listed decision factors in the survey and therefore seen with minor importance. What emerges from the responses of the pilots surveyed is that 70 % of the pilots who are not convinced by electric propulsions for a glider are not in possession of a vehicle that has an electric drive or assistance while 40 % of the critics have no experience with electric engines in other vehicles at all. In general, 75 % of the pilots who have not yet own glider are interested in or thinking of a decision of purchasing a glider in the future. Under pilots that have already a glider are 50% interested in a future glider acquisition. The level of experience with electric vehicles in general as well as the possession of a glider have, based on the survey results, an impact on the openness of the purchase of a glider with electric propulsion in the future.

5.2 Limitations

The study provides valuable insights and helps to address the three research questions RQ1, RQ2 and RQ3. However, several limitations must be considered. A major limitation of this study is the potentially low response rate, a common problem with online surveys anyway. Studies have shown that despite strategies to increase participants, such as personalized invitations and reminder emails, responses rates can remain suboptimal, affecting the representativeness of the data. For example, the *Alaska Aviation Operators Survey* had an overall response rate of 14.3 %, highlighting the challenge of recruiting participants for such studies (Schroeder et al., 2024). Additionally, the survey was limited geographically, as it included only pilots from North Rhine- Westphalia, Germany, most of whom were members of a single gliding club in Krefeld. In addition, the exclusive focus on the members of one gliding club in North Rhine-Westphalia in Germany may limit the generalizability of the results to a broader population of glider pilots.

5.3 Further Research

Since this study gives a small regional insight of how gliding pilots in Germany and more specific in North Rhine-Westphalia think, a further investigation could include surveys from other pilots in different German regions or other countries in Europe and on other continents that have different preconditions in whether conditions, societies and industrial preconditions. Living in other countries than Germany can mean for glider pilots a more difficult access to the manufacturers of gliders with electric propulsion. This could result in different opinions of how important factors like delivery time and pricing are. A valuable addition to this research could be as well a survey including manufacturer of sailplanes in the future. Hereby it would be interesting to investigate what feedback they receive from glider pilots, how they are structuring their market research and what from their point of view are the most important factors to glider pilots when making a purchase decision for a sailplane. When having results from the offering side of the market survey results between potential customers and sellers could be directly combined and mismatches determined that could lead to recommendations on how to make sustainable solutions for propulsions in sailplanes more attractive and successful. Furthermore, the study connected the topic of electric propulsion in gliding with scientific fields such as innovation and technology, environmental considerations, and consumer behavior. However, other relevant areas, such as governmental regulations, sustainability goals, or legislative frameworks for emerging technologies, were not explored. Expanding future research to include these aspects, as well as engaging a more diverse and larger group of participants from various gliding clubs, would strengthen the robustness and applicability of the findings. Finally, this survey could be repeated in the upcoming decades and the results compared to the potential seen at the current state and soon.

References

Adu-Gyamfi, B. A. & Good, C. (2022). Electric aviation: A review of concepts and enabling technologies, Transportation Engineering, 9, e100134, https://doi.org/10.1016/j.treng.2022.100134

Avogadro, N., & Redondi, R. (2023). Demystifying electric aircraft's role in aviation decarbonization: Are first-generation electric aircraft cost-effective?, Transportation Research Part D, 14, e104191, https://doi.org/10.1016/j.trd.2024.104191

Barke, A., Thies, C., Popien, J.-L., Melo, S. P., Cerdas, F., Herrmann, C., & Spengler, T. S. (2021). Life cycle sustainability assessment of potential battery systems for electric aircraft, CIRP Conference on Life Cycle Engineering, 6, 660-665, https://creativecommons.org/licenses/by-nc-nd/4.0

Barke, A., Thies, C., Popien, J.-L., Melo, S. P., Cerdas, F., Herrmann, C., & Spengler, T. S. (2022). Comparison of conventional and electric passenger aircraft for short-haul flights – A life cycle sustainability assessment, CIRP Life Cycle Engineering Conference, 6, 464-469, https://crea- tivecommons.org/licenses/by-nc-nd/4.0

Baumeister, S.; Simi´c, T. K. & Gani´c, E. (2023). Emissions reduction potentials in business aviation with electric aircraft, Transportation Research Part D: Transport and Environment, 136, e104415, https://doi.org/10.1016/j.trd.2024.104415

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D. J., Newig, J., Reinert, F., Abson, D. J., & von Wehrden, H. (2013). A review of transdisciplinary research in sustainability science, Ecological Economics, 92, 1–15, https://doi.org/10.1016/j.ecolecon.2013.04.0088

Chen, C., & Song, M. (2019). Visualizing a field of research: A methodology of systematic scientometric reviews. PLOS ONE, 14(10), e0223994. https://doi.org/10.1371/journal.pone.0223994

Cruz-Jesus, F.; Figueira-Alves, H.; Tam, C.; Pinto, D. C.; Oliveira, T. & Venkatesh, V. (2023). Pragmatic and idealistic reasons: What drives electric vehicle drivers' satisfaction and continuance intention?, Transportation Research Part A: Policy and Practice, 179, e103626, https://doi.org/10.1016/j.tra.2023.103626

Callegaro, M.; Manfreda, K. L.; Vehovar, V. (2015). Web survey methodology, Sage, Thousand Oaks, https://doi.org/10.4135/9781529799651

Doward, J., (2018). New Law to Tackle Electric Cars' Silent Menace to Pedestrians. The Observer

Eaton, J., Naraghi, M., & Boyd, J. G. (2022). Market capabilities and environmental impact of all-electric aircraft, Transportation Research Part D, 25, e103944, https://doi.org/10.1016/j.trd.2023.103944

Figueroa, R. Q., Cavallaro, R., & Cini, A. (2023). Feasibility studies on regional aircraft retrofitted with hybrid-electric powertrain, Aerospace Science and Technology, 18, e109246, https://doi.org/10.1016/j.ast.2024.109246

Gao, Y., Cheong, B., Bozhko, S., Wheeler, P., Gerada, C., & Yang, T. (2022). Surrogate role of ma- chine learning in motor-drive optimization for more-electric aircraft applications, Chinese Journal of Aeronautics, 15, 213-228, https://doi.org/10.1016/j.cja.2022.08.011

George, D. & Mallery, P. (2018). Descriptive statistics, IBM SPSS Statistics 25 Step by Step, Routledge, 126-134, https://doi.org/10.4324/9781351033909

He, L., Chen, F., Tian, P., & Gou, H. (2023). An improved energy management strategy for hybrid electric powered aircraft based on deep reinforcement learning, Aerospace Science and Technology, 11, e109137, https://doi.org/10.1016/j.ast.2024.109137

Herziger, A., & Sintov, N. S. (2022). Give it a Try! How electric vehicle test drives influence symbolism perceptions and adoption intent, Journal of Environmental Psychology, 10, e101907, https://doi.org/10.1016/j.jenvp.2022.101907

Le, T. T., Jabeen, F., & Santoro, G. (2023). What drives purchase behavior for electric vehicles among millennials in an emerging market, Journal of cleaner production, 16, e139213, https://doi.org/10.1016/j.jclepro.2023.139213

Li, Z., Ma, Y., Wei, Z., & Ruan, S. (2022). Structured neural-network-based modeling of a hybrid-electric turboshaft engine's startup process, Aerospace Science and Technology, 14, e107740, https://doi.org/10.1016/j.ast.2022.107740

Ludin, D.; Schreier, N.; Mueller, E.; Wellbrock, W.; Melber, P.; Sollner, J. (2023): Acceptance of EMotorcycles: A Longitudinal Survey at Loewensteiner Platte, South Germany, World Electric Vehicle Journal, 14 (12), e120326, https://doi.org/10.3390/wevj14120326

Ma, Y., & Elham, A. (2023). Designing high aspect ratio wings: A review of concepts and approaches, Progress in Aerospace Sciences, 27, e100983, https://doi.org/10.1016/j.paero-sci.2024.100983

Nguyen, M. H., Pojani, D., Nguyen-Phuoc, D. Q., Ha, T. T., & Nguyen, T. C. (2023). Who is more likely to upgrade to e-cars? Comparing the intentions of electric and conventional motorcycle riders in Vietnam, Travel Behaviour and Society, 13, e 100810, https://doi.org/10.1016/j.tbs.2024.100810

Pandey, H. P., Maraseni, T. N., & Apan, A. A. (2024). Enhancing systematic literature review adapting 'double diamond approach'. Heliyon, 10, e40581. https://www.sciencedirect.com/science/article/pii/S2405844024166121

Pardo-Ferreira, M.C., Torrecilla-García, J.A., Heras-Rosas, C.de las, Rubio-Romero, J.C., 2020. New risk situations related to low noise from electric vehicles: perception of workers as pedestrians and other vehicle drivers. Int. J. Environ. Res. Public Health, 17, 6701. https://doi.org/10.3390/ijerph17186701

Reid, S. J., Perez, R. E., & Jansen, P. W. (2024). Hybrid electric aircraft design with optimal power management, Aerospace Science and Technology, 16, e109479, https://doi.org/10.1016/j.ast.2024.109479

Schroeder, A. K.; Kopriva, M.; Hannigan, A.; Passini, J.; O'Connor, M. (2024). Surveying aircraft operators about aviation safety in Alaska: Survey Development, Design, Methodology, and Ad- ministration, Transportation Research Interdisciplinary Perspectives, 26, e101191, https://doi.org/10.1016/j.trip.2024.101191

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines, Journal of Business Research, 104, 333-339, https://doi.org/10.1016/j.jbusres.2019.07.039

Torrejón-Guirado, M.-C., Martín-Erice, I. S., Martín-Rodríguez, L. S., & Lima-Serrano, M. (2023). Methodological and strategic insights for online survey studies: an analysis based on the CHER- RIES checklist, Enfermería Clínica, 7, 207-213, https://doi.org/10.1016/j.enfcle.2024.06.001

Thonemann, N., Pierrat, E., Dudka, K. M., Saavedra-Rubio, K., Tromer Dragsdahl, A. S., & Laurent, A. (2023). Towards sustainable regional aviation: Environmental potential of hybrid-electric aircraft and alternative fuels., Sustainable Production and Consumption, 15, 371-385, https://doi.org/10.1016/j.spc.2024.01.013

Vali˘s, D., Hlinka, J., Kol´a˘cek, J., Proch´azka, P., Pokora, O., Cipín, R., & Ko˘stial, R. (2023). Com- prehensive study on reliability, deterioration, and ageing of lithium-ion batteries in electric-powered aircraft assessed after a storage period using functional data analysis and non-parametric back up, Engineering Failure Analysis, 27, e107661, https://doi.org/10.1016/j.engfailanal.2023.107661

Wojnar, T., Kozuba, J., & Mrozik, M. (2020). Influence of the use of electric drive in a glider on its aerodynamic parameters on the example of GP-15 glider. Transport Problems, 5, 254-258, https://doi.org/10.1109/NTAD51447.2020.9379086

Xun, Q., Xun, B., Li, Z., Wang, P., & Cai, Z. (2015). Application of SiC power electronic devices in secondary power source for aircraft., Renewable and Sustainable Energy Reviews, 7, 1336–1342, http://dx.doi.org/10.1016/j.rser.2016.12.035

Yang, C., Lu, Z., Wang, W., Wang, M., & Zaho, J. (2023). An efficient intelligent energy manage- ment strategy based on deep reinforcement learning for hybrid electric flying car, Energy, 14, e128118, https://doi.org/10.1016/j.energy.2023.128118

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