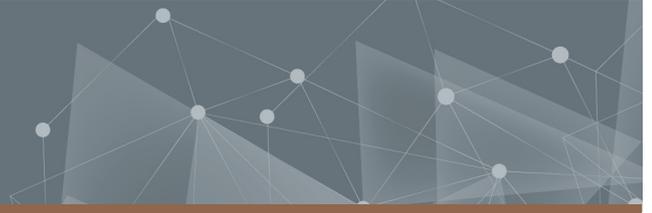




CHALMERS
UNIVERSITY OF TECHNOLOGY



Airship diffusion in Swedish agriculture

Sociotechnical barriers and opportunities

Master's thesis in Industrial Ecology

AMANDA ANDREASSON
FIA FJELDDAHL

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF ENVIRONMENTAL SYSTEMS ANALYSIS

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025
www.chalmers.se

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Supervisor & examiner: Björn Sandén, Environmental System Analysis, Chalmers
University Of Technology

Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone +46 (0)31-772 1000

Gothenburg, Sweden 2025

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AMANDA ANDREASSON
FIA FJELDDAHL

Department of Technology Management and Economics
Chalmers University of Technology

SUMMARY

Agriculture is under increasing pressure to adapt to climate change while reducing its environmental impact. One of the challenges is to maintain or increase food production without intensifying soil degradation, emissions, or fossil dependency. This thesis applies the Technological Innovation Systems (TIS) framework in combination with scenario analysis to explore the potential for implementing lighter-than-air technology in Swedish agriculture. Semi-structured interviews were complemented by literature research and a bibliometric analysis. The study examines the current state of the Swedish agricultural system and the emerging airship market by identifying possible configurations for market integration. Findings show that airships have potential applications such as lifting heavy objects, transporting, spraying pesticides, and monitoring. Key drivers and barriers were identified, focusing on the capabilities and willingness of various societal actors to adopt lighter-than-air technology in agriculture. Diffusion is currently constrained by financial and human resource mobilisation, critical components, regulations and limited legitimation and collaborations. Four future scenarios were developed, covering different ownership models and degrees of functionality of airships. The thesis discusses policy measures that could facilitate the diffusion of LTA technology within the Swedish agricultural sector.

Keywords: Airships, Agriculture, Sustainability, Lighter-Than-Air technology, Technological Innovation Systems, Socio-technical scenarios, Climate adaptation, Policy innovation.

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Amanda Andreasson, Gothenburg, June 2025

Fia Fjelddahl, Gothenburg, June 2025



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List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

EASA	European Union Aviation Safety Agency
EU	European Union
HTA	Heavier-Than-Air
LTA	Lighter-Than-Air
LRF	Lantbrukarnas Riksförbund (The Federation of Swedish Farmers)
SDG	Sustainable Development Goal
TIS	Technological Innovation Systems
UAV	Unmanned Air Vehicle

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1

Introduction

This section describes the background, as well as the aim and scope of the study. Agriculture is under increasing pressure to reduce emissions while ensuring food security. In Sweden, this transformation requires, among other things, innovative solutions that minimise soil degradation and fossil fuel use. One possible technology is lighter-than-air technology, which offers a new way to perform agricultural tasks with reduced environmental impact.

1.1 Agricultural challenges

The agricultural sector plays a central role in addressing global sustainability challenges, thus making its transformation crucial to achieving the United Nations' 17 Sustainable Development Goals (SDGs). Among these, SDG 9 highlights the necessity of sustainable industry, innovation, and infrastructure, emphasising the role of technological advancements in reducing environmental impact while fostering economic growth (The Global Goals, n.d.). In line with this, the Federation of Swedish Farmers (LRF) has set a target of becoming 100% fossil-free in fuel, heating, and drying by 2030, which is seen as a significant challenge (Fossilfritt Sverige, 2020). The Swedish Government (2025) further reinforces this ambition by outlining that, by 2030, the Swedish food value chain should be globally competitive, innovative, and sustainable. This strategy aims to enable companies to make investments in new technology, which opens up for exploration of different technological solutions. Similarly, Swedish Climate Policy Council (2025) notes that the Swedish agricultural sector is in need of increased climate action.

Agriculture is highly vulnerable to the effects of climate change, and the need for a resilient and environmentally responsible agricultural system becomes more critical as climate change intensifies. While climate change may offer certain benefits to Swedish agriculture, such as longer growing seasons, it also brings risks like more frequent droughts and flooding, which already affect production. Moreover, as productivity is expected to decline in other parts of the world, Swedish agriculture may face increased pressure to compensate for global food shortages (Khattak et al., 2025; Swedish Climate Policy Council, 2025). The growing global population, projected to reach 9.7 billion by 2050, will further drive the need for sustainable food production and resource efficiency (Springmann et al., 2018).

Globally, the agricultural sector is responsible for around a third or a fourth of

the total human-caused greenhouse emissions. In Sweden, territorial emissions from agriculture totaled approximately 11.3 million tons CO₂-equivalents in 2023. Of these, 0.6 million tons are linked to fossil fuel use in primarily agricultural machinery, but also heating (Swedish Climate Policy Council, 2025; Cederberg et al., 2012; Kungl. Ingenjörsvetenskapsakademien (IVA), 2019). The reduction of fossil fuel dependency is one of the technological challenges in the Swedish agricultural sector, where fossil fuels are used more compared to other sectors. According to the Swedish Climate Policy Council (2025), agricultural machinery have a big potential to reduce emissions.

Even though there is much potential to reduce emissions, the Swedish Climate Policy Council also notes the risk of increased emissions while conducting climate adaptation measures, such as investment in technology that increases the energy usage. Implementing heavy machinery is another risk because this exerts pressure on the soil, reducing its porosity and ability to retain water and nutrients, thereby harming plant growth and long-term soil health (Nielsen et al., 2018). Soil compaction is difficult to remediate, making it essential to explore alternative solutions such as lighter machinery designs and innovative transport technologies.

1.2 Innovative technologies

To meet growing food demand while minimising environmental degradation, agricultural systems must integrate innovative technologies, improved land-use practices and climate adaptation strategies. Promising possibilities include investments in low emission machinery, enhanced biodiversity conservation, electrification of farming equipment, and AI-driven analytics for precision farming (Fogelfors et al., 2009; The Federation of Swedish Farmers (LRF), 2023; Kungl. Ingenjörsvetenskapsakademien (IVA), 2019). One approach that is being explored is to reduce ground pressure entirely by performing agricultural tasks from the air. It has been proposed that Heavier-than-air (HTA) Drones or Unmanned Aerial Vehicles (UAVs) could have applications such as crop monitoring, targeted fertilisation, and pesticide spraying (Lucia and Vegni, 2023). Lucia and Vegni (2023) argues that UAVs can yield savings regarding both time and cost.

Another technology operating from the air is lighter-than-air (LTA) technology, such as airships, hot air balloons and hybrid air vehicles. LTA technology uses buoyant gases such as helium or hydrogen to remain airborne without continuous energy input. This makes them significantly more energy-efficient than conventional aircraft (Oxford English Dictionary, n.d.; Dumas et al., 2013; Bheekhun et al., 2018). This study focuses on airships. While balloons drift passively with air currents, airships are equipped with propulsion systems and steering mechanisms, enabling them to transport heavy and bulky cargo with potentially lower emissions than conventional transportation methods (Bestaoui and Hima, 2007; Mendes and Lepikson, 2018). Airships are considered quieter than conventional aircraft because they remain airborne through buoyancy rather than engine thrust. This is particularly relevant given the growing concern over traffic-related noise. In western Europe, traffic-

related noise contributes to poor health conditions and premature deaths, causing a total loss of at least one million life years per year (World Health Organization, 2011). Noise also causes large effects on wildlife and biodiversity (Newport et al., 2014).

The successful transition toward a climate-resilient agricultural sector will require not only technological advancements but also policy incentives, financial investments and farmer engagement (The Federation of Swedish Farmers (LRF), 2023; Kungl. Ingenjörsvetenskapsakademien (IVA), 2019). A Technological Innovation System (TIS) framework is here applied to understand and analyse barriers and drivers of airship diffusion in Swedish agriculture, and to explore potential sociotechnical configurations of a future system.

The structure of the report begins with an explanation of the Theoretical framework (Chapter 2), followed by the Methodology (Chapter 3). The results are presented across four chapters: Actors and Technology (Chapter 4); Potential Market Configurations, which includes socio-technical scenarios (Chapter 5); Drivers and Barriers (Chapter 6); and Implications for Policy (Chapter 7). These chapters are followed by a discussion of the results (Chapter 8) and, finally, the conclusion (Chapter 9). This report focuses on user needs and potential applications for airships, therefore it was decided not to include any images of airships. This choice was made to avoid constraining the reader's imagination to a specific airship design or a limited number of design concepts.

1.3 Aim & scope

The focal production-consumption system is LTA technology use in Swedish agriculture. The aim of the study is to investigate factors driving, hindering and shaping the development and growth of such a system. These factors can be framed as a Technological Innovation System, which has an international geographical scope. The production-consumption system as well as the innovation system are comprised of both social and technical elements. Some factors of geophysical or ecological nature are also considered.

Since the potential of LTA technology in other sectors may affect the growth and use cases of the production-consumption system in focus, other potential sectors were also identified and briefly explored. The temporal scope of the study was defined based on empirical observation. The study is future oriented, but to understand the development of the airship technology data gathering was conducted for the years 1852 - 2025, beginning with the construction of the first successful airship in 1852 (Encyclopaedia Britannica, n.d). At a more detailed level, the study aims to answer four research questions:

1. What market and technology trends within the TIS can be identified?
2. What are the possible market configurations for lighter-than-air technology in the Swedish agricultural sector?

1. Introduction

3. What sociotechnical drivers and barriers influence the diffusion of lighter-than-air technology in the Swedish agricultural sector?
4. What type of policy instruments can help diffuse lighter-than-air technology?

2

Theoretical framework

This chapter explains the theoretical framework used in this report. Firstly Technological Innovation Systems Theory is explained. Thereafter, the Technology life-cycle theory is described and lastly socio-technical scenarios followed by policy interventions is presented.

2.1 Technological Innovation Systems Theory

To understand the dynamics of sustainability transitions and emerging technologies, a systems approach can be applied. When the dynamics are of socio-technical nature, they can be studied through various analytical concepts, such as innovation systems that aims at understanding system dynamics through the components actors, networks and institutions. Innovation systems can be studied through many different theoretical frameworks and one of them is Technological Innovation Systems (TIS). TIS is an analytical construct that can describe the growth of a specific production-consumption system. TIS uses systems thinking to analyse technological and industrial change, and can be used to study the diffusion, development and application of emerging technologies. (Bergek et al., 2008b; Andersson et al., 2023)

The structural scope of a TIS describes what type of structural elements are included in the system model, and can contain social and technical elements. Social elements include actors, institutions and networks. Actors are defined as the organisations and firms that are interconnected with the supply chain. Institutions describe the interactions between the actors, such as norms and regulations, resulting in frames which can affect decisions. Networks consist of several different types of networks. Actor networks can consist of learning networks to exchange information, as well as other networks such as political networks that can influence policy making. There can also be networks of artifacts, such as infrastructure systems or components of a product. Technical elements include both knowledge and artifacts, such as infrastructure that is linked to the technology. Social and technical elements can be used to identify and map out the system. They do not necessarily need to be deliberately working together, but they interact with each other. (Bergek et al., 2008a)

Functions describes a concept used to identify aspects of innovation that influence the system (Andersson et al., 2023), for example factors that drives or hinders growth of the new technology (Bergek et al., 2008b). Bergek et al. (2008b) uses

seven functions in TIS; knowledge development, influence of the direction of search, entrepreneurial experimentation, market formation, legitimation and resource mobilisation, development of positive externalities.

“Knowledge development” represents the amount of knowledge within the TIS and how this knowledge changes over time. There must be enough incentives for organisations to enter an industry, in order for the TIS to develop. This is investigated via the function “Influence on the direction of search”. The uncertainties about a TIS’s technologies, applications and markets is a fundamental feature of its development. By doing entrepreneurial experimentation, these uncertainties can be reduced, which is measured by the function “entrepreneurial experimentation”. “Market formation” explores the current market phase of the technology, since this affects what actions are spreading or hindering the diffusion of airships. The function “legitimacy” explores whether the technology is perceived as suitable and appealing by key stakeholders, which is essential to enable resource mobilisation, stimulate demand, and strengthen the political influence of actors within the emerging TIS. “Resource mobilisation” is about understanding to which extent the TIS can mobilise human capital such as education, complementary assets like changes in infrastructure, and also financial capital. “Development of positive externalities” is a function that is connected to all other functions. It indicates the strength of the total functional dynamics of the TIS by exploring new entrants and external economies such as political power and specialised intermediaries, which in turn affects the other functions. (Bergek et al., 2008b)

The functions described by Bergek et al. (2008b) can be grouped in various ways as they overlap in many cases. As this study examines an emerging technology, certain functions may be more or less difficult to assess. To address the assessment challenges, the TIS functions defined by Bergek et al. (2008b) are grouped into two overarching categories: capacity and willingness to implement the technology. In this framework, knowledge development is interpreted as the capacity to generate new knowledge. The same argument can be said about the capacity to execute entrepreneurial experimentation. Market formation is also placed under the category of capacity as the market phase indicates what capacity the system have. Resource mobilisation, particularly in terms of financial capital, also influences the system’s capacity to support technological development. Willingness, on the other hand, is primarily assessed through the legitimacy function, as perceptions of the technology directly affect the willingness of actors to adopt and support it. Additionally, influence on the direction of search can also be grouped into willingness as it measures incentives to enter an industry. Lastly, since positive externalities can enhance multiple functions, they are considered to span both capacity and willingness.

2.2 Technology life-cycle theory

It is important to understand at which development level the system is at in order to make reasonable assumptions. The development phase can be identified by exploring drivers and barriers in the TIS. The technology’s development can be categorised

into five different phases; concept development phase, demonstration phase, niche market phase, commercial growth phase and maturity phase. In the early concept development phase, knowledge about the emerging technology is generated through the creation and small-scale testing of prototypes, models, and new ideas by researchers, companies, and other stakeholders. This is followed by a demonstration phase, where these early solutions are refined and scaled into more complete systems. Testing in real-world settings helps reveal the technology’s practical potential and allows for feedback from users, customers, and society at large. In the niche market phase, the technology is introduced in protected environments where it can evolve without immediate pressure from dominant alternatives. These markets may arise from specific user demands or be shaped through supportive policies. As the technology improves and proves itself, it can enter the commercial growth phase, where it begins to compete with established solutions and expand into larger markets. Eventually, in the maturity phase, widespread adoption leads to the displacement of incumbent technologies, contributing to broader transformations in how society produces and consumes. (Swedish Energy Agency, 2014)

However, the development of an innovation is not linear as it might seem from these phase divisions. Instead when a technology moves towards the next phase, new aspects are added to the already existing activities. To some degree, for every new phase the process starts over as every phase needs new design concepts and prototypes to solve the socio-technical challenges that might emerge as seen in figure 2.1.

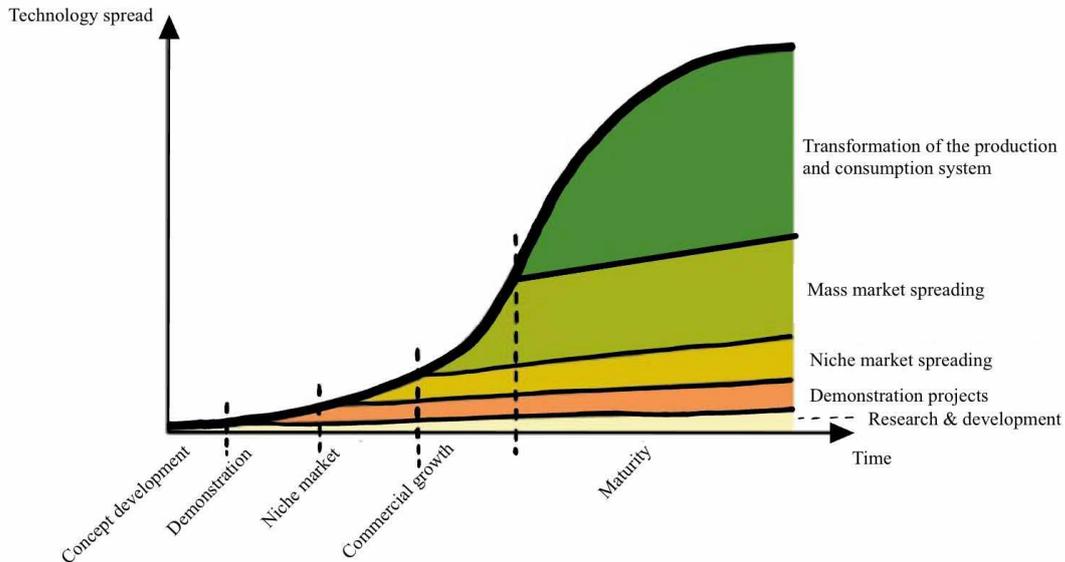


Figure 2.1: Technology development phases (translated). Translated from Bergek (2014) p.19. Original in Swedish.

2.3 Socio-technical scenarios

To shape desirable futures, the TIS framework can be combined with scenario methodology from prospective studies. While the TIS framework offers insights into how a specific technology evolves and which factors influence its growth, scenario methodology enables the exploration of multiple possible futures. Together, these approaches can provide a more comprehensive understanding of both current system dynamics and potential development trajectories. According to Konrad and Böhle (2019) "...by socio-technical futures we refer to futures that couple techno-scientific potentials and prospects with envisioned societal change and new social arrangements" (p. 1). As part of the socio-technical futures, socio-technical scenarios involves management of innovation (Konrad and Böhle, 2019) and can guide innovation pathways, potentially shifting perceptions about what is possible (Bechtold et al., 2017). This enables exploring of different scenarios that could capture alternative development pathways of the system, as well as possible market configurations for the production-consumption system. By examining more extreme or unconventional possibilities, that are based not on desirability but rather what is technically achievable, socio-technical scenarios can bypass the limitations of defining what constitutes a "realistic" future (Sandén and Hillman, 2011).

2.4 Policy intervention

Each of the seven functions developed by Bergek et al. (2008b) gathers information about the system (Swedish Energy Agency, 2014). This can be used to understand which functions that need policy guidance to further support the system's development (Bergek et al., 2010). TIS analysis is therefore often used to inform and support policymaking (Bergek et al., 2008b). By conducting a functional analysis, it becomes possible to identify blocking mechanisms that hinder technological development or diffusion. This enables the recognition of key policy issues that need to be addressed. The analysis also explores the conditions under which a technological transition could occur, depending on the current phase of the TIS. Based on this understanding, the framework can help guide the formulation of policy goals and suggest targeted policy interventions that support a desirable transition pathway. To complement the TIS analysis, socio-technical scenarios could also be used as a support for policymaking (Konrad and Böhle, 2019).

3

Methodology

The theoretical framework outlined in the previous chapter provides a basis for understanding the key dynamics of the TIS, as well as what can be done to support the system. The following chapter describes the methodology used to apply this framework in the case of airships within agriculture. Data was gathered primarily through semi-structured interviews, and was also complemented with information from literature and a bibliometric analysis. The study was explorative and focused on mapping actor perspectives and exploring system dynamics. Four socio-technical scenarios were constructed to illustrate possible configurations of the system.

3.1 Data gathering

To establish a fundamental understanding of both the agricultural system and the airship system, a literature review was conducted using both academic and grey literature. This approach was chosen because identifying and specifying the area of study is important when analysing a TIS (Bergek et al., 2008b). Bergek et al. (2008b) also explains the necessity for an iterative process when conducting TIS analysis, since improved knowledge about the system could require reconsideration of initial assumptions and boundaries. Therefore, mapping of the system was an iterative process by digging deeper into relevant literature or by asking new questions about a subject in the interviews. The literature was found on Scopus, Google Scholar and Google. Two initial search strings were used; one regarding airships; (Airship OR (Lighter than Air Technology) OR LTA) and one regarding agriculture; (Agriculture AND (Challenges OR Transition) AND (Climate change)). A third search string that combined both airships and agriculture was also used ((Airship OR (Lighter than Air Technology) OR LTA) AND agriculture). The method of pearl growing (Schlosser et al., 2006) was used in the initial state of system understanding to find relevant literature.

A bibliometric analysis was conducted via Scopus to analyse trends for LTA technology. The bibliometric analysis was used to analyse if there has recently been an increased academic focus on LTA technology. This was carried out by analysing if the word “airship” was found in the article title, abstract or keywords on the database Scopus. A Google Trends analysis was also conducted, however Google Trends can only analyse search trends on Google from 2005 to now. The result was presented with and without being normalised. In order to normalise the result, the number of articles that use “it” on the years that “airship” have been published was

used as a base. To better illustrate trends, annual fluctuations were smoothed by using a three year moving average.

3.2 Identification of interviewees

To find relevant stakeholders for the interviews two initial interviews were made. One interview was with Grönroos (2025a) who gave us the initial idea of utilising airships within agriculture. He had done some prior work related to airship implementation in Sweden, therefore some of his contacts were used to find interviewees. The other interview was with Cederberg (2025), professor of Sustainable Agricultural Systems at Chalmers University of Technology. She was chosen due to her knowledge of agricultural challenges and stakeholders. Relevant airship stakeholders were also found using Google and through asking each interviewee if there were stakeholders they think would be of interest for us, which could be seen as a form of snowball sampling. Four airship companies were interviewed from the U.S, France, England and Germany, together with several actors who have conducted research on LTA technology. It was decided to interview several types of stakeholders related to the agricultural sector: farmers, researchers, one agricultural advisor, one machinery company and one member organisation. A professor in forest technology was also interviewed as forestry came up as an alternative sector where airships might be useful. All interviewees are presented in table 3.1 below.

3.3 Interviews

A total of 18 interviews were conducted to gather information about agriculture and airships. They ranged from half an hour to two and a half hours, with a median duration of one and a half hours. Two interview templates were used: one tailored to the agricultural sector and one to the airship sector. The templates were inspired by the International Energy Agency's TIS-related interview questions (van Noord et al., 2023), as well as the functions defined by Bergek et al. (2008b). As more knowledge was gathered through interviews, more questions were added. The reason for semi-structured interviews was to allow the answers to be comparable but at the same time leave room for the possibility to deepen the conversation and ask about new perspectives. The interview template, which can be found in appendix A.3, covered TIS functions, main barriers, drivers, and opportunities for LTA technology, as well as challenges in the agricultural sector. Also, potential other sectors that could benefit from using LTA technology were also identified since this could affect the market formation. All interviews were held online, and were recorded and transcribed if the interviewee gave consent.

3. Methodology

Table 3.1: List of interviewees with their role and organisation

Name	Role	Company / Organisation	Sector	Date
Christel Cederberg	Professor of Sustainable Agricultural Systems	Chalmers University of Technology	Agriculture	2025-01-30
Thomas Grönroos	Arable farmer	Farm, Södermanland	Agriculture	2025-03-10
David Andersson	Business Development Officer	Falkenberg Municipality	Agriculture	2025-03-07
Jörgen Dahl	Senior Vice President Product & Development	Väderstad	Agriculture	2025-03-12
Wictoria Bondesson	Head of business and development	The Federation of Swedish Farmers (LRF)	Agriculture	2025-03-17
Fredrik Tidström	Advisor	VäxtAB	Agriculture	2025-03-19
Bengt Engdahl	Dairy farmer with previous collaboration in arable farming	Farm, Västergötland	Agriculture	2025-03-20
Mikael Gilbertsson	Technical agronomist	RISE Research Institutes of Sweden AB	Agriculture	2025-03-25
Martin Grönroos	–	–	Agriculture & Airships	2025-01-23
Ulf Svensson	Former researcher in Architecture	Chalmers University Of Technology	Airships	2025-03-05
Jeremy Fitton	CEO	Skyflifter Ltd	Airships	2025-03-13
Laure de Laforcade & Florian Lannou	Sales Managers	Flying Whales	Airships	2025-03-25
Bob Boyd	President and CEO of AT ² Aerospace	At ² Aerospace	Airships	2025-03-25
Barry Prentice	Professor and Director	University of Manitoba Transport Institute	Airships	2025-04-03
Steffen Schäufele	Project Engineer Aerospace	Zeppelin NT	Airships	2025-04-08
Åke Sivertun	Project Leader at Drone Center Sweden	RISE Research Institutes of Sweden AB	Airships	2025-03-05
Victor Krusell	Flight inspector, specialized in drones	the Swedish Transport Agency	Regulations	2025-04-03
Ola Lindroos	Professor of forest operations	Swedish University of Agricultural Sciences (SLU)	Forestry	2025-03-12

3.4 Socio-technical scenarios

This report is conducted independently of any explicit demand from either the agricultural sector or the airship industry. Its purpose was to explore the market situation of the technology in focus and whether this technology could play a role in the future of agriculture. Since neither sector has defined a vision for such a future, there is no predetermined objective guiding this exploration. Therefore, a common assumption for all four scenarios was set to be that by the year 2050, all agricultural operations in Sweden should have access to an airship. The year 2050 is chosen in alignment with the Paris Agreement's climate goals, which require net-zero emissions by that date (United Nations, n.d), as well as being concrete and tailored to the market situation of the technology in focus (here LTA technology) (Swedish Energy Agency, 2014).

To be able to analyse and understand the barriers and drivers of a system, it was not only important to have a target regarding the amount of airships, but also to understand what socio-technical configurations of airship use in agriculture could be possible in the future, and which configuration face fewer barriers. To evaluate different configurations, four possible scenarios for airship usage were created. These scenarios do not cover all possible futures, but are developed to illustrate a few contrasting alternative ways of airship deployment in the agricultural sector.

4

Actors and Technology

To lay the ground for an investigation into the potential integration of airships and agriculture, this section provides an overview of the structure of Swedish agriculture and the emerging airship industry.

4.1 The agricultural system in Sweden

The following provides a broad picture of Swedish agriculture, including land use and farm structure. In 2019, 2 551 500 hectares in Sweden were classified as arable land (Statistiska centralbyrån (SCB), 2020), which corresponds to around 7% of the total area in Sweden (Statistiska centralbyrån (SCB), 2023). There are around 56 000 farming companies in Sweden (Swedish Climate Policy Council, 2025) that employ almost 160 000 people full-time and part-time. Swedish agriculture is characterised by a mix of small and large farms (more than 100 hectares per enterprise). Most of the arable land is concentrated in southern Sweden whether it being large or small farms.

There are some trends that benefit small or large farms. One trend is growing interest in sustainable and environmentally friendly farming practices, which has benefited small-scale and organic farmers (Rydén, 2007). Another trend is that over time the number of farms has declined due to economic pressures and the merging of smaller operations into larger entities (Jordbruksverket, 2022; Milestad et al., 2011; Swedish Climate Policy Council, 2025). One reason why they merge into larger farms is the benefit of higher productivity and efficiency (Nybom et al., 2021). Larger farms also tend to have better access to financial capital compared to smaller ones (Wästfelt, 2018). The larger farms cultivates 62% of all arable land in Sweden (Jordbruksverket, 2022). Around half of these large-scale farms are located in four regions within the country's southernmost geographical area; Västra Götaland, Skåne, Östergötland and Uppsala county.

Several sources have emphasised that the agricultural sector is in need of actions for a sustainable transition. In order to take action, it is important to understand the driving forces that influence change in agriculture. One such factor is legislation, for instance whether a technology is permitted or banned. Another factor is the tradition of industry agreements in Swedish agriculture, where farmers collectively decide how to manage production even in the absence of formal legislation. Changes in the supply chain, both upstream and downstream, can also have an impact. For

example, a product may become unavailable, or consumer preferences may shift if the demand for organic food changes. Finally, efficiency and productivity considerations can also drive change, for example by saving time, reducing costs, or improving workplace safety. However, the extent of such changes often depends on the farmer's openness to innovation, underlying values and cost of implementation. (Bondesson, 2025)

There was consensus between the interviewees that farmers have a positive attitude towards new technology, however the technology needs to be economically profitable. In addition, new technology must be easy to use and efficient, especially since it may only be used during certain times of the year, requiring the farmer to recall how to operate the equipment. Time-management is also an important factor for farmers when considering new technology. Furthermore, autonomous vehicles and precision farming are emerging trends.

4.2 The Airship Market

Most airships were used between mid 1800's to the beginning of the second world war (György et al., 2008; Encyclopaedia Britannica, n.d). Thereafter airplanes became the more common vehicle used in air. The airplanes were developed just before the start of the first world war, and military demand in both wars incentivised investment and innovation (Prentice, 2025). These wars provided two major windows of opportunity for airplane development. Another big driver for the development of airplanes were the jet engine that was developed in the late part of the second world war. The jet engine was safe, fast and reliable, which contributed to airplanes dominating the market. This decreased the market for other technologies such as LTA, propeller-driven airplanes and trains (Ballal and Zelina, 2004; Prentice, 2025).

A bibliometric analysis was conducted to identify patterns or trends in the academic literature concerning airships, presented below in figure 4.1 and figure 4.2. Figure 4.1 presents normalised data with a three year moving average, while figure 4.2 presents data which is not normalised, also with a three year moving average. The normalised results indicate that the relative interest in airship appeared to be high in the early 1900s, likely corresponding with the historical use of airships during that time. However, this interest declined significantly around the 1940s. Moreover, a relatively slow trend of increased interest in airships has emerged since the 1970's. In figure 4.2 the amount of academic literature published regarding airships increases after 1970's and in absolute numbers more reports are published when this report was written than at the peak interest of airships in the beginning of 1900's. To summarise, there seems to be a trend with increased interest in literature regarding airships. In addition to the bibliometric analysis, a Google Trends analysis was also carried out. This analysis showed no significant rise in public interest regarding the term "airship". Figures related to the Google Trends analysis can be found in the appendix, section A.4.

4. Actors and Technology

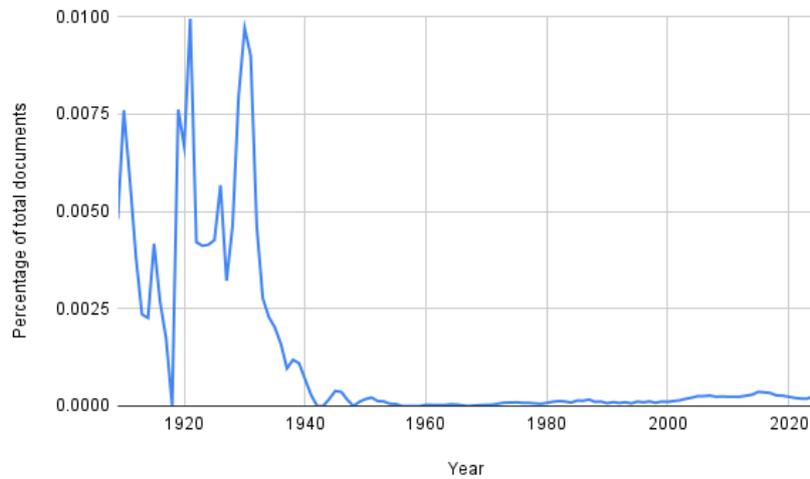


Figure 4.1: Bibliometric analysis of Scopus, airship. Three year moving average. Search within: Article title, abstract, keywords. Normalised with the total amount of documents published in Scopus each year. Source: Scopus (accessed on [27-03-2025])

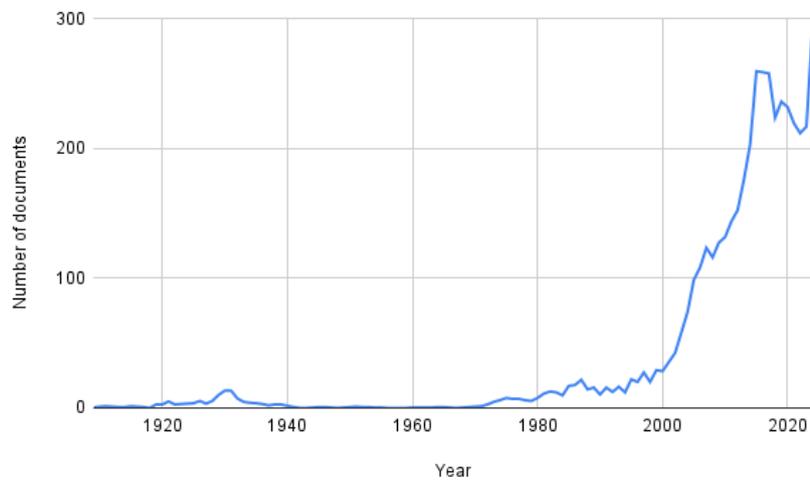


Figure 4.2: Bibliometric analysis of Scopus, airship. Three year moving average. Search within: Article title, abstract, keywords. Source: Scopus (accessed on [27-03-2025])

The current aircraft market is dominated almost entirely by HTA craft. LTA technology is in the demonstration phase, with a few niches being explored. At the time of the interviews, only Zeppelin NT were actively manufacturing airships and have airships operating whereas Skylifter, At²Aerospace and Flying Whales were constructing prototypes. Other airship companies were identified from the Airship Association website (The Airship Association, n.d a). It was noted that there are more companies that use LTA technology than what the Airship Association show-

cases, as Zeppelin NT and Flying Whales were mentioned at the website but not Skyliifter or At²Aerospace (nor its prior owner Lockheed Martin). From the Airship Association website, five additional airship manufactures and five airship operators were identified. In the interviews, three additional companies using LTA technology were mentioned. There is an uncertainty of how many airship companies that exist and operate today. For example a Brazilian airship company (Airship Do Brazil) were mentioned during the interviews that had transporting operations over the Amazonas for some years. This company does not operate anymore and their website does not work today. This shows that there is a fast pace of firms that are entering and exiting the market. In general, there are not many airships operating and most companies are start-ups with theoretical projects.

No airship companies were identified operating in Sweden, although the Finnish airship company Kelluu is expected to begin operations in Sweden during spring or summer 2025 (Kelluu, 2024). From the airship companies interviewed, At²Aerospace and Flying Whales focus on cargo transport to locations that are remote or have little to no infrastructure, though their loading and unloading solutions differ significantly. Both Flying Whales and another airship company called Skyliifter focuses on transporting components to wind farms and other bulky objects. Additionally, Skyliifter have shown interest in surveillance. Zeppelin NT focuses mainly on passenger transport, operating air cruises in Germany. Zeppelin NTs airships have also been used for advertisement and to broadcast events.

Table 4.1: Table showcasing main markets for the airship companies interviewed

Company	Main market focus
At ² Aerospace	Cargo transport
Flying Whales	Cargo transport
Skyliifter	Lifting objects
Zeppelin NT	Passenger transport & advertisement & media

4.3 Airship designs

The envelope of an airship can be categorised into three different designs: blimp, semi-rigid and rigid. Blimps have no internal framework and their shape is mainly due to the pressure of gases. Rigid airships, on the other hand, have a complete internal framework made from lightweight and hard material. Semi-rigid is a mix with some internal framework such as a keel or a series of rings while still using gas pressure to maintain the shape. Historically, rigid-bodied airships required permanent hangars which made them better suited for civil aviation than other purposes. In contrast, semi-rigid or blimps, were more adaptable and could be rapidly deployed directly at locations without established infrastructure (Karataev et al., 2018). Ac-

According to Prentice (2025), an airship’s lifting capacity depends on its structural design, with rigid airships better suited to lift heavier loads. Among the airship companies interviewed, all expressed interest in or were already working a semi-rigid design, although this was not the only design that was explored. The airships can be of different sizes, although most of the companies interviewed primarily focused on larger designs with over 70 metres length.

The choice of lifting gas used in the envelope directly affects the buoyancy of the airship. While most airship companies today use helium, hydrogen is also a viable lifting gas. As shown in Appendix A.2, hydrogen has approximately 8% more gross lifting capacity compared to helium. Therefore, it is relevant to calculate the required envelope diameter based on different lift requirements. The corresponding calculations can be found in Appendix A.2. Table 4.2 below illustrates the approximate diameters of a spherical envelope under different lifting capacities, assuming the structural and functional weight is zero. In reality, the total weight of the material that constitutes an airship depends on several design and operations factors such as if the envelope consists only of textile materials or also includes other materials such as aluminium. The weight categories considered are 750 kg, 1000 kg, 10,000 kg and 100,000 kg, which represents examples of weights for fertilisation, sowing, and harvest (Gilbertsson, 2025; John Deere, 2025). However, the weight categories can vary widely. These weight categories are further illustrated in Section 4.2 and 5.2. As shown in the table 4.2, although hydrogen has 8% higher lifting capacity than helium, this does not translate into an 8% reduction in envelope diameter. Due to the geometric relationship between volume and diameter in a sphere, the corresponding reduction in diameter is approximately $\sqrt[3]{1.08} \approx 1.025$, or 2.5%. Conversely, using helium instead of hydrogen increases the diameter by approximately 2.5%. While this difference in gas performance is theoretically significant, for the moderate lifting capacities identified through interviews, the practical impact of switching from hydrogen to helium remains relatively small. The 2.5% increase in envelope diameter probably becomes more relevant at higher lifting requirements.

Table 4.2: Table showing the diameter of a sphere containing hydrogen or helium that would lift a certain weight

Gas type	Weight (kg)	Diameter (m)
Hydrogen	750	10.6
Helium	750	10.9
Hydrogen	1000	11.7
Helium	1000	12.0
Hydrogen	10000	25.1
Helium	10000	25.8
Hydrogen	100000	54.2
Helium	100000	55.5

4.4 Technical attributes of airships

Generally, airships are suitable for flying low, slowly, silently and for extended periods (Schäufele, 2025). The following outlines capabilities mentioned during the interviews.

Compared to HTA aircraft such as fixed-wing planes, airships are considerably slower. From the interviews, airships reported speeds reach up to 100 km/h depending on the design, although historical examples such as the Hindenburg achieved speeds up to 135 km/h (Encyclopaedia Britannica, n.d). Lifting capacity varies widely across different airship designs. The highest capacity discussed during interviews was over 100 tons.

Regarding altitude, an upper limit of 3,000 meters is defined by EASA regulations, although these altitude restrictions vary depending on whether the airship is manned or unmanned (Krusell, 2025). The lower technical altitude limit should be at least half the airship's length above the ground, primarily for safety reasons (Schäufele, 2025), though today's airships do not operate at such low levels. It should also be noted that flying at low altitudes is more demanding for the pilot, as it requires more awareness of the airship's surroundings.

Airships can land without the need for fixed infrastructure and possess vertical take-off and landing capabilities. One benefit of airships is that they require no energy input to remain aloft, which allows them to hover in place and, for example, wait out storms rather than perform emergency landings. Airships can operate in rain and fog, though hailstorms pose a risk of damage.

5

Potential market configurations

This chapter investigates how the introduction of airships could reshape physical configurations and operational practices in agriculture. It examines potential changes in transport systems, pesticide application, and monitoring practices. Moreover, the chapter explores how these uses could vary depending on different ownership models and degrees of specialisation in airship design.

5.1 Identified market segments

To understand the usage of airships within agriculture the interviewees were asked if they think there is any part of the agricultural sector where airships can be of use. As airships within agriculture is a relative new idea to support the agricultural sector to become more sustainable, all of the potential areas of use that have been found in the interviews will be listed. Some areas of use have been mentioned many times which is shown in table 5.1 by counting how many sources mention this area of use in a total of 18 interviews. Table 5.1 also shows what type of actor gave the idea.

Table 5.1: Potential areas of use for airships within agriculture that were mentioned in the interviews.

Area of use	Mentioned	Actor type
Lift heavy or big objects (harvesting container, equipment too big to fit on roads, biomass waste)	11	Agriculture (7), Airship (2)
Spray pesticides	6	Agriculture (5), Airship (1)
Lift (fertilization, pesticide, seed bag)	4	Agriculture (4)
Monitor fields	4	Agriculture (2), Airship (2)
Distribution of food products (fresh food, shorter travel time, to/from remote places)	3	Airship (3)
Scare away animals	2	Agriculture (2)
Continuous energy supply to equipment	2	Agriculture (2)
5G transmission	2	Airship (2)
Monitor animals	1	Agriculture (1)
Deliver animals and semen	1	Agriculture (1)
Tillage	1	Agriculture (1)

5.1.1 Lifting objects

Within agriculture there are many practices and one distinct difference can be made between livestock and arable farming. In arable farming, some approximate weights were identified where lift is needed, presented in table 5.2 (Gilbertsson, 2025). These weights serve as examples, and the rate at which the bags or containers are utilised depends on several factors, including the type of crop and the operational speed of the equipment used for distributing fertiliser or seeds. Regarding harvesting, one interviewee mentioned 100 000 kg harvest per hour. This estimate is consistent with information provided at the website of one manufacturer of harvesting equipment (John Deere, 2025).

Table 5.2: Different segment of the arable farming that would be in need of lift per bag or container.

Segment	Weight
Fertilisation	750kg/bag
Sowing	500-1000kg/bag
Harvesting	10,000kg/container

The most frequently suggested solution to increase the profitability for farmers was to increase production, which aligns with the government's food strategy "Livsmedelsstrategin 2.0", emphasising yield and profitability (The Swedish Government, 2025). One factor that can reduce production is soil compaction (European Soil Data Centre (ESDAC), 2025). If airships were used to lift fertilisers, pesticide, seed bag, harvest container or other heavy equipment, soil compaction would decrease, potentially leading to higher yields. The current agricultural system relies on ground-based machinery, and driving on productive land can lower the yield, not only because of soil compaction but also by spreading diseases between fields. The risk of disease transmission may increase due to climate change, as the ground is no longer expected to freeze completely throughout the year, allowing disease-causing organisms to survive and spread more easily (Bondesson, 2025).

One interviewed farmer and researcher explained that he sows seeds in rows with 12.5 cm between each row (Gilbertsson, 2025). This is common in conventional cultivation where you spray pesticides and fertilisation several times per crop. These permanent driving lanes is usually distributed every 12 m or 24 m depending on the equipment's size. To allow space for the tractor's tyres, he leaves three rows unsown for the tyres to create these driving lanes. In these driving lanes, no crops grows. The number of rows that must be left empty depends on the width of the tyres. There is a benefit of having wider and less pressure on the tyres as it decreases soil compaction since the weight is distributed over a bigger area (Ding et al., 2020). Another solution is to use tracks instead of tyres to decrease the soil compaction. If no rows were left unsown, the total productive land would increase by approximately 2.6%, based on the scenario with 12.5 cm · 3 rows and 12 m equipment width. Calculations can be found in appendix, section A.1. If soil compaction is also considered, the potential yield could increase more than 4% (Godwin et al., 2019). In fact, Godwin et al. (2019) found that soil compaction can reduce crop yield with 10-15%. In the scenario where all agriculture operations regarding crops were conducted from the air, production could increase even further by eliminating the need for driving lanes. This would increase productive land area, reducing soil compaction and minimising disease spreading (Tidström, 2025). However, most stakeholders that were interviewed found it unlikely that all ground-based activities could be replaced by air-based operations because tasks like sowing or soil cultivating is difficult to do completely from air as it requires some type of handling with the soil. For cultivating the soil, Gilbertsson (2025), mentioned an idea of his to use ultrasound to dissolve soil lumps which would enable more work to be done by air.

5.1.2 Transporting machinery

If airships were used to transport equipments from the farm to the field, the size of the equipment would not be constrained by road width limitations. Objects wider than 350 cm are permitted to drive on Swedish roads but requires special dispensation from the roadkeeper (The Swedish Transport Agency, n.d). This means that it is not certain if the equipment is allowed to drive on the road. Objects with a width of 260 cm or less require no special dispensation. The trend in agriculture has moved towards larger equipment as it in general enables more efficient production. To address the conflict between width restrictions and efficient agriculture, many machines are foldable to fit onto roads, sometimes leading to heavy equipment on roads. According to our interviews, transporting machinery by air would decrease pressure on road infrastructure and make it feasible to use even larger and more efficient equipment. An airship can also be used as energy supplier for ground equipment that is electric.

5.1.3 Transporting products

Rising global population levels are expected to increase the demand for resource efficiency in food systems (Springmann et al., 2018). According to Bondesson (2025), Swedish agriculture may need to increase its productivity due to droughts and other climate changes in other parts of the world. She also noted that there is more potential for agricultural production in the north of Sweden compared to what is used today. There might also be a need to change what crops are cultivated due to changing climate. Lannou (2025) meant that airship technology has the potential to increase agricultural production by decreasing losses of crops due to the logistics and transporting system. For instance, the integrated cold chain inside the airship could enable better conservation conditions during transit, for temperature sensitive goods. This could moreover lead to the distribution of fresher products with higher-value, such as flowers, fruits and certain vegetables (Boyd, 2025; Lannou, 2025; Prentice, 2024). If an airship offers better preservation capabilities for perishable goods, this allows for a greater initial variety of crops to be grown because they can be chosen not for their ability to withstand long transport times, but based on other, more valuable qualities such as taste, nutritional value, or ecological suitability (Lannou, 2025). However, about 40% of Sweden's crop production is grain and grass/clover and around 20% is used for rapeseed, potatoes, sugar beets and fallow land (Swedish Climate Policy Council, 2025) and so for now, there is not a lot of perishable food in Sweden. Still, introducing airship have the potential to shift production from robust and easily stored crops to more delicate crops that have a higher market value or better climate resilience, potentially increasing overall yield. According to Bondesson (2025), it is important that the crops are suited for the Swedish climate, resistant to pests and maintain high quality. There is an aim to consume and produce more Swedish plants. However, currently there are no problems with slow transportation of these products, but could be of other agricultural products such as semen processing or transporting spare parts for important machinery in critical times such as during harvest season. In summary, airships have the potential of distributing agricultural products faster compared to methods used

in Sweden today, and to decrease losses of perishable products. This could enable a shift in choices of crops, however this is as of today not an aspiration from the Swedish agriculture.

Another reason why airship can contribute to a more reliable transportation option is that more frequent extreme weather events because of climate change, such as heavy rainfall, can render dirt roads impassable in global south countries. Since today's ground-based logistics uses trucks, impassable roads can interrupt the transport of food, leading to greater food losses (Lannou, 2025). Two airship companies emphasised the potential to transport agricultural goods from remote areas with poor infrastructure. In these contexts, airships can offer a resilient transport solution, particularly for perishable goods that must reach markets quickly (Prentice, 2025). Similarly, muddy conditions pose operational challenges in farming, as heavy equipment often gets stuck, further highlighting the need for alternative logistics solutions. These climate-related disruptions to conventional systems is an external factor to why airships can be of use and could increase the perceived relevance of airships and strengthen their problem-solution legitimacy.

5.1.4 Spraying pesticides

Several interviewees highlighted pesticide spraying as a potential application area for airships. A key trend mentioned was the move toward increased precision in pesticide application, driven by the need for resource efficiency, without compromising the time it takes to spray the field. Targeted spraying reduces the volume of chemicals required, leading to both environmental benefits and cost savings. To enable this level of precision, certain operational attributes were considered essential. These include the ability to move quickly across large agricultural fields while maintaining high precision to target specific areas. Autonomous operation was also seen as beneficial to improve efficiency and reduce labour demands. The capacity of heavy lifting was also seen desirable, since lifting large amounts of spraying liquid is beneficial due to increased time effectiveness. Additionally, compliance with chemical regulations and the need for precise application in order to minimise excess spreading of pesticides, requires spraying at very low altitudes, ideally not more than one meter above the ground. Flying silently was also seen as important to avoid disturbing surrounding communities. (Tidström, 2025)

When comparing these requirements to the attributes of airships, some alignment is evident. Airships have high lifting capacity, long flight endurance, and are relatively silent compared to other aircrafts. However, other requirements may present challenges. Flying fast is not an attribute that airships possess, flying on low altitude could pose challenges, and stakeholder opinions varied on the precision capabilities of current airship technology.

An alternative concept proposed was the use of airships as a support platform for HTA drones. In this scenario, the airship would act as a "mother ship," carrying large volumes of pesticide and possibly serving as a mobile charging or supply sta-

tion for smaller, more agile drones that carry out the actual spraying. (Prentice, 2025)

5.1.5 Monitoring

As for monitoring, airships have the possibility to stay in the air without using any excess energy to stay afloat due to its buoyancy properties, making it ideal from an energy perspective compared to HTA crafts. It can also be used as movable 5G distributor, giving autonom vehicles in agriculture the necessary connection in an energy efficient way and without investing in infrastructure.

5.2 Potential sociotechnical configurations

In this section, four different scenarios will be explored that spans between ownership concentration to ownership distribution and between multifunctionality to specialisation, presented in figure 5.1. These factors were chosen because they were considered important for agricultural stakeholders.

5.2.1 Multifunctionality to specialisation

There are many ways to describe relationships between technologies. One of them is looking at downstream applications, with regards to the end use of the technology (Sandén and Hillman, 2011). The applications used in this report ranges from multifunctionality to specialisation, focusing on amount of applications that an airship can perform. For example, a single design, such as a 25-meter-wide lenticular envelope, may either accommodate multiple agricultural applications or be optimised for a singular, specialised task within the sector.

From the interviews, the agricultural sector highlighted several use cases for airships, such as transporting fertiliser bags, spraying crops, lifting pesticide tanks, and carrying harvest containers. These operations occur during different points in the agricultural calendar, suggesting that airships with multiple capabilities could serve complementary roles over time. Moreover, airships developed for agricultural lifting tasks may also find applications in other sectors, such as construction. Similarly, if airships are used for monitoring farmland or wildlife, they could also serve surveillance functions in other contexts for example border control or large public events (Schäufele, 2025). A multi-purpose airship could, therefore, reduce the total cost per use and increase profitability through cross-sector deployment (Sivertun, 2025).

On the other hand, if airships instead of being used for multiple purposes, had different airship designs that each were used specifically for one purpose, the airship market would move towards specialisation of the function of an airship. Apart from the production cost reduction benefits when producing one design for each purpose airships, there could be negative financial effects for costumers if they want to use airships for several purposes. Covering all potential tasks, lifting, spraying,

transporting, or monitoring, within agriculture would require access to many different airships. In the interviews it was identified that agricultural stakeholders could see several potential areas for an airship, but that there was a scepticism towards a technology being proposed as a solution which serves several or all agricultural challenges (Bondesson, 2025). There is especially scepticism when there is no realistic plan for implementation. In alignment with this, interviews with current airship manufacturers indicate that airships are often designed for specialised purposes, suggesting that technical specialisation is a likely trajectory for the sector.

If airships only had one specific usage for each airship, there could be low utilisation rates for each airship, making it a more expensive investment. However, airships could have the potential to overcome this challenge due to their long-range capabilities. For instance, an airship could assist with harvesting in southern Sweden during one part of the season and then move northward as the season progresses, thus increasing utilisation over time. Though this requires their seasons to be misaligned because farmers often need to use their equipment during the same time periods (Grönroos, 2025b). Alternatively, they could serve farms in different countries with complementary growing seasons. This geographical mobility could make seasonal use more efficient and improve the business case for investment.

5.2.2 Ownership Concentration to Distribution

The interviews revealed two perspectives on ownership: the agricultural interviewees indicated that Swedish farmers strongly prefer owning their equipment, while the airship companies, on the other hand, supported various ownership models depending on operator preferences. From a social acceptance perspective, a model in which the farmer owns the airship may appear more aligned with existing cultural and institutional norms in agriculture, thereby facilitating legitimacy and adoption. During the high season, if the airship is owned by a single owner, there is an assurance that it will be available to perform its tasks.

One potential advantage of distributed ownership is logistical proximity. If airships are owned and stored near the farms where they are used, this could enable more flexible and frequent use. However, such a model also requires access to suitable infrastructure, such as hangars or docking areas which are big and expensive to build.

As an effect of distributed ownership, different forms of clustering could emerge. These clusters could be formed dependent on geographical location or airship functionality. Considering geographical location, close farms could coordinate airship use by diversifying their crops or livestock to avoid overlapping time windows. However, this may require farms to adapt their production patterns to match technological constraints. If the clustering is based on the airships function, airship access could be shared between farms with non-overlapping seasonal demand regardless of location. This could work on a national or even international scale for instance if Swedish farms collaborate with farms in countries with opposite growing seasons.

However, trends such as the increasing use of catch crops in Sweden to improve soil carbon storage (The Federation of Swedish Farmers, 2025) may require increased use of the airship throughout the year, which could reduce the possibility of sharing airships between farms.

A model in which one or many companies own and lease out the entire airship service, including the aircraft, pilot, and necessary infrastructure, could offer operational advantages. This would resemble the forestry sector, where contractors are hired for multi-year service agreements and bring specialised expertise (Lindroos, 2025). Such a model may be especially beneficial given the regulatory complexity of operating airships in low-altitude airspace and the advanced skills required for piloting. Unless airships become fully autonomous and safety is ensured through automation, widespread diffusion would require a significant increase in the number of trained airship operators and pilot training facilities.

Leasing may also be favourable during the phases of technological development when there are rapid technical improvements of airships. Leasing enables users to access the most updated versions without bearing the full cost of ownership. Similar, the HTA UAV stakeholders think leasing is the suitable ownership model because of their rapid development (Tidström, 2025). However, the argument for leasing HTA UAV is also because the motor will wear out eventually, needing replacement. This is not the same for LTA as its buoyancy require less motor efficiency.

5.2.3 Scenarios

Scenario 1: ownership concentration; few actors own an airship, such as an airship company who provides it as a service to all farmers. Multifunctionality; the airship serving multiple purposes in agriculture and potentially serving purposes in other sectors as well.

Scenario 2: ownership distribution; many actors owning an airship such as every farmer, or a clusters of farmers, or many service companies, or a combination of all three. Multifunctionality; the airship serving multiple purposes in agriculture and potentially serving purposes in other sectors as well.

Scenario 3: ownership concentration; few actors own an airship, such as an airship company who provides it as a service to all farmers. Specialisation; the airship serving one specific purpose in agriculture.

Scenario 4: ownership distribution; many actors owning an airship such as every farmer, or a clusters of farmers, or many service companies, or a combination of all three. Specialisation; the airship serving one specific purpose in agriculture.

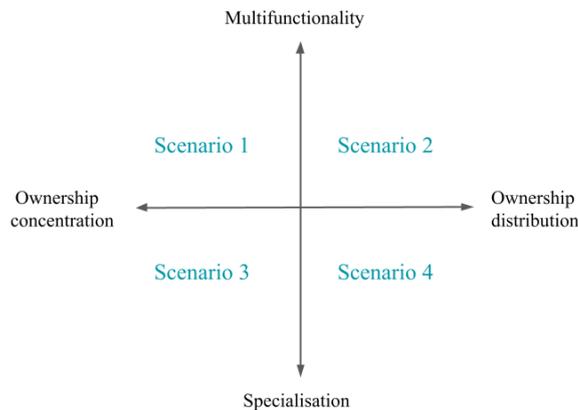


Figure 5.1: Showcasing the four different scenarios.

5.2.4 Scenario analysis

Considering scenario 1, farmers would find it easier to justify the investment, as the airship could potentially replace multiple pieces of agricultural equipment currently in use. Additionally, leasing the service would reduce the time farmers spend troubleshooting machinery failures. Another advantage is that farmers would only need to learn to operate the airship once, as the same platform would be applicable across various functions, thereby lowering the learning threshold for adoption. Furthermore, by leasing the service, operational responsibilities could be included, eliminating the need for farmers to recruit or train personnel for airship operation. The leasing company could take care of the risk analysis needed to operate the airship.

In scenario 2, the farmers would have an easier time accepting the business model since they traditionally own their equipment. The ownership model would also open up for opportunities for storing facilities nearer the location of use. Farmers would find it easier to justify the investment, as the airship could potentially replace multiple pieces of agricultural equipment currently in use. Another advantage is that farmers would only need to learn to operate the airship once, as the same platform would be applicable across various functions, thereby lowering the learning threshold for adoption. This scenario also opens up for increased collaboration between farmers which could yield other benefits.

For scenario 3, farmers would likely prefer leasing airships due to the possible need for multiple airship types throughout the year. Leasing would lower the financial threshold, as farmers would not be required to purchase each specific type of airship but could instead access services as needed. Given the diversity of airship designs, leasing companies would also provide operational support, addressing the specialised pilot skills required for different airship configurations as well as managing the regulatory knowledge necessary for each type. This arrangement would significantly reduce the need for farmers to recruit or train human capital, as both equipment

and skilled personnel would be supplied as part of the service package. As a result, this would have time-saving benefits for the farmers. The farmer's role would shift towards that of a project manager, overseeing the integration of airship services into farm operations. Furthermore, leasing companies could distribute airships across broader geographic areas, facilitating continuous utilisation throughout the year on different farms.

In scenario 4, it is plausible that either collaboration between farmers, in the form of national or international clustering would emerge as the preferred ownership model. Since collective ownership models require lower upfront investments compared to individual ownership, this type of ownership would be more feasible for farmers to access multiple airships to fulfill the variety of agricultural tasks, in contrast to individual ownership which also is a possibility for this scenario. Additionally, during the early stages of market development, concentrating on a specific application may serve to demonstrate the viability of airships in agricultural contexts. Such a strategy could stimulate market growth, potentially enabling widespread access to airships for all Swedish farms by 2050.

6

Drivers and barriers

This chapter covers identified key drivers and barriers for airship diffusion within Swedish agriculture. The analysis is structured around two overarching categories: capacity and willingness. By identifying both enabling and constraining factors, this chapter provides a foundation for understanding the systemic conditions that shape the potential integration of airships in agriculture.

6.1 Capacity

This section handles the capacity of airship implementation in Swedish agriculture, by highlighting key drivers and barriers.

6.1.1 Mobilisation of financial and human capital

Considering financial resource mobilisation, several actors within the airship sector highlighted the lack of available funding as a key barrier to technological development and market entry. Securing investment is particularly difficult, as many investors are risk-averse and reluctant to support unproven technologies. Moreover, airship development typically requires significant capital expenditures even before the first prototype is constructed. Many airships are large in size and require extensive infrastructure, including sizeable indoor facilities for assembly. The freight cost varies between different airships, for one type of airship estimated at 0.5 USD per tonne-kilometre, making them more expensive than sea, rail and road transports, but cheaper than operating on ice roads and other aircraft (Prentice and Lau, 2016). For the agricultural sector, most individual farmers lack the financial capacity to invest in innovative technologies, with the possible exception of very large-scale agricultural enterprises. This limited access to financial resources among potential end-users further complicates market formation and may hinder airship diffusion in agriculture.

There appears to be no additional technical knowledge development required for the implementation of airships, actors mean that the technology itself is not new and has been proven to work. However, some interviewees expressed that there is a resource shortage in human capital, such as lack of education for airship pilots. Some actors say that educations for airship pilots already exists. For instance, Zeppelin NT, an established airship company with several years of operations experience, expressed interest in sharing their expertise to others and collaborating with other

companies on engineering, crew training and pilot training (Schäufele, 2025). This is an example of creation of positive externalities, which can act as a driver for airship diffusion.

6.1.2 Material resource mobilisation

A few critical components of an airship were highlighted during the interviews. Large airships seem to be of main interest by the airship companies and the size and cost of the hangar door is a critical component. These doors account for about half of the price of a hangar (Prentice, 2025). The airship envelope is another critical component. There are very few companies manufacturing these envelopes and they are currently handmade. The price of the envelopes make up about a third of the production cost (Boyd, 2025), contributing significantly to an airship’s overall production cost.

Helium, which is a key component used in the envelope, is expensive and requires continuous supply since the envelopes leak 1% to 10% helium annually, as they age (Prentice, 2025). Helium supply may represent a potential barrier to the diffusion of airships. While Boyd (2025) argued that helium is not a critical concern and that companies from the helium sector means that extraction could be scaled up if demand increases, other interviewees identified helium availability as a significant risk. On a global scale, helium shortages have raised concerns about long-term supply stability as the supply of helium is finite (Mahesh and Barker, 2016). Helium is an essential resource in several industries, including medical imaging, where MRI machines rely on helium for cooling, as well as in emerging sectors such as high-performance computing and data centres (Schäufele, 2025; Das and Molki, 2023; Luo et al., 2025; Mahesh and Barker, 2016). Although alternative cooling technologies are being explored in the medical sector (Luo et al., 2025), the growing demand for helium across industries may still constrain its availability for airship applications. This competition over a finite resource could pose a long-term challenge to the viability and scalability of helium-based airship technologies.

One alternative to using helium in airships is using hydrogen, which is a lighter gas compared to helium, thus creating a higher buoyancy. The public perception of hydrogen is that it is dangerous, which is partly due to some accidents regarding airships that used hydrogen (Prentice, 2025). This perception was also mentioned by some interviewees. Other interviewees said that this perception is a misconception and that hydrogen is less flammable than people think, which also can be found in literature (Carcassi and Fineschi, 2005). Almost all airship companies use helium and this choice is largely due to helium’s non-flammable properties, as well as historical regulatory bans on hydrogen. However, this restriction has recently been lifted within Europe. In the European Union Aviation Safety Agency’s (EASA) consultation case “Special Condition Gas Airships”, the regulation now states: “If the lifting gas is toxic, irritant or flammable, adequate measures must be taken in design and operation to ensure the safety of the occupants and people on the ground in all envisaged ground and flight conditions including emergency conditions” (European

Union Aviation Safety Agency (EASA), 2022). The shift from hydrogen being a prohibited to a conditionally accepted lifting gas could act as a driver for the diffusion of airships.

Some technical details regarding helium and hydrogen were also discussed. Helium must be transported from extraction sites, and there are differing views on whether these are limited to a few locations or can be scaled up. In addition, the transportation of helium causes losses on the way (Prentice, 2025). A technical risk identified regarding hydrogen was long-term exposure, with uncertainties about how hydrogen leakage might affect other materials in the airship over time (Schäufele, 2025). For example, hydrogen has the ability to embrittle metals (Rigas and Amyotte, 2013). Schäufele (2025) also noted that leaked hydrogen might collect over time in cavities, hollow tubes and sandwich core materials. This could create small local volumes with combustible hydrogen-air-mixtures, which are very difficult to vent, detect or flush with inert gases. There would be an inherent danger of small local explosions or fires due to local static electric discharges in the presence of such unvented volumes. According to Prentice (2025), it is possible to detect hydrogen leakage much earlier compared to the period when most airships were operational, and take suitable measures to ensure safety. This is due to “hydrogen sniffers” that can detect parts per million of hydrogen leaks. Hydrogen will not ignite at less than 4 parts per hundred. This indicates that hydrogen can be detected earlier than before, however there is a risk that small local volumes accumulate in certain parts of the airship. In contrast to the technical barriers, hydrogen also offers a potential advantage that according to one interviewee many companies are looking into (Prentice, 2025). Hydrogen fuel cells could be used to power electric propulsion systems, and in the event of a leak or rupture in the envelope, hydrogen from the fuel tank could be redirected, which is not possible when using helium. This could be especially beneficial when operating in remote areas.

Further contrasting views was found regarding the cost linked with hydrogen and helium. Hydrogen is significantly less expensive than helium, which was of consensus. One of the reasons to that helium is more expensive is the storage and transportation of helium, where it needs to be stored in liquid form and transported from the extraction place. Hydrogen on the other hand could be manufactured anywhere, which reduces transportation costs. The cost of hydrogen is likely less than one hundredth the cost of helium (Prentice, 2025). Others noted that the buoyant gas does not make up for a large part of the total production cost of the airship, less than 1% of the total cost (Boyd, 2025). Another cost discussed were the cost of fire detection. One interviewee argued that the cost of the fire detection system would eliminate the cost advantage of using hydrogen (Boyd, 2025), while another argued that this could be done through hydrogen sniffers which are inexpensive (Prentice, 2025). Also, at the time of the interviews, insurance of an airship using hydrogen would be expensive, even if the airship was type certified (Boyd, 2025). This shows misalignment and debating views in the airship sector, which could hinder development of positive externalities.

6.2 Willingness

This section describes the willingness to implement airships in Swedish agriculture, highlighting key barriers and drivers. These are related to the overall legitimacy of airship technology, the legitimacy of airships in the agricultural sector, and collaboration within and across technical fields.

6.2.1 Legitimation of airships overall

One significant barrier to the general diffusion of airships, both generally and within agriculture, is the lack of public awareness. As noted by Schäufele (2025), very few people are even aware that airships still exist. All companies interviewed emphasised the need for greater exposure and public understanding of LTA technology in order to build trust and recognition among potential users. Increasing cognitive legitimacy is essential to ensure that stakeholders perceive airships as a viable and functional technology. Demonstration projects play a critical role in this process. For example, one interviewed company expects to have its prototype airborne by 2026, and increased visibility of existing airships such as the Zeppelin could further strengthen public awareness and support the normalisation of airships as a modern transport solution.

One driver for general airship diffusion is the presence of public incentives and governmental support for airship-related projects. For instance, the company Flying Whales has received support from the French Government. Another example is the MAAT project, which was funded by the European Union to explore advanced airship technologies (European Commission, 2024). Such initiatives indicate a growing level of legitimacy for the technology, which can contribute to accelerating its diffusion.

Another potential driver for the general diffusion of airship technology is the increasing societal awareness and political emphasis on climate change. According to Bergek et al. (2008a), the relative importance of specific legitimation arguments can vary depending on the dominant societal problem agenda. In the current regime, airplanes with jet engines dominate airborne transportation, offering speed and reliability but also contributing significantly to greenhouse gas emissions (Prentice, 2025). In contrast, airships present a potentially more environmentally friendly alternative compared to airplanes that uses jet engines. The airships have lower fuel consumption, and they also have the possibility to carry large fuel tanks of hydrogen without impinging on the space for cargo or passengers. Consequently, they can be powered hydrogen-electric with zero carbon emissions during operational flight. This environmental potential aligns with national policy objectives such as the Swedish Government's food strategy, which emphasises the need for a more sustainable agricultural sector (The Swedish Government, 2025). However, despite this alignment, airships have yet to be widely recognised by environmental actors as a green innovation. As noted by Prentice (2025), environmental organisations have not actively promoted airships as part of the solution to climate-related challenges.

Increasing awareness among these stakeholders could therefore play a key role in building normative legitimacy of airships and accelerating diffusion.

6.2.2 Legitimation of airships in the agricultural sector

The legitimation of airships within agriculture was assessed through interview questions regarding stakeholders' perceptions of using airships in agricultural applications. The responses were mixed: while some expressed scepticism, others viewed airships as a promising innovation or an exciting possibility. These mixed reactions are consistent with what airship companies typically encounter when presenting their technology. One airship company reported receiving very positive reactions when their airships are seen in flight (Schäufele, 2025), while another noted that people generally respond favourably, describing airships as both visually appealing and quieter than helicopters (Fitton, 2025). Notably, all stakeholders from the agricultural sector reported farmers as having a generally positive attitude towards new technology. Though for some farmers, the tractor holds symbolic and emotional value, as they enjoy operating it, which may pose a barrier to replacing it with new technology. Nevertheless, the overall positive or neutral public perception may facilitate the diffusion of airships within agriculture.

Another barrier for airship diffusion within the agricultural sector concerns conflicting business model preferences. In Sweden, by tradition farmers own the majority of their equipment and when asked, the farmers said that ownership is preferred as it ensures the equipment is available when needed. As a result, much time is spent for farmers to carry out maintenance and repairs themselves and that the increasing complexity and digitalisation of agricultural machinery require the farmers to spend more time troubleshooting software and system components. This reduces the time available for traditional agricultural tasks. Interviewees from the airship sector described alternative business models, such as offering airships as a service or selling the airship while retaining responsibility for maintenance and support. This is also described as an alternative configuration in scenario one and scenario three, as seen in section 5.2. This has the potential to reduce the time spent maintaining the equipment, possibly yielding benefits in the form of time management for farmers. Though, business models such as "software as a service" have had little success in the Swedish agricultural market. This indicates a difference in business model preferences which could hinder the diffusion of airships.

6.2.3 Collaboration within and across technical fields

The number of actors involved in developing and supporting a new technology, as well as the level of trust among them, plays a critical role in development of positive externalities. According to Bergek et al. (2008), forming "packs of entrepreneurs" can strengthen system functionality and help influence institutional change. However, such collaboration requires a sufficient density of actors operating within the market space. From the interviews it was found that cooperation and trust among airship companies are currently low. This is partly because airship companies do

not want to share their knowledge in fear of other companies advancing and getting a head start over them. In other cases, companies disagreed on the fundamental purpose or design of the airship, making collaboration difficult. One interviewee suggested that the market's instability further undermines cooperation, as actors hesitate to engage with companies whose long-term survival is uncertain. These findings point to a low level of inter-firm trust, which may hinder the legitimization, and thereby, diffusion of the airship technology.

However, “packs” do not necessarily have to consist solely of actors within the same sector. Cognitive relatedness, such as the perception that different technologies are connected, can facilitate collaboration across adjacent technological domains. In this case, connections were observed between the airship sector and HTA drones. These Unmanned Aerial Vehicles (UAV) related technologies appear to be gaining increasing legitimacy, supported by cross-sector collaboration involving research institutions, industry actors, and regulatory frameworks. This cognitive alignment may provide a pathway for airship actors to benefit from the momentum and legitimacy of related innovation systems.

Airships have the possibility to be designed as UAVs, though only one of the airship companies interviewed is currently considering UAV integration. The broader airborne technology market in agriculture is increasingly moving towards drone-based solutions. According to (Tidström, 2025), the agricultural sector can save billions of SEK by reducing its dependency on ground-based operations. These savings stem from several factors: less arable land is lost to driving lanes, the risk of transmitting diseases between fields is lowered, and pesticide use can be optimised by applying them precisely when needed rather than when conditions allow for tractors to drive on the farmland. When agricultural stakeholders were asked about aerial operations, some respondents had already experimented with airborne technologies for monitoring or spraying purposes. In Sweden, companies are currently developing HTA drones for such applications. In Västervik, Sweden, there is a dedicated drone centre which was established in collaboration with RISE Research Institutes of Sweden AB (RISE) (Sivertun, 2025). This drone centre is actively supporting both technological development and regulatory alignment. Given that HTA UAVs are already being developed for agricultural applications, leveraging these advancements in the development of airships could act as a driver for their diffusion within the agricultural sector.

Another big concern in agriculture is labour supply where interviewees noted the difficulty of finding and affording skilled staff. The demand for reduced human labour in agriculture further reinforces the potential for UAVs. UAVs offer several technical and regulatory advantages: most notably, they enhance safety by eliminating the need for onboard personnel, which simplifies compliance with regulations for vehicles operating below 150 meters (Prentice, 2025; Krusell, 2025). From a technical perspective, removing the pilot also eliminates the need to adjust buoyancy for human weight, making the system more energy-efficient and easier to operate.

There are also efforts being made to transition into more precision-based agriculture for increased resource-efficiency. The precision of airship positioning depends on energy consumption as greater precision requires more energy usage due to the need to counteract wind gusts and maintain stability. There are mixed perceptions regarding how precisely an airship can be manoeuvred. Answers were ranging from hundreds of meters to some actors claiming centimetre-level precision is achievable, whereas others believe this is impossible.

6.2.4 Policy & regulations

Insights from the interviews revealed that stakeholders in the agricultural sector experimenting with HTA drones believe that existing regulations need to be adapted to better support agricultural applications. This referred to both chemical regulations and aviation rules. According to the Swedish Transport Agency, current regulations do permit aerial operations in agriculture, including the use of drones and UAVs, regardless of whether they rely on LTA or HTA technology (Krusell, 2025). However, Krusell also mentioned that the rules could be difficult to interpret, and efforts are being made to improve clarity. Ultimately, operational approval depends on a risk assessment of each individual scenario. They emphasised that most cases are unique, and thus requires a tailored risk evaluation. To address this, the Specific Operations Risk Assessment (SORA) handbook is currently being updated to be easier to interpret. An easier interpretation of the regulations could ease the implementation of airships and thereby act as a driver for airship diffusion.

Considering operating altitude, agricultural stakeholders has mentioned that some agricultural tasks, such as pesticide spraying, require lifts to be only a few meters from the ground to comply with chemical regulations (Tidström, 2025). In contrast, airship companies reported plans to operate at higher altitudes, often 600 meters or more. As previously discussed in the section on technical attributes, this is not due to technical constraints, but rather strategic decisions based on their targeted market applications. This difference in intended height from the agricultural and airship sector may hinder the diffusion for airships in some agricultural applications. Regulatory constraints may also pose challenges here. According to the Swedish Transport Agency, manned aircraft are not allowed to operate below 150 meters above ground unless special permits are granted (Krusell, 2025). Most airship designs currently include an onboard pilot. The reason for this could be because they plan to operate higher than 150 meters above ground. This regulatory requirement could present a barrier to some use cases for airships in agriculture, where low-altitude operations are necessary.

7

Implications for policy

The TIS analysis complemented with socio-technical scenario analysis can be used to identify policy issues and recommendations (Bergek et al., 2008b; Konrad and Böhle, 2019). This section is divided into policy implications directed towards the capacity and willingness for airship diffusion in Swedish agriculture.

7.1 Policies directed towards capacity

Increased financial capital is necessary for airships to diffuse. The airship market is in an early stage of market development and requires more research, development, demonstration and spreading on niche markets. During this stage, certain production components remain costly due to limited economies of scale, and for some agricultural applications mentioned, the airships need to be adapted for enabling use within current institutions. Public sector investment may play a critical role in this context, as governments are often seen as stable and credible actors capable of reducing market uncertainty.

Since airship technology is an emerging technology, the companies all identified difficulties in finding investors who are willing to invest in this early stage of market development. It was identified that there is a big investment step before airships can operate due to the extensive infrastructure surrounding airships manufacturing. To address this, a reliable investor that has both financial resources and the possibility to invest for a long term return could step in. A typical example of this type of institutional investor is the government (Pereira and Andraz, 2005). Governmental financial incentives could enable a public-private relationship together with private investors that ensures support for airships. Flying Whales already has support from the French government and as a result they are also one of the leading airship companies. Flying Whales' aim is to have their first airships flying by 2026 (West, 2023), indicating that governmental support represents an appropriate policy pathway. In addition, governmental support will help increase the legitimacy of the technology.

Furthermore, in order for airships to become affordable for farmers, measures must be taken to reduce production costs. Several components currently used in airships remain expensive due to their limited use in other industries. For instance, the market for producing airship envelopes is relatively small, and production is largely manual, which contributes to the envelope accounting for approximately one-third of the total manufacturing cost. Industrialising the production of key components

has the potential to lower material costs and thereby reduce the overall price of airships. However, the investments required to enable such industrialisation are substantial and necessitate the involvement of a reliable investor to ensure long-term commitment and risk mitigation. This support could be provided either by allocating funding directly to the production of critical components or by stimulating demand for airships. Government involvement is particularly important in this context, as it can reduce investment risks for other actors, support industrial scaling by allocating targeted funding, and foster legitimacy for emerging technologies through early and large-scale procurement.

Airships also need to be adapted towards agriculture. This can be done by developing complementary technology that would enable airships to be used within current institutions. In order to be able to use airships for various agricultural applications, further resource mobilisation is needed. This includes financial resources, human resources and possibly complementary assets. One example of an area that requires further development for airships to become a realistic option is the spraying of pesticides. This requires lifting pesticide tanks while simultaneously spraying close to the crops in order to comply with regulations. Since most airships at current technological state prefer to operate at altitudes above 150 meters, an idea is to develop long spray nozzles in order to spray close to the ground. Allocating specific innovation funds towards developing complementary technology for airships would solve this issue.

7.2 Policies directed towards willingness

One barrier to airship diffusion is the lack of legitimation. Actors do not know airships exist or deem the technology too uncertain. Knowledge diffusion is therefore of importance in order to increase visibility and changing the perspectives of airship technology. To address these challenges, more pilot- and demonstration projects could be implemented. These pilot- and demonstration projects should target different stakeholder groups. Examples of such stakeholders are farmers and operators. In addition, supporting actors such as environmentalists has yet to recognise airships as a potential "green technology" even though it can have benefits with reduced energy use and the potential to reduce fossil-fuel dependency. The pilot- and demonstration projects could therefore also target supporting actors whose action can have a positive side-effect on legitimacy by recognising and advocating airships potential benefits. A potential policy measure could involve allocating financial subsidies to facilitate the development and execution of pilot- and demonstration projects.

Another important barrier for the expansion of knowledge is the need for collaboration. It was identified that four different collaborations are needed; producers to producers, HTA to LTA, regulatory authorities to regulatory authorities and lastly, nations to nations. These collaborations can be centralised to one location in Sweden. As there already is an established test centre for HTA drones in Sweden, this could be utilised. Whether the test centre for LTA is integrated into an existing one for HTA drones, or if a new one is created specifically for LTA, these test centres can

serve as a collaboration and knowledge centre. These test centres could also provide a space for regulators to align policies to enable different market configurations for LTA technology, specifically targeting Sweden. Furthermore, this test centre could be an intervention point between different nations, aligning international interests, creating international alliances and enabling collaboration among all producers.

The first collaboration, producers to producers, is recommended due to observations that several companies had negative views about competitors, often asserting that their own designs were superior while dismissing others. This competitive posture has seemingly prevented cooperative efforts to collectively promote the technology, including initiatives to standardise education and training. Rather than viewing each other as primary competitors, airship companies might benefit from collaborating to address the larger challenge posed by HTA technologies, which currently dominate the market. Though it already exist a network of airship enthusiasts (The Airship Association, n.d b), there is a need for a network that promotes more collaboration between airship producers as it currently is insufficient. By collaborating producer to producer, the focus can be to gain market shares from HTA and other similar technologies, increasing the technology's legitimacy.

The second collaboration, HTA to LTA, is based on the fact that HTA drones was identified as a potential bridging technology since HTA has a cognitive relatedness that could help the diffusion of the airship sector. Test centres for HTA drones already exist in Sweden (Drone Center Sweden, n.d), and airships could utilise these test centres for expansion of knowledge and skills. Developing methods for spraying crops or lifting products in agriculture, as well as exploring possibilities to act complementary to HTA drones, could help the implementation of airships in agriculture. In addition, these test centres create natural sites for dialogues, collaborations and knowledge exchange between parties, either being producers to producers or HTA to LTA, such as having sites for pilot educations or develop frameworks for operating licenses for airborne agricultural methods. Leveraging existing HTA drone test centres for LTA airships will require targeted governmental support to expand and adapt current infrastructure.

The third collaboration, regulatory authorities to regulatory authorities, is based on the fact that the agricultural sector already interacts with numerous regulatory authorities. Regulations concerning airspace and operational requirements as well as other regulatory areas, such as chemical use, influence agricultural practices and pose as a barrier for airship diffusion in agriculture. For airships to achieve wider diffusion, enhanced collaboration between these various authorities will be essential. This is particularly important since existing regulations conflict with one another and create barriers to the integration of airships. In addition, with enhanced collaboration airship companies will need to use less resources for promoting adapted regulations, enabling both financial and human resources to focus on other areas.

The forth collaboration, nations to nations, comes from the fact that one possible scenario that would enable airship diffusion is if they were used by farms with

non-overlapping seasonal demand. A natural path for this would be for nations to collaborate with each other as they would serve as reliable institutions, enabling these collaboration to exist even if farmers entry and exist the market. While there exists agricultural collaborations across nation borders, such as the EU, one approach for Sweden could be to collaborate with countries on the southern hemisphere to ensure complementary seasons. In addition, the nation partners can share the investment costs done by the state in order to reduce the investment risk. Moreover, these nation to nation collaborations can also be suitable when considering airships for other sectors than the agricultural sector. For example, France is planning on using airships in the forestry industry (Zhou and Renaud, 2022), which also is an important sector for Sweden. Notably, Sweden and France have different conditions for the forestry industry. France has more forestry on terrain with higher incline compared to Sweden, (Lundbäck et al., 2020) making it more difficult to use traditional machinery for France (Lindroos, 2025). Even though this need is less in Sweden, there could be other potential benefits using airships in forestry, as well as other possible benefits collaborating with other countries and thereby expanding the knowledge base to Sweden as well. All together creating the necessity for an international test centre based in Sweden.

8

Discussion

This chapter synthesises the findings of the study by reflecting on the identified trends, potential market configurations, and the drivers and barriers influencing the diffusion of airships in Swedish agriculture. The discussion offers critical reflections as well as limitations and suggestions for further research.

8.1 Trends

Firstly, trends regarding the interest of airships were examined. According to the bibliometric analysis, documents related to airships were published more frequently relative to other subjects between 1910 and 1940 than after 1940. However, a relatively slow trend of increasing interest in airships was observed starting from the 1970s. While more documents are published today regarding airships, the subject is still relatively unpopular compared to early 1900s. The increase of published articles indicates a rising academic interest regarding airship technology.

Secondly, technological trends in the airship sector were identified. One handled the type of lifting gas used, where helium often was the preferred gas but recent changes to regulations could change preferences. Another trend referred to the ability to lift heavy cargo, where most airships are designed to lift significantly heavier loads than typically required for agricultural applications. Moreover, many current airship designs are optimised for other use cases than required in agriculture, resulting in technical attributes that do not fully align with the specific needs and preferences of stakeholders in the Swedish agricultural sector.

Thirdly, trends regarding Swedish agriculture were identified. One major trend was the need to increase productivity. In addition, agriculture is moving towards more precision agriculture, whether that being sowing, spraying pesticides or distributing fertiliser. The reason for this is resource efficiency and efforts to reduce environmental impact without compromising productivity. Another trend identified was the increased interest of unmanned vehicles as labour supply is declining in agriculture. Rather than a trend, ownership appears to be a stable norm within Swedish agriculture, where farmers typically prefer to own their equipment.

8.2 Market configurations

There are different possible market configurations for LTA technology in the Swedish agriculture. One application for airships within agriculture include lifting objects which can reduce soil compaction and decrease the transmission of diseases between fields. In addition, airships could potentially reduce the amount of driving lanes on the field which would increase available land and thereby increase productivity. Airships can also be used to transport machinery which would eliminate constrains of road limitations. Transport of products is also an application where airships can be useful. These products include perishable food items and products with time-critical shipping such as animal semen and spare parts to machinery. In addition, transporting products to places with limited infrastructure, no matter if they need to be transported relatively fast or slow, is also a relevant application. Another application for airships could be to spray pesticides. While there is some alignment with the attributes of an airship, such as an aspiration to be able lift heavy pesticides tanks, there are also a few challenges. Most notably, speed and high precision is of the essence. Lastly, monitoring is another potential application, where airships can contribute by hovering without using excessive energy. Four different alternative sociotechnical configurations were explored, giving insights in how airship implementation could look like if airships were to be diffused in Swedish agriculture. These configurations focused on the amount of tasks one airship could execute and different types of business models.

8.3 Drivers & barriers

The drivers and barriers are analysed through the capacity and willingness to implement airship within agriculture. More barriers than drivers were identified. Considering airship implementation within Swedish agriculture, there seems to be a number of barriers. Firstly, the airship sector needs more financial investments for it to diffuse. Secondly, some components, such as the envelope, are expensive due to small-scale production. The manufacturing of an airship requires a large financial investment in facilities before production can begin. Regarding willingness and allowance, one significant barrier was the lack of public awareness. Furthermore, the current lack of cooperation between airship companies could pose as a barrier for its diffusion.

Regarding food transport, it was suggested that the shipment of perishable goods may offer greater economic viability due to their generally higher market value. However, the production of perishable food currently represents only a small segment of Swedish agriculture and existing lower-cost transportation methods are adequate to meet the required delivery times of current agricultural products. This points to that transportation of perishable food is not an option that is fitting for the Swedish market.

Regarding drivers identified, one airship company expressed interest in sharing their

expertise to others and collaborating with other companies on engineering, crew training and pilot training. There has also been a change in regulations, where hydrogen that earlier was a restricted gas now is allowed to use. The shift from hydrogen being a prohibited to a conditionally accepted lifting gas could act as a driver for the diffusion of airships. Public investments and increased interest in climate change could further driver the diffusion of airships. In addition, farmers generally have a positive attitude towards new technology.

A misalignment in expectations between airship companies and agricultural stakeholders has been identified as a potential barrier to implementation. Such differences were found regarding operating height, where agricultural stakeholders meant that there is a need for low flying vehicles for some applications, while airship companies are developing the airships to fly at higher altitudes. Also, mentioned legislations serve as a barrier for operating on low altitude with a pilot. For it to be viable to use airships for these purposes, the airship design needs to be adapted to the use cases, which would require increased knowledge development within these areas. On the other hand, some suggested applications for airships is possible to do with the currently intended operating altitude for the airship. These areas could be monitoring, transportation of products and remote 5G. In addition, the airship companies focused on markets with heavy lifts that needed hovering over the same place for a longer time. The potential users also had ideas that focused on airships ability to stay afloat for a long time while not using a lot of excess energy. However, the applications the intended end users mentioned had a significant difference in required lifting weight, with airship companies targeting significantly heavier lift than what was mentioned by the potential users.

8.4 Insights & reflections

One significant finding was that there were more barriers than drivers for airship diffusion within the agricultural sector. In general, these findings point to that agriculture may not be the most fitting sector for airship implementation in Sweden. However, as airships were a new idea for most stakeholders, the lack of drivers found might come from the fact that they never thought of using airships before. Several interviewees indicated that certain tasks, particularly those involving direct soil manipulation, would likely remain impractical to perform exclusively from the air. This perceived limitation may partly reflect cognitive path dependency. Since airships represent a radical innovation within agriculture, there is a tendency to assess their potential within the constraints of existing paradigms. Interestingly, when a similar question was posed to a researcher within agriculture, they proposed solutions for soil processing that could, in theory, be executed from the air. This suggests that with innovative thinking, even seemingly unrealistic processes might become reality.

In addition it was found that Sweden may not be the first country where airships for agricultural purposes become established. One key barrier is the different prevailing ownership models between farmers and airship manufacturers, which suggest that diffusion may be more feasible in countries where leasing is more widely accepted

by farmers. Additionally, the market research regarding the transport of perishable food products has not focused on Sweden. Instead, these studies have primarily targeted markets with more production of perishable food, suggesting once again that other markets are easier to enter than the Swedish one.

Moreover, one possibility could be to transition to fully aerial agricultural systems. This has potential benefits such as reduced soil compaction and increased productivity. Such a transformation would require a fundamental transformation of all processes within the sector. Although such a systemic shift is not inherently negative, it presents significant challenges due to the deeply rooted nature of existing systems and the extensive adaptations required for equipment and workflows. Notably, stakeholders within agriculture found the feasibility of transitioning to fully aerial agricultural systems very unlikely. A more pragmatic approach would be to integrate airship technologies into the current agricultural system gradually. This would allow for a stepwise replacement of existing equipment and practices over time, where this is deemed beneficial, in order for airships to be part of the agricultural sector.

Although the culture in Swedish agriculture is to own the equipment, having a leasing system could offer significant time-saving benefits, something that is of critical importance for many farmers. A leasing company could also manage responsibilities such as risk assessments, licensing, and staffing, thereby lowering the threshold for adoption and simplifying integration into existing farm operations. However, the leasing companies needs to make sure the airships are available to perform its tasks when needed. This is particularly important given that farmers located in close proximity typically require access to the same type of equipment during the same periods.

Since legitimization and financial capital were identified as key barriers to airship diffusion, it would be appropriate for a leasing company to retain ownership of the airships. Purchasing an airship would represent a substantial investment, which farmers may be reluctant to make due to both financial constraints and the current low legitimacy of the technology. Leasing offers a lower-risk opportunity to test the technology without committing to full ownership.

While multifunctionality could increase profitability through cross-sector use, specialisation is considered more likely to lead to a successful outcome. Despite the identification of several potential application areas, agricultural stakeholders expressed scepticism toward solutions that attempt to address multiple agricultural challenges simultaneously. Airship companies also emphasised that airships are typically designed for specialised purposes. This aligns with the broader trend of precision farming, which favours highly specialised equipment tailored to specific tasks.

Based on identified trends, market configurations as well as drivers and barriers, scenario 3 seems to be most likely for successful diffusion of airships in the agricultural sector. In this scenario, leasing the airship appears to affect farmers by

reducing the need for human capital, saving time, and shifting their role toward that of project managers.

8.5 Policy instruments

Two categories of policy interventions were identified for supporting the diffusion of airships technology in agriculture. These handled policies directed towards capacity and willingness.

Policy interventions directed towards capacity focused on the necessity of increasing financial capital to enable airship diffusion. Governments are often seen as stable and credible actors, capable of reducing market uncertainty. Therefore, policies increasing financial capital, such as public investment and allocating funds that are specific for airships are deemed as relevant policy interventions. Governmental support will also increase legitimacy and thereby contribute further to the diffusion of airship technology. This would help developing the airship market in areas such as reducing the production cost by industrialising production, and to adapt the technology to agricultural needs, as well as further strengthening the legitimacy and thereby increase the likelihood of finding private investors.

Regarding willingness, targeted policies could foster increased legitimation and collaboration between stakeholders. Regarding legitimacy, one key barrier was found to be that actors do not know airships exist or deem the technology too uncertain. Another central issue was the lack of collaboration among airship companies, which at times appear to be working against one another instead of aligning to compete with more dominant technologies such as HTA aircraft. Strengthening cooperation within the airship sector could help coordinate innovation efforts and create a unified front. Similarly, airships may benefit from HTA drones being positioned as a bridging technology, particularly in light of the growing legitimacy of HTA drones. Furthermore, collaboration between regulatory authorities was seen as essential to develop regulations that accommodate air-based agricultural practices, thereby supporting the diffusion of airships. Another possible collaboration was the one between nations to nations, which could reduce the investment risk. It could also enable airships to be used more effectively since they could be used during complementary seasons in the case of a specialisation of airship usage, as well as allowing collaborations in other sectors that could use airship. To increase the legitimacy and collaboration between various stakeholders, financial subsidies could target pilot- and demonstration projects. Furthermore, a test centre could be established, either to be integrated with the HTA-drone test centre that already exist in Sweden, or a new one specifically focused on LTA technology could be created.

8.6 Limitations

The study involves a number of limitations. Most farmers have difficulties securing enough money to make investments in new technology. Therefore, the possibility

for airships to diffuse within agriculture relies heavily on the cost of airships. It was identified that airships are expensive, but it was difficult obtaining sufficient data on the production or operational cost of airships. Most airship companies are not yet producing airships and are not targeting agriculture, making it even more difficult to obtain data regarding cost. Given that this is an emerging system, cost estimation at this stage is challenging. Therefore, the limitation regarding cost estimation could affect the result of the study, as there are limited financial resources in both the agricultural and the airship sector.

Likewise, as many of the companies are start-ups and have projects that have not yet been realised, some mentioned characteristics of airships have not been proven. An example is the claim that LTA technology is environmentally friendly compared to other aircrafts. While the operating of the airship has the potential to be very environmentally friendly, it is not certain to what extent this is actually the case for different designs and different applications. In our understanding, no assessment has been made considering the environmental impact of the components of an airship. However, one company interviewed has been operating airships for many years, which increases the reliability for some claims of the characteristics of an airship.

The study included all forms of Swedish agriculture, but these varies widely in what they do and their geographical location. Hence, the specific needs of individual potential customers could be overlooked. The study is using a holistic perspective to understand the main barriers and drivers for airship diffusion in Sweden. While a holistic perspective is useful to understand the full picture, there is also a risk of missing important details. However, some applications appear in most cases of agriculture, such as heavy lifting, monitoring and transportation of products.

The study intentionally did not decide upon a specific design of airship, since the aim was to understand needs and use cases of airships within agriculture without being limited to a specific design. While this is less limiting, it can also be difficult for the interviewees to understand the airship technology and its potential applications. There is a risk that the interviewees instead were influenced by technologies that are more familiar to them. For example, since HTA drones is an emerging trend in agriculture, it is possible that some potential applications were mentioned because this is intended use cases for HTA in agriculture.

When conducting foresight research, it is often essential to map the entire system in order to generate actionable insights. One common approach is to identify and map all relevant stakeholders within the system. In this study, a key strategy was to conclude each interview by asking participants whom they would recommend for subsequent interviews. The underlying assumption was that if multiple respondents mentioned the same individuals or organisations, these actors could be considered key stakeholders. However, the scope of the research was too limited for this method to fully reveal such central actors. Although some interviewees did suggest the same individuals, the research initially built upon contacts provided by a single informant who had already engaged with several relevant stakeholders. As a result, it was

unsurprising that certain names recurred. Moreover, because the majority of interviewees were selected based on recommendations, it is likely that some important stakeholders were overlooked. The relatively small interview pool may also have contributed to a certain homogeneity of perspectives, as participants were likely to be acquainted with one another and to share similar views. Nevertheless, efforts were made to expand the range of perspectives by identifying additional interviewees through brainstorming exercises. These steps aimed to mitigate potential sampling bias and to ensure broader representation within the stakeholder mapping process.

8.7 Further research

Climate change will probably require changes in many sectors. There has been much research on how to make agriculture more sustainable, as well as research on utilising airships for transporting agricultural products. This report contributes to a radical approach of exploring solutions to sustainability issues in Sweden, by examining the combination of airships within agriculture. No report to the authors knowledge have focused on potential for airships within the Swedish agricultural sector.

Some areas for further research were identified. Firstly, there is a need to investigate the environmental impact of airships, therefore further research could focus on environmental assessments of airships and how this varies with different design alternatives. The assessments could focus on several areas. One area could be related to the components of the airship during different stages of the lifecycle. Some of the components are very specific to airships, such as the envelope which is very durable and strong. For this, life cycle assessments (LCA) could be conducted and circular strategies for the end-of-use phase could be explored. Another area that is of relevance is environmental impact when operating an airship. For example, the impact of noise pollution from airship could be explored and what effects this has on biodiversity within the agricultural sector.

The study did not focus on specific design alternatives, since choosing a specific design were deemed limiting when discussing potential applications. Therefore, the next step would be to understand what designs fits the different applications best. This is especially interesting since we found that the choice between designs specialised on one task and designs with multifunctional capabilities could be of vital importance for system shaping.

Furthermore, more research can be done on the relationship between HTA drones and LTA technology since HTA drones were identified as a bridging technology to airships. This further research could study how these two technologies could work complementary or in which cases HTA drones are more suited than airships and vice versa.

This report outlined four scenarios of airship implementation in Swedish agriculture. These scenarios aimed to provide an initial understanding of different configurations and which of them may best support the diffusion of airships. The likelihood

of these scenarios depends on many factors, such as potential policies that favours or oppose airships. Since it is impossible to know what will happen in the future, some educated guessing was made when conducting the scenarios. Two suggestions of future research regarding scenarios is suggested. Firstly, the outlined scenarios from this study could be further investigated to understand benefits and drawbacks with the different possible configurations, as well as which of the scenarios that is more likely to enable airship diffusion. Secondly, analysing the potential of airship diffusion from other scenarios would further develop knowledge of the TIS.

9

Conclusion

This report represents one step toward understanding a possible transition from ground-based to airborne agriculture in a world where technological change is accelerating. The study identified an increased trend regarding interest in lighter-than-air technology. The research has also shown that different stakeholders have different views of applications of LTA technology in the Swedish agricultural sector. The producers had ideas on heavy lifts and transportation of products for agricultural purposes, and they focused on operating at altitudes above 150 meters. The consumer's ideas consisted mostly of applications that are closer to the ground such as spraying pesticides, lifting fertilisation and pesticide tanks or lifting seed bags. Drivers and barriers were identified regarding the capacity and willingness of society. It was identified that there are more barriers than drivers for airship implementation in the Swedish agricultural sector. However, some policies could be implemented in order to minimise the barriers, targeting the capacity and the willingness in society. The report highlights multifunctionality versus specialisation and ownership concentration versus distribution as two important dimensions when discussing possible future system configurations. These scenarios showcase futures where airships are part of the agricultural sector even though current actors find it difficult to recognise the opportunity. Considerably more work will need to be done to determine the effects airships can have on the Swedish agricultural sector and whether it is feasible and desirable.

Bibliography

- Andersson, J., Hojcková, K., & Sandén, B. (2023). On the functional and structural scope of technological innovation systems - a literature review with conceptual suggestions. *Environmental Innovation and Societal Transitions*, *49*, 100786. <https://doi.org/https://doi.org/10.1016/j.eist.2023.100786>
- Ballal, D. R., & Zelina, J. (2004). Progress in aeroengine technology (1939-2003). *Journal of Aircraft*, *41*(1), 43–50. <https://doi.org/https://doi.org/10.2514/1.562>
- Bechtold, U., Fuchs, D., & Gudowsky, N. (2017). Imagining socio-technical futures—challenges and opportunities for technology assessment. *Journal of Responsible Innovation*, *4*(2), 85–99. <https://doi.org/https://doi.org/10.1080/23299460.2017.1364617>
- Bergek, A. (2014). Vägledning för analys av teknologiska innovationssystem. In *Teknologiska innovationssystem inom energiområdet: En praktisk vägledning till identifiering av systemsvagheter som motiverar särskilda politiska åtaganden* (pp. 13–40, Vol. 2014:23). Energimyndigheten.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008b). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research policy*, *37*(3), 407–429. <https://doi.org/https://doi.org/10.1016/j.respol.2007.12.003>.
- Bergek, A., Jacobsson, S., Hekkert, M., & Smith, K. (2010). *6: Functionality of innovation systems as a rationale for and guide to innovation policy*. Edward Elgar Publishing.
- Bergek, A., Jacobsson, S., & Sandén, B. (2008a). ‘legitimation’and ‘development of positive externalities’: Two key processes in the formation phase of technological innovation systems. <https://doi.org/https://doi.org/10.1080/09537320802292768>
- Bestaoui, Y., & Hima, S. (2007). Modelling and trajectory generation of lighter-than-air aerial robots - invited paper. *Lecture Notes in Control and Information Sciences*, *360*, 3–28. https://doi.org/https://doi.org/10.1007/978-1-84628-974-3_1
- Bheekhun, N., Talib, A. R. A., & Cardenas, F. (2018). Towards a sustainable aerogel airship: A primer. *International Journal of Engineering and Technology(UAE)*, *7*(4), 141–145. <https://doi.org/https://doi.org/10.14419/ijet.v7i4.13.21346>
- Bondesson, W. (2025, March). Personal communication.
- Boyd, B. (2025, March). Personal communication.

- Carcassi, M., & Fineschi, F. (2005). Deflagrations of h₂-air and ch₄-air lean mixtures in a vented multi-compartment environment. *Energy*, *30*(8 SPEC. ISS.), 1439–1451. <https://doi.org/https://doi.org/10.1016/j.energy.2004.02.012>
- Cederberg, C. (2025, January). Personal communication.
- Cederberg, C., Landquist, B., & Berglund, M. (2012). *Potentialer för jordbruket som kolsänka*. SIK Institutet för livsmedel och bioteknik. <https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A944136&dswid=-2535>
- Das, S., & Molki, M. (2023). Optimized thermal performance of cpu coolers using different working fluids. *Proceedings of the ASME 2023 International Mechanical Engineering Congress and Exposition*, *10*. <https://doi.org/https://doi.org/10.1115/IMECE2023-115305>
- Ding, Z., Li, Y., & Tang, Z. (2020). Compaction effects of wheeled vehicles and tracked on farmland soil. *Transactions of the Chinese Society of Agricultural Engineering*, *36*(5), 10–18. <https://doi.org/https://doi.org/10.11975/j.issn.1002-6819.2020.05.002>
- Drone Center Sweden. (n.d). *Drone center sweden* [Retrieved May 07, 2025]. <https://www.dronecentersweden.se/>
- Dumas, A., Madonia, M., & Trancossi, M. (2013). A predictive climatic model for ballast in a fixed volume blimp. *SAE Technical Paper 2013-01-2204*. <https://doi.org/https://doi.org/10.4271/2013-01-2204>
- Ekholm, P. U., Fraenkel, L., & Hörbeck, S. (2014). *Formler & tabeller i fysik, matematik & kemi för gymnasieskolan* (9th ed.). Konvergenta.
- Encyclopaedia Britannica. (n.d). Blimp (aircraft). Retrieved March 3, 2025, from <https://www.britannica.com/technology/blimp-aircraft>
- European Commission. (2024). *Multibody advanced airship for transport (maat) – project results* [Retrieved April 17, 2025]. <https://cordis.europa.eu/project/id/285602/results>
- European Soil Data Centre (ESDAC). (2025). Soil compaction [Accessed 2025-04-29]. <https://esdac.jrc.ec.europa.eu/themes/soil-compaction1>
- European Union Aviation Safety Agency (EASA). (2022). Special condition sc gas: Gas airships. <https://www.easa.europa.eu/en/downloads/134946/en>
- Fitton, J. (2025, March). Personal communication.
- Fogelfors, H., Wivstad, M., Eckersten, H., Holstein, F., Johansson, S., & Verwijst, T. (2009). Strategic analysis of swedish agriculture. *Report from the Department of Crop Production Ecology (VPE)*, (10).
- Fossilfritt Sverige, L. (2020). Färdplan för fossilfri konkurrenskraft lantbruksbranschen. <https://fossilfritt sverige.se/roadmap/lantbruksbranschen/>
- Gilbertsson, M. (2025, March). Personal communication.
- Godwin, R., Misiewicz, P., White, D., Dickin, E., Grift, T., Pope, E., Millington, A., Shaheb, R. M., & Dolowy, M. The effect of alternative traffic systems and tillage on soil condition, crop growth and production economics - extended abstract. In: 2019, 133–134. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85085726859&partnerID=40&md5=eccd8422f32874a880fc7bcbedf76bc>
- Grönroos, M. (2025a, January). Personal communication.
- Grönroos, T. (2025b, March). Personal communication.

- György, R., Broichhausen, K., & Seifert, J. Potentials of lighter-than-air technology in future markets - an evaluation. In: In *26th congress of international council of the aeronautical sciences. 2.* 2008, 3024–3031. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84878946575&partnerID=40&md5=97ed7602462590201c582ff8df1e56fa>
- John Deere. (2025). *X-serien: Tröskor* [Retrieved April 17, 2025]. <https://www.deere.se/sv/tr%C3%B6skor/x-serien/>
- Jordbruksverket. (2022). *Jordbruksmarkens användning 2022. slutlig statistik* [Retrieved April 17, 2025]. <https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2022-10-20-jordbruksmarkens-anvandning-2022.-slutlig-statistik>
- Karataev, V. B., Grosheva, P. Y., & Shkvarya, L. V. (2018). From the history of the development of controlled aerostats (airships) in the xix - early xx centuries. *Bylye Gody*, 49(3), 1159–1165. <https://doi.org/https://doi.org/10.13187/bg.2018.3.1159>
- Kelluu. (2024). Kelluu begins operations in sweden [Retrieved April 21, 2025]. <https://kelluu.com/news/kelluu-begins-operations-in-sweden>
- Khattak, W. A., Abbas, A., Hameed, R., Balooch, S., Jalal, A., Zaman, F., Shafiq, M., & Sun, J. (2025). Climate change induced environmental adversities and their impact on agricultural productivity. *Challenges and Solutions of Climate Impact on Agriculture*, 1–28. <https://doi.org/https://doi.org/10.1016/B978-0-443-23707-2.00001-5>
- Konrad, K., & Böhle, K. (2019). Socio-technical futures and the governance of innovation processes: An introduction to the special issue. *Futures*, 109, 101–107. <https://doi.org/https://doi.org/10.1016/j.futures.2019.03.003>
- Krusell, V. (2025, April). Personal communication.
- Kungl. Ingenjörsvetenskapsakademien (IVA). (2019). *Så klarar det svenska jordbruket klimatmålen*. Kungl. Ingenjörsvetenskapsakademien (IVA). <https://res.slu.se/id/publ/102109>
- Lannou, F. (2025, March). Personal communication.
- Lindroos, O. (2025, March). Personal communication.
- Lucia, L. D., & Vegni, A. M. (2023). *Uav main applications: From military to agriculture fields*. In: Kerrache, C.A., Calafate, C., Lakas, A., Lahby, M. (eds) Internet of Unmanned Things (IoUT); Mission-based Networking. Internet of Things. Springer, Cham. https://doi.org/https://doi.org/10.1007/978-3-031-33494-8_1
- Lundbäck, M., Persson, H., Häggström, C., & Nordfjell, T. (2020). Global analysis of the slope of forest land. *Forestry: An International Journal of Forest Research*, 94(1), 54–69. <https://doi.org/https://doi.org/10.1093/forestry/cpaa021>
- Luo, C., Liu, G., Deng, Y., Long, Z., & Lin, M. (2025). Design and optimization of liquid helium-free cooling systems for magnetic resonance imaging device using multi-physical modeling. *Case Studies in Thermal Engineering*, 66. <https://doi.org/https://doi.org/10.1016/j.csite.2025.105761>

- Mahesh, M., & Barker, P. B. (2016). The mri helium crisis: Past and future. *Journal of the American College of Radiology*, *13*(12, Part A), 1536–1537. <https://doi.org/https://doi.org/10.1016/j.jacr.2016.07.038>
- Mendes, C. B., & Lepikson, H. A. Airships as a possible logistic solution for the transport of special and bulk loads. In: In *Freitag, m., kotzab, h., pannek, j. (eds) dynamics in logistics. Idic 2018. lecture notes in logistics. springer, cham.* 2018. https://doi.org/https://doi.org/10.1007/978-3-319-74225-0_48
- Milestad, R., Ahnström, J., & Bjrklund, J. (2011). Essential multiple functions of farms in rural communities and landscapes. *Renewable Agriculture and Food Systems*, *26*(2), 137–148. <https://doi.org/https://doi.org/10.1017/S1742170510000529>
- Newport, J., Shorthouse, D. J., & Manning, A. D. (2014). The effects of light and noise from urban development on biodiversity: Implications for protected areas in australia. *Ecological Management Restoration*, *15*(3), 204–214. <https://doi.org/https://doi.org/10.1111/emr.12120>
- Nybom, J., Hunter, E., Micheels, E., & Melin, M. (2021). Farmers' strategic responses to competitive intensity and the impact on perceived performance. *SN Business and Economics*, *1*(74). <https://doi.org/https://doi.org/10.1007/s43546-021-00078-1>
- Oxford English Dictionary. (n.d.). Lighter-than-air. <https://doi.org/https://doi.org/10.1093/OED/3853245819>
- Pereira, A. M., & Andraz, J. M. (2005). Public investment in transportation infrastructure and economic performance in portugal. *Review of Development Economics*, *9*(2), 177–196. <https://doi.org/https://doi.org/10.1111/j.1467-9361.2005.00271.x>
- Prentice, B. (2024). Intermodal competition: Cargo airships versus long-haul trucking for perishable commodities. *Journal of Transportation Technologies*, *14*, 195–211. <https://doi.org/https://doi.org/10.4236/jtts.2024.142012>
- Prentice, B. (2025, April). Personal communication.
- Prentice, B., & Lau, Y.-Y. Market potential for transport airships in service to hong kong. In: In *Int. j. of aviation management.* 2016. https://www.researchgate.net/publication/286929257_Market_Potential_for_Transport_Airships_in_Service_to_Hong_Kong
- Rigas, F., & Amyotte, P. (2013). *Hydrogen safety*. CRC Press, Taylor Francis Group. <https://doi.org/https://doi.org/10.1201/b12267>
- Rydén, R. (2007). Smallholders, organic farmers, and agricultural policy. *Scandinavian Journal of History*, *32*(1), 63–85. <https://doi.org/https://www.tandfonline.com/doi/abs/10.1080/03468750601160004>
- Sandén, B. A., & Hillman, K. M. (2011). Exploring technology paths: The development of alternative transport fuels in sweden 2007-2020. *Technological Forecasting and Social Change*, *75*(8), 1279–1302. <https://doi.org/https://doi.org/10.1016/j.techfore.2008.01.003>
- Schäufele, S. (2025, April). Personal communication.
- Schlosser, R. W., Wendt, O., Bhavnani, S., & Nail-Chiwetalu, B. (2006). Use of information-seeking strategies for developing systematic reviews and engaging in evidence-based practice: The application of traditional and compre-

- hensive pearl growing. a review. *International journal of language & communication disorders*, 41(5), 567–582.
- Sivertun, Å. (2025, March). Personal communication.
- Springmann, M., Clark, M., Mason-D’Croz, D., Wiebe, K., Bodirsky, B. L., Las-
saletta, L., De Vries, W., Vermeulen, S. J., Herrero, M., Carlson, K. M., et
al. (2018). *Options for keeping the food system within environmental limits*.
Statistiska centralbyrån (SCB). (2020). *Use of arable land 1990–2019. hectares* [Re-
trieved April 17, 2025]. [https://www.scb.se/en/finding-statistics/statistics-
by-subject-area/agriculture-forestry-and-fishery/agricultural-production/
general-agricultural-statistics/pong/tables-and-graphs/use-of-arable-land/](https://www.scb.se/en/finding-statistics/statistics-by-subject-area/agriculture-forestry-and-fishery/agricultural-production/general-agricultural-statistics/pong/tables-and-graphs/use-of-arable-land/)
- Statistiska centralbyrån (SCB). (2023). *Marken i sverige* [Retrieved April 17, 2025].
[https://www.scb.se/hitta-statistik/sverige-i-siffror/miljo/marken-i-
sverige/](https://www.scb.se/hitta-statistik/sverige-i-siffror/miljo/marken-i-sverige/)
- Swedish Climate Policy Council. (2025). *Klimatpolitiska rådets rapport 2025*. <https://www.klimatpolitiskaradet.se/wp-content/uploads/2025/03/klimatpolitiskaradetsrapport2025.pdf>
- Swedish Energy Agency. (2014). *Teknologiska innovationssystem inom energiom-
rådet. en praktisk vägledning till identifiering av systemsvagheter som mo-
tiverar särskilda politiska åtaganden*. Statens Energimyndighet. [https://
publications.lib.chalmers.se/records/fulltext/218305/local_218305.pdf](https://publications.lib.chalmers.se/records/fulltext/218305/local_218305.pdf)
- The Airship Association. (n.d b). *The airship association* [Retrieved May 07, 2025].
<https://www.airship-association.org/>
- The Airship Association. (n.d a). *Manufacturers* [Retrieved April 29, 2025]. <https://www.airship-association.org/manufacturers>
- The Federation of Swedish Farmers. (2025). *Klimatåtgärder i lantbruket: Mer mat
och mindre utsläpp: En sammanställning av ett antal möjliga klimatåtgärder
i lantbruket* [Retrieved April 17, 2025].
- The Federation of Swedish Farmers (LRF). (2023). *Kostnader för jordbrukets gröna
omställning*. Lantbrukarnas Riksförbund. [https://www.lrf.se/las-mer/
kostnader-for-jordbrukets-grona-omstallning/](https://www.lrf.se/las-mer/kostnader-for-jordbrukets-grona-omstallning/)
- The Global Goals. (n.d.). *9 industry, innovation and infrastructure*. Retrieved Jan-
uary 21, 2025, from [https://www.globalgoals.org/goals/9-industry-
innovation-and-infrastructure/](https://www.globalgoals.org/goals/9-industry-innovation-and-infrastructure/)
- The Swedish Government. (2025). *Livsmedelsstrategin 2.0*. [https://www.regeringen.
se/contentassets/77b9be17a33f4d8a804512d4aceea517/livsmedelsstrategin-
2.0.pdf](https://www.regeringen.se/contentassets/77b9be17a33f4d8a804512d4aceea517/livsmedelsstrategin-2.0.pdf)
- The Swedish Transport Agency. (n.d). *Odelbar last och fordon som överskrider vikt-
och dimensionsbestämmelser* [Retrieved April 17, 2025]. [https://www.trans-
portstyrelsen.se/sv/vagtrafik/yrkestrafik/gods-och-buss/matt-och-vikt/od-
elbar-last-och-fordon-som-overskrider-vikt--och-dimensionsbestammelser/](https://www.transportstyrelsen.se/sv/vagtrafik/yrkestrafik/gods-och-buss/matt-och-vikt/odelbar-last-och-fordon-som-overskrider-vikt--och-dimensionsbestammelser/)
- Tidström, F. (2025, March). Personal communication.
- United Nations. (n.d). *For a livable climate: Net-zero commitments must be backed
by credible action* [Retrieved April 21, 2025]. [https://www.un.org/en/
climatechange/net-zero-coalition](https://www.un.org/en/climatechange/net-zero-coalition)
- van Noord, M., Kovacs, P., Karltorp, K., & Vroon, T. (2023). *Guide for technological
innovation system analysis for building-integrated photovoltaics. Report IEA-*

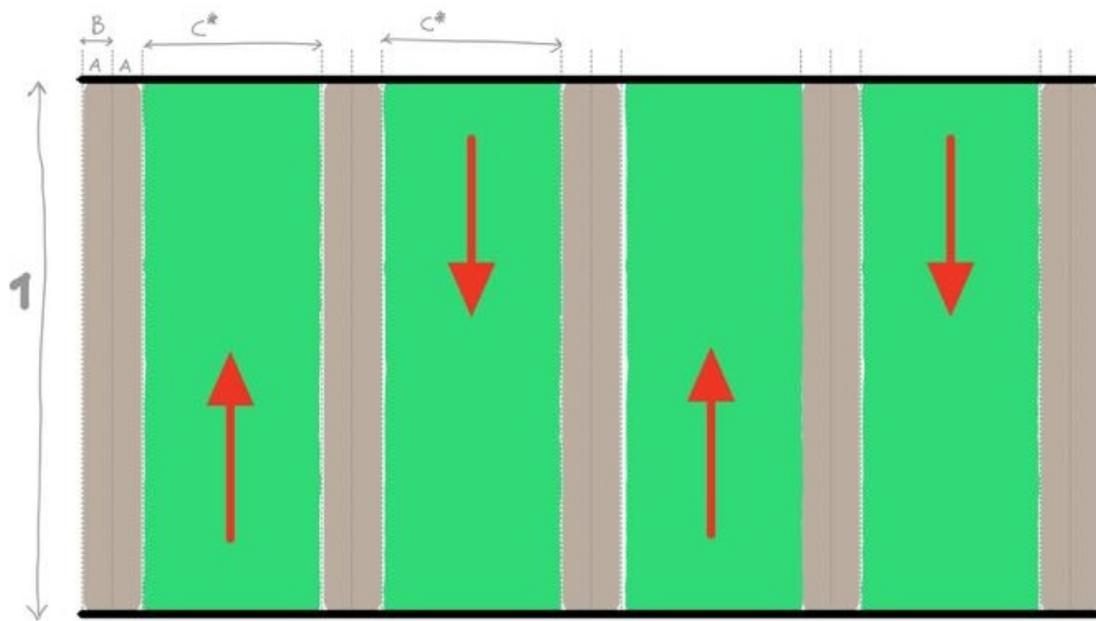
- PVPS T15-16:2023*. <https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1831608&dswid=-8601>
- Wästfelt, A. (2018). *Shifts in agriculture praxis: Farm modernisation and global integration*. Routledge. <https://doi.org/https://doi.org/10.4324/9781315647692-10>
- West, S. (2023). *Hybrid-electric airship capable of transporting up to 60 tonnes of cargo*. <https://breakbulk.com/articles/bollere-hooks-up-with-flying-whales>
- World Health Organization. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in europe*. WHO Regional Office for Europe. <https://iris.who.int/bitstream/handle/10665/326424/9789289002295-eng.pdf?sequence=1>
- Zhou, S. Y., & Renaud, M. Airship in wood harvesting: The case of the flying whales' lca60t. In: In *Xv world forestry congress*. Food; Agriculture Organizations of the United Nations, 2022.

A

Appendix

A.1 Calculations on productive land

The increased area of productive land was calculated based on the scenario stated by Gilbertsson (2025). This was calculated based on the fact that a tractor would drive twice on the same closed rows (except for those at the sides of the field). In this calculation example the tires are aligned like a car, but many tractors have smaller front wheels which are not aligned with the back tires. In those cases even more rows would need to be closed, increasing the area of productive land. This simplified scenario does not consider the fact that the tractor needs to turn in order to drive in the next direction, which would be areas with a different driving pattern than straight up and down. In reality, the situation is more complex. In Sweden, most fields are neither flat nor straight enough to allow for simple, linear driving lanes. However, as working completely from air is a radical approach, this pre-calculation can help paint the picture of how it would look like. The red arrows in the pictures showcases the driving direction however, the tires are only driving on the grey area. The green areas are the areas being cultivated.



- ⊖ = Sowing rows
- 2A = driving lane
- B = 0.125 m
- C* = 24m or 12 m depending on size of equipment.

Scenario 24m:

$$\text{Total area: } 1 \times ((0.125 \text{ m} \times 2 + 24 \text{ m}) \times 4 + (0.125 \text{ m} \times 2)) = 97.25 \text{ m}^2$$

$$\text{Area used by driving lanes: } 1 \times (0.125 \text{ m} \times 2) \times 5 = 1.25 \text{ m}^2$$

$$\text{Productive area: } 97.25 \text{ m}^2 - 1.25 \text{ m}^2 = 96 \text{ m}^2$$

$$\text{Increased area of productivity: } \frac{97.25 \text{ m}^2}{96 \text{ m}^2} \approx 1.013 = 1.3 \%$$

Scenario 12m:

$$\text{Total area: } 1 \times ((0.125 \text{ m} \times 2 + 12 \text{ m}) \times 4 + (0.125 \text{ m} \times 2)) = 49.25$$

$$\text{Area used by driving lanes: } 1 \times (0.125 \text{ m} \times 2) \times 5 = 1.25 \text{ m}^2$$

$$\text{Productive area: } 49.25 \text{ m}^2 - 1.25 \text{ m}^2 = 48 \text{ m}^2$$

$$\text{Increased area of productivity: } \frac{49.25}{48} \approx 1.026 = 2.6 \%$$

Figure A.1: Picture showing how the increased area of productive arable land was calculated

A.2 Calculation on lifts

Using helium or hydrogen affects the size of the airship. Hydrogen is the lightest gas existing and the density is $0.0899 \frac{kg}{m^3}$ at standard temperature and pressure (STP) (Ekholm et al., 2014). At STP, the density of air is $1.293 \frac{kg}{m^3}$. At STP, the lifting capacity of hydrogen in air per unit volume is therefore $1.203 \frac{kg}{m^3}$. For helium the density at STP is $0.178 \frac{kg}{m^3}$ and the lifting capacity of hydrogen in air per unit volume is approximately $1.115 \frac{kg}{m^3}$. Gross lifting capacity is therefore $\frac{1.203}{1.115} \approx 1.8$ or 8%.

The diameter was calculated as follows:

$$V = Volume[m^3]$$

$$W = Weight[kg]$$

$$L = Liftingcapacity[\frac{kg}{m^3}]$$

$$V = \frac{4\pi r^3}{3}$$

$$V = \frac{W}{L} \tag{A.1}$$

$$r = \sqrt[3]{\frac{3V}{4\pi}} \tag{A.2}$$

$$D = 2r$$

A.3 Interview templates

Below, the interview templates are presented and divided into a first section with formalities. Thereafter, the template for airship stakeholders are presented, divided into five steps. This is followed by the template for agricultural stakeholders, consisting of four steps.

Formalities

Before we begin the interview, we would like to confirm a few practical matters:

- ❖ **Consent for Data Use:**
Are you comfortable with us using the information from this interview in our report?
- ❖ **Company Name Confidentiality:**
Would it be okay if we mention your [company's] name in our thesis, or should it remain anonymous?
- ❖ **Personal Name Confidentiality:**
Would you like us to include your name in our thesis, or would you prefer to stay anonymous?
- ❖ **Recording Permission:**
Is it okay if we record the interview to ensure accuracy in our research?

TEMPLATE FOR STAKEHOLDERS CONNECTED TO THE AIRSHIP SECTOR

STEP 1 - INTRODUCTION

- ❖ We have chosen to interview you because you have [this position], which we find relevant to our study. Could you describe your work in your own words?
- ❖ We have seen that your airships can be used in [these applications]. Is it correct or where do you consider your airships can be used? Are there any other sectors where you think your airships could be utilized?
- ❖ What is your initial reaction when you think about utilizing lighter-than-air or airships within agriculture? (**legitimation**)

STEP 2 - ACTORS, INSTITUTIONS, NETWORKS

- ❖ Are there any key actors, organizations or suppliers that are essential for successful production and diffusion of airship technology?
 - Any industry alliances?
 - Are there any key actors, organizations, or suppliers missing or difficult to obtain that hinder successful production and widespread adoption?

- Are there enough people educated in this field to further develop airship technology?
- ❖ Is there any knowledge exchange between parties, for example networks of knowledge?
 - What are the main actors that do these knowledge exchanges?
 - Are these knowledge exchanges also across geographical borders?
 - Do you think the knowledge exchange could improve?

STEP 3 - FUNCTIONS

Influence on the direction of search

Have you noticed any demand for airships?

- From what user groups?
 - What are their expectations on the technology?
- ❖ Do you think it's a promising and feasible technology?
 - Why/why not?
 - Do you have any indicators of its promise or limitations?
 - For example, any niche markets where it can be more established?
 - Have you done any calculations on airships performance or potential?
 - Do you think it could be a promising technology in Sweden?

Entrepreneurial experimentation

- ❖ Does the airship industry have a shared vision for the development of the technology?
What are the vision/s in the industry?
 - Are there a sufficient variety of actors involved in the development of airship technology?
- ❖ Can you describe the current size of your business and share your vision for its growth over the next five years?
- ❖ In what phase of development are you?
 - What kind of projects have you been doing or are doing in the present?
 - Are you planning on any projects in the future?
 - Have you a production? To what extent/how many?
 - Have you sold any products?
 - to which user group? (sector or types of companies/users)
 - If not, are you planning on selling and if so, when?
 - Are you interested in expanding your market?
 - Would you be interested in expanding your market to target the agricultural sector?
 - Would you be interested in expanding your market to Sweden?

Market formation

- ❖ Can you briefly describe the airship market? Maturity, type of projects, stability...
 - Are there any specific actions that entrepreneurs could do to stimulate the development of the airship market?
 - In order for airships firms to continue to innovate or develop on the market, is the current size of the airships markets sufficient enough to support, fit or stimulate these firms?
 - Is there enough financial capital within the market for the firms?
- ❖ Which business models do you see as the most realistic for diffusion of airships? (product sales, subscription-based, “as-a-service”, leasing, “pay-per-use” or others)
 - Do you think there can be different business models depending on the user group, if so how?
 - Do you think the business model will change depending on in which market phase airships are? If so, how?

Legitimation

- ❖ What is your perception of how other people react when talking about airships?
 - How do people react within your target sector?
 - Do people in other sectors react differently?
- ❖ Do you think airship technology is socially acceptable?
 - Do you do anything to make airships more socially acceptable?
 - Are there any norms that you think are hindering diffusion of airship technology?

Resource mobilisation

- ❖ What are the most critical components of your technology?
 - Where do they come from?
 - Are the components difficult to obtain and if so, what would make it easier to obtain them?
 - Does the current demand for airships affect your ability to secure components?
- ❖ Is the existing physical infrastructure sufficient to support the wider adoption of airships (e.g., roads, manufacturing capacity, testing facilities, or energy networks)? If not, what improvements are needed?

Knowledge development

- ❖ Do you think there is enough knowledge to further develop the airship sector?

- Are there any specific areas that lack knowledge and need further development? For example, institutional, market preferences, technical?
 - Can you use some knowledge from other technologies in developing airships?
- ❖ Is most of the R&D carried out domestically, or does it primarily take place abroad?

STEP 4 - OPPORTUNITIES & BARRIERS

- ❖ Have you found any standards, policies or regulations that are affecting the development of airships, either hindering or driving?
- Do you feel like you know if the policies are mainly positively or negatively oriented towards airship technology?
 - Are the policies sending a clear message about what their opinion is of the future potential of airship technology?
 - Do you engage in any initiatives to influence policy or public support for the development of airships, such as advocating for subsidies?
 - If not, do you think there is a need to actively promote airships to decision-makers or funding bodies?
- ❖ Are there geopolitical, economic, or regulatory risks affecting your supply chain?
- ❖ What do you consider are the most significant barriers in hindering the further development and adoption of airship technology?
- ❖ What are the most significant opportunities that could accelerate the development and wider adoption of airship technologies?

STEP 5 - ENDING

- ❖ Is there anything you would like to add that we haven't covered in this interview?
- ❖ Are there any individuals you believe would be valuable to speak with regarding the topics discussed?
- ❖ Is there any possibility for us to contact you again if we have additional questions or thoughts?

TEMPLATE FOR STAKEHOLDERS CONNECTED TO THE AGRICULTURAL SECTOR

STEP 1 - INTRODUCTION

- ❖ We have chosen to interview you because you have [this position], which we find relevant to our study. Could you describe your work in your own words?
- ❖ What are the biggest challenges in the agricultural sector when transitioning to a sustainable future?
- ❖ What is your initial reaction when you think about utilizing lighter-than-air technology or airships within agriculture? (*legitimation*)

STEP 2 - FUNCTIONS

Knowledge development

- ❖ What kind of knowledge do you think you would need to develop in order to use airships?
 - What type of experience, education or certificates that might be beneficial for airship technology do you have as a farmer? For example driving license, drone license, handling of heavy machinery.
- ❖ Are there any networks you can utilize to discuss or develop ideas for technology development, such as airships, within agriculture to enhance the transition?
 - Within Sweden?
 - Outside of Sweden?
 - Only farmers or also other stakeholder groups?
 - Are there any actors that should be more involved?
 - Do you think the knowledge exchange could improve?

Influence on the direction of search

Do you think Sweden is at the forefront when it comes to adopting new technology in agriculture?

- Have you noticed any demand for airships??
 - What would you want the airships to do?
 - Considering the number of hours you work each day and the tasks you would like an airship to assist with, do you think airships could help reduce your workload by cutting down the time spent on those tasks?

- ❖ Do you think UAV, Drones and/or AI has a future in agriculture?
 - Are you already using some of these technologies?
 - What do you like or dislike about them?

- ❖ Do you think airships seems to be a promising technology?
 - Why/why not?
 - Do you think it has potential to be of importance to the agricultural transition?
 - Which parts of agriculture?
 - Do you think it could be promising in Sweden?
 - Thinking about airships in Sweden, do you see potential for airships in agriculture to serve multiple purposes beyond farming, such as fire protection, land monitoring, or forestry applications?
 - What potential risks do you associate with using airship technology in agriculture?
 - What measures could help increase your confidence in adopting this technology? For example, would demonstrations or hands-on experience make a difference?

- ❖ Are there any policies or regulations regarding transitioning your agriculture towards a more sustainable agriculture that you are obliged to follow?
 - Which ones?
 - Can you think of any that would help or hinder the diffusion of airships within agriculture?

- ❖ Are you experiencing any external pressures or influences that encourage you to adopt new technologies?
 - Who are the key actors influencing these changes?
 - If multiple actors are involved, are they conveying a consistent message?
 - What is the main message they are sending?

Entrepreneurial experimentation

- ❖ What are the main efforts that need to be made to implement airships into agriculture?

Market formation

- ❖ Have you heard about airships within agriculture before?

- ❖ How willing & interested are you to use new technology in your work to support the transition towards more sustainable agriculture?
 - Would you be willing to buy airships?
 - What would make you more willing?

- ❖ Are there any specific actions that could be done to stimulate the development of the airship market within agriculture?
- ❖ If airships were available for agriculture, how would you prefer to access them? For example, would you rather:
 - Own one yourself? (Buy it outright)
 - Lease it for a season or a few years?
 - Pay only when you use it, like renting a tractor when needed?
 - Share ownership with other farmers in a cooperative?
 - Subscribe to a service where the airship is provided, and you only pay a fixed fee?
 - When it comes to maintenance, would you prefer to handle it yourself, or have someone else that takes care of it for you?

Legitimation

- ❖ When hearing about new technology within agriculture, such as airships, is your perception that people have a positive attitude towards new technology, or more negative?
 - Are there any norms that you think are hindering airship technology?
 - Can you think of something that would make it more socially acceptable?

Resource mobilisation

- ❖ What would you need in order to invest in new technology such as airships? (education, financial...)
 - How easy or difficult is it to secure additional funding for investing in new technology?
- ❖ Do you think you would need to develop the infrastructure , such as buildings and roads, within your property in order to facilitate and use airships?

STEP 3: OPPORTUNITIES & BARRIERS

- ❖ What do you see as the largest opportunities for you to use airships within agriculture?
- ❖ What do you see as the largest barriers for you to use airships within agriculture?
- ❖ Are there any other sectors where you think your airships could be utilized?

STEP 4: ENDING

- ❖ Is there anything you would like to add that we haven't covered in this interview?

- ❖ Are there any individuals you believe would be valuable to speak with regarding the topics discussed?
- ❖ Is there any possibility for us to contact you again if we have additional questions or thoughts?

A.4 Google trends analysis

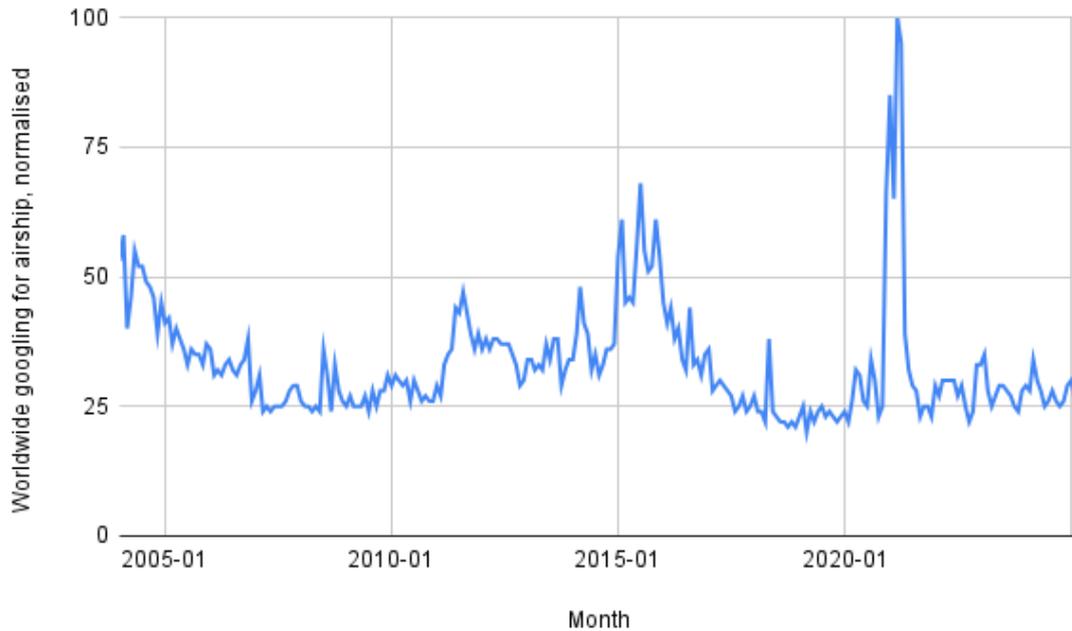


Figure A.2: Trend analysis, Worldwide, google trends, searchword airship, year 2004-2025. The graph is normalised so that the value 100 refers to when the searchword had the highest interest, 50 represents when the interest was half compared to the highest and so forth. Source: Google Trends (accessed on [27-03-2025])

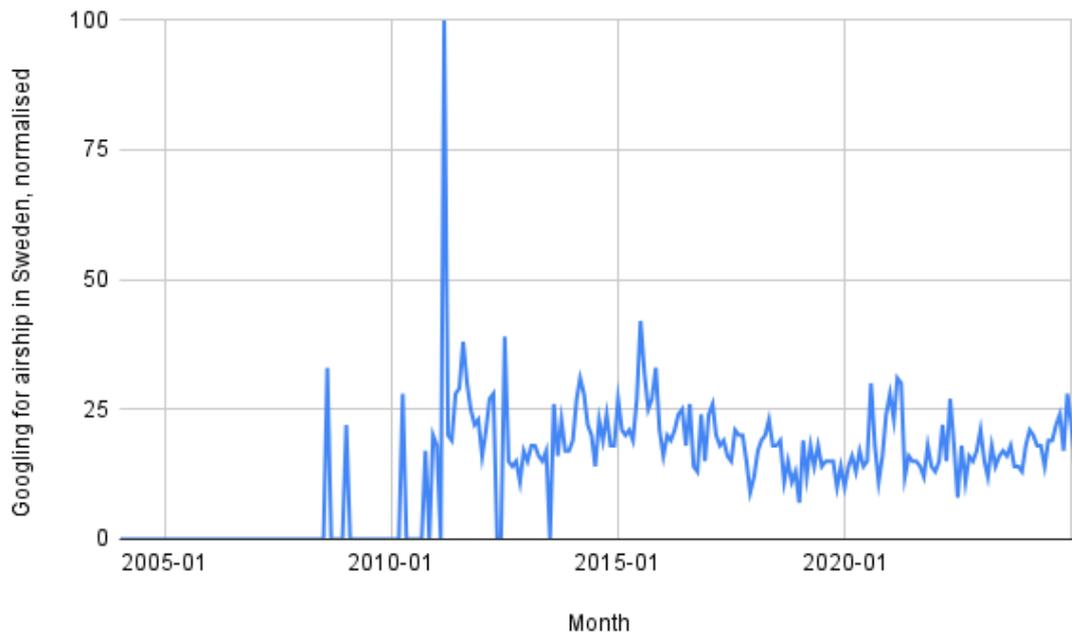


Figure A.3: Trend analysis, Sweden, google trends, search word airship, year 2004-2025. The graph is normalised so that the value 100 refers to when the search word had the highest interest, 50 represents when the interest was half compared to the highest and so forth. A value of 0 indicates no data. Source: Google Trends (accessed on [27-03-2025])

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF ENVIRONMENTAL SYSTEMS ANALYSIS
CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden

www.chalmers.se



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