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The transition to sustainable aviation in Northern Norway

Key drivers and barriers in a transition to sustainable aviation in Norway from a social-technical perspective, using Lofoten as a case study

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Abstract

This thesis investigates the key drivers and barriers of the energy transition in aviation in Northern Norway. The regional project Lofoten the Green Islands 2030 represents a radical change, which is necessary to phase out fossil fuels and reach the goals of fossil-free aviation by 2050 set by Norwegian authorities. Using literature review, observations, and interviews from key political, public, and industrial actors in Lofoten, the thesis explores the key factors influencing the niche development in the aviation regime in Norway. It also explores how the niche technology interacts with the broader aviation landscape, leaning on Geels´ framework on the Multi-Level Perspective (Geels, 2002; Geels & Kemp, 2007). The perspectives of key actors affect the process of Lofoten the Green Islands´ goal to halve Lofoten´s aviation GHG (greenhouse gas) emissions by 2030. The data shows how the goals and ambitions during the transition process vary among the different actors, especially regarding the ambitious timeline. On the other hand, the actors often share the same perception of what the end goal will be. The end goal is sustainable aviation with electric-driven aircrafts on Norway´s short-haul network where the archipelago group of Lofoten should be a national pilot. Further, the thesis reveals how the energy transition can result in radical change where both traditional actors and new stakeholders both in the air and on the ground will take on new roles and evolve along with the changes from the regime. The knowledge and communication that comes from the interaction between government, industry, academia, and population look to play an important role in the energy transition. Such political and social interaction should be arranged for and prioritized as it will strengthen each actor. This is identified in the quadruple helix model, where roles and knowledge in the transition to sustainable aviation are important. The thesis further explores a definitional sustainability discussion, as sustainability is presented as social, economic, and environmental sustainability, and the different actors have different sustainability goals with their participation in the energy transition. Finally, the thesis identifies the drivers and barriers that form a socio-technical system: society and culture, policy, industry, technology, and science. Developing a multi-level perspective understanding of the energy transition in aviation, and presenting the key drivers and barriers found in the Lofoten case, is critical to a full accounting of the challenges and opportunities that the actors of Lofoten and Norwegian aviation may face.

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1 Introduction

This chapter introduces the thesis topic, as well as the objective of the research, and presents the research questions that will be answered in the thesis. It outlines the global climate situation, and emission numbers from the transport and aviation sector. Further it introduces Norway´s role in global aviation, and most importantly Norway´s ambitions for sustainable aviation through energy transition. The project Lofoten the Green Islands 2030 (LTGI) presents a unique case of how the local government authorities in Lofoten embodies energy transition in aviation and looks to be a pilot and an early bird for new technologies and infrastructure.

The climate crisis is modern time´s biggest challenge, and it requires urgent actions. According to the latest Intergovernmental Panel on Climate Change (IPCC) report, it is "almost inevitable" that temperatures would rise above 1.5C (IPCC, 2022), and the working group behind the report, states that: "It's now or never, if we want to limit global warming to 1.5°C. Without immediate and deep emissions reductions across all sectors, it will be impossible." (Harvey, 2022) . The assessment underscores the urgency of reducing emissions of carbon dioxide (CO_2) to limit global warming to preferably 1.5°C, and maximum 2 °C.

The transport sector is one of the biggest contributors to CO_2 emissions. Transport has the highest reliance on fossil fuels of any sector, and while it was one of the sectors most affected by the Covid-19 pandemic, emissions are likely to resume rising as demands increases and the uptake of alternative fuels remains limited (IEA, 2021b). Transport demand in 2021 is rebounding, with demand for passenger and cargo transport expected to continue increasing rapidly. Even with anticipated growth in transport demand, the Net Zero Emissions by 2050 Scenario requires transport sector emissions to fall by 20% to 5.7 of total CO_2 emissions (Gt) by 2030 (IEA, 2021b). Achieving this drop would depend on policies to encourage modal shifts to the least carbon-intensive travel options, and operational and technical energy efficiency measures to reduce the carbon intensity of all transport modes (IEA, 2021b).

The aviation sector is one of the most difficult subsectors in transport to abate emissions, due to long lifespan of the aircrafts and cost of alternative solutions (Shell, 2022). CO_2 emissions from aviation and shipping have been rising rapidly in the past two decades. While global aviation passenger numbers are expected to return to peak 2019 levels as early as 2023, air travel demand is projected to grow over the next decades (IEA, 2021a, 2021b). The aviation sector produces 13.9% of the emissions from the transport sector, making it the second biggest source of GHG emissions from transport after road transport (European Commission).

Norway has committed itself, together with the EU, to reduce emissions by 50-55% by 2030 under the Paris Agreement (Regjeringen, 2021). It has also been decided that Norway will be a low-emission society by 2050, with GHG emissions reduced by 80-95% compared to 1990 numbers. These goals are regulated by Norway´s Climate Action Plan for 2021-2030 (Norwegian Ministry of Climate and Environment, 2020-2021). The goals are ambitious, and both Norway and the EU seems to be moving towards shared goals. The most important general measures in Norway are the EU Emission Trading System allowances for the sector and the national CO_2 tax (Avinor, 2020a; Norwegian Tax Administration, 2022).

Norway is the first country in the world to have a blending mandate for advanced biofuels in aviation (Avinor, 2020a). Norwegian airlines have started and continue to implement plans for increased phasing-in of sustainable fuels, aligned with Norwegian authorities´ target to implement 30% biofuel in aviation by 2030 (Avinor, 2020a). There are several political measures that are directly or indirectly climate-motivated in Norwegian aviation, and it seems that Norway is one of the countries that so far has implemented the most measures for aviation in the world (Avinor, 2020a). One of the measures is CO_2 tax on domestic aviation, which was introduced in 1999, and as of 2020, this amounted to a tax of 1.39 NOK per liter of fuel, which is equivalent to 545 NOK per ton of CO_2 (Avinor, 2020a). In the peak year of aviation, 2019, the Norwegian aviation industry paid a total of 530 million NOK in CO_2 tax (Avinor, 2020a). Norway is therefore a leading nation of policies and measures to enhance sustainable alternatives in aviation. However, in accordance with international agreements, a CO_2 tax is not implemented on international traffic (Avinor, 2020a).

Norway has taken an international example and a leading position in creating an early market for low- and zero-emissions technologies in the transport sector, such as electric cars and ferries. Norwegian aviation has shown to be a pioneer in the implementation of new solutions, such as the biofuel blending mandate and Oslo Airport being the world´s first international airport to blend jet biofuel into the ordinary fuel system, and to offer this to all airlines that refuel there (Avinor, 2020a). Norway is well-positioned to play a leading role in the phasing in of low- and zero-emissions solutions for aviation, and many developers such as Tecnam and Heart Aerospace are interested in Norway´s short-haul network for demonstration and testing of electrified aircrafts (Heart Aerospace, 2022). This thesis will therefore focus on electric aviation, but it will include discussions of other alternative energy solutions.

Figure 1: Short-haul distances ranging from 150 km to 350 km with Bodø as base. Source: (Avinor, 2020a)

Although aviation is a big contributor to CO_2 emissions, the Northern region of Norway experience limited transport options to aviation. Air travel is used for relatively short distances as figure 1 shows, because of the geographical conditions with mountains and fjords, as well as a scattered population, makes land-based travel very time consuming and expensive (Avinor, 2020a; Avinor & Luftfartstilsynet, 2020; Nordic Council of Ministers, 2020). Alternative transportation options are car, bus, and boat, but they are very time consuming. These transportation options also generate a great share of emissions. Avinor (2020) has compared emissions from various distances in Norway using car, trains, and air transport. The distance Oslo-Bodø produced 175 kg CO_2 equivalents from travelling by car, and 101 kg CO_2 equivalents when travelling the distance by air per passenger. These emissions are from direct emissions, infrastructure and fuel (Avinor, 2020a). Air travel is the dominant transport mode between Norway´s capital Oslo and throughout other counties such as Nothern Norway. Air travel is also dominant for shorter journeys such as Oslo-Trondheim, and between northern regional capitals such as Bodø-Tromsø (Avinor, 2020a). Due to the dependency and vast use of air travel, it is coherent that Norway is an early pioneer in implementing sustainable solutions in aviation.

Lofoten is an archipelago region in Northern Norway that is highly dependent of the short-haul network, and air travel is very important to the population and industry. Therefore, aviation is one of the six program areas where the municipalities of Lofoten wants to facilitate an energy transition. LTGI´s goal is to reduce CO_2 emissions by energy transition in different transportation sectors, including the aviation sector. This ambition is portrayed in the project of LTGI, which is a growth strategy by Lofotkraft, Destination Lofoten and Lofotrådet, the latter a regional body for the six municipalities in Lofoten: Røst, Værøy, Moskenes, Flakstad, Vestvågøy and Vågan.

Norway´s climate goals are to reduce GHG emissions by 50-55% percent by 2030, and to be a low-emission society by 2050 (Regjeringen, 2021). Lofoten wants to contribute to these reductions and has their own ambition of reducing their local total emissions by 50-55% by 2030, and to become a low-emission society by 2040 (Lofotrådet et al., 2022). They aspire to be a national pilot for realizing the potential of a green shift locally and regionally, through both public and private sectors - and including both locals and tourists (Lofotrådet et al., 2022).

LTGI has committed to being a first mover in zero-emission aviation. Their goals are to be a pilot region for zero-emission aviation, with the specific goal of having the first commercial zero-emission flight to depart in Lofoten, and zero direct CO_2-emissions on all air traffic to, from and in Lofoten by 2035 (Lofotrådet et al., 2022). For Lofotrådet and LTGI, it is important that the Lofoten region is portrayed as a driver to facilitate the energy transition towards zero-emission aviation, because Norwegian aviation is moving towards fossil free solutions, and the current Widerøe Dash-8 aircrafts operating on Lofoten´s short-haul routes are retiring (King, 2022). Widerøe is one of several short-haul airline operators that are looking to electrify their next generation of air crafts, considering the zero-emission goals from the Norwegian government, supported by the IPCC and the Paris Agreement, and because their current Dash-8 fleet is retiring.

The short-haul network with Widerøe as the dominating operator is crucial for Lofoten´s mobility. When the Dash-8 regional aircrafts are retiring and being replaced with new technology, it puts the mobility in a more vulnerable position. A technology transition in aviation should fulfill expectations regarding cost, mobility, and social acceptance for the users in both the development process and as final products.

In the literature review around 400 articles showed up when searching the key words "energy transition" and "aviation", these were mainly focused around economic and technological perspectives. The research that includes social aspects are very limited but directing the search towards society and culture revealed four articles with social perspectives in the energy transition in aviation: Gangoli Rao et al. (2020); Kim et al. (2019); Nakamura et al. (2013); Santos and Delina (2021). These articles mainly discuss energy transitions from fossil fuels to sustainable aviation fuels, and not the transition to electrical aviation.

Analyzing energy transitions through the lenses of socio-technological systems enables more emphasis on the role of society within the transition process and its outcomes (Bridge et al., 2018; Miller, 2013). Energy transitions are complex and involves different actors, and it is important to understand how the actors work and interact with each other. Interactions between technology and diverse social factors, and the actors involved, are essential for the development and implementation of technology in society. Overall, in existing literature, there are no assessments of how elements from society and culture, policy, industry, technology, and research influence each other in the electric energy transition in aviation.

As global aviation transitions towards fossil free solutions by 2050, and multiple actors in Norwegian aviation has started investing in new electric aircraft propulsion systems towards 2030, (SAS, 2022; Tecnam, 2021), the Norwegian aviation regime is likely changing. The mobility that the short-haul network provides to decentralized regions is important for the communities. Previous research has shown that society both affect and is affected by energy transitions, and therefore the population and industries of Lofoten will play an important role in both the process and the result of the energy transition.

This background leads to the objective of this thesis and the following research questions:

What are the key drivers and barriers for a transition to sustainable aviation in Norway from a socio-technical perspective, using Lofoten as a case study?

The first part of the problem statement leads to the question:

- *What are the key factors influencing the niche development in the aviation regime in Norway?*

The second part of the problem statement creates the following two research questions:

- How do the visions of key actors in Lofoten align with the Lofoten the Green Islands sustainability goals to halve Lofoten's aviation GHG emissions by 2030?
- How does the niche technology interact with the broader aviation landscape and regime?

These questions will be answered through using different theoretical framework, and linking it to the empirical findings during interviews, observation, and literature review.

The Quadruple Helix Model is used to identify the coexistence of various actors and arenas involved in Lofoten and Northern Norway, including government, industry, academia, and population. This includes how relevant actors in Lofoten work together and apart, analyzing their ambitions and goals. Vision theory is used to discuss how the sustainability perspectives of key actors in Lofoten align with the broader goals of emission cuts by LTGI. The multi-level perspective (MLP) of Geels (Geels, 2002; Geels & Schot, 2007) is used to describe how energy transition may take place, where the niche-innovation are electrical aircrafts breaking into the established aviation regime. The MLP objective is also used to discuss how the niche technology that is electrical aircrafts interact with the aviation landscape. The MLP framework is further used to categorize drivers and barriers within elements that are present in a regime. This will uncover the key factors influencing the niche development of electrical aircrafts in the Norwegian aviation regime.

In the next chapter, a background on aviation and relevant actors in Norway is presented. Followed by chapter 3 which provides a description of the theories used in the analysis. Chapter 4 discusses the research design and methodology of the thesis. Chapter 5 presents findings and analysis, starting with different visions of sustainability. Thereafter a section of identified drivers and barriers is presented, where they are categorized using the typology from MLP framework. Chapter 6 includes a further discussion of the analysis and findings. Chapter 7 concludes with a summary and suggestions for further research.

2 Background

This chapter will build upon the emissions numbers and Norway´s positioning presented in the introduction. Norway might be in a unique position regarding the energy transition in aviation. Firstly, because Norway has been a pilot in energy transition in other transport segments, such as the electrification of cars and thus relevant experience and insight into what policy measures can be taken. Secondly because Norway is dependent on aviation to maintain mobility and accessibility for their population and industries, especially in the north, and therefore needs to find alternative solutions as fossil fuel is planning on being phased out. Third, Norway has many actors engaged in the energy transition and is in a good position to build green aviation value chains. This chapter will provide the necessary background on sustainable aviation in Norway for later analysis. These are topics such as the aviation network in Norway, aviation value chains in Lofoten and sustainable innovation energy alternatives. The new technologies represent value chain development and future industry and field establishment in Lofoten and Norway.

2.1 Aviation network in Norway

The actors within the Norwegian aviation organizational structure are as followed: Avinor is a wholly state-owned company that is responsible for operating the 43 state-owned airports in Norway. To ensure safe and authorized operations, Luftfartstilsynet (Civil Aviation Authority) oversees the compliance of laws and regulations by both Avinor and airline operators. The main airline operators in Norway are Widerøe, SAS, Norwegian and Flyr. DAT (Danish Air Transport) also operates some short-haul routes in Norway, but only the route of Lakselv-Tromsø in Northern Norway. Since Norway is a deregulated market, any airline operator is free to operate domestic flights in Norway if they meet the safety requirements.

The Norwegian short-haul network consists of several bigger airports, such as Bodø and Tromsø in Northern Norway, that are connected to and function as hubs to the smaller airports that serves the remote and coastal regions. The distances of the routes are short, around 100 km. Short-haul routes where smaller aircrafts operate, such as the present Widerøe´s Dash-8, is therefore suitable as a test and for pilot routes for phasing in electric aviation and developing the surrounding infrastructure. This is because Norway already has an established network of short-haul flights with smaller aircrafts, significant experience and interest in electric aviation and electric transport, as well as the national electricity production that is produced by renewable energy (mainly hydropower). Norway, according to the industry itself, is therefore in a unique position to test and integrate electric aviation (Avinor, 2020a). Due to its size and range, short-haul domestic flights will be the first aircrafts that can operate using battery-electric power.

Electrification of the aviation energy system is an important method to fulfill the Paris agreements goals, and to efficiently utilize the renewable energy sources where the energy is needed. The new electric developments represent a great opportunity for Norwegian industry actors and to build new value chains. Norway has historically had high competence and degree of electrification and has been a pilot in electrification of cars and ferries (Valstad et al., 2020). However, Norway is not a dominating actor in production and development within the aviation sector. No Norwegian company has produced or developed aircrafts or propulsion systems since 1952 (Dahle), until Rolls-Royce Electric in Trondheim recently has started cooperating with Widerøe and Tecnam (Tecnam, 2021), working on electric propulsion systems for aircrafts. This might provide Norway with a unique opportunity to become a leading actor within energy transition in aviation, possibly being the first country to have a commercial route powered by an electric aircraft in place. To build "green electric value chains" is about further developing the advantages Norway has within renewables based on interactions and synergies in other industries, including the oil and gas industry (Valstad et al., 2020, p. 10)

2.2 Aviation value chain in Lofoten

Lofoten is an archipelago group above the Arctic circle in Northern Norway and is part of the Nordland County. As already mentioned in the introduction, the region is composed by six municipalities on six different islands: Vågan, Vestvågøy, Flakstad, Moskenes, Værøy and Røst. As a popular tourism destination, in 2019 an estimated 233 400 passengers travelled to and from one of the four airports in the region, including the helicopter base at Værøy (Antonsen, 2020, p. 29). To travel in and out of the region, its 24 604 residents and tourists are highly dependent on air travel (Sundby et al., 2020; Thorsnæs, 2021). In 2019, 9 922 flights were operated at its 3 commercial airports: Leknes airport, Værøy Airport, Røst airport and Helle airport in Svolvær. Within the 150-km air travel range, there are a total of 7 airports, including Bodø and Mo i Rana.

Table 1: Key characteristics of Lofoten

Key characteristics of Lofoten	
Population	24 604 (2021)
Municipalities	6: Vågan, Vestvågøy, Flakstad, Moskenes, Værøy and Røst
Airports	3: Leknes Airport, Røst Airport and Helle Airport
Total tourism arrivals	558 000 (2018)
Total flights	9 922 (2019)

In 2020, the Lofoten district published a roadmap "Lofoten the Green Islands 2030" (LTGI) and has set sights on reducing its CO_2 emissions in different transportation sectors, including the aviation sector (De Grønne Øyene, 2022; Lofotrådet et al., 2022). The project is led by three main actors: Lofotkraft (the local energy producer), Lofotrådet (the regional council for the six Lofoten municipalities) and Destination Lofoten (the local tourism and marketing company). As part of the roadmap, LTGI is collaborating with Lofotkraft Muligheter and Energi i Nord (EiN) to promote Lofoten as an attractive test region for airline operators and technology providers. Pilot projects such as LTGI´s program for zero-emission aviation will be dependent on economic measures and subsidies to succeed. LTGI therefore partakes an important task of working closely with Avinor, Widerøe, as well as regional and national authorities to present and talk forward Lofoten as an alternative arena to test zero-emission technologies in aviation. LTGI aims to cooperate with businesses, organizations, politicians, the population and researchers to create a diversity of solutions that contributes to their sustainability goals in Lofoten (De Grønne Øyene, 2022).

It is important to underline the uncertainty of Northern Norway and Lofoten´s geographical positioning and dependency of air transport and the short-haul network on a general basis. The island-structure and a complicated topographic scene make traveling by road more time consuming than by air. Lofoten is dependent on air traffic to maintain comparable mobility and accessibility as other mainland districts throughout Norway have. Widerøe is the dominant airline operator of Norway´s domestic short-haul network. With their partners Tecnam and Embrayer, Widerøe is investing in electrical aircrafts for commercial use in Norway. LTGI envisions to be an appropriate pilot arena for implementing electrical aircrafts on Norway´s short haul network. Lofoten´s complicated topographical and geographical setting, along with the dependency of air travel to maintain fundamental mobility make them invested in the future of the short-haul network.

Figure 2: Airports around 150, 250 km from Bodø.

The characteristics of the short-haul network are airports suited for aircrafts that can land on an 800-1000m runway. The short-haul networks in Norway are Vestlandet north of Bergen, and the coastal routes from Trondheim to Kirkenes (Avinor & Luftfartstilsynet, 2020). There are 25 current airports connected to the network, 8 of them are in Nordland county, including the Lofoten region, shown in figure 2. The short-haul routes in Northern Norway are directed around the closest biggest airport, such as Bodø, Tromsø and Evenes. The flight distance is typically 100-250 km, as figure 2 shows. Figure 2 illustrates the demanding topographical conditions of the Lofoten region. Around two thirds of the passengers are local travelers (Avinor & Luftfartstilsynet, 2020).

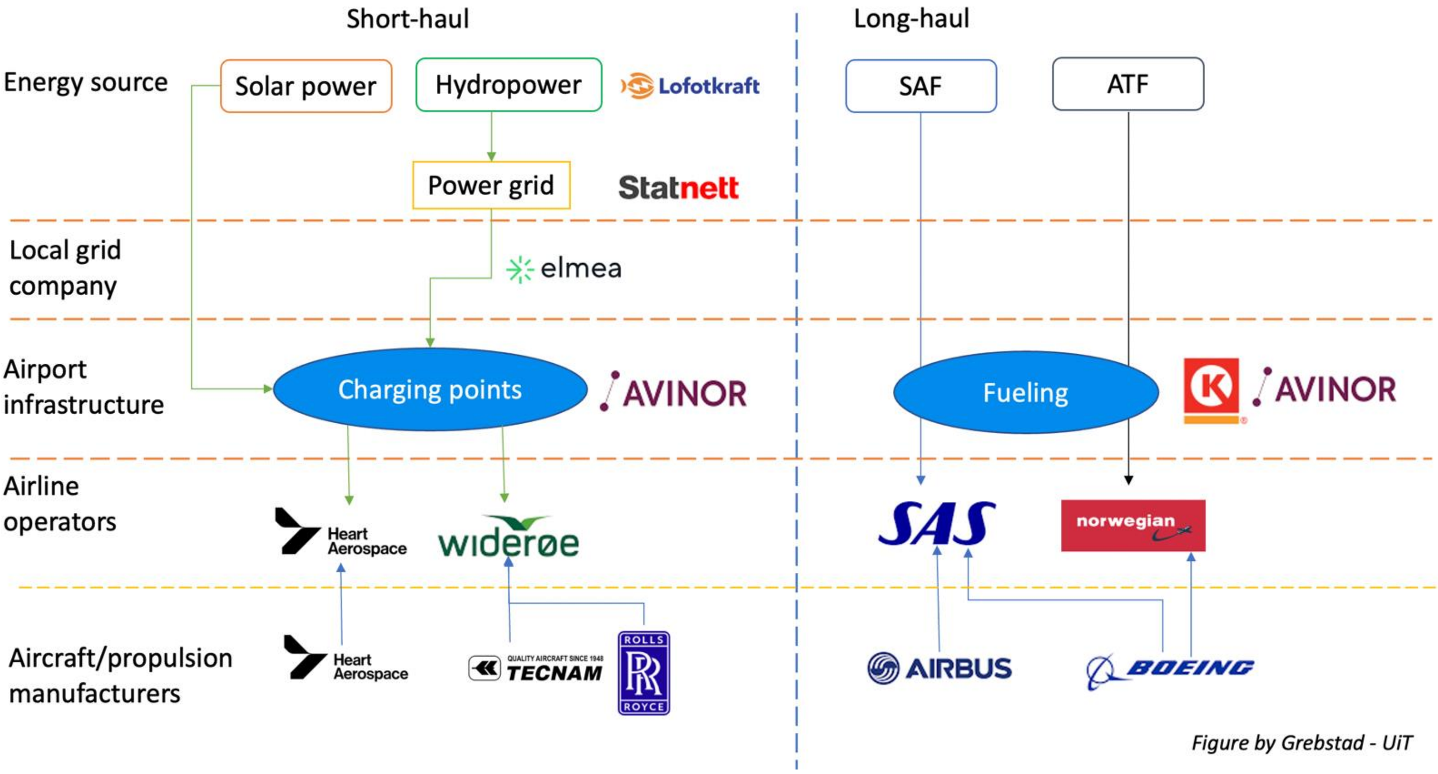

Figure 3: Aviation value chain in Lofoten

Figure 3 is an attempt to map out the present aviation value chain in Lofoten and the stakeholders today. There are other actors involved in the energy transition that are not mentioned in the figure. Other key stakeholders that can become important actors are Energi i Nord, a network that works towards the participation of Northern Norwegian businesses to facilitate and take part of the green transition, that has a focus on sustainable aviation, including infrastructure linked to electrical power or hydrogen on ground, if the aviation regime changes. SAS might also become an important player, they have as of September 2022 (SAS, 2022) also joined the electrical aircraft scheme by buying two 19-seater aircrafts from Heart Aerospace (ES-19), but at the time being they will likely mainly be used on longer regional routes such as Bodø – Tromsø, since SAS is not an operator on Norway´s short-haul routes. However, SAS and the ES-19 aircraft are adequate candidates to operate on short-haul routes, but the tender processes are what decides which operator wins what routes.

2.3 Sustainable innovation in aviation

There are various solutions to reduce greenhouse gas emissions from air traffic. Fleet replacements and efficiency in the airspace are measures that have been in place over time and have already produced significant results in emission reductions (Avinor, 2020a). Measures such as an energy transition is linked to sustainable aviation fuel (SAF), battery-electric, hybrids and hydrogen alternatives.

Sustainable aviation fuel is in the process of being phased in, and a future with electric airplanes is realistic. In September 2020, Airbus launched its plans to develop and put into use zero-emission aircraft by 2035 on regional routes, where the plan is to use hydrogen as an energy carrier. The technologies have different levels of maturity, and they can also have different areas of use because the operational range is expected to vary. Battery electric operation will primarily be in the short term suitable for relatively short routes with small aircrafts. Battery development and any new battery types may affect this. Hybrid solutions and hydrogen are being developed to initially could cover the need for intermediate distances, and perhaps in the long term longer distances. SAF such as bio jet fuel and e-fuels will continuously be phased in and is relevant for existing aircrafts and for long flights (Avinor, 2021).

SAF – cheapest and least complicated alternative energy to fossil fuel

SAF is the cheapest and the least complicated process of energy transition. SAF has a relatively similar chemical structure to traditional fossil jet fuel. When using SAF, the amount of greenhouse gas emissions is reduced compared to fossil fuel. SAF can to a large degree be used in existing infrastructure such as transport and storage, and it will be possible to use SAF in today´s fuel tanks and aircraft engines. In order for SAF to be qualified as sustainable, it must meet certain sustainability criteria such as reduced carbon emissions in the life cycle, limited use of fresh water, no competition with necessary food production and lastly no deforestation (International Air Transport Association IATA, 2022). CO2 emissions that are absorbed by plants in the growth of biomass are approximately equal to the amount of CO2 emissions during the combustion of SAF. In contrast, there are emissions regarding the production of SAF, in connection with growing crops, as well as during transport and processing of the fuel. When these emissions are taken into account, one can operate with SAF cutting around 80% of CO2 emissions in a life cycle compared to fossil fuel (International Air Transport Association IATA, 2022).

There are also geographical advantages to the production of SAF, as the production does not require being in a specific location compared to where fossil energy sources are drilled. Such decentralization of production results in a more diverse geographical supply. SAF can be produced locally in more places than fossil energy sources, also on a smaller scale, and thus more nations and aircraft operators can produce their own energy, and this results in greater energy security (International Air Transport Association IATA, 2022). SAF is also more secure and protected from price fluctuations of crude oil (International Air Transport Association IATA, 2022). SAF can contribute to economic and social benefits, as it can be produced in diverse environments and locations, including cultivation of land that is not viable for food production. In this In the Nordic region, Neste in Finland produces approximately 125 million liters annually, but there is planned startup plants and an upscale of production in Norway, Sweden and Denmark by various actors (Avinor, 2021, p. 3). A social sustainability component is related to job creation. SAF can stimulate job opportunities and create a market opportunity to make SAF from waste that is produced in various societies. Implementing SAF can thus also create beneficial strategies for waste management, especially in developing countries (International Air Transport Association IATA, 2022). There are two main problems that stop the wider use of SAF, one is scarcity of supply, and the other is high costs. Today´s production of SAF accounts for less than 0.05% of the total global demand for jet fuel (International Air Transport Association IATA, 2022).

Battery-operated electric planes – most relevant for short-haul flights

Battery density and energy storage is the main key to the transition from fossil energy to a renewable energy system. Better battery technology is considered one of the most important technical barriers to rapid development of battery driven electrical aircrafts (Reimers, 2018). Reimers, on behalf of Avinor, Norwegian Air Sports Federation (Norges Luftsportsforbund, NLF) and Federation of Norwegian Aviation Industries (NHO Luftfart) the problem is discussed, pointing to the dire need for energy storage solutions with high energy densities. Airplanes cannot be directly connected to a grid as a constant energy source, such as rail line can. Airplanes have size constraints, which means that all the energy needed for their operation need to fit within the airplane in a relatively small volume. There is great potential and an inevitable development ahead, but the battery technology is not yet sufficient. The potential itself is a driver for the energy transition. But as the thesis will elaborate on when it comes to what the actors in the field shows, the immaturity of the technology is more of a barrier. This then might represent a division between the expectations of the public and the experts within the aviation industry. This could be explained by the lack of knowledge or lack of technological optimism. There is yet measurable results to point to regarding battery use in an aircraft, which could hold back the technological optimism for the general public. Many actors are therefore working in anticipation of improved battery technology with various hybrid solutions to achieve greater range, which includes both series and parallel hybrids. The hybrid solutions can therefore also be used to extend range, which will be important to fulfill the requirements for energy reserve that applies in aviation.

Hybrid solutions

A hybrid-electric aircraft is powered via a combination of electricity from batteries, or another electrical energy storage source, and an internal combustion engine (Grünfeld et al., 2022). There are various technological options when it comes to building such a propulsion system. The two most dominant and promising options are called serial and parallel. A serial hybrid uses only electric motors for propulsion but makes use of a fossil combustion engine connected to a generator to produce additional power as needed. This is the same technology as in serial hybrid cars. A parallel hybrid directly uses an electric motor and a fossil combustion engine for propulsion (Grünfeld et al., 2022). The hybrid solutions that are common today, which are used by the car industry, consist of an electric system and a fossil system. The fossil fuel is used to generate electricity which ultimately drives electric motors. Such a traditional hybrid solution also works by replacing the fossil energy carrier with other renewable fuel types, such as hydrogen. Hydrogen is therefore promising for producing electricity on board aircrafts.

Hydrogen - knowledge and competence in hydrogen is considered high in Norway

Knowledge of the hydrogen industry in Norway is considered high, and hydrogen has been produced and used industrially in Norway for decades. In Norway, large-scale production of hydrogen has been in place since 1927 for the purpose of manufacturing ammonia fertilizer, methanol and oil refining processes (Cheng, 2020; Aarnes et al., 2019). Norway knows how to produce large volumes of hydrogen and is experienced in safe handling protocols to ensure a safe production environment. Norway has major competitive advantages for value creation and industry in Norway for sustainable fuels, hydrogen, and electrification. A high share of renewables in the power grid also gives Norway a good starting point for the production of green hydrogen (Avinor, 2020a).

Hydrogen storage on board aircrafts

There are many challenges regarding hydrogen storage on board. 4 liters of hydrogen corresponds to 1-liter ordinary jet fuel. This means that the hydrogen fuel tanks need to be considerably larger than traditional jet fuel. The temperature is also a central factor, because hydrogen becomes liquid at -253 degrees Celsius. To maintain such a temperature demands special tanks, and for the time being these tanks of one inner and one outer shell that draws vacuum between them. This technology minimizes the heat transfer by radiation, and the preferred technology for this are cryogenic tanks. Cryogenic tanks are already in use in different industries, such as space travel, which shows another example of how the aviation industry can transfer knowledge and solutions from other industries. Because hydrogen takes up a larger volume than usual fuel, the tanks need to be considerably larger to deliver and perform the equivalent effect. This will impact the air crafts´ passenger capacity and therefore will hydrogen fueled aircrafts be best suited for medium distance routes and shorter (Grünfeld et al., 2022, p. 19).

This chapter has mapped out the background on aviation in Norway, including the relevant actors within the field, the potential green aviation value chain in Lofoten and the 4 main energy alternatives to fossil fuel, SAF, battery-electric, hydrogen and hybrid solutions. The thesis will focus on battery-electric solutions, as this is the most relevant solution for short-haul flights and in the light of the projects of LTGI and Widerøe. The different energy technology solutions are important because they are linked to both traditional and untraditional actors that will shape the future of value chains in Lofoten.

3 Theory

This section will outline the theoretical foundation for the thesis, consisting of the Quadruple Helix Model, visions theory and the multi-level perspective. In the previous chapter, relevant actors in and around the aviation sector were presented. In this chapter, they will be positioned within a Quadruple Helix approach to emphasize their interactive structure. Vision theory will contribute to the study by highlighting the relation between society and technology and show how an energy transition facilitates the interaction between stakeholders across government, industry, academia, and society. The objective is to look at the energy transition in aviation as seen in the Lofoten case to analyze how the transition could take place. Actors and actions involved in the energy transition in Lofoten will be identified within the MLP to strengthen empirical findings with theoretical framework.

3.1 The Quadruple Helix Model (QH Model)

The Quadruple Helix approach is an innovation and collaboration model with a citizen/end-user perspective (Värmland County Administrative Board, 2018). It is a useful innovation analysis tool where the citizens are a central part of the innovation process. A reoccurring issue in innovation studies are the lack of involvement of the population and end-users (Roman et al., 2020). The Quadruple Helix model (QH Model) in figure 4 illustrates how the interaction between government, industry, academia and society are intertwined, and further analysis will show how the QH model approach can strengthen democracy in the decision making of innovation (Roman et al., 2020). Consequences of the lack of involvement of citizens might lead to products and services not being used, lack of transparency between representative authorities, miscommunication between innovators and citizens, frustration and lastly that there only occurs a technical innovation and not a social innovation (Värmland County Administrative Board, 2018). Using the QH model can therefore contribute to more successful and user-oriented innovations (Värmland County Administrative Board, 2018).

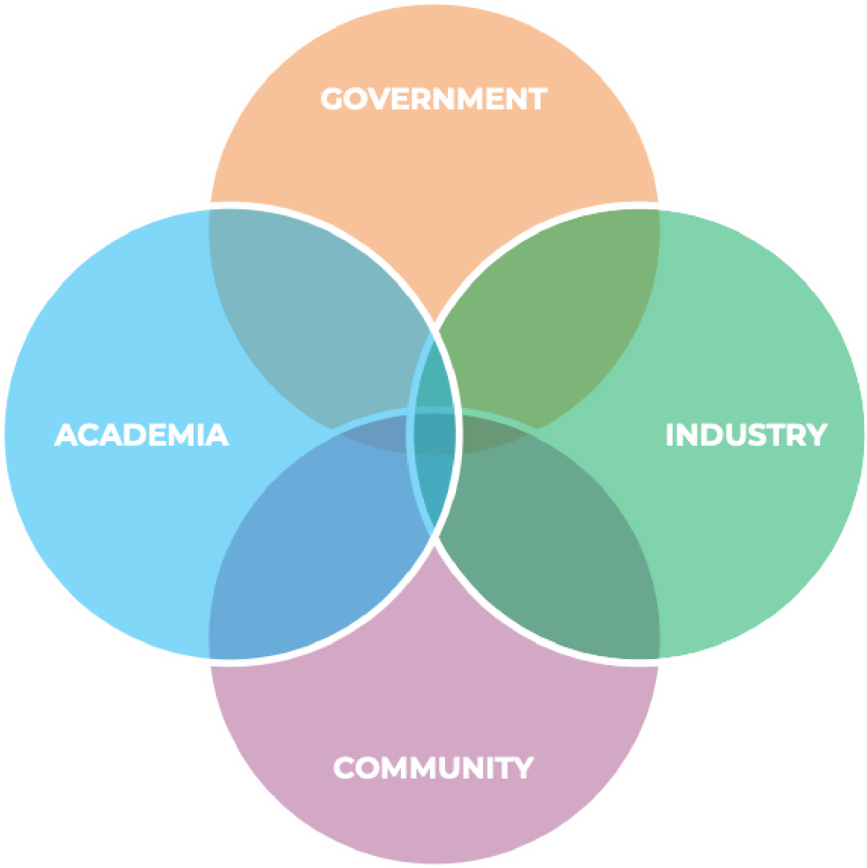

Figure 4: The Quadruple Helix Model. (GRRIP, 2020).

The QH model contains representatives from all members of society, public authorities, industry, academia, and citizens. The main key for a QH approach is interaction between the different dimensions, which is also strongly emphasized in the MLP analysis. Every member or branch of the model is decisive and will impact and affect the process and/or the product. An energy transition is complex and vast, and it is not something one quad can implement alone. Lofotrådet is dependent on its fellow government bodies, but also the industry, academia, and community, to succeed with their ambitions regarding the LTGI project.

3.2 Vision Theory

This section will combine ideas of visions, mainly from Sovacool et al. (2020) and Eames et al. (2006). Vision theory will be used to explain the visions of key actors for later analysis.

Sovacool et al. (2020) defines visions as a description of what could occur in the near-term, mid-term, or long-term future. While shaped by ideological constraints, visions reveal alternative narratives or futures, thus inviting contestation within themselves, and between alternative perspectives. Energy visions are invented, modified, circulated and/or resisted by actors from the public sphere, such as users, consumers, citizens and the media (Sovacool et al., 2020). Expectations and more formalized visions are recognized to play important performative roles in processes of technological change (Eames et al., 2006). Visions of the future shape and guide the activity and actions in the present, and the process of creating and acting upon these visions are a key part of social and technological change (Eames et al., 2006).

Visons and expectations have four functions in technological change (Eames et al., 2006). First, they facilitate alignment around common goals, creating a shared purpose for actors involved. Second, they stimulate resources and support in research and development, deployment, and political support. Third, they provide meaning and steer the direction for research workers and engineers working on the technology. Lastly, visions and expectations are used in the relationship between technology developers and the decision-makers, providing insight and information of the technology development (Eames et al., 2006). Visions can guide a society towards its sustainability goals; however, challenges arise when deciding what the shared normative visions should be. Sustainability can be defined in many ways, and what kind of sustainability people envision varies. This thesis will focus on environmental sustainability and economic sustainability, although both visions of sustainability have a common goal of social sustainability. These visions uncover different expectations and different levels of technological optimism in the transition from fossil fueled aircrafts to electric solutions.

There are contested visions of the energy transition to electric aviation in Lofoten, and they can be understood as two overarching and competing narrative themes: environmental sustainability and economic sustainability. The two dimensions have different illustrative problems and ideographs. There are naturally different levels within these visions, some versions of the visions may be more radical than others. This thesis will not discuss the various levels within the visions, but the general perceptions of the two. The environmental sustainability vision focuses on problems like climate change and nature degradation (Sovacool et al., 2020). The environmental vision values ecological conservation, and actions that protect the nature from further deterioration. This vision focuses on the role of renewable energy in nature and society and phasing out fossil fuels that are harmful to the environment. This vision takes account for both short-term and long-term beneficial factors from renewable energy. A short-term benefit of less fossil fuel burning is better air quality in immediate surroundings, and long-term could be less CO_2 emissions and limiting the rising global temperatures. The use of electric aircrafts could fulfill both these factors, and the innovation could therefore align with the environmental sustainability vision.

The economic vision focuses on problems and cues regarding unemployment, economic recession and unstable financial markets (Sovacool et al., 2020). The ideographs are around profit and economic growth, and employment and industry matters. Here, the focus is on maintaining and expanding the economic values of a society. The idea of an economically viable society is that it strengthens social sustainability, and creates opportunities for business life, securing employment and education. The economic vision itself does not reject sustainable technology, but it prioritizes the socio-economic sustainability within a society.

The environmentally sustainable vision and economic sustainable vision are addressing two problems and possess a functional utility rather than a symbolic one. The development and use of electricity in aircrafts may play a role in the creation of social communities, as it provides decentralized and local communities with technological empowerment (Sovacool et al., 2020). “This discursive relationship between problem and solution can serve to broker relationships between relevant social groups and create a dynamic of ‘promise and requirement’ where actors make promissory commitments to the technology, forging a shared agenda that requires action.” (Sovacool et al., 2020, p. 662). Shared visions can therefore gather resources to solve problems and implement new solutions.

This chapter has outlined the theoretical framework that is the base for the analysis of this thesis. The QH model is used to identify actors within the QH approach and emphasize their interactions and influences with each other. The MLP framework is used to explain how transitions can occur, and how the niche-innovation interacts with the broader aviation regime and landscape. Vision theory is used to present perceptions from key actors that are present and influencing the energy transition in aviation in Lofoten. The next chapter will outline the methodology and research strategy used to gather and analyze the data and findings.

3.3 The multi-level perspective (MLP) framework

The energy transition in focus is the transition away from fossil fuel to renewable energy in aviation, with a focus on electric aircrafts on the short-haul network. Geels and Schot introduce the MLP as a heuristic framework that "understand transitions as outcomes of alignments between developments at multiple levels" (Geels & Schot, 2007, p. 399). The MLP is used to understand how transitions come about through interaction processes within and among three analytical levels: niches, socio-technical regimes, and socio-technical landscape (Geels, 2010; Geels & Kemp, 2007; Geels & Schot, 2007). Given the focus of the analysis, this thesis will focus more on regime-niche interactions, than landscape-regime and landscape-niche interactions.

The MLP is one of the most established frameworks in the sustainability transition research because it incorporates all the different aspects of sustainability transitions into one analytical model. It is known for its systemic approach, which means it recognizes that change is not driven by one technological change, but multiple changes in various dimensions which all interact with each other (Geels, 2012, p. 474). There is a strong focus on actors, perceptions, strategies, and actions so that we can understand the dynamics of the sociotechnical transitions. This framework is also helpful in allowing us to identify the system lock-ins and path dependencies (Geels, 2012, p. 472). The MLP also recognizes that transitions can be subjected to complex dynamics of knowledge generations through social learning. This means that actors learn from each other by interaction, and through interaction they either reinforce or produce new knowledge, which explains the cycle of constant interaction. It allows us to identify reoccurring patterns, that can later be generalizable lessons, as well as it allows us to understand how transitions can be influenced to move towards a desired direction, which in this case is sustainability.

3.3.1 The key concepts of MLP

The MLP operates with three levels of analytical concepts to study technological transitions. They are sociotechnical landscape, socio-technological regime, and niche-innovations. Starting with the sociotechnical landscape, consisting of heterogeneous factors such as oil prices, economic growth, wars, migration, broad political coalitions, cultural and normative values, and environmental problems. These are deep structural trends and technological trajectories. The landscape describes an external structure or context for interactions of actors. Socio-technical landscape refers to wider technology-external factors as electricity infrastructures. The socio-technical landscape in this thesis is characterized by climate change and the goal of Norwegian aviation to be fossil free in 2050, that represents macro-political developments (Avinor, 2020a; Geels & Kemp, 2007). Changes at the landscape level may put pressure on the regime, creating "windows of opportunity" for new technologies to break into the regime (Geels, 2002, p. 1261; Geels & Kemp, 2007, p. 400).

The socio-technological regime consists of the organizations and actors involved, that form a routine-based behavior (Geels, 2002, p. 1259). The regime represents the meso-level of socio-technical systems. There are seven dimensions in the socio-technical regime: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge (Geels, 2002, p. 1262). In the context of this thesis, the regime actors are Widerøe, SAS, Norwegian, and Flyr as the biggest airline operators in Norway, and their respected aircraft manufacturers, De Havilland Aircraft of Canada, Boeing, and Airbus. Avinor is also a regime actor as owner of Norwegian commercial airports and the dominant provider of ground infrastructure. Regimes usually generate incremental innovations, while radical innovations are generated in niches (Geels, 2002, p. 1260).

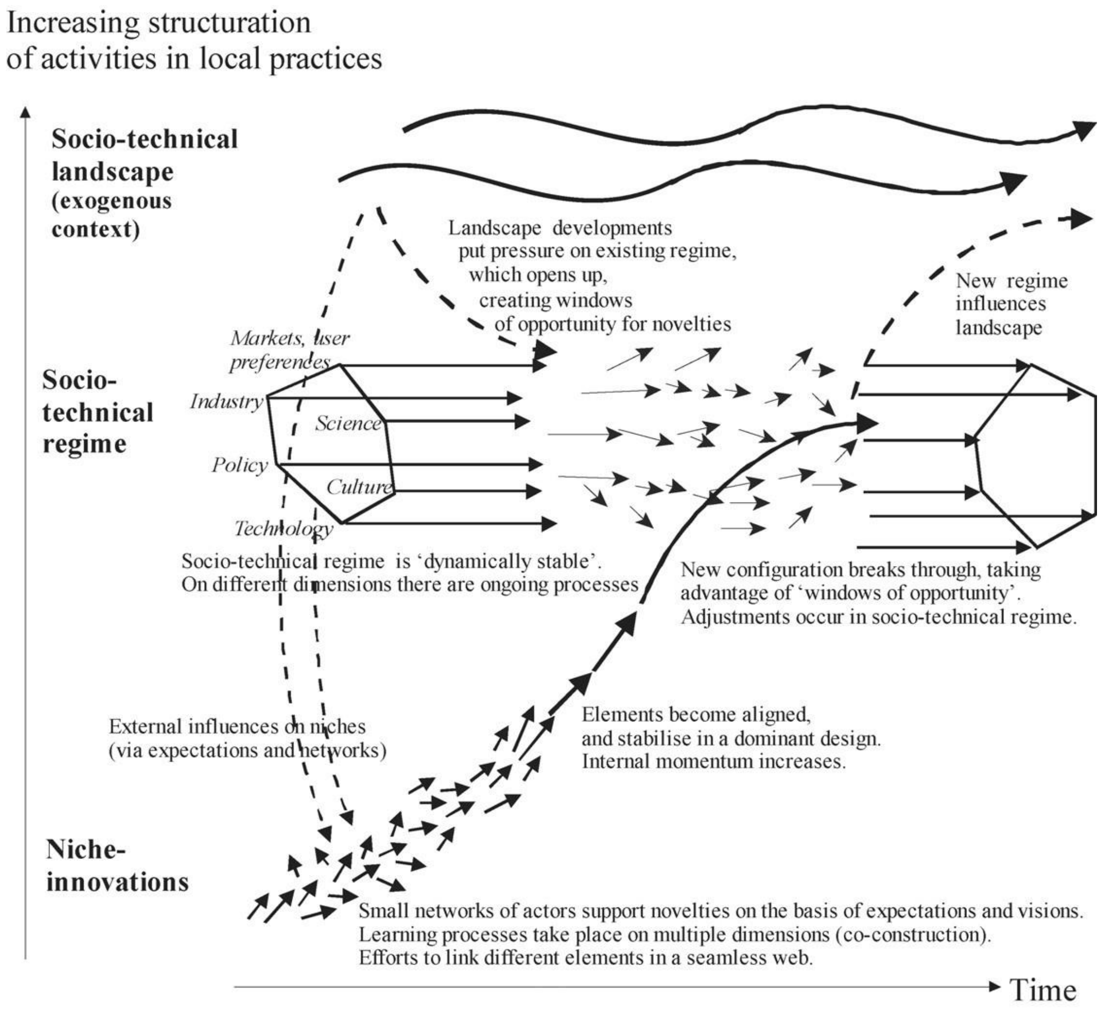

Figure 5: Illustration of MLP dynamics. (Geels & Kemp, 2007, p. 401)

Figure 5 is an illustration of the dynamics and interactions between the three MLP levels. Transitions can occur by the niche-innovations at the bottom level building internal momentum, supported by networks of actors. Changes at the landscape level at the top create pressure on the regime, and destabilization of the regime creates windows of opportunity for niche-innovations to break into the regime. The arrows from the regime down to the niche-level indicates the regime and landscape´s broader influence on niches. These processes can explain how a niche-innovation breaks through into an existing regime (Geels & Kemp, 2007).

The third analytical level of the MLP model are niche-innovations. In this thesis, the niches in focus are electric aircrafts, electric propulsion systems and related actors. Here we find Heart Aerospace, Tecnam and Rolls-Royce Electric. The radical innovation of electric aircrafts are niches generated at the micro-level of socio-technical systems. As figure 5 illustrates, small networks of actors within the niche-level support innovations on the basis of expectations and visions (Geels & Kemp, 2007, p. 401). This works as an incubation space for the niche-innovation, where it stays until there is a window of opportunity for the innovation to break into the regime.

3.4 The MLP transition pathways

There are four main types of transition pathways according to Geels and Schot (2007), substitution, transformation, reconfiguration or de-alignment and realignment. The propositions of the four pathways are developed from what type of relationship the niche-innovations have with the landscape developments, and what relationship the niche-innovations have with the existing regime, whether it is competitive or symbiotic (Geels et al., 2016; Geels & Schot, 2007). What pathway that could arise also depends on the technological maturity of the niche-innovation at the time of the opening of the window of opportunity. Electric aircrafts are niche-innovations produced by manufacturers that are outside of the established aviation regime. But at the same time, airline operators who are established in the regime, such as SAS and Widerøe, support the novelties by investing in new technologies produced by actors at the niche-level such as Heart Aerospace and Rolls-Royce. The next section will introduce the four transition pathways that could occur in the energy transition in aviation.

Transformation pathway

The transformation pathway can occur over a moderate landscape pressure, such as a "disruptive change", which creates pressure on the regime that leads to reorientations by regime actors themselves (Geels & Schot, 2007, p. 406). This pathway happens with a change within the existing regime, by the regime actors who gradually reorientates their direction by changing their routines, investment strategies and institutional logics (Geels & Schot, 2007). Gradually, with small changes over time the existing regime revives itself and may look very different after a long time.

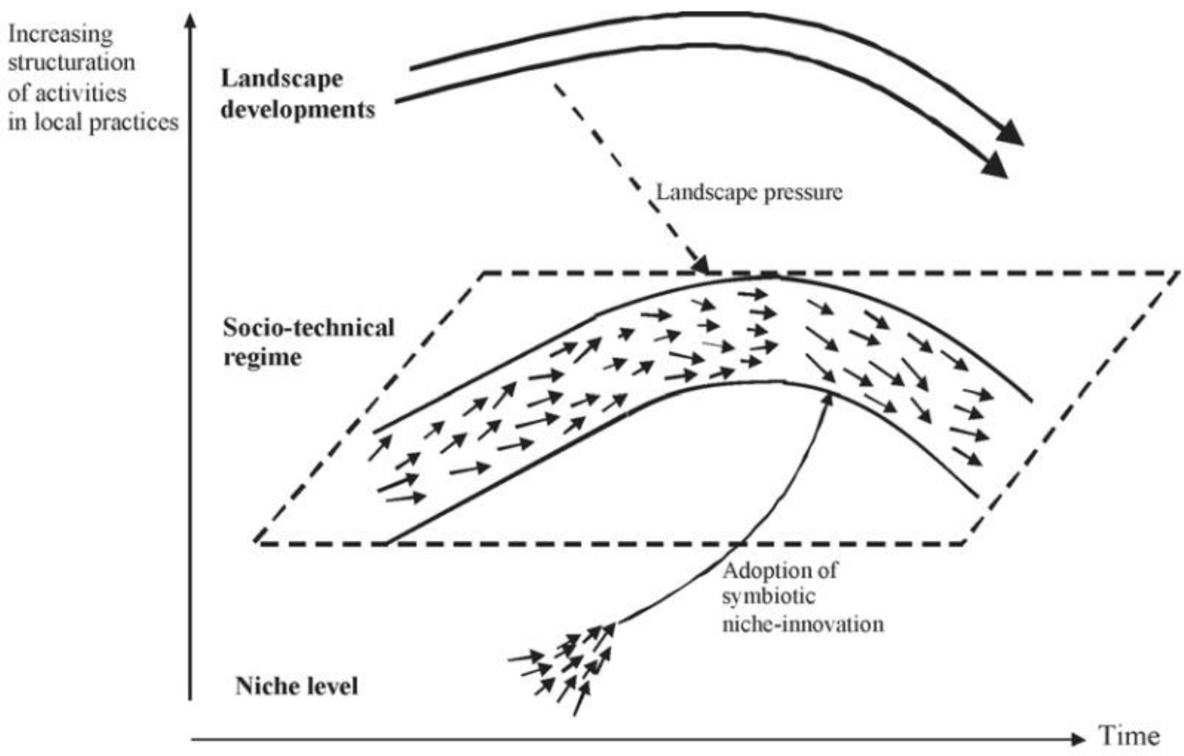

Figure 6: The MLP Transformation pathway. (Geels & Schot, 2007, p. 407).

The transformation pathway can happen if there is moderate landscape pressure while the niche-innovations have not yet been sufficiently developed, and therefore not mature enough to overthrow the regime itself. The niche technology is nascent, but not sufficiently developed, and the relationship between the regime and niche is symbiotic. Figure 6 illustrates how the new regimes grow out of old regimes through cumulative adjustments and reorientations (Geels & Schot, 2007, p. 407).

Dealignment and realignment

The de-alignment and re-alignment pathway can take place where landscape change is large and sudden, called an "avalanche change", which creates such a major shock on the systems, the regime may experience major internal problems, collapses, erodes and de-aligns. This creates a window of opportunity for niche-innovations to emerge. If there are no niche innovations that are sufficiently developed, there will be a regime vacuum. In this pathway, relationship between the regime and the niche-innovations are competitive.

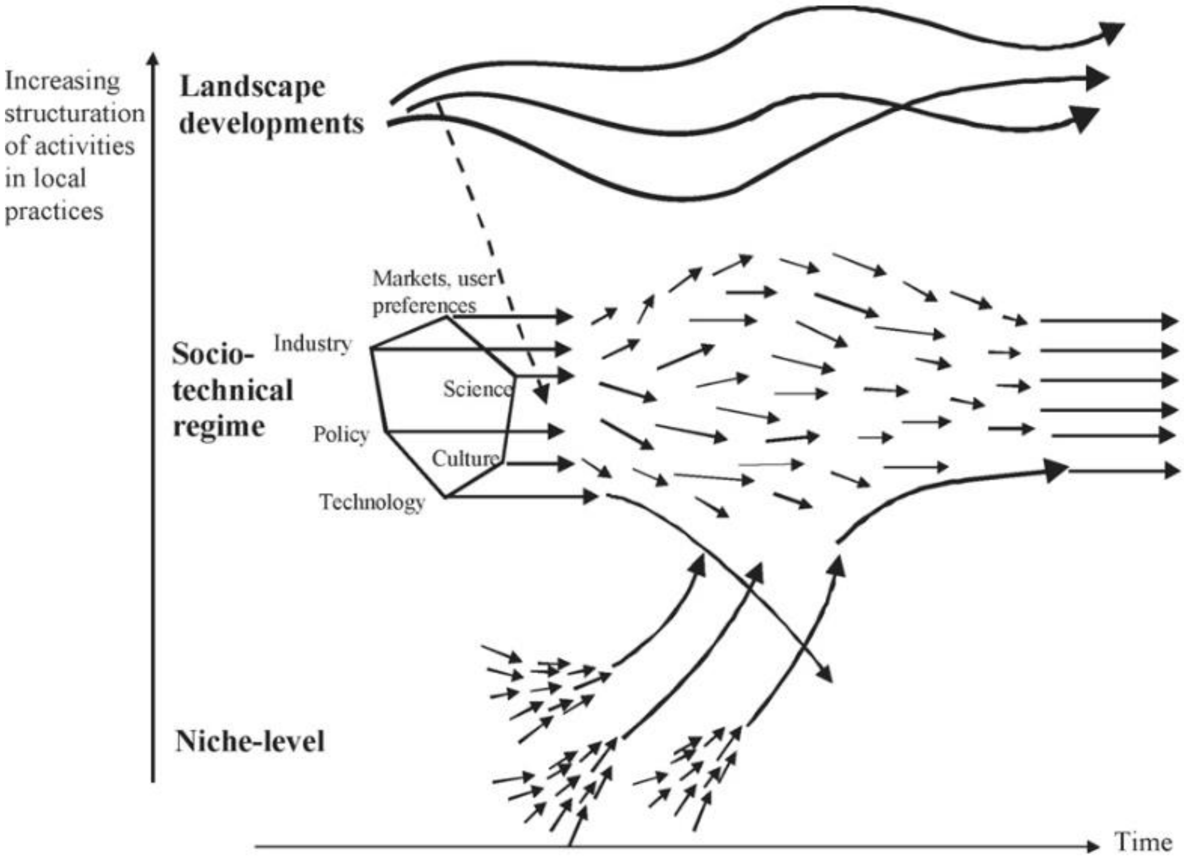

Figure 7: The MLP De-alignment and Re-alignment pathway (Geels & Schot, 2007, p. 409).

Figure 7 illustrates how an avalanche shock to the landscape causes the regime to collapse, creating a regime vacuum. The vacuum results in a window of opportunity for niche-innovations to break into the regime, re-aligning the regime.

Substitution pathway

Under the substitution pathway, a niche-innovation emerges, and multiple substitutions can take place, primarily in the technological dimensions. This is often facilitated by a landscape pressure like a “specific shock”, an “avalanche change” or a “disruptive change”, but the shock is characterized by being short and specific (Geels & Schot, 2007, pp. 409-410). Here, the niche-innovations have developed sufficiently, they are mature and have a competitive relationship with the regime.

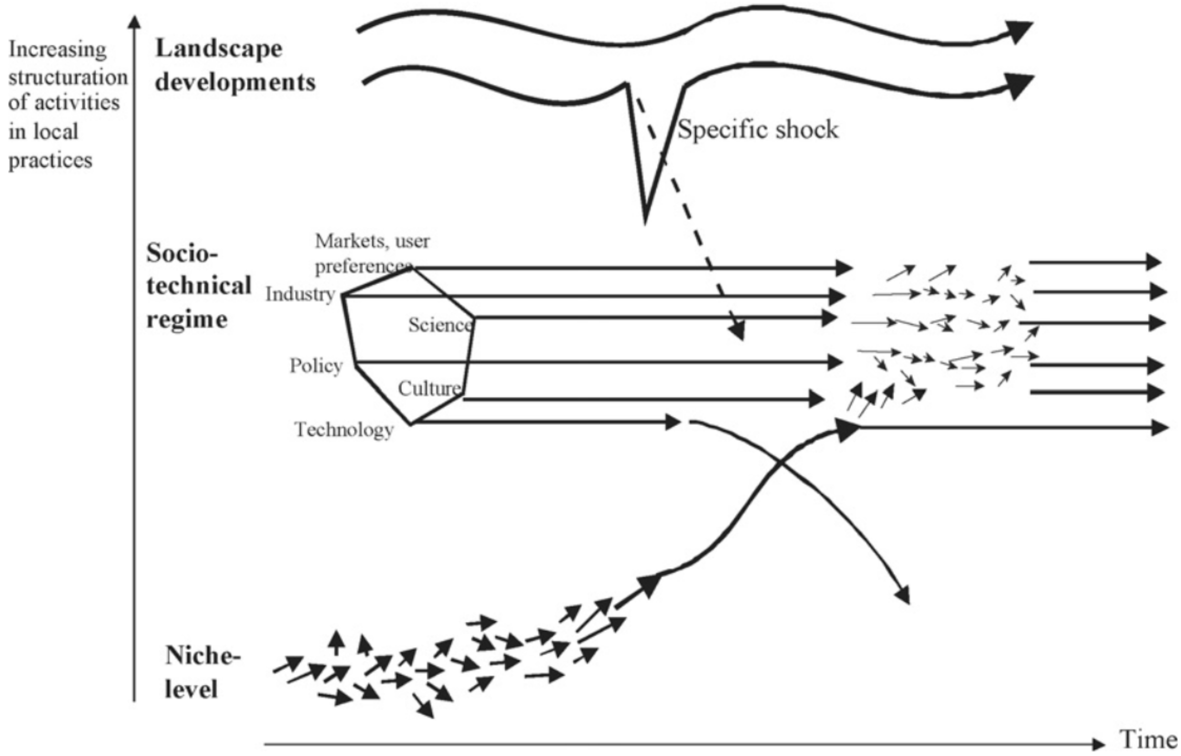

Figure 8: The MLP Substitution pathway (Geels & Schot, 2007, p. 410).

The substitution pathway is the idea of the niche-innovation moving up into the regime and substituting the regime actors, which in this case is fossil fueled aircrafts with operators and manufacturers. Figure 8 shows how niche-innovations break into the regime after a window of opportunity has opened from a specific shock, that comes from landscape developments. The mature niches replaces old technology, that leads to knock-on effect and further regime changes (Geels & Schot, 2007).

Reconfiguration pathway

In the reconfiguration pathway, radical innovations are developed in niches. The landscape pressure is moderate. The relation between the established regime and the innovations are symbiotic, and the established regime actors can adopt the innovations as add-ons or component replacements when needed (Geels & Schot, 2007). This can be for economic considerations, where the innovation can improve performance and/or solve small problems, and the symbiotic relations leaves the regime rules mostly unchanged. However, over time the reconfiguration pathway experiences substantial changes in the regime´s basic architecture, resulting in major reconfigurations and regime changes (Geels & Schot, 2007, p. 411).

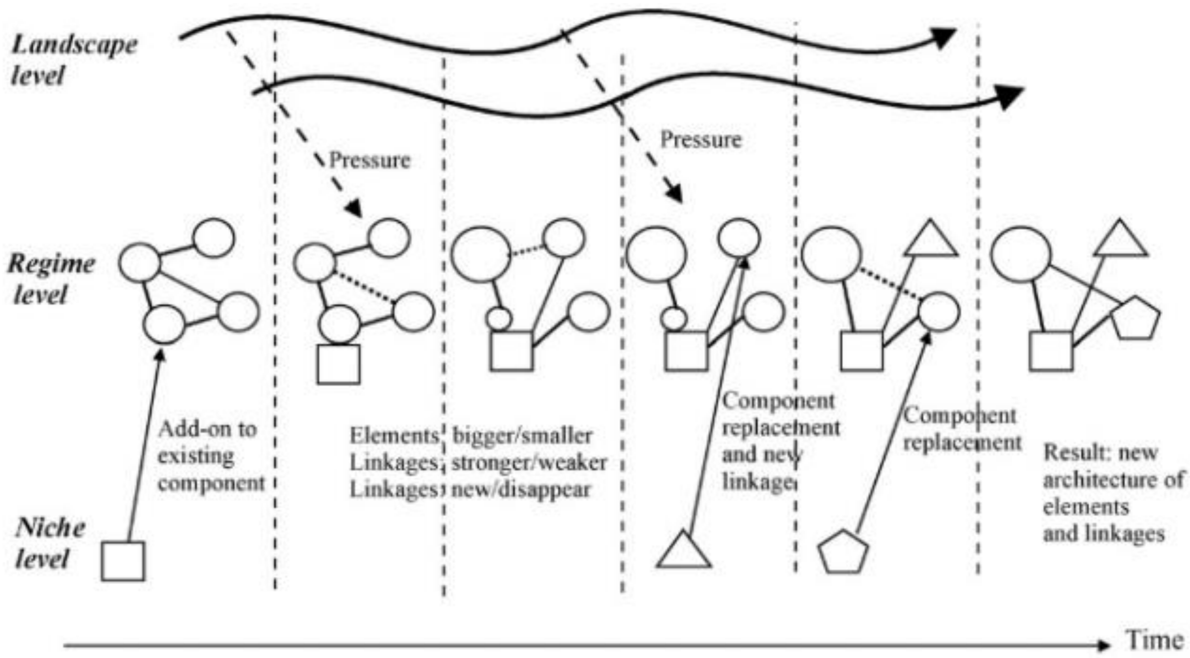

Figure 9: The MLP Reconfiguration pathway (Geels & Schot, 2007, p. 412).

The radical innovations are emerging in niches, and are mature at the time they break in. Figure 9 illustrates how the mature niches are incorporated into the existing system, and then from there on triggering further learning processes and knock-on effects and may even change the entire architecture of the system. This is more of a pattern where new actors and old actors work together, so it is more about new alliances rather than an overthrow of the regime.

4 Methodology

This chapter presents the research strategy and qualitative methods used to answer the research objective and research question. The methods presented includes literature review, interviews, and observation. The value of these methods is also discussed.

4.1 Research strategy

The purpose of this thesis is to study the key factors influencing the niche development in the aviation regime in Norway, which includes identifying central drivers and barriers that emerges in various spheres during an energy transition. This is done through a qualitative research method, by adopting a critical social science approach. A combination of three research methods is used to answer the research objective and the additional research questions. A literature review is used as an important base for this thesis, that places the research in a wider context. The literature review creates an understanding of related research in the energy transition field steering the thesis in a relevant direction, it points to debates, issues and questions in the field, as well as uncovering research gaps in literature (Ridley, 2012). Interviews are used to strengthen the qualitative framework and facilitates an opportunity to engage in the field with relevant stakeholders and give depth to relevant perspectives in the Lofoten region. Observations is also used in this thesis, from the Norwegian Aviation Conference 2022 (May, 2022) and a workshop meeting with Lofotrådet and Widerøe Zero (January, 2022). Observation is useful for approaching the field in a natural and open setting and especially observing the Aviation Conference gave insights into the industry´s directorial work. The objective is to understand how societal factors are present in the energy transition in the aviation industry, and to gain insights into the relation between technological factors and societal factors.

Energy transitions are characterized by being complex and multifaceted, and by adopting this methodology one ensures a better understanding of an energy transition. There are several elements that are focused on in this thesis that are of particular interest in an energy transition, and inherently also in the Lofoten case. One is how new sustainable technology impacts actors within and outside the regime, as well as the implications the new technology has on the connected value chains. These changes are not isolated, and when the local and national transitions have settled, one can look toward how this effects Norway´s global position in aviation. Another interesting element is how the technological change unfolds in the society and how social factors influences the energy transition. This thesis seeks to understand these elements through the QH model, vision theory and MLP.

Building on the theories presented in chapter 4, this section describes how the theories will be used to build upon the analysis. The QH model contributes to the analysis by emphasizing the importance of co-creation of four different spheres in society: industry, government, academia, and population. Using the QH model, the analysis includes findings on the importance of cooperation between networks of knowledge institutions, public administration and end-users, and the passenger and general population´s position in the energy transition. The result of these two findings will inform a need to enhance cooperation to pursuit an energy transition with low risk of "failing", such as dealing with local resistance. The vision theory provides general future scenarios found in the energy transition toward electric vehicles. These visions provide useful insight and a theoretical base for the data collected during the interviews, as many factors within the vision theory are identified in dialogue with stakeholders in Lofoten and the aviation industry. The QH model and vision theory are frameworks that fit into the MLP analysis because they both discuss the actors and users´ role in innovation. Sovacool et. al. (2020) operates with the terms niche, innovation, regime and landscape which makes their findings understandable and transferable into a MLP model.

4.2 Literature reviews

This thesis consists of literature reviews to look at the wider context of energy transition. It is beneficial to undertake a literature review as part of the research because it provides a broader framework and background around the energy transition in Lofoten. A literature review contextualizes this thesis, and presents the research as one piece of a larger "jigsaw puzzle" (Ridley, 2012, p. 6). The focus during the literature review have been on the concepts of MLP and energy transitions, because the two are fundamental frameworks for this thesis. The aim of the literature review is to explore the concept of energy transition through a multi-level perspective, and then transfer the framework and ideas to the Lofoten case. The review will show how earlier work on energy transitions have effectively been analyzed using the MLP framework such as the transition from sailing ships to steamships (Geels, 2002; Geels & Kemp, 2007), and the electrical energy transition in the car industry (Geels, 2012; Geels et al., 2016). Therefore, it will demonstrate how MLP is an adequate theory to analyze the data found in this thesis and for further studies of the the energy transition in Norwegian aviation.

The scholarly works involved in the literature review were located in one of three ways, they were either 1: subject in earlier courses in the Master´s program, 2: found by searching specific key words in different arrangements in Oria and Google Scholar (Energy Transition + Aviation + Communities + Social Science + Case Study), or 3: located because the works were used and cited in literature located from using steps 1 and 2. When using Oria there was an extensive need to reel out relevant literature, and this was done by proceeding to search for energy transition in aviation using more key words. At the time, Energy Transition + Aviation gave 391 peer reviewed hits, whereas Energy Transition + Aviation + Social Science gave 37 peer reviewed hits. Exploring with different compositions of the 5 initial key words, and reading abstracts to select relevant literature, 4 scholarly works that fulfilled the criteria of including energy transition, aviation and social perspective were found (Gangoli Rao et al., 2020; Kim et al., 2019; Nakamura et al., 2013; Santos & Delina, 2021). This is a relatively narrow search result, as it describes related research in the field and shows how this thesis addresses a gap in the field.

Another crucial part of finding relevant literature, were locating documents such as reports, press releases and news articles. This includes the Avinor reports (Avinor, 2020a, 2020b, 2021; Avinor & Luftfartstilsynet, 2020; Avinor & Statens Vegvesen, 2020), as well as press releases and articles from the airline companies and manufacturers themselves (King, 2022; Ogre, 2022; SAS, 2022; Tecnam, 2021; Trumpy, 2022). It is important to point out that none of these are peer reviewed and are produced by the companies with subjective intentions and are reviewed accordingly.

4.3 Interview

This section will describe the interview process, including preparation, selection, and the execution of the interviews. Interviews and observation are an opportunity to engage in the field. This thesis uses interviews to gather information and knowledge about the energy transition in aviation in Lofoten, and the objective of using interviews is to gain insight on perspectives and information that I could not obtain from solely reviewing literature and reports. The interview process, from composing the interview guides, while conducting the interviews, to transcribing and comparing the finished interviews, also created an opportunity to reflect over the chosen theme and research objective. During this process, many thoughts matured, and steered analysis and discission. The interview process provided an effective way to gather information from the people in the field, their personal and cultural meanings within the energy transition (Magnusson & Marecek, 2015). Energy transition in aviation is mostly discussed through the technological aspects in literature, but with my focus on social and societal factors, the interview process enabled to understand actors´ and people´s accounts and concerns from their point of view.

4.3.1 Selection

The participants were chosen because they are visible names and faces in the energy transition in aviation in Norway, either because they represent a relevant business actor, or because they are engaged in the local debate of LTGI and aviation. The interviewees were contacted by me via e-mail or text message. The outcome of the selection process resulted in eleven interviewees, four representants from the Norwegian aviation industry, and seven representants with different interests from Lofoten. Following is a description of what perspective the participants represented.

The participants are identified within the QH model, as industry, government, or community actor. Four industry actors were interviewed: Widerøe Zero represents the national aviation industry, Lofotkraft Muligheter represents local industry, Bodø Lufthavnutvikling is a partner in Energi i Nord and represents national industry and ground infrastructure. Scandic Leknes Lofoten represents a local tourist business. Five government actors were interviewed, the first two represent the local politics perspective: the mayor of Flakstad from the Centre Party (Norway), and the mayor of Vestvågøy from the Labour Party (Norway). Other government actors are from Avinor: the VP of sustainability at Avinor, who represents the national aviation industry, and the Avinor airport manager at Leknes who represents the local aviation industry. The last government actor is from the Civil Aviation Authority, which is the national aviation industry perspective. Lastly are the community actors, which is from BirdLife Norway that represents an NGO and local/national nature conservation, and a representant from Vest-Lofoten Business Association that represents local business interests. See appendix for the list of interviewees.

I pursued to ensure a representative selection from the national aviation industry, as well as locally from the Lofoten case. Some of the representatives could represent more than one body in terms of the QH model, but for the sake of overview and limitations, they have been categorized after their clearest role. This also speaks to how dynamically the different bodies interact, which is shown in the following analysis.

4.3.1.1 Interview preparation and execution

The interviews were conducted between January 2022 to March 2022, ten interviews and eleven interviewees. Five of the interviews were conducted in person, where I travelled to Lofoten to conduct field work for a week. The remaining interviews were conducted online Teams. Upon agreement to be interviewed they were then sent an information summary and consent form. Before the interviews started, I ensured that I had received back a signed consent form, where the interviewees informed their consent to participate, that they could be quoted and if their names could be published. All interviewees consented to these three options, thus are none of them anonymized. The representants from the aviation industry, respectively Widerøe Zero, Avinor and the Civil Aviation Authority, made it clear that they spoke on behalf of their organization, as well as they were comfortable with contributing with their own personal educated reflections. All quotes were approved over e-mail before submission of the thesis.

The interviews were based on an interview guide created by me with the research objective and questions in mind. I had two different interview guides, one for industrial actors and one for local business actors and politicians. The two guides were based on the same research objective but differed in the approach of the questions. For industry actors, I focused on their role in the energy transition, their visions and expectations to sustainable aviation and their deliberations on green technologies as an innovation coming into the market. For local business actors and politicians, I focused on their local role and engagement, their visions, and expectations for sustainable aviation in Lofoten as a community, and their reflections around implementing change in their local community. The interview guides were semi-structured and allowed for discussion and elaborations in any direction that the interviewee preferred. Like the interview guides, the interview situation was therefore semi-structured with open-ended questions. This created a relaxed and conversational tone, which allowed the interviewee to offer reflections and opinions (Magnusson & Marecek, 2015). This contributed to a positive experience of the interview at both ends of the table. The interview guides did however act as an anchor, with relevant follow-up questions which kept the dialogue dynamic, and the discussions were on topic.

4.3.2 Observation

In addition to literature review and interviews, observation is a method used to gather data. Like interviews, observation puts the researcher in the field, accessing data directly from ongoing discussions among key actors. As previously mentioned, I conducted two workshop observations, one meeting with Lofotrådet and Widerøe Zero on Teams, and I participated as an observer on the two-day national Aviation Conference in Bodø. These events gave me the opportunity to explore how the socio-technical development within aviation is emerging and how the relevant stakeholders for this thesis understands these.

Meeting between Lofotrådet and Widerøe Zero on Teams

The meeting with Lofotrådet and Widerøe Zero was conducted 27.01.22 on Teams. The purpose of this meeting was for Lofotrådet to express their interest and discuss a potential future with Widerøe´s testing of electrical aircrafts. This meeting was one of several workshop meeting hosted by Lofotkraft. Andreas Kollbye Aks were Widerøe Zero´s representant and presented their plans and values. This was essentially a summary of what Widerøe and Widerøe Zero has presented in various reports and press releases. For Lofotrådet´s position, this meeting was truly important as they continued to plant their interest and will to cooperate with Widerøe Zero. My role in this meeting was to observe how the government body of Lofotrådet interacted with the industry body of Widerøe. Of particular interest was to observe what discussion topics were focused on, and to clarify exactly what future plans Lofotrådet and Widerøe had for each other. The latter was harder to understand clearly, as Widerøe Zero portrayed strong commercial values and could not commit to using Lofoten as a test arena for their electrical aircrafts. Lofotrådet on the other hand, has a clear ambition that they want to be the pilot region for Widerøe´s first electrical aircrafts (Lofotrådet et al., 2022), and clearly expressed this in the meeting.

Aviation Conference in Bodø

During my data collection, the annual Aviation Conference in Bodø took place 10.-11. May 2022. I participated as a student and observed numerous presentations and workshop meetings held by and for essential actors within Norwegian and Nordic aviation. One of the most relevant and interesting presentations were “Electrification of regional aviation” by Anders Forslund, the founder and CEO of Heart Aerospace. Here, Forslund presented Heart Aerospace´s clear intentions of using their electrical aircrafts in the Norwegian short-haul network. Being present at the Aviation Conference gave me an understanding of the interactions between actors in the Norwegian industry beyond the professional input given in the presentations. It also gave me an understanding of what some of the dominant actors, such as the Civil Aviation Authority, Avinor and the airline companies´ visions are for the future. It was also an opportunity to engage with the stakeholders in a more informal setting, as they were eager to discuss the content and relevance of the thesis questions that I was exploring.

The combination between literature review, interview and observation provided many opportunities and different arenas to gather information and gain knowledge about the topic. This chapter has described how the research was conducted, and what value the different qualitative methods brings to the research. The next chapter will include the analysis of the findings, presented through the QH model, vision theory and MLP.

5 Findings and analysis

This chapter will connect the empirical findings to the theoretical framework of chapter three. First, the aviation actors that are connected to the aviation in Lofoten will be identified and presented through their affiliation within the QH model. Then their role and contribution to the energy transition in Lofoten will be explained. The actors will also be identified within in the niche or regime level. Then the visions of the key actors will be presented, in the light of environmental sustainability or economic sustainability. Thereafter follows a section of drivers and barriers found in the energy transition in aviation in Lofoten, categorized by the elements that form the regime of a socio-technical system: society and culture, users and markets, policy, industry, technology, and science.

5.1 Quadruple Helix Model and aviation actors in Norway

The QH model brings together industry firms, research centers, independent investors and lead users (Roman et al., 2020). Ideally there is collaboration between the different QH actors continuously throughout the process of energy transition, and the processes are identified as “agenda and ambition planning, decision making, implementation and evaluation” (Roman et al., 2020, p. 4). The QH model emphasizes coopetition and coevolution, which are described as the dynamically intertwined processes of cooperating and competing in socio-technological evolution (Carayannis & Grigoroudis, 2015). The coopetition and coevolution take place across the QH actors. All QH actors play an important role in the energy transition, and no single actor or group of actors are more important than other (Rodríguez-Pose & Wilkie, 2016; Roman et al., 2020). The next section will present the key actors in the different QH groups (Government, Academia, Industry, Community) in Lofoten, the nature of their interactions and why they are relevant to the thesis.

5.1.1 Government

The government actors represent the political systems (Carayannis & Grigoroudis, 2015), and in the Lofoten case they are Lofotrådet, the Civil Aviation Authority, the Ministry of Transport and Avinor. Lofotrådet is the intermunicipal cooperation of the 6 municipalities in Lofoten. Their tasks include region advisory and political cooperation, and they have prepared the road map to sustainability in Lofoten which included the ambitions for low-emission aircrafts in Lofoten´s short-haul network (Lofotrådet et al., 2022).

The Civil Aviation Authority, the Ministry of Transport and Avinor are the national government bodies that are directly connected to aviation and short-haul networks. The government actors define policies and programs, including subsidies and measures directed at actors in academia, industry, and community. In return they are influenced by markets and the competitiveness and productivity within innovations (Carayannis & Grigoroudis, 2015).

5.1.2 Academia

Academia represents the education system, referring to universities, higher education systems and schools (Carayannis & Grigoroudis, 2015). There are many research-focused institutions that are involved in the studies of sustainable aviation, such as SINTEF and The Institute of Transport Economics (Transportøkonomisk institutt – TØI) (Wangsness et al., 2021). In the Lofoten case, UiT – Arctic Univeristy of Norway has been academically involved. UiT has a Master´s program in aviation where sustainable aviation is in focus. In addition, UiT and University of Tromsø School of Aviation (UTSA) own two electrical aircrafts that are used fort training purposes (Eidum, 2020; Rolland, 2019). The Master´s program and the two electrical aircrafts at UTSA "is a result of close cooperation with central actors in aviation" and "there has always been decent interaction around the development of the Master´s program, either it being identifying knowledge gaps or learning objectives" (Eidum, 2020) (author´s translation). UiT has also incorporated sustainable aviation in courses at the Department of Social Sciences, emphasizing the interaction between technology and society and interdisciplinary approach to energy transitions.

5.1.3 Industry

Industry represents the economic system, involving industry/industries, companies and services (Carayannis & Grigoroudis, 2015). The industry actors present in Lofoten are Lofotkraft, Elmea, Destination Lofoten, Energi i Nord, Widerøe/Widerøe Zero, and Heart Aerospace. Lofotkraft and Destination Lofoten are partners with Lofotrådet in the LTGI project, while Elmea is the local grid company in Lofoten. Lofotkraft, Elmea and the northern industry network and cluster Energi i Nord are the most prominent potential actors to offer new infrastructure in the energy transition. This includes among other things power lines, charging infrastructure and battery storage. The details of the future infrastructure are not ready but said actors are involved and interested in the planning process. Widerøe is an established actor within the regime in Norway, involving their start-up company Widerøe Zero that works exclusively with electric aviation. Heart Aerospace is currently Widerøe

Zero´s closest competition. Both actors are close during the development of the electric aircrafts and both actors have expressed their intention of using their innovation in the Norwegian short-haul market. The main difference is that Widerøe with Widerøe Zero is well-established within the Norwegian short-haul network, whereas Heart Aerospace, as a manufacturer, is dependent on an entrance through an airline operator or operate themselves after tender processes. For the electrical aircrafts to be certified, they need to go through certification and legal processes, framed by both international and national government bodies. The certification process and its role will be discussed later in the analysis.

5.1.4 Community

Community represents the civil society, which includes culture, tradition, and values. The community is Lofoten´s population, the 24 604 people who lives and works in the region, and who will represent a fair amount of the end-users in the energy transition. “The role of civil society and citizens is seen as especially valuable for strengthening social innovations in regions.” (Carayannis & Campbell, 2009; Carayannis & Rakhmatullin, 2014; Roman et al., 2020). The citizens and consumers in Lofoten represents the demand-side perspective in contrast to the industry´s supply-side (Roman et al., 2020). Communities can therefore be important participants when implementing new innovations, as they can express their sustainability and development visions. The involvement of communities can boost trust and social acceptance towards government actors, as the general population feel like they are involved and prioritized. This is true in the case of Lofoten and LTGI, where an NGO representative from BirdLife Norway expressed demands of being involved from environmental and ecological interest views (BirdLife, Interview), and also local businesses express a need to be prioritized (Scandic Leknes, interview). Figure 4 shows the four bodies of the QH model, where the actors of Lofoten are identified as government, industry, academia, or community. These are examples of actors from civil society and business interests that would like to take part of the process, and they see involvement as a prerequisite for having a legitimate process of energy transition.

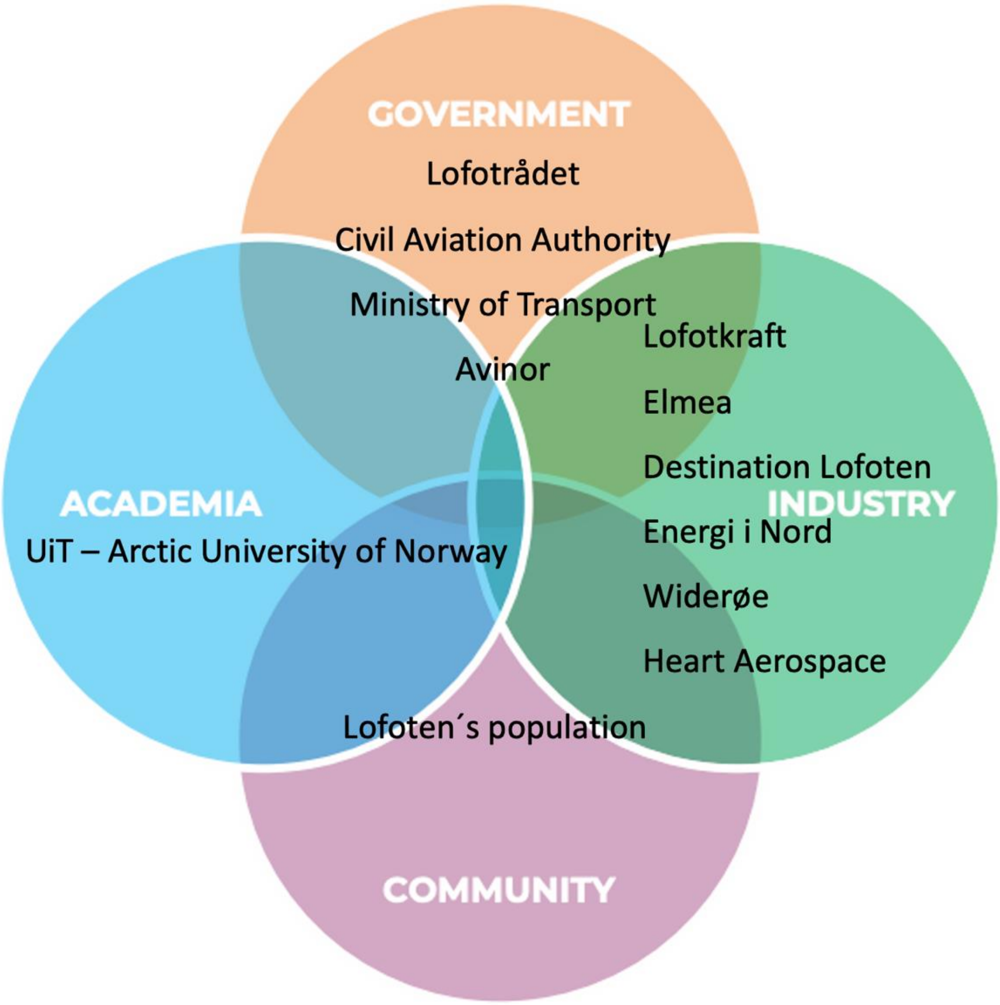

Figure 4: The QH model with Lofoten´s actors in aviation.

5.1.5 The roles of Lofoten´s aviation actors

During the introduction, various actors were presented as well as their position within the MLP model. This section will discuss how the actors of the energy transition in aviation in Lofoten fit into the three different levels of MLP, landscape, regime, and niche-innovation. The landscape represents the aviation sector. The regime is the airline companies, and providers of aviation infrastructure on ground. The niche-innovations are new technologies of low-emission aircrafts, such as electrical aircrafts, electric hybrids, SAF, and hydrogen solutions. As mentioned earlier, this thesis focuses on electrical aircrafts.

The aviation industry has various technological niche-innovations on new propulsion systems in aircrafts. These innovations can come from experienced actors in the field because they have delivered fossil fueled related propulsion systems for generations, such as Rolls-Royce and Tecnam. And as well as operators such as Widerøe that now uses fossil fuels but has invested in the niche-innovation of electric aircrafts. These actors generally find themselves well established in the regime of the aviation sector, contributing, and following the behavioral systems that are in place. The niche-innovations can also emerge from new or untraditional actors. Heart Aerospace is a start-up company that is new to the aviation sector in that sense that they have not before produced or operated in the established fossil fuel regime of the sector. Their niche-innovation, a 19-seat electric airliner (ES-19), was generated in the niche-innovation concept of the MLP, supported by other actors that have the same expectations and visions. There are actors that are new to the aviation field, that traditionally has not had any affiliation with the sector. These are actors that will enter the aviation industry because the energy transition calls for a change in power supply and infrastructure. The potential opening of the aviation regime creates opportunities for actors to enter that previously has delivered their electric and hydrogen services to other sectors. Energi i Nord, and many of their subgroups, plan to deliver on a new demand of power supply of both electric power and hydrogen to the infrastructure on ground. Lofotkraft and their grid company Elmea will also enter the aviation sector as a new actor. Lofotkraft and Elmea aim to deliver electric power and shape their electric grid based on future demand.

Selected members of Energi i Nord, such as power companies like Troms Kraft, as well as Lofotkraft/Elmea that are already established actors in the electric energy sector vis-à-vis regimes. They now enter the aviation sector through a window of opportunity where the landscape is abrupted by environmental problems, following broad political mobilization to make changes to relevant sectors and regimes. Their services and behavior in other regimes are appealing to the transition in the aviation regime because they possess the supply which an energy transition in aviation demands. In a potential transition pathway, these actors could be placed somewhere between the niche-innovation sphere and the socio-technical regime. The actors are not innovations themselves nor is the technology or energy that they possess. The new infrastructure and new use of that technology and energy may be placed in the innovation sphere, and the new roles of the actors could also be considered to belong in the niche-innovation concept. While these actors and services could be considered innovations in a MLP perspective, they are not brand-new companies that are created specifically to operate in the aviation regime. They are already established actors in other sectors and regimes, even in another transportation sector, making them more stable than they would be if they were startup companies with no experience from any sector.

However, the hydrogen actors from Energi i Nord are in a slightly different position. Hydrogen as an energy carrier in the transportation sector is not as established as electric energy carriers in the same sector. Therefore, they are new to both the aviation sector and the transportation sector. Their position as a niche-innovation moving toward establishment in the socio-technical regime, is strengthened as they gain more support from innovation networks as well as support from actors that are already established in the regime. Established actors will become dependent of new innovations along the energy transition path. This process is dynamic, and the speed of innovation and transition will vary depending on exogenous and endogenous factors.

In the niche-innovation sphere there are many networks of actor and niches. In the aviation industry, the actors working on sustainable aviation through new technology share expectations and visions. They may be developing similar technology, but separately with their respected goals and capital. This can be described as coopetition and is the act of cooperation between competing companies. The coopetition in Norwegian aviation industry was a subject discussed at the Aviation Conference in reference to new technology entering the industry (Aviation Conference, observation). Each actor and niche-innovation gain momentum as the networks of actors support the novelties, but also compete in developing new technology. The topic of coopetition could be fitting for further research on innovation actors in the aviation industry, where technology transition may be studied further through innovation and business studies. Coopetition is also fitting to illustrate through the MLP, which is used to analyze the sectoral systems of innovation approach and the roles of actors in different stages of system innovations (Geels, 2002).

5.2 Visions of key actors

This section will include the different visions of sustainability found among the key actors in Lofoten. The definition of sustainable development per the Paris Agreement is limiting global warming to 1.5°C to achieve a fair, equitable and sustainable world (United Nations, 2015). However, the actors portray different perceptions of what sustainability means for Lofoten. The findings of this thesis point to an ambiguous understanding of what sustainability could be, and lead to two main visions of sustainability: environmental sustainability and economic sustainability, which both interact with social sustainability. This speaks to how economic factors are just as important as environmental factors in innovation processes.

The different perceptions of the sustainability term create diverse visions for Lofoten´s future. What sustainability is, and just as important what it is not, is discussed differently among the informants. A key factor is the discussion of tourism in Lofoten and how to ensure the best possible economic and environmental future for Lofoten. The tourism industry is important for economic revenue, at the same time as the tourist flow creates environmental decomposition, and increased emissions from fossil air traffic. LTGI has set a goal of reducing their total emissions by 50% by 2030 and to become a low-emission society by 2040 (Lofotrådet et al., 2022). These numbers are created in line with the goal of the Paris Agreement to limit global warming to preferably 1.5°C, maximum 2°C. This means that the world needs to be a zero-emission society by 2050, and a majority of the world´s countries have committed to introducing measures to reach this goal (Avinor, 2020a; United Nations, 2015). The definition of environmentally sustainable can therefore be considered any action that will help reach this goal. Economic sustainability speaks to the practices that ensures long-term economic growth, such as increased activity in business in all sectors. Economic growth strengthens social factors, as it creates jobs and opportunities and could boost the livelihood of the communities. Environmental sustainability also strengthens social benefits as it can create community bonds, improve environmental surroundings and quality of life, and provide hope for an improved future. There is a fine line between the two visions of sustainability, and the two visions do not always correlate.

5.2.1 The environmental sustainability vision

The nature conservation counsellor at BirdLife, based in Lofoten and identified as a community actor, reflects two specific climate measures that would help reach the goal of decreasing today´s CO_2 emissions by 50%, and deserve the description of sustainable. One is land management, which means to not expand more infrastructure than there already is, with the goal of not losing any more nature and bird and animal population. The second is overall cuts in CO_2 emissions, where the method should be reducing CO_2 emissions in every area and sector as possible. According to the representative from BirdLife, the bottom-line total emission is what matters, and the lower that bottom line is, the more sustainable it is (BirdLife, interview). “Sustainability for me is to not deteriorate the nature further, we need to restore nature and cut GHG-emissions to reach the climate goals. I believe we can go far with area neutrality, meaning not expanding more buildings or roads.” (BirdLife, interview). Implementing zero-emission aircrafts does not alone earn the term sustainable or reduce enough cuts in CO_2 emissions. The belonging infrastructure on the ground also need to meet certain sustainable qualifications. Reflected by the representative from BirdLife, this means that no more land, nature, or animal population should be deteriorated by expansion of infrastructure, such as airport buildings or renewable energy power plants (BirdLife, interview). According to the BirdLife representative, it is not enough that the energy provided for zero-emission aviation is renewable; it cannot come from a power plant that deteriorates untouched nature. The BirdLife representative called for an objective perception of sustainability that sets the right regulations that truly does protect nature and cuts enough CO_2 emissions to actually meet the goal of 1.5°C. As the representative from BirdLife puts it, "A decent concept of sustainability could set the right limitations" (BirdLife, interview). However, the concept of sustainability is differently interpreted among the interviewees, and this shows how perceptions on environmental protection and climate change can be very widespread within the same local cases.

The representative from BirdLife reflects on how emission reduction and conserving nature as much as possible be the bottom-line goal. A potential remission in air traffic and tourists and population growth would not be a barrier for sustainability. Quite the opposite, it would be positive to decrease fossil traffic that leads to emissions via a potential remission in air traffic while the technology is being developed. When asked if the population and tourism of Lofoten could afford to have potentially limited mobility in the implementing phase of sustainable aviation, the BirdLife representative responds: "What we cannot afford is to not start the transition to a sustainable society. The fundament of everything is a well-functioning climate and nature. What we cannot afford is to continue to destroy our climate and nature." (BirdLife, interview).

5.2.2 The economic sustainability vision

Investing in sustainable technology may generate economic benefits and gaining economic revenue can accelerate energy transitions. This driver is especially clear in discussions by government actors such as Steinland (Civil Aviation Authority, interview), Aks (Widerøe Zero, interview), Larsen (Avinor Sustainability, interview), community actor Voie (Local Business Association, interview) and industry actor Lervik (Lofotkraft Muligheter, interview). Although it varies if the economic motivation is present as a bonus in addition to reducing emissions, or if the motivation for investing in green technology is solely for economic capital. Some of the actors may have stronger economic intentions than they have environmental and ecological ambitions but investing in sustainable technologies in aviation will nevertheless reduce CO_2 emissions. It is not for this thesis to conclude their exact intentions. The public and semi-public actors that have interests in aviation in Lofoten, such as Lofotkraft and Widerøe, are clear on their benefits from sustainability. The representative from Lofotkraft Muligheter discusses how there is an anticipated economic growth in the renewable energy field. “A driver for this project is the economic gain, as an actor in the energy sector, we can expect more attention and increased economic revenue attached to the renewable energy sector” (Lofotkraft Muligheter, interview). This suggests that investing in green technology is a smart tactical move for the businesses in and around Lofoten and would have both environmental and economic benefits.

The vision of economic sustainability is discussed by a representative from Vest-Lofoten Local Business Association (interview). The representative from the Local Business Association discusses how Lofoten cannot lose neither population nor income at the expense of reaching the goal of reducing emissions by 50% by 2030 and limit global warming 1.5°C (Local Business Association, interview). In response to the question if the representative for the Local Business Association supported the vision of reducing Lofoten´s emissions by 2030, he responded “as a vision yes, but we must wait and see if the vision reaches specific measurable results, but it is appropriate to have a vision to reach for”, followed up by reflecting on how important increased air traffic and expanded infrastructure would be for the communities of Lofoten: “I see only benefits with an expanded airport in Leknes, we will have cheaper fares, more flights to Oslo, Europe and the rest of the world. It will benefit the population, as well as local businesses that are competing (…). I also believe that it will give tourism a boost.” (Local Business Association, interview).

Building on this reflection, I ask how increased CO_2 emissions and ecological footprints that comes with increased tourism and population growth could be associated with the sustainability term. The Local Business Representative discusses how “when we get zero-emission aircrafts, it will remove a major part of this that is not sustainable, and it will cut emissions.” (Local Business Association, interview). This suggests that it is not the increased air traffic and tourism that is not compatible with sustainability. It is rather limitations on travel habits and regulated traffic that will lead Lofoten down a non-sustainable path. The representative from the Local Business Association´s main concern is the time cap for the vision of LTGI, and that limiting fossil traffic while waiting for renewable energy solutions would decrease mobility and would therefore not be sustainable for Lofoten´s population and business. The representative points out “I think we need a longer time frame.” (Local Business Association, interview).

This discussion could appear as two separate discussions, one debate being the conversation of whether to expand the Lofoten airport or not, and the other debate being whether to implement electric aviation in Lofoten or not. The two does not necessarily exclude the other, because small electric aircrafts can land on both the short runway that is there today, and a potentially longer runway. However, expanding the runway and increasing air traffic, while cutting CO_2 emissions are two conflicting ideas. The two positions are not compatible, purposely increasing CO_2 emissions through increased air traffic, and expanding the airport at the expense of nature could not be categorized as sustainable regarding the Paris Agreement goal and backed by the representative from BirdLife´s discussion. Theoretically it could be compatible if other sectors cut more, in order for the aviation sector to cut less. This is unrealistic as all sectors should be aiming for as many cuts as possible. Ultimately one can conclude that increasing air traffic with fossil fueled aircrafts and expanding runways could not be compatible with the term environmental sustainability. In the case of Lofoten and LTGI, the two visions of economic and environmental sustainability are present in the local airport discussion.

5.3 The local airport discussion

Avinor and the Norwegian Public Roads Administration has prepared a concept proposal for a new transport solution in Lofoten, with a planned expansion of the airport in Leknes (Avinor, 2020b). This would mean that Svolvær Airport will be closed, with one argument in this debate being that one cannot have a small airport in Svolvær in addition to the large airport in Leknes, and therefore Helle Svolvær must be closed down (Avinor & Statens Vegvesen, 2020). Keeping both airports is not economically possible for Avinor, as the VP of sustainability from Avinor puts it “the two airports would not be too close geographically, but economically” (Avinor Sustainability, interview). A larger airport in Leknes would mean that the airport would be able to receive more and larger arrivals, such as larger charter flights. As discussed in the introduction, Lofoten has been a popular tourist attraction, and has seen an increase in visitors the last years, both by air traffic and road traffic. The investigation of the expansion is still ongoing, and the financial plans are not ready. The financial plans will unfold in the official Government budget and National Transport Plan and has not yet been assessed. A large airport in Leknes would mean that the road between Svolvær and Leknes must be improved so that travel time by car is shortened and more efficient. For residents in Svolvær, this would mean a shorter travel time to the nearest major airport, compared to the travel to Evenes airport. The tourist industry considers it positive to be able to fly tourists directly to Vestvågøy and expects that a large airport would increase and spread the volume of tourists throughout the year. Ticket prices to Oslo will be cheaper, which is positive for both businesses and the population. Avinor and the Norwegian Public Roads Administration (Avinor & Statens Vegvesen, 2020) concludes that a large airport at Leknes will be the best socio-economic solution with the best airport coverage since the entire region then lies within 30-60 minutes' drive from the new airport at Leknes (Sundby et al., 2020).

The expansion of Leknes airport is a hot topic among the population in Lofoten. On one side of the discussion, the businesses and various industry would benefit from an increased flow of people and increased accessibility. On the opposite side, increased flow of people and goods would mean increased environmental and ecological footprints in Lofoten. The increase of fossil air traffic would contribute to CO_2 emissions, and the region´s increased accessibility would result in immediate consequences such as increased degradation of nature, and of infrastructure such as roads, bridges, and tourist attractions. There are many economic and social benefits to an expansion of the Leknes airport, such as generating revenue from increased flow of people and goods, and increased accessibility to Oslo/Gardermoen and other international airports. It is considering these appealing benefits that the implementation of electric aircrafts meets local opposition.

In earlier work (Grebstad & Arctander, 2022; Sundby et al., 2020) the discussion of the local airport extension and the discussion of implementing electrical aircrafts have gone hand in hand. However, the analysis of this thesis show that these two discussions are in fact two separate discussions. One of the initial arguments for this finding is that an electrical aircraft can land on both a short runway and a longer runway meant for larger Airbus and Boeing machines.

The first generations of commercial electrical aircrafts will seat from 9 to 19 passengers, and for these to be used on a larger scale in Lofoten indicated that the infrastructure will not develop in the direction of large airport hosting large flights. The air crafts would require a long charging time, and this could indicate that the capacity in the air traffic will be reduced as a result of fewer daily departures. In such a future scenario, some air traffic would apparently be transferred to other means of transport such as bus and ferry. This would require greater demands of road infrastructure and a well-developed differentiated public transport offer. However, one argument that avoids the decrease in air traffic, is Widerøe´s proposal of parallelly implementing the electrical aircrafts while fossil fueled air traffic is still in place. This would cut the total CO_2 emission of air traffic in Lofoten, but not cut the number of arrivals and departures, or increase road travel. Implementing electrical aircrafts therefore does not immediately result in less departures, and the discussion is redirected to the willingness to commit to test and use electrical aircrafts on Lofoten short-haul network.

5.4 The multi-level interaction of key actors

This section will identify drivers and barriers categorized by the dimensions that form the regime of a socio-technical system; society and culture (user preferences), policy, industry, technology, and science. Every dimension is connected to actors, and the dimensions along with the regime actors are connected in an intertwined network. The drivers and barriers will be identified within the three levels of MLP, landscape, regime, and niche.

5.4.1 Society and culture

Regime:

Driver: Mobility for the Lofoten region

The short-haul network and Widerøe as the dominating operator is crucial for Lofoten´s mobility. When the Dash-8 regional aircrafts are retiring and being replaced with new technology, it puts the mobility in a more vulnerable position. A technology transition in aviation must fulfill the important criteria of good mobility for the users in both the development process and as final products. This implies mainly the number of departures and ticket fares. Zero-emission aircrafts should deliver the same or an increased level of quality and quantity of mobility. Widerøe´s regional aircraft fleet is retiring; at the same time the aviation industry is entering a new era and many new aircraft concepts are being developed. The representative from Widerøe Zero describes this as a “generational change”, where Widerøe has taken strategic choices to invest in the technology that they predict will succeed in the future (Widerøe Zero, interview). They extended the life expectancy for the current Dash-8 regional aircrafts, which gives them the opportunity to operate their outgoing aircrafts parallelly while new technology and tomorrow´s aircrafts are being developed. Further, the representative from Widerøe Zero explains how mobility is important for Widerøe as a company and Norway (Widerøe Zero, interview). It is challenging to use road transportation such as car and bus because of the region´s islands, mountains, and many fjords. It is also common to use ferry as transportation, which could be both time-consuming and expensive. The communities of Lofoten therefore uses air transportation in the same manner as other cities use buses and trains. Good mobility for Lofoten means that the outside world is easily accessible, for import and export of both people and goods. It is essential to be well-connected to the regional center Bodø and internationally through Oslo/Gardermoen for people to settle down in district areas.

Barrier: Low community involvement can result in low social acceptance

Research show that increased awareness and increased knowledge boost the overall willingness to counteract climate change and to accept climate friendly technologies (Spence et al., 2012; Strazzera et al., 2012; Thøgersen & Noblet, 2012). Along with awareness and knowledge, comes the subjective opinion of fairness by the affected population. If a solution or a technology that is being phased in a local community does not present itself as proportional in regards of how big of an effect it will have (e.g., will it truly reduce climate emissions, and/or will it deteriorate nature or biodiversity), or will it strengthen social or economic differences in a community, then the new solution is more likely to be subjected to resistance or indifference regarding the population´s participation (Svartdal & Kristoffersen, 2022). Lofotrådet has hosted workshops for the communities of Lofoten, sharing their visions for LTGI (De Grønne Øyene, 2022). However, during the interviews, people within the community and local industry category expressed that they did not feel involved in the project. The representative from BirdLife discussed a perception of not being involved, feeling that his organization were directly unwanted (BirdLife, Interview). The representative from the local tourist business discussed an uncertainty of his and his organization's role in LTGI and had no clear vision of what their involvement would be (Scandic Leknes, interview).

The degree of fairness that the population experience in both the preparation phase and the decision-making phase affects their support of the project. Meanwhile it is challenging to accommodate every objection, wish, and need a community will have in an energy transition process, but one must pursuit a decent process. Research from 1990´s and 2000´s focused on how and why people are skeptical toward changes in their local communities and immediate areas, is often because of a personal fear of negative consequences and lesser quality of life (Sijmons & van Dorst, 2012). This phenomenon is described as “Not In My Back Yard “NIMBY” effect, emphasizing that these interventions can result in vast engagement and negative reactions. One can also be met by indifference when phasing in new green solutions or renewable energy in a local community, because the population do not see the value that green technologies can do for social sustainability, their industry base, or their community (Svartdal & Kristoffersen, 2022).

Barrier: Skepticism towards the vision of Lofoten´s role in climate change

Building on the visions that were mapped out earlier in the analysis, findings show that many of the representatives doubt that Lofoten as a region has a key role in the fight against climate change. It is especially the timeframe that is discussed as problematic. This was most clearly expressed by the Local Business Association representative. The representative from the Local Business Association reflects over Lofoten´s position in a global perspective and criticizes the timeframe and the scope of the energy transition which LTGI has vowed to engage in, the Local Business Association representative explains “I think we need a longer time frame. I support the LTGI vision, but it takes time to go from a vision to concrete measurable results, but it is good to have something to reach after.” (Local Business Association, interview). In the meantime, between introducing electric aircrafts and until it becomes a reality, the representative from the Local Business Association argues that the fossil air traffic structure already in place should be strengthened to increase social and economic revenue in the region. “The technology can cause social and economic barriers if implemented before it is mature.” (Local Business Association, interview). During the interview, it became clear that the word “mature” refers to when electrical air crafts will not decrease the number of departures and the passenger ability of the short-haul network. The Local Business Association representative emphasizes a gradual transition over fast transition.

The representative from the Local Business Association does not accept a scenario where Lofoten offers itself as a test region for electrical aircrafts, because the population and local businesses are in a vulnerable position due to being a district region with already challenging infrastructure. The representative Bodø airport development also expresses concern regarding the timeframe and scope of LTGI, stating “I do not think Lofoten is aware of what they have started on” (Bodø airport development, interview).

Trond Kroken, the Mayor of Flakstad municipality and member of Lofotrådet also expressed concern regarding the role that Lofotrådet has taken upon them.

"I´m worried that Lofotrådet has undertaken too much here. We are also engaging in other cases; we must have the time to reach over everything. Right now, it is fine, but soon every detail of the LTGI needs to be detailed and we will have a bigger workload." (Mayor Flakstad, interview).

Remi Solberg, Labour Party mayor of Vestvågøy municipality explains that this is why they are dependent on cooperating with other actors across the LTGI project,

"The most important thing we do is to talk to our residents, keeping them informed in the process and being honest. Also having collaborative consultations with operators such as Widerøe, and Avinor and Luftfartstilsynet, because they are important actors involved. I also think that it is important for us as politicians to work close with the Ministry of Transport and Stortinget, so we will receive the support we need to succeed." (Mayor Vestvågøy, interview).

Barrier: Lofotrådet´s reputation among NGO´s

The representative from BirdLife also expressed concern against Lofotrådet. In his experience, Naturvernforbundet (Friends of the Earth Norway) and BirdLife Norway are not pursued as interesting cooperative partners for Lofotrådet. "Neither Naturnvernforbundet nor BirdLife Norway have been contacted or involved by LTGI in any way. We have come up with suggestions for Vågan and Vestvågøy municipality about their climate plan. We have particularly emphasized safeguarding carbon-rich nature, in addition to several other perspectives on climate an energy." (BirdLife, interview). When asked how this has been received by LTGI, the Birdlife representative says

"*We have not received any feedback on this. Unfortunately, there are strong societal forces in Lofoten that wants to build houses over wetlands. We have had no impression that there has been any interest from Lofotrådet or the municipalities in presenting these counterarguments. It does not seem as if this is a discussion that is welcomed, and it seems as if they only want to prioritize their own project in the National Transport Plan."* (BirdLife, Interview).

This represents a strong barrier regarding Lofotrådet´s role and reputation among local nature conserving actors. This is a barrier that Lofotrådet cannot afford to have as the project escalates.

5.4.2 User and market

Regime:

Driver: User power and managing customer expectations

Technology development, timing, cost, and social acceptance are factors that will affect the development of the mobility toward 2030. First and foremost, this issue is dependent on the future technology to be developed to be used in a commercial setting, initially in short-haul flights. Then the new aircrafts must enter the commercial market at an appropriate time, preferably before the current Dash-8 aircraft fleet is fully retired. This means that new climate friendly aircrafts can be implemented parallelly to the current traditional flight offer. This way the passengers will get a soft introduction to new technologies and the opportunity to choose their preferred transportation.

"There are a lot of questions and unforeseen issues when phasing in new technology. This is an argument for why we will prioritize a parallel implementation of our electrical aircrafts, in this way we can secure the operating drift of the new aircrafts at the same time as we gather customer insight. We would not get customer insight if we remove the fossil alternatives." (Widerøe Zero, Interview).

This is an important point that the representative from Widerøe Zero emphasizes in the interview in his description of how Widerøe values the customers´ behavior and acceptance,

"We do not know how the market will respond to these new solutions. The aircrafts might be silent when operating, and they will produce less emission, but they might have longer in-flight times, and they might be narrower inside the cockpit. How will the customers react to this, what will they choose? We must study customer expectations before we launch our plans. What will the customers think in the future, and what will they value, is extremely important to us." (Widerøe Zero, Interview).

The cost of the project by production and distribution will be reflected through the ticket fares, which is a clear factor that affects willingness and social acceptance. If the ticket fares are lower or approximately the same, it will be natural to choose such an aircraft if all other personal objections are handled. This idea is supported in literature where the technology transition in aviation is not considered a binary transition, and electrification of aircrafts will happen gradually (Grünfeld et al., 2022).

Driver: Parallel implementation of electrical aircrafts boosts social acceptance

The first electrical aircrafts that are planned for commercial use is the 9-seater from Tecnam and Rolls-Royce (P-Volt), planned operated by Widerøe, and the 19-seater from Heart Aerospace (ES-19). Thus, the new aircrafts will be smaller than every Dash-8 aircraft in Widerøe´s current fleet. By phasing in the new aircrafts simultaneously while maintaining operations with a certain percent of the current fleet, it may eliminate negative consequences regarding the number of departures. The soft launch of the new technology may also boost social acceptance.

A likely scenario to sustain good mobility with the new electrical aircrafts, would be to aim for an increased number of departures but with less passengers. This would naturally have to line up with the procedures and requirements of charging. The aviation industry in Norway is self-financed, which means that the industry is financially responsible for its own infrastructure. The passenger basis, which includes passenger numbers and behavior, is crucial for what the airline operators and airports can supply. This indicates that if there are enough passengers and enough revenue gained, then the offer will remain, and best-case scenario it could improve in terms of increased number of departures and lower ticket fares. In order for the new travel solutions to successfully incorporate people´s travel habits, it must have a reliable and accessible reputation.

5.4.3 Policy

Landscape:

Driver: Climate change and the Paris Agreement

Through the Paris Agreement, the majority of the world´s countries have committed to implement measures that will limit global warming to a maximum of 2 °C, preferably 1.5 °C in the fight against climate change (United Nations, 2015). This means that the world must be close to a zero-emission society by 2050. This is a global policy within the landscape level, a factor that is beyond the influence of the regime and niche actors in the short term. The Norwegian aviation industry have set ambitious goals to meet the global policy. Norwegian aviation is taking aims to be a pioneer and has goals that Norwegian aviation is going to be fossil free by 2050. This means that no domestic or international flights to or from Norway will be run on fossil fuels. This goal is very ambitious and demands significant investments and changes in the entire aviation value chain, as well as effective measures from government. A key prerequisite is technology development such as solutions for electric aircrafts, as well as SAF and hydrogen as an energy carrier (Avinor, 2020a).

Regime:

Driver: Risk relief phase, operating phase, exemption of taxes and fees, and subsidies

In *Forslag til program for introduksjon av elektrifiserte fly i kommersiell luftfart* (2020), Avinor and the Civil Aviation Authority of Norway (CCA Norway) point to the need of subsidies in different stages and arenas of the technology transition. In the operating phase of the new zero-emission aircrafts, measures like exemption or reduction in VAT on tickets for these flights, exemption or reduction in air passenger tax, startup costs, and reducing electricity fees. If Norway were to support a system of ecolabeling in the aviation industry, that would also encourage behavioral change (Grünfeld et al., 2022). Establishing subsidies towards building charging infrastructure on ground would relieve economic risk for actors. Subsidies could also be used for purchasing new technology such as electric aircrafts, because the aviation operators risk that early technology does not have long duration (Avinor & Luftfartstilsynet, 2020). Subsidies for both charging infrastructure and purchase of electric aircrafts may be arranged through Enova, owned by the Ministry of Climate and Environment. These two kinds of subsidies could protect actors´ capital when investing in new technology and energy transition in the air as well as on the ground. Similar framework conditions have been used in the market of electric cars. Multiple actors in aviation have emphasized the need for favorable, stable, and long-term conditions to make it possible to use electrical aircrafts in Norwegian commercial aviation. An exemption from passenger tax towards 2040 in electrical aircrafts would also benefit the niche. Another suggestion is to reduce entry fees for Avinor, as well as reducing the electricity charge for electrical aircrafts in commercial activities, model after similar terms used in energy transitioning in the shipping industry. Tax reductions of this sort could provide additional incentives to boost electrical aviation beyond what the relief of CO_2 taxes will provide (Grünfeld et al., 2022).

With these tax reliefs in mind, the report points out that because we are facing a significant period of development of technology and infrastructure within green aviation, this type of tax cuts must be tied in for a long time in the future in order to achieve the incentive effects.

Driver: Strict certification process creates technological trust

The energy transition in aviation is characterized by being in an early phase of the development of zero and low emission technology with several possible technology tracks and energy carriers. There are very high requirements for security with a comprehensive international regulation, the certification runs are long and expensive, and it will require a broad and interdisciplinary approach and cooperation to accelerate development.

In line with the technology being developed and produced, certification processes and regulations that does not yet exist are being developed. New aircrafts must be certified by the producer as well as government authorities, and the airline operator also needs to be approved. European passenger aircrafts must be certified by EASA which is EU´s aviation authority. It is understandable that people have concerns toward new technology that potentially could cause major consequences if something technical were to fail. The aviation industry has extreme safety demands compared to other industries, and there are extremely high requirements for safety of passenger transport in aviation. The time perspectives for development of new, more climate-friendly propulsion systems are therefore relatively long.

New types of aircrafts must go through many rounds of vast certification and approval, which works as a severely strict safety net. This safety net guarantees that if a certain type of aircraft is certified for commercial use, it will not operate with any more or less risk than other certified air crafts. Every aircraft that makes it through the eye of the needle is verified though the same safety standard (Civil Aviation Authority, interview). Per today, certification requirements for electric aircrafts and hydrogen-based aircrafts are not yet defined. The aviation industry has unique and strict requirements that other transport industries does not have, these strong regulations may boost social acceptance because even though it slows down the implementation phase, it creates time and space for the technology to mature and eventually be accepted by the public.

Driver: Public Service Obligation (PSO) can secure green innovation

Public Service Obligation (PSO) is the grant of an operating license on district air traffic routes given to airline operators by the government. These allocations come with subsidies, because operating these routes are not profitable for the airlines. The routes are on the other hand very important for mobility in the districts that are dependent on air traffic. Avinor and Luftfartstilsynet (2020) propose that the PSO can secure extended use of clean technologies. They further argue that the PSO-scheme in Norway can reduce the risk of investing in new technology for the operators, because new technology can be costly and that it may not have a long lifespan (Avinor & Luftfartstilsynet, 2020). In interview, the representative from Bodø airport development described the importance for PSO measures to be included in the technology transition in the aviation sector:

"It is a great political question how this competition of innovation is formed, especially in Norway who needs to follow competition regulations of innovation because we are a part of EEA with strict regulations. We need to have PSO program involved in order to deviate from the competition regulations. Thereafter, actors such as Lofotrådet, Widerøe and Energi i Nord can form an innovative partnership which would be very beneficial and create opportunities to create a joint development program for climate neutral aviation in Norway and Lofoten." (Bodø airport development, interview).

Barrier: Using Public Service Obligation (PSO) for implementation of green technologies can interfere with district mobility

Avinor and Luftfartstilsynet (2020) argue that the PSO-scheme can secure the implementation of green technologies on the Norwegian short-haul network. On the contrary, Grünfeld et al. (2022) argues that the PSO arrangement should not be mixed with the implementation of green technologies in aviation. This is because the PSO arrangement is meant to solve the mobility issues within district regions, and that the testing of electric aircrafts could possibly interfere with this. Grünfeld et al. (2022) discusses that from a socio-economic point of view, the economic measures taken should to the greatest extent possible, be aimed directly at the problem it wants to solve. A measure can only in some cases contribute to several goals at the same time, and then primarily achieve the certain goals that are achieved by stimulating the same activity. If the PSO-scheme were to be used to stimulate a faster energy transition in aviation (for example by awarding and subsidizing implementation of greener propulsion systems), then one uses a measure that's primarily focus is to solve the problem of transportation in decentralized districts.

Another element that argues against using PSO-schemes to energy transition is linked to the fact that the scheme does not include commercial routes connected to the short-haul network. All relevant routes will therefore not be covered, like domestic routes outside of Lofoten and Bodø. However, the need for lower emissions is no less on these routes. With these arguments in mind, Grünfeld et al. (2022) does not recommend using the PSO-scheme as an economic measure for transitioning to green aviation. They argue that PSO should be dedicated to district political goals, not environmental goals. This means that reducing emissions on the short-haul network and encouraging airlines to invest in green technology, should be done through other measures than the PSO (Grünfeld et al., 2022).

Barrier: Time-inconsistent domestic climate policy

Environmental policies and innovation policies will affect the development of environmentally friendly technologies. One barrier connected to climate policy is a general issue regarding government authorities potentially having time-inconsistent preferences in their climate policies, where they to a very small extent are committed to delivering as strict climate policy in the future as it should to meet emission goals (Glomobek et al., 2015). Uncertainty about future climate and domestic energy policy can negatively affect the use and meaning PSO and Research and Development (R&D) (Glomobek et al., 2015). The problem is further complicated by the fact that assessments of the correct dosage of environmental policy can change over time – what appears a correct dosage of environmental policy for one period of time, may not be the right dosage for the next period, even if no external circumstances have changed. This means that environmental policy can be time-inconsistent, and this can reduce the incentives such as PSO and R&D to drive environmental innovation (Glomobek et al., 2015, p. 10). Glomobek et al. (2015) point to two main problems, one being the government authorities can choose to tax the use of fossil technologies more heavily than the cost of emissions, to compensate for insufficient support for environmental innovation. However, there is still a danger that this policy is time-inconsistent, especially if one seeks to influence the level of environmental innovation by promising high environmental taxes in the future. The second being the time inconsistency problem indicates that the private sector may become uncertain about if the future environmental taxes will be as high as the authorities advertise. The level of environmental policies such as PSO and R&D, as well as refinement and the spread of new environmental technology may therefore be too low. In principle, this could be solved by the authorities binding themselves to a given environmental policy, or by the public authorities' support for environmental innovation is increased (Glomobek et al., 2015). This issue of missing sufficient climate policy is brought up by the representative from BirdLife "One must secure a national legislation that protects land. The world has lost 85% of its wetlands, and Norway cannot lose more land." (BirdLife, interview). The BirdLife representative sought out better national legislation and environmental municipal plans for nature conservation and decreased CO_2 emissions. The BirdLife representative discussed how economic growth through increased housing to secure population growth was prioritized in municipality plans, ultimately disowning environmentally friendly policies.

5.4.4 Industry

<u>**Regime:**</u>

Driver: Strengthening the value chain creation in Norwegian aviation

Green aviation is expected to play an important role in Norway´s economy in the years ahead and toward 2030. New technology can play a direct part of accumulating value creation in both the renewable energy field itself and in the aviation industry in Norway. The representative from Widerøe Zero stated in his interview that "…with new technology comes new value creation." (Widerøe Zero, interview). The VP sustainability representative from Avinor supports this thought and discusses how zero-emission aviation will be important for business development and population settlements in Norway, "I think there is a great potential to achieve value creation and create jobs in the entire ecosystem of the aviation sector. A lot of things will change by implementing new energy carriers, opportunities will arise for Norwegian companies, and we see a great potential here that we continue to study." (Avinor Sustainability, interview).

An example of this is the niche-actor Rolls Royce Electric in Trondheim that has 60 employees working solely on technology development, such as electric propulsion systems in air crafts. The Norwegian Rolls-Royce Electric market branch is unique and distinctive for the Norwegian aviation market because they are one of few companies that contributes and strengthens the Norwegian aviation value chain. New electric developments create an opportunity for Norway as an actor to enter and flourish as producers and developers in the global aviation industry. Norway is in an apparent suitable position to enter this market, as they have historically high competence in electrifying other transportation sectors such as cars and ferries. Therefore, one should aim to transfer knowledge and capacity from these sectors to create business opportunities in aviation. The advantages from establishing a dominant role in the electric aviation regime are many, it may secure future jobs and investment in Norwegian based or owned companies, further strengthening and securing the country´s financial state. It may generate increased production of renewable energy, whilst phasing out fossil fueled energy. There is unquestionably great environmental value in contributing to solutions that leads to overall cuts in CO_2 emissions, without considering the economic advantages that comes with it.

Barrier: The lack of investment from leading established actors

Regional aircrafts are a demanding segment for air operators and producers, as their economy and revenue are pressured because the aviation industry is highly exposed to competition. The market for regional aircrafts is less attractive for producers. Producers such as Embraer, Bombardier, ATR and Textron have experienced economic challenges regarding production size and quantities (Grünfeld et al., 2022). It is more profitable to produce in bigger quantities, and production of regional aircraft models are less prioritized by aircraft manufacturers. This leads to the big producers, that are highly influential in the current regime, not investing in aircrafts for regional use, nor investing in regional aircrafts with zero-emission propulsion systems (Grünfeld et al., 2022). Actors that are investing in these types of aircrafts are Tecnam, Rolls-Royce, and Heart Aerospace. Tecnam is already an established actor within the global aviation regime and has produced fossil fueled regional aircrafts for decades. Rolls-Royce is also established within the regime, as they deliver jet engines to the Airbus-Boeing duopoly. Heart Aerospace on the other hand, is a newly established actor that is leading in the innovation development, but not in the established commercial regime of aviation. The lack of investment from leading established actors within the regime could slow down the progress for zero-emission aircrafts to move from the niche-innovation sphere and implement the regime. The niche-innovation is dependent of many things to break into the regime, and the support of existing actors could boost this.

5.4.5 Technology

Landscape:

Driver: Norwegian electricity prices

Hospodka (2021) states that the introduction of electric power in the aviation sector comes from the pressure for decarbonization in aviation. Electricity prices are influenced by annual electricity consumption. When a large project is considered, the price of electricity is estimated based on the planned annual consumption in the future. In addition to annual consumption, national taxation, the global economic situation, and the type of electricity network also influence electricity prices. Prices may differ from geographical location, time of year and the provider of electricity (Hospodka, 2021). The niche and regime actors have little to no control over the electricity prices, placing them in the socio-technical landscape level. Electricity prices can be slow-changing, or they can experience sudden shocks that puts pressure on the aviation regime. Hospodka (2021) suggests that to achieve the lowest price for electricity, one would have to switch an extremely high number of flights to electricity. “The whole year consumption of Jet A1 fuel from Praha Václav Havel airport was about 300 000 tonnes in 2019. This means that to achieve the lowest price of electricity it would be necessary to switch one-third of flights to electricity.” (Hospodka, 2021, p. 258). This suggests that electrification on only the short-haul network in Northern Norway might be very expensive compared to running the same flights on traditional fuel. However, Norway´s production of hydro power, and the cheap electricity in Northern Norway might change this calculation.

Driver: Fluctuating fossil fuel prices

In the long term, electric aircrafts are expected to have lower operating costs and investment costs than comparable fossil fueled aircrafts (Avinor & Luftfartstilsynet, 2020). The aviation sector has seen a rapid spike in fuel prices since the start of January 2022, when the jet fuel price increased by approximately 90 percent, costing approximately 120 percent more on average in January 2022 compared to January 2021 (Bouwer et al., 2022). Oil prices are a commodity and will continue to fluctuate (Bouwer et al., 2022). The pressure of fluctuating fossil fuel prices and oil price shocks is a driver for decarbonization of the aviation sector. Electric aircrafts will not be directly reliant on fossil fuel prices, but increased fossil fuel prices drives the development of electric aircrafts (Yeoh, 2016). If fossil fuel prices are high, it may make the transition to electric aircrafts look more attractive.

<u>Regime:</u>

Driver: Retiring Dash-8 fleet creates opportunity for technological development

Widerøe has extended the lifetime of their current aircrafts, creating a leeway to explore new technology. The current Dash-8 fleet is set to retire, and parallelly to this a new renewable energy era is approaching. The Dash-8 fleet is soon worn out not from the number of in-flight hours, but from the number of landings (King, 2022). However, Widerøe put a process in progress which extended the lifespan of the current Dash-8 fleet from 2025 to 2035, creating space to explore new technology (Widerøe Zero, Interview). The retirement of the current fleet in addition to the increased requirements of climate friendly operations created a window of opportunity for Widerøe to implement battery-electric aircrafts on their short-haul flights.

"We worked on finding a fossil replacement, but we very quickly realized that we are now about to enter a new era in aviation, where very many new aircraft concepts are in process of being developed. With a lot of focus on low- to zero-emission but also more modern solutions for navigations and steering, more use of computers meaning autonomy. We saw it as a generational change that was coming before us." (Widerøe Zero, Interview).

<u>Niche:</u>

Driver: The electric aircraft design and performance is suited for the existing short-haul network infrastructure

In early phases electric battery driven air crafts will be best suited for short-haul routes and small aircrafts. Introducing electric aviation to Lofoten will keep the short-haul network in place and will facilitate the characteristics of the short-haul flights such as frequent departures and arrivals. The electrical aircrafts must be able to land on an 800-meter runway, such as the Dash-8 fleet, and both the Tecnam 9-seater and Heart 19-seater will fulfill said criteria. The development of Lithium-ion batteries has been a very important reason for the electric car to break into the regime, and there still is potential to further improve technology for use in aviation. Today, the best Lithium-ion batteries can roughly calculate an energy density of about 250 Wh/kg, with a cost of 156 USD/kWh. Both parameters are expected to improve. The next generation of batteries is expected to be "solid state" batteries which as it seems today, can have a maximum capacity more than 650Wh/kg, but there is uncertainty present. With today´s battery technology and certifications standards (mainly due to weight restrictions) it seems that an aircraft up to 19 seats and about 350-400 km effective range, with a >500 km maximum range reserve requirement, is the most relevant design for a battery-electric aircraft in the short term. This is sufficient for short-haul flights in Norway (Avinor & Luftfartstilsynet, 2020). Figure 10 shows the short distances between 15 airports that serves the population of Northern Norway from Bodø to Honningsvåg.

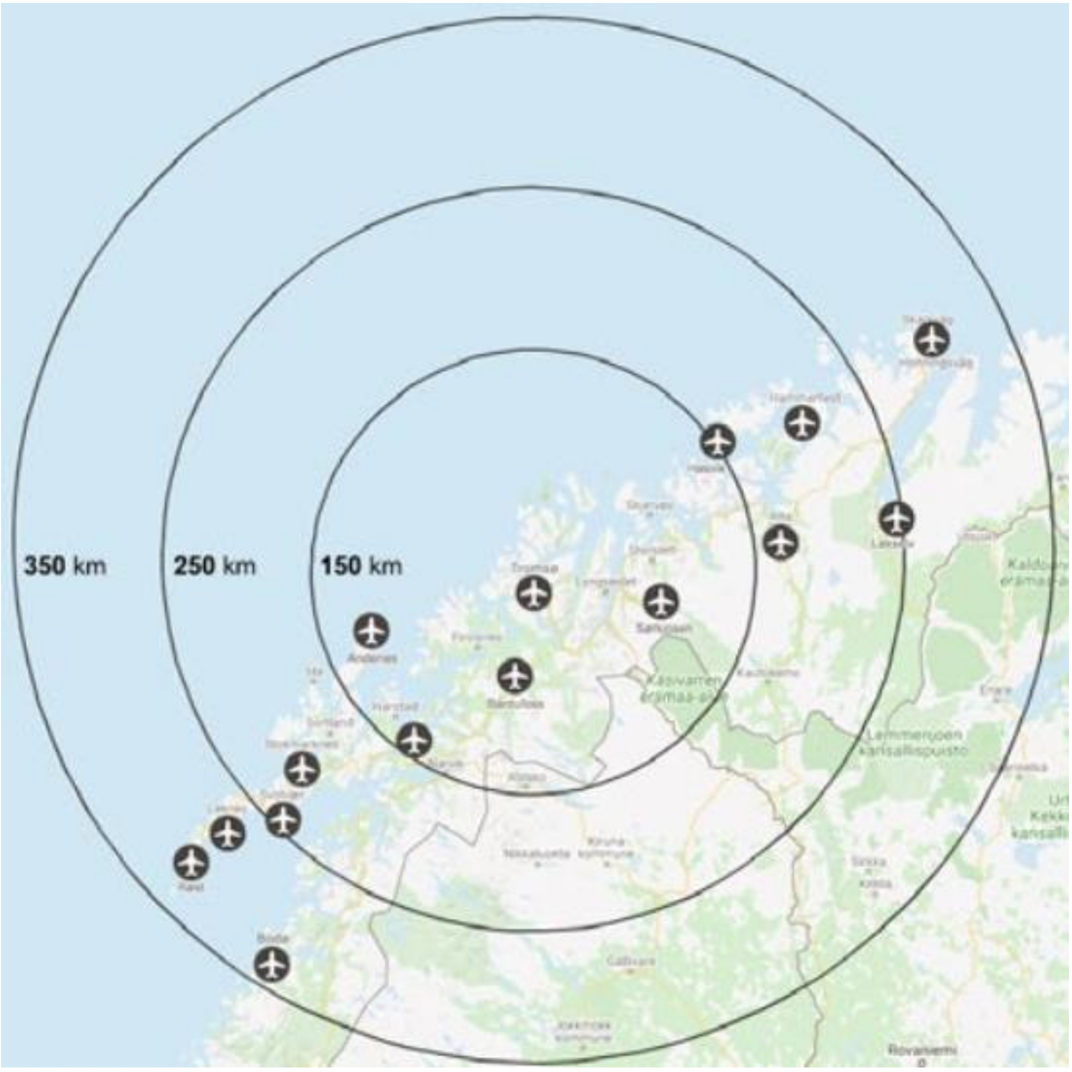

Figure 10: Airports with route traffic within 150, 200 and 250km from Tromsø Airport. (Avinor & Luftfartstilsynet, 2020, p. 46)

Driver: Electric aircrafts could save bird population and nature

The nature conservation association has identified 80 global important bird areas in Norway, the immediate surroundings of Leknes in Lofoten is one of them, named Leknes IBA (BirdLife, interview. There are globally threatened bird species that has dense populations in these areas. The intended extension of the Leknes airport would deteriorate habitats such as wetlands in the airport area. The current airport infrastructure and traffic is not as harmful to the birds as an extension would be (BirdLife, interview). This represents an immediate harmful consequence to the nearby environment, as the loss of wildlife due to the loss of habitat will be visible early in the construction process. The construction and the operation of the new Leknes airport will inevitably destroy the biodiversity and ecosystem components. In the evaluation of a possible new airport at Gimsøy in Lofoten, only the operational conditions were considered. The wind conditions are the main factor that has put the project on hold, and not the objections regarding bird population and wetlands.

Driver: Scarcity of supply and high costs for SAF – boosting electric innovation

There are two main problems that stop the wider use of SAF, one is scarcity of supply, and the other is high costs. Today´s production of SAF accounts for less than 0.05% of the total global demand for jet fuel. In the Nordic region, Neste in Finland produces approximately 125 million liters annually, but there is planned startup plants and an upscale of production in Norway, Sweden, and Denmark by various actors. Several different technologies must be developed to reduce risk and for the long term fin the solutions that have the best climate effect and lowest cost (Avinor, 2021). In the sense that the production of SAF is slow and costly, it can be presented as a driver for implementation of electrical aircrafts. There is need for new technology to achieve reductions in emissions in aviation, and a scarcity in the niche-innovation of SAF can boost the innovation of electrical aircrafts.

Barrier: Battery density and energy storage

Battery density and energy storage is the main key to the transition from fossil energy to a renewable energy system. Better battery technology is considered one of the most important technical barriers to rapid development of battery driven electrical aircrafts. In Reimers (2018) on behalf of Avinor, Norges Luftsportsforbund (NLF) and NHO Luftfart, the problem is discussed, pointing to the need for energy storage solutions with high energy densities.

Aircrafts cannot be directly connected to a grid as a constant energy source, and aircrafts have size constraints, which means that all the energy needed for their operation need to fit within the airplane in a relatively small volume. There is great potential and development ahead, but the battery technology is not yet sufficient. There are not yet measurable results to point to regarding battery use in aircrafts, which could hold back the technological optimism for the general public. Many actors are therefore working in anticipation of better battery technology with various hybrid solutions to achieve greater range, which includes both series and parallel hybrids. The hybrid solutions can therefore also be used to extend range, which will be important to fulfill the requirements for energy reserve that applies in aviation.

5.4.6 Science

Regime:

Driver: Research and development (Forskning og utviklingsarbeid, FOU Norway): Research and development (R&D) is a term used for activities related to development of new knowledge and technology in fields where the outcome is uncertain. FoU actors in Norway consist of the following actors: *UiT Faculty of Science and Technology, Norwegian Fuel Cell and Hydrogen Centre, NTNU, IFE, Mobility Zero Emission Energy Systems, Arendal Fossekompani, TØI, Mozees, CAE Center og Traning, EHC, Luftfartskolen, Maritime Robotics and Nordic Unmanned* (Grünfeld et al., 2022, p. 25). These actors create a research environment with the goal of stimulating more innovation and value creation in the aviation market. They front research and development with instrument actors, through grants and cooperation. Such instrument actors are: *Enova, Siva, Innovation Norway, The Research Council of Norway and IN* (Grünfeld et al., 2022, p. 39). Norwegian technology suppliers have a relatively weak position in technology development and international development. Therefore, it is necessary to strengthen the position of R&D and business development in Norway. The optimal goal of strengthening the aviation research environment in Norway is to partake in international development of aviation technology and sustainable solutions (Grünfeld et al., 2022, p. 6). The powerhouse of sustainable aviation in Europe lies in Germany, France, Italy, and United Kingdom and are strongly connected to the Airbus environment. The other dominating aviation milieu is the USA with Boeing as their dominant civil actor. Aviation environments and actors who are outside of this duopoly would especially benefit from public research and development grants to stay marketable. Norway is a leading supplier for zero- and low emission solutions within the maritime sector, but

Norway´s position in aviation is weaker. Norway has around 20 technology suppliers for the aviation industry, with Rolls-Royce Electric in Trondheim as the most prominent actor. However, the demand of sustainable aviation in Norway is undoubtably present, causing many traditional and untraditional actors within aviation to invest in the technology transition. The possibility for Norway to position itself in the center of green aviation globally, with research and competence, is feasible. But for this to happen, sufficient support from R&D, through cooperation and grants, needs to be present. This is reinforced by the representative from Bodø airport development, who discussed in the interview how the support from R&D and deviation from potential competition rules is important for Norway´s positioning in the green aviation field (Bodø airport development, interview).

This section has identified the actors in aviation in Lofoten through a QH approach, uncovering the interactions between them and the importance of involvement from all the four QH bodies. Thereafter the visions of key actors were disclosed, with focus of the environmental sustainability vision and the economic sustainability vision. The discussion of Leknes airport is a case where these two visions become visible. Lastly, the key drivers and barriers in the energy transition for aviation in Lofoten were presented, found through the chosen research methods of literature review, interview, and observation.

6 Discussion

This chapter will build upon the analysis and discuss the key findings further. First the drivers and barriers will be presented in two tables, to get a clear view of the findings. The drivers and barriers will then be further discussed, a discussion that will focus on why these key factors were particularly visible during the research. Then the Leknes airport discussion and the testing of electrical aircrafts in Lofoten will be discussed further as a vision conflict. The discussion concludes with a discussion of potential pathways for the possible energy transition in aviation in Lofoten.

6.1 Key drivers and barriers

The analysis included the key drivers and barriers for a transition to sustainable aviation in Norway. Due to the focus of the analysis, there are more regime-niche interactions found in the analysis, than there are landscape-regime and landscape-niche interactions. The key drivers and barriers are illustrated in table 3 and 4. They are systematized by which MLP level they are considered to belong to and the dimension they represent within the socio-technical system.

Table 2: Key drivers in the energy transition in aviation in Lofoten

		Drivers
MLP Level	**Dimension**	**Key factors**
Landscape	Policy	• Climate change and the Paris Agreement
	Technology	• Norwegian electricity prices • Fluctuating fossil fuel prices
Regime	Society and culture	• Mobility for the Lofoten region
	User and market	• User power and managing customer expectations • Parallel implementation of electrical aircrafts boosts social acceptance
	Policy	• Risk relief phase, operating phase, exemption of taxes and fees, and subsidies • Strict certification process creates technological trust • Public Service Obligation (PSO) can secure green innovation
	Industry	• Strengthening the value chain creation in Norwegian aviation

	Technology	• Retiring Dash-8 fleet creates opportunity for technological development
	Science	• Research and development (FOU Norway)
Niche	Technology	• The electric aircraft design and performance is suited for the existing short-haul network infrastructure • Electric aircrafts could save bird population and nature • Scarcity of supply and high costs for SAF – boosting electric innovation

Some of the drivers and barriers found overlap each other on one or multiple dimensions, which made it challenging to place them in only one dimension. However, they were identified within the dimension that seemed most prominent for the factor. This reinforces the argument illustrated in the QH approach, where the actors and sectors overlap and influences each other continuously. An example is how strict certifications processes creates technological trust, which boosts social acceptance. This is also the case for the user and market element, where a driver is that a parallel implementation of electrical aircrafts also can reinforce social acceptance.

Table 3: Key barriers in the energy transition in aviation in Lofoten

Barriers		
MLP Level	**Dimension**	**Key factors**
Regime	Society and culture	• Low community involvement can result in low social acceptance • Skepticism towards the vision of Lofoten´s role in climate change • Lofotrådet´s reputation among NGO´s
	Policy	• Using Public Service Obligation (PSO) for implementation of green technologies can interfere with district mobility • Time-inconsistent domestic climate policy
	Industry	• The lack of investment from leading actors
Niche	Technology	• Battery density and energy storage

There seem to be more drivers than barriers in the case of energy transition in aviation in Lofoten. This might not be entirely true, as the chosen research strategy and approach influences the findings. However, due to the scope and focus of this thesis, there are less barriers found. As previously discussed, this could be because there is limited literature on electric energy transition in Norwegian aviation. They key findings were therefore found during interviews and observation with stakeholders from the field. The representatives´ focus and preferred topics during interviews and observation undoubtedly formed the findings within this thesis. If this thesis were to focus on more niche-innovations such as SAF and hydrogen, there surely would have been more drivers and barriers uncovered.

Following is a discussion of potential barriers. A potential landscape technology barrier for a global energy transition for electric aviation could be high electricity prices in the rest of EU. The EU is more dependent on fossil energy than Norway is, and they do not have the same level of production of electricity from renewable energy. This is a factor outside of Norway, but as it affects the EU´s energy landscape, it may also affect the Norwegian electricity landscape. There are also more technological barriers, but they were not approached as much due to the social science focus. These technological barriers are connected to the development of electrical aircrafts, and beyond the issues regarding battery density and storage, there are extended issues regarding producing aircrafts that can operate in an arctic climate. There is also a potential driver within science, where there is an apparent overweight on fossil knowledge, compared to knowledge of renewable energy. This can be particularly true for the EU. There is also an apparent focus on R&D and subsidies on fossil energy, compared to renewables, as suggested in (Acemoglu et al., 2012). However, this article is ten years old, and a lot of things has changed in terms of research, subsidies, and policy.

6.2 Vision conflict

Conflicting visions arise in the relationship between sustainability and business. The vision of Lofoten as a sustainable tourist destination and business hub is not compatible with the vision of mass tourism industrial principles. Reports show that the people and businesses of Lofoten would preferably have it both ways, with one vision being increased income and the other increased sustainability (Grebstad & Arctander, 2022; Sundby et al., 2020). The findings suggest that the environmental sustainability vision and the economic sustainability vision are not aligning. One vision includes no more land intrusion, and less CO_2 emissions in the future, and is willing to put population growth on hold to achieve this. The other vision includes increased fossil fuel use, more land intrusion, and more CO_2 emissions in the near future. This represents a social phenomenon of wanting to get the best of both worlds, but when looking at the big picture, the visions do not align.

Multiple interviewees for this thesis pointed out that it must be economically sustainable to operate environmentally sustainability. “It is important to have a viable community development. Which means that Lofoten inhabitant should be prioritized over invasive measures. We do not know what consequences these measures will entail for businesses in the communities of Lofoten.” (Scandic Leknes, interview). Several of the interviewees expressed that environmental measures may have a bad impact on economic aspects, and that too big reductions in favor of environmental sustainability will have consequences for local business. This represents a win-lose conflict, where to win environmental sustainability, one loses economic sustainability. This is supported by Bridge et.al. that describes profitability as an important driver to operate environmentally sustainable (Bridge et al., 2018). However, there are exceptions to this argument because one must account for development over a longer time. In Widerøe´s future plans with electrical aircrafts, they actively work to obtain insight in the startup phase where they possibly will face less revenue regarding the operation itself (Widerøe Zero, interview). Relying on fossil fuels and plans to continue to use it in the future may interfere with sustainable transition in aviation. If Lofoten plans to make future earnings through the current non-sustainable paradigm structures, then it will take longer to switch to a green solution paradigm. Air traffic is a major polluter and an extended runway in Leknes would degrade nature and would make a paradigm change before 2030 less realistic. The challenges for sustainable aviation become greater if Lofoten envisages increasing revenue from more tourism, more travelling, and more traffic of goods. If Avinor moves forward with the extension of Leknes airport and the closing of Svolvær airport, it would provide an infrastructure designed to handle large masses of people and goods. Even though this may lead to increased total profit, it will also result in the closure of small airports which might make it more difficult to use the generation of electric aircraft that are now being developed. It may also display the short-haul network of Lofoten as less attractive as a test arena for electrical flights. One might argue that closing small airports for increased use of fossil fueled aircrafts and then implementing new technology is the wrong order of doing things. Preferably from both an environmentally sustainable and socially sustainable point of view, Lofoten should first work towards and prioritize implementing climate friendly solutions, and then thereafter adapt partially back to old solutions if the new solutions do not meet the bare social and economic needs of the region. Avinor envisions to start testing electrical aircrafts by 2025, but it will likely take around a decade of development before these are ready for commercial use (Avinor & Luftfartstilsynet, 2020). It is therefore important to preserve the short-haul network and small airports to be equipped to use future electric aircrafts. Closing small airports in favor of more centralized structures might result in it taking longer to adopt sustainable technology, as electric aircrafts are adapted to a more decentralized structure with lower numbers of travelers.

The fundamental problem therefore redefines itself to being if the Lofoten region can wait or refrain from projects that will increase tourism and traffic. In other words, can Lofoten sustain without the economic and social revenue that would be generated through increased mass accessibility and air traffic? If Lofoten wants to contribute to the Paris Agreements goals and not degrade nature further, then they must take climate-neutral actions, and extending the Leknes airport and increasing fossil air traffic could not be defined as climate-neutral actions. Waiting for electrical aircrafts and preserving the air traffic infrastructure already in place would be a more climate-friendly decision. The future electrical aircraft scheme would allow to preserve the current infrastructure, as well as facilitate an air traffic system with a potential of delivering more departures and arrivals run on climate friendly technology, correspondingly in the future when the technology allows for it. One likely scenario is that there will be provided more electrical aircrafts eventually as the battery technology and production develops further, which means that the battery electric aircrafts will be able to replace fossil fueled aircrafts one by one on the short-haul network, and eventually beyond short-haul routes. These arguments point to technological optimism and patience, with the main goal of environmental sustainability and social stability, and not necessarily boosting population and economic revenue.

All forms of sustainability are important for the communities of Lofoten, and they are worthy of discussion. However, the environment is in a crisis and vast changes are needed to reach the climate goals of reduced emission. The businesses and communities of Lofoten are dependent of economic and social sustainability, to secure income to the region, as well as avoiding businesses shutting down and depopulation in the region. Although what type of sustainable future people value and prioritize varies according to their visions. This suggests that the population of Lofoten have different opinions and degrees of what they consider economic, environmental, and social sustainability.

6.3 Possible pathways for electric aircrafts in Norway

The MLP operates with three heuristic levels, socio-technical landscape, socio-technical regime, and niche-innovation. The MLP transition pathways can be used to explain how energy transitions occur within these three levels, as presented in chapter 3.4.

The landscape pressure that climate change and the Paris Agreement put on the Norwegian aviation regime can be described as a disruptive change, because it is an infrequent change that may appear small and moderate at first, but gradually builds momentum to have a high impact on one environmental dimension. Disruptive environmental change is characterized by low frequency, high amplitude, low speed and low scope (Geels & Kemp, 2007). Disruptive is a moderate change and can be seen in the substitution pathway and the transformation pathway.

The aviation regime in Norway is characterized by dominant actors who are established within the fossil fuel scheme but are also investing in new technology. Widerøe have partnered up with Tecnam and niche-actor Roll-Royce Electric (Tecnam, 2021), and SAS has signed letter of intent to buy electric aircrafts from niche-actor Heart Aerospace (SAS, 2022). The characteristics of the transformation pathway could fit into this scenario. Moderate pressure from the landscape creates incremental adjustment to the regime, where incumbent actors perform adjustments. The actors within the regime therefore remains the same to a great degree, and the reorientation of the regime happens due to a change in perceptions of viable alternatives. The niche-innovation is symbiotic, and not in direct competition with the established solutions and actors within the regime. The aviation regime in Norway could also draw familiarities to the reconfiguration pathway at the actor level, where new alliances are formed by incumbents and new entrants, and the main regime actors remain like Widerøe, SAS and Avinor. Some regime actors may be replaced by new entrants, such as niche-innovation actors Heart Aerospace, Rolls-Royce Electric and Tecnam might replace manufacturers like de Havilland Canada. However, the niche is not sufficiently developed and therefore the transition to electric aviation in Norway is likely to happen through a transformation pathway. The reconfiguration pathway could be more fitting regarding the energy transition to SAF, as introduced in 2.3 as an additional niche-innovation.

The electric aircraft engineering and development is being influenced by the current regime, as they aim to gradually and ultimately cover the same demands as the current airlines and aircrafts now deliver on the short-haul network. The need for reducing emissions in aviation is a pressure that comes from the landscape, influencing the innovation processes. The niche-innovation of electric aircrafts are as discussed not sufficiently developed; they are nascent. The certification processes for electric aircrafts are also not sufficiently developed, and at the time of writing there is no certification requirements by EASA in place for electric aircrafts (Civil Aviation Authority, interview). Such a certification scheme will take time to complete. The niche-innovation of electric aircrafts can be labelled as symbiotic, as they are being adopted by incumbent actors, and even though they are nascent they are eventually a solution to a problem in the regime.

This chapter has discussed the key findings from the analysis. The key drivers and barriers were presented in table 2 and table 3. This provided a clear overview that shows that there are more drivers than barriers in this study. This could be explained due to the focus of the interviewees and therefore the focus of the analysis. The Leknes airport discussion portrayed the two key visions, environmental sustainability, and economic sustainability, among the representatives from the Norwegian aviation sector and communities of Lofoten. The next chapter makes recommendations for further research and concludes this thesis.

7 Conclusion

The case of Lofoten and LTGI illustrates the relationship between technology and society in a possible energy transition. LTGI aims to be a pilot region for the innovation of electrical aircrafts, and their goal is to be a model, and an example for other local communities to facilitate sustainable development. This transition is driven by their goal to halve Lofoten´s GHG emissions by 2030. Lofoten is a small region and makes up a small proportion of air traffic passengers and CO_2 emissions from aviation. However, an energy transition at a local and/or national scale will be able develop and set the foundation for energy transition at a larger, global scale. There are many advantages, challenges and opportunities connected to sustainability and energy transition at a local scale, such as decentralization of energy production, energy security, energy democracy and self-reliance (Bridge et al., 2018). To analyze these opportunities further for the Lofoten region and Norway could be recommended for future research. A comprehensive academic assessment of the visions and perspectives of the communities of Lofoten would further strengthen the understanding of the social aspects of the energy transition in aviation in Lofoten. This thesis suggests that including academia and community could vastly increase the success rate of an energy transition, that is driven by industry and government succeeds.

As shown in the analysis of the Lofoten case, there are many drivers and barriers in the transition to sustainable energy in Norway in the case of Lofoten. The social and cultural, as well as the user and market factors of Lofoten´s aviation are most prominent in the data collected from interviews and observations. Policy, industry, and technology factors are widely discussed in the reviewed literature and reports. However, it is discussed in a more general context of energy transition in aviation. The relationship between technological and societal factors are a regular theme throughout the study, and they seem to be the two biggest factors that are influencing each other and the energy transition. However, the findings uncover that all elements (society and culture, user and market, policy, industry, technology, science) within the socio-technical system is present and influential in the Lofoten case. A major finding is the varying social acceptance among different actors, for the new technology of electrical aircrafts. There are factors that boost social acceptance, such as strict certification processes and simultaneously phasing in electric aircrafts. Also, there are factors that negatively affect the social acceptance of the new technology, such as skepticism towards Lofoten´s role in climate change.

The energy transition in aviation is driven by the landscape factors of climate change and the Paris Agreement goal to limit global warming, which represents a moderate, disruptive change. The Norwegian aviation regime is possibly changing, incrementally by the established actors investing in new technology. This suggest that the niche-innovation of electrical aircrafts is symbiotic, even though they are not sufficiently developed. The energy transition in Norwegian aviation shares a lot of the same characteristics as the transformation pathway. However, the transition is in its early stages, and many changes can happen in the future, at all MLP levels: landscape, regime, and niche-innovation. The innovation of electrical aircrafts may gain momentum from the project of LTGI, where it is supported and incorporated in future plans.

The perspectives of key actors in Lofoten may differ from being driven by environmental sustainability, economic sustainability, or both. However, it seems that they are mainly aiming for the same end goal, which is viable communities in Lofoten. The role that electrical aircrafts have in the goal of sustainability differs among the actors. Government actors (from Lofotrådet, Avinor and the Civil Aviation Authority), and industry actors (Widerøe Zero, Lofotkraft Muligheter and Bodø Lufthavnutvikling) see the economic benefits that sustainable technologies may bring. Community actor and NGO representative from BirdLife has a strong focus on environmental visions and see electric aircrafts as an opportunity to cut emissions and preserve nature in terms of not expanding airport infrastructure. Community actor from the local business association see challenges regarding the uncertainty of the technology of electrical aircrafts and emphasizes the protection of Lofoten´s mobility. Issues among actors arise regarding the level of community involvement, as well as the timeframe and scope of the LTGI project. There are also issues regarding Lofoten and LTGI´s role in the global fight against climate change.

LTGI can be a prominent project and driver for electrification in Norwegian aviation, but for the project to succeed many factors must be taken in consideration. Findings show that the project of LTGI was discussed as a vision in some cases. However, it is important for the further development of LTGI to be understood as a growth strategy. Within the growth strategy and road map of LTGI, environmental and economic issues should be addressed. For the time being there is no concrete assessment or clear understanding of what the best possible economic versus environmental/ecologic solutions will be for Lofoten. The are many arguments supporting both key visions of the analysis, some in favor of securing Lofoten´s economy, and some in favor of environmental and ecological protection. The LTGI is characterized by being in the early stages in its projects, but they should pursuit a decent process continuously and into the future. The analysis of this thesis suggests that a proper process should include involvement from the different QH bodies of actors within government, industry, academia, and especially the communities. Approaching an energy transition using the principles of the QH approach could strengthen the democracy of the innovation process (Roman et al., 2020). This increases the support of electrical aircrafts, in terms of support and social acceptance of the technology. The QH approach also facilitates transparency between representative authorities, and quality in communication between innovators, government, and citizens. In the energy transition to sustainable aviation, there are also socio-economic aspect that should be addressed. It is important for key actors to acknowledge the social aspects of the energy transition, because of the important role of society and culture in a technology transition.

A clear goal for Lofotrådet and LTGI could be to be more inclusive towards population, with openness and transparency, and aim to discuss and manage both rational objections within the electrical aviation projects, as well as counter concerns from the population with information, knowledge, and discussion. It is important to build trust towards the LTGI project as well as the managing partners behind the project: Lofotrådet, Destination Lofoten and Lofotkraft. Even though Lofotrådet cooperates with various actors from national and local government, as well as from various industries, they should consider strengthening their role and reputation among the population and local businesses of Lofoten, through for example engaging them and considering their perspectives.

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Appendix

Interviewee list

Name of interviewee	Title	Date of Interview
Aks, Andreas Kollbye	Chief Executive Officer, Widerøe Zero	02/02-22
Eggen, Martin	Nature conservation counselor, BirdLife Norway	25/01-22
Kroken, Trond	Mayor Centre Party (Norway), Flakstad municipality	27/01-22
Larsen, Olav Mosvold	VP Sustainability, Avinor	09/03-22
Lervik, Randi	Project Manager, Lofotkraft Muligheter AS	24/01-22
Solberg, Remi	Mayor Labour Party (Norway), Vestvågøy municipality	27/01-22
Steinland, Jan Petter	Head of Innovation and Development, Luftfartstilsynet	25/03-22
Sørensen, Einar	Special advisor, Bodø airport development	03/02-22
Talmo, Kristian	Hotel Manager, Scandic Leknes	26/01-22
Voie, Søren Fredrik	Vest-Lofoten Local Business Association	26/01-22
Worum, Terje	Airport Manager, Leknes Airport (Avinor)	02/04-22

Workshop observations

Luftfartskonferansen 2022, Bodø. Observation conducted 10/05 & 11/05-22.

Meeting with Lofotrådet and Widerøe Zero, Teams. Observation conducted 27/01-22.

Attachment 1

Interview guide 1 – Local politician and business actors

Sustainability and the local political agenda

1. Do you have a role in LTGI?
2. What role does the LTGI have in your daily work as a local actor?
   - ➔ No role – why?
   - ➔ Role – what?
3. Do you support the growth strategy of halving emissions in Lofoten by 2030?
   - ➔ No: what should Lofoten focus on?
   - ➔ Yes: how do you envision Lofoten´s future?
4. Why has LTGI decided to involve aviation in its' road map?
5. How did the aviation sector get involved in the LTGI? Who involved it and when?
6. What is your role right now as a local actor, in the transition to sustainable aviation?
7. In what way does the politicians work to facilitate change and invest in green transitions?

The role of sustainable aviation

8. What can a sustainable short-haul network mean for Lofoten?
9. What does renewable energy mean for Lofoten´s future?
10. What economic, social, and political impact in/from the energy transition, do you envision in Lofoten and Norway?
11. Does the investment in sustainable innovation have any negative consequences for other visions and/or projects for Lofoten?

The road towards sustainable development in aviation

12. What are important drivers in the transition to sustainable aviation?
13. What are important barriers in the transition to sustainable aviation?
14. What would be positive and negative consequences of such an investment?
15. How will you evaluate the development of different technologies regarding the 2030 goal?
16. In your experience, how do you see the technological crossroads of electrification vs. hydrogen as an energy carrier in greener aviation?

Attachment 2

Interview guide 2 – Industrial actors

Visions and expectation to sustainable aviation

1. How did you start the work with alternative energy carriers in aviation?
2. What role will sustainable aviation have in Norwegian economy in 2030?
3. How sure are you that there will be a viable market for sustainable aviation? Why, why not?
4. What will the consequences/impacts from the energy transition have on jobs in aviation? Will jobs within the fossil sector be retrained?
5. What would it mean for Norway to be a pilot and a "first mover" in the development of renewable energy carriers in aircrafts?
6. Where will the renewable energy be produced? Locally, nationally, imported? Why?

The road toward sustainable aviation

7. Where do we stand with the technological development of sustainable aircrafts?
8. Which technology is most relevant for Norway to invest in?
   - ➔ Battery electric?
   - ➔ Hybrids?
   - ➔ Hydrogen?
9. What are the key drivers and barriers with electric and hybrid aircrafts?
10. What are the key drivers and barrier with hydrogen as an energy carrier in aircrafts?
11. Are there other alternatives or solutions that could be used?
12. How would you consider the speed and scope of the technology development?
13. How would you consider the investment and prioritizing of the development of low/zero-emission aviation?
    - ➔ Sufficient?
    - ➔ Not sufficient?

The role of industry actors to create a market for sustainable aviation

14. How do you consider your role as an industrial actor to participate in the development of sustainable aviation in Norway?
15. Who are your cooperative partners in the renewable energy sector?
16. How would you evaluate the cooperation?
17. Who are the most important people of interest and actors within the use of renewable energy in aviation?
18. What differentiates the actors?
    - ➔ Energy carriers?
    - ➔ Innovation?
    - ➔ Level of investment?
19. What can actors like you do to boost the development of sustainable aviation in Norway?

The transition from fossil fuels

20. How do you envision Norwegian aviation in 2030?
    - ➔ The number and scope of fossil aircrafts in operation
    - ➔ The number and scope of electric aircrafts in operation
    - ➔ Total emissions from aviation
21. Who are your partners in the fossil energy sector?
22. How will the cooperation with the fossil energy sector be affected by the investment in renewables? Are they transitioning as well?