IIIEE Theses 2023:13

A process to assess fossil-free transport transition pathways and develop a sustainability roadmap for transport purchasers:

A case study of a road freight transport purchaser in Sweden

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, 17-May 2023

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ISSN 1401-9191

Acknowledgements

The thesis derives from a discussion with the logistics manager and sustainability manager at Nestlé Nordic in Copenhagen. They have supported this thesis tremendously by allowing me an inside perspective on Nestlé Sweden's business to be able to fully understand the complexity of reaching their voluntary agreement of fossil-free transportation by 2025 in Sweden. I owe deep gratitude to these two external supervisors for providing me this opportunity, for connecting me with key stakeholders, and providing resources such as a Nestlé laptop, and generally supporting me throughout the process.

I want to express my gratitude to Philip Peck, my supervisor at IIIEE, for supporting and investing time in me and my thesis with insightful feedback that has helped me produce a thesis I am proud of. I want to thank my fellow classmates of B28 for moral support during the thesis writing process and I am grateful for the last two years getting to know such a diverse and intelligent group of changemakers.

Lastly, I would like to provide a huge thank you to my family and friends who have provided me with endless support over the last two years. Your encouragement and positivity have provided me the energy to be able to keep going.

Abstract

Most (93%) of the greenhouse gas emissions in the transport sector come from road traffic in Sweden which includes passenger and freight transport activity (Trafikverket, 2022). The aim of this thesis was to understand pathways that transport purchasers can pursue to reach the fossil-free transportation goals from manufacturing plant to customer and to develop a process for assessing a market and developing a roadmap for achieving fossil-free transportation. The research design will take an inductive approach to identify transition pathways for fossil-free transportation in Sweden. It will then follow a deductive approach based on a pre-existing theory by Turnheim & Nykvist (2019) to organize the data using pre-determined themes (Creswell et al., 2018). The approach taken in the qualitative design is a case study of Nestlé Sweden's fossil-free transportation goal to explore how a transport purchaser can develop a roadmap for reaching fossil-free transportation by 2025 in Sweden. The chosen method of data collection was five semi structured interviews with open-ended questions with key stakeholders for Nestlé Sweden's transition towards fossil-free transportation. Desk research was conducted to triangulate the findings from the interviews. The results identified six transition pathways: battery electric trucks, biofuels, biogas, hydrogen trucks, rail, and transport efficiency. Using the theoretical framework, each pathway was assessed based on five conditions and four potentials to realize each pathway. Biofuels are a highly compatible, 'transient' transition pathway but it is recommended to be complemented by biogas and electric trucks as they become more mature and affordable. Biofuels may become less available or more expensive due to potential supply constraints. Rail and transport efficiency should be used as much as possible. Hydrogen would not be a recommended transition pathway for reaching fossil-free transportation by 2025. This thesis has made some changes to the framework to better align with the needs of transport purchasers by adding a color-coding system to the framework and economic acceptability as an additional condition. This thesis provides a process for transport purchasers to understand a specific sectoral and geographic context to develop, identify, and assess transition pathways and support the development of a sustainability roadmap.

Keywords: Roadmap, corporate carbon strategy, decarbonisation, transportation, fossil-free

Executive Summary

The transport sector is responsible for nearly a quarter of total global carbon emissions, of which, road transport is responsible for three quarters and is projected to grow at a faster rate than any other sector (Sun et al., 2022). The road transport sector is largely dependent on oil seeing as it consumed half of the global oil supply in 2015 (Wang & Ge, 2019). The significance is highlighted when compared to the sector's electricity consumption which from 2000 to 2015 only increased from 0.7% to 1% (Wang & Ge, 2019). There is a clear need to transition to fossil-free transportation if countries are going to meet their national commitments under the Paris Agreement (Wang & Ge, 2019). The sector is currently facing pressure to halt its dependency on fossil fuels so they can stop being the sector with the fastest growing emissions. There is a need for studies on how to build a feasible sustainability roadmaps to reduce emissions so the transport sector can reach its climate targets (Sun et al., 2022).

The Swedish parliament has set their national target of reaching net-zero by 2045 and set the target for the domestic transport sector, excluding aviation, of a reduction of at least 70% by 2030 compared to their baseline year 2010 (Fossil-free Sweden, 2022a). There are 85,000 heavy duty vehicles in Sweden that need to be fossil-free by 2030 (Trafikverket, 2022). The fuel chosen should result in a 70% reduction compared to fossil alternatives. Acceptable fuels that meet this requirement are battery and fuel cell electric trucks, biogas, HVO, FAME, and ED95 (Fossil-free Sweden, 2022b). Most (93%) of the greenhouse gas emissions in the transport sector come from road traffic in Sweden which includes passenger and freight transport (Trafikverket, 2022). This highlights the importance of transitioning to fossil-fuel free transportation in Sweden as a means of reducing GHG emissions and inching closer to the established net-zero goals. Sweden is taking a unique approach to reaching fossil-free transportation in the Nordics through a multi stakeholder agreement called *Fossil-Free Sweden* (Stockholm Environment Institute, 2021). The initiative covers most industries including the heavy-duty transport sector. The heavy-duty transport challenge has been signed by 310 actors in Sweden that have all pledged to reach fossil-free transportation by different target years spanning from 2020 up to 2030 (Fossil-free Sweden, 2022b). Transportation is considered fossil-free if there is an emissions reduction of 70% compared to its fossil fuel alternative and can be battery or fuel-cell electric trucks, biogas, acceptable biofuels (HVO- 100), FAME, or ED95.

Nestlé Sweden signed the fossil-free Sweden agreement in 2019 and pledged to reach domestic fossil-free road transportation by 2025 in Sweden. Sweden is Nestlé Global's only Nordic market in which they have signed a multistakeholder agreement of this nature. Priority for decarbonizing Nestlé Nordic's transportation has been focused on Sweden seeing as road transportation is a hotspot for their net-zero goals in the Nordics. Nestlé Nordic faces additional complexity with decarbonizing their logistics as the transportation is handled by third party logistics providers. Although Nestlé Global has set a high-level strategy, they would benefit from a process to identify and assess transition pathways in Sweden to develop a roadmap to reach fossil-free transportation.

This thesis will draw inspiration from Bauer et al. (2022)'s study that used the framework by Turnheim & Nykvist (2019) combined with Dahlgren & Ammenberg's (2022) work on Swedish freight buyer's thoughts on renewable fuels. This thesis will complement previous research by applying a system-wide approach using the theoretical framework by Turnheim & Nykvist (2019) to assess Sweden's renewable fuel transition pathways for transportation and to suggest a roadmap for reaching fossil- free transportation by 2025. Taking what Bauer et al

(2022) did in a geographically agnostic way, and now testing it by applying it to a specific company, Nestlé Sweden, and country specific context, Sweden, to explore its effectiveness in supporting roadmap development. The aim is to provide a currently unexplored theoretical perspectives of potential value to freight purchasers in Sweden trying to reach fossil-free transportation. This research will ideally support companies in their transition away from fossil fuel consumption, leading to emissions reductions, and contributing to the goal attainment set out in the Paris Agreement.

The aim for this thesis is to understand pathways that transport purchasers can pursue to reach the fossil-free transportation goals from manufacturing plant to customer and to develop a process for assessing a market and developing a roadmap for achieving fossil-free transportation. Case study research focuses on why or how kinds of questions with the aim of understanding the phenomenon in greater detail and usually focus on "explain, explore, describe, understand" for their activities (Yin, 2018; Schoch, 2020). Therefore, the research questions are as follows and will be addressed through the following activities. (1) How is the market transitioning to fossil-free freight transportation?; (2) How do the current conditions and potentials for fossil-free transportation transition pathways compare to each other in Sweden?; (3)How can a transport purchaser map their preferred decarbonization pathway?

The research design will take an inductive approach to identify transition pathways for fossil-free transportation in Sweden. It will then follow a deductive approach based on a pre-existing theory by Turnheim & Nykvist, 2019 to organize the data using pre-determined themes (Creswell et al., 2018). The framework is rooted in transition theory and the authors identified "three 'facets' of pathways (i) pathways are representations of change processes that can support forward-looking evaluations; (ii) pathways are potentials in the sense of 'hopeful' new orientations providing focus to change efforts; and (iii) pathways are (sets of) conditions that can underpin the realization of such potentials in practice" (Turnheim & Nykvist, 2019). This thesis will focus on pathways as potentials and conditions. Pathways as potentials refers to two main aspects that are integral in evaluating dynamic potentials and pathways which are: "i) the development of new knowledge (learning) that may strengthen or weaken the promise of pathways; ii) the possible existence of branching points in which (groups of) actors make decisions or take actions that create lock-ins to pathways (convergence) or break with them (divergence)" (Turnheim & Nykvist, 2019). This study using the framework by Turnheim & Nykvist (2019) was effective in assessing the feasibility of different transition pathways that guide decision makers when developing their roadmap. Pathways as conditions refers to the dimensions that affect a pathways feasibility and update in its specific context. The four identified conditions for the realization of a sustainability pathways are (1) maturity of options (2) system integration and infrastructure requirements (3) social acceptability and (4) political feasibility. The approach taken in the qualitative design is a case study of Nestlé Sweden's experience with reaching their fossil-free transportation agreement by 2025 and how a transport purchaser can develop a feasible roadmap to reach said goal. The chosen method of data collection was five semi structured interviews with open-ended questions with key stakeholders for Nestlé Sweden's transition towards fossil-free transportation. The interview data was analyzed by coding with a computer program called NVivo. Desk research was conducted to triangulate the findings from the interviews. The results identified six transition pathways: battery electric trucks, biofuels, biogas, hydrogen trucks, rail, and transport efficiency. Using the theoretical framework, each pathway was assessed based on five conditions and four current potentials to realize each pathway.

The first research question is: How is the market transitioning to fossil-free freight transportation? The market is transitioning to fossil-free freight transportation by exploring transition pathways such as biofuels, battery-electric trucks, hydrogen trucks, biogas as well as continuing to implement multi modal shifts to rail and transport efficiency wherever possible. The second research question is: How do the current conditions and potentials for fossil-free transportation transition pathways compare to each other in Sweden? Based on the data analysis, biofuels are a highly compatible, 'transient' transition pathway but is recommended to be complemented by biogas and electric trucks as they become more mature and affordable. If companies decide to move beyond fossil-free transportation into emissions-free or net-zero transportation, transitioning away from biofuels can support achieving these goals. Electric trucks require a higher investment, but the technology is ready, and the infrastructure and initial investment is expected to fall towards 2030. For now, electric trucks are positioned as a transition pathway for short haul transportation and the market is complementing this with biogas and biofuels for long haul transportation. Both biogas and electric trucks require a higher investment to biofuels however are recommended options for phasing out fossil-fuels. Lastly, although the market is discussing hydrogen, the infrastructure and technology is expected to be ready closer to 2030 and therefore would not be a recommended transition pathway for reaching fossil-free transportation by 2025. The third research question is: How can a transport purchaser map their preferred decarbonization pathway? Transport purchasers can apply the process used in this thesis of applying the theoretical framework by Turnheim & Nykvist (2019) along with Table 7 to create a temporal, geographically specific evaluation of transition pathways and derive roadmap for reaching fossil-free transportation. This thesis has shown that it is feasible to apply the framework to a specific sector and geographic context.

My contribution to research can be summarized in three succinct points. Firstly, this thesis provides a process for transport purchasers to understand a specific sectoral and geographic context to develop, identify, and assess transition pathways and support the development of a sustainability roadmap. Although previous studies had used similar approaches to applying the theoretical framework, this is the first study to apply the framework developed by Turnheim & Nykvist (2019) to a geographical context of Sweden and sectoral context of road freight transportation.

Secondly, this thesis adapted the framework in two distinct ways to better align with the needs of transport purchasers. Firstly, through adding the economic acceptability to the pathways as conditions. This was a logical step that provided a more holistic view on each transition pathway. For example, electric vehicles are on the market and ready in present day, but they are nearly double the cost of a diesel truck providing a lower economic acceptability than biofuels. The additional conditions have led to a more realistic overview of the feasibility of each transition pathway. The second way in which the framework from adapted was through adding a color-coding system to Table 5 and Table 7. The color system of green, yellow, and red was used to have a clear visual representation of the transition pathways. Logistics managers are busy and are juggling many tasks at once, this visual representation makes it quick to judge each transition pathway. For example, at first glance at Table 5 on current conditions for transition pathways, one can derive that rail and transport efficiency are transition pathways that can be implemented today without issues and that biofuels and biogas are also ready to implement today but there are certain considerations.

Lastly, following Buettner's (2022) recommendation of creating a mutual understanding and clarity of terminology is an important success criterion for all involved stakeholders. Although this was not part of the aim of this thesis, it was an additional insight worth mentioning. Part of the final recommendations provided were to create clarity around terminology as not all stakeholders were able to define terminology related to fossil-free transportation.

In terms of practical implications and recommendations for non-academic audiences, Nestlé Sweden found these insights helpful to concretize what they were already seeing in the Swedish context. In most cases, managers have worked on various projects with stakeholders and have a solid understanding of the available transition pathways and their pros and cons, but the process used in this thesis provides a way to organize, concretize, and verify what they may already know. This is important for two reasons: (1) it helps with organizing and creating a holistic assessment of the market and (2) it helps as a communication tool to relevant stakeholders and to achieve buy-in for support for the roadmap. Nestlé Sweden provided feedback that this process is useful for them, and they foresee operationalizing it in their business to apply to other Nordic markets. This process can be applied to any sector or geography in sustainability roadmap development.

Although previous literature has used varying qualitative and quantitative methods to assess transition pathways, they did not translate them into a roadmap towards a climate target. This thesis has contributed to filling this research gap by providing an evaluation of transition pathways in Sweden for fossil-free road transportation by 2025 and provide a process that can be used by the public or private sector to develop a realistic sustainability roadmap. There are a few recommendations for future researchers regarding this thesis. Firstly, future researchers are recommended to set more extensive thresholds for the color-coded system. For example, what indicators need to be fulfilled for a condition to achieve green. This may be context specific but could strengthen the tool. As of now, the color-coded system is based on if there are considerations and how risky those considerations are. This could be further developed to strengthen the assessment. The economic acceptability condition could be explored further to provide a more comprehensive overview of the actual costs of each technology and how they compare to each other. A more technical financial analysis could be included in the methodology of the framework that could strengthen the assessment. Similarly, future researchers could add another condition to the framework on the emissions reduction potential of each transition pathway. This was not in the scope of this thesis due to resource constraints but would prove valuable when estimating the reduction capacity of each pathway. It is also recommended that future researchers apply the framework to other geographies and sectors to see whether this process is helpful in other contexts to develop sustainability roadmaps. Lastly, it is recommended to perform a case study on a company that is operationalizing this process in their roadmap development to understand how a company may adapt it and use it in practice.

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Abbreviations

EU – European Union

GHG - greenhouse gas

GSCM - green supply chain management

ASI - 'Avoid-Shift-Improve' Framework

IPCC - Intergovernmental Panel on Climate Change

KPIs - Key performance indicators

LEED - Leadership in Energy and Environmental Design

ASIF - Activity-Structure-Intensity-Fuel Framework

RV - Relational view

NRBV - Natural resource-based view

CDP - Carbon Disclosure Project

CCI - Carbon capture and use

CCS - Carbon capture and storage

LHV - Longer and Heavier Vehicles

Capex – Capital expenditure

Opex – Operating expenditure

kW - Kilowatts

NASA - National Aeronautics and Space Administration

1 Introduction

The transport sector is responsible for nearly a quarter of total global carbon emissions, of which, road transport is responsible for three quarters and is projected to grow at a faster rate than any other sector (Sun et al., 2022). The road transport sector is largely dependent on oil, seeing as it consumed half of the global oil supply in 2015 (Wang & Ge, 2019). The significance is highlighted when compared to the sector's electricity consumption which from 2000 to 2015 only increased from 0.7% to 1% (Wang & Ge, 2019). There is a clear need to transition to fossil-free transportation if countries are going to meet their national commitments under the Paris Agreement (Wang & Ge, 2019). The sector is currently facing pressure to halt its dependency on fossil fuels so they can stop being the sector with the fastest growing emissions. There is a need for studies on how to build a feasible sustainability roadmap to reduce emissions so the transport sector can reach its climate targets (Sun et al., 2022). Furthermore, global consumer demand for products is on an upward trend leading to greater demand for transportation making decarbonization ever more important (Mission Possible Partnership, 2022).

Europe's transport sector also accounts for nearly a quarter of its total emissions (European Coucil, 2023). Road transport in the European Union (EU) and Nordic countries is the highest emitting segment of total transport emissions and heavy-duty vehicles are responsible for over a quarter of the transport emissions (Ambel, 2017). The EU has set a climate reduction target of 40% by 2030 compared to their baseline year 1990 (Ambel, 2017). Emissions from the heavy-duty vehicle sector have steadily increased over the past decade from higher demand for road transport and its emissions were 30-40% higher than the aviation and maritime sector (European Commission, 2023). Nearly all (99%) of the EU's fleet of heavy-duty vehicles run on internal combustion engines powered by imported fossil fuels. Reflecting the EU's commitment to decarbonize their logistics emissions, they have set specific caps for emissions from heavy-duty vehicles. The carbon emissions targets for all new heavy-duty vehicles that enter the market need to have a 45% emissions reduction from 2030, 65% from 2035, and 90% from 2040 (European Commission, 2023). This will help accelerate the clean energy transition in the EU and lower the demand for fossil fuels. In addition to the climate targets, the EU has developed the Alternative Fuels Infrastructure Regulation creating requirements for sufficient availability of refueling and recharging infrastructure as well as other incentives to channel investments into zero-emission and fossil-fuel free vehicles (European Commission, 2023).

In non-sector specific terms, the Nordics, in this case Denmark, Finland, Norway and Sweden, have responded by all putting formal legislation in place mandating governments to report on their progress towards reaching their net-zero goals (BCG, 2022). That said, in absolute terms none of the Nordic countries are on track to reach their emission targets due to a gap of 80 megatons in emissions that would need to be reduced by 2050. Transportation is a focus of the Nordics' decarbonization strategy, as it accounts for 30% of their total greenhouse gas (GHG) emissions and is the largest emitting sector after industry in the region. For these countries to reach their net-zero goals, a BCG report estimates a need for investing 157 billion EUR into net-zero transportation among other sectors (BCG, 2022). The TIMES-Nordic tool by the Technical University of Denmark is a modelling tool that analyses the feasibility of different energy scenarios that could lead to the Nordic region reaching its net-zero goals (Venturini, n.d.). The model assumes competitive markets, technological innovation, and economic projections up to 2050 to provide a system analysis of the Nordic energy sector. The tool is based on two scenarios, *Nordic Base* and *Nordic CO_2 2040*. In both scenarios, Sweden had the highest emissions overall compared to Denmark and Norway from 2010 to 2050 and Sweden's hotspot for emissions is the transport sector. The highest consumed renewable fuel for the freight transport sector were biofuels blended with diesel up to 2050, followed by heavy fuel oil and electricity (Venturini, n.d.).

The Swedish parliament has set their national target of reaching net-zero by 2045 and set the target for the domestic transport sector, excluding aviation, of a reduction of at least 70% by 2030 compared to their baseline year 2010 (Fossil-free Sweden, 2022b). There are 85,000 heavy duty vehicles in Sweden that need to be fossil-free by 2030 (Trafikverket, 2022). Most (93%) of the greenhouse gas emissions in the transport sector come from road traffic in Sweden which includes passenger and freight transport (Trafikverket, 2022). This highlights the importance of transitioning to fossil-fuel free transportation in Sweden as a means of reducing GHG emissions and inching closer to the established net-zero goals. This can be done through electrification, efficiency of existing fleets, and biofuels or biogas to meet interim goals as well as expansion of charging infrastructure (Trafikverket, 2022).

Sweden is taking a unique approach to reaching fossil-free transportation in the Nordics through a multi stakeholder agreement called *Fossil-Free Sweden* (Stockholm Environment Institute, 2021). The initiative covers most industries including the heavy-duty transport sector. The initiative was launched in 2015 by the Swedish government with involved parties from companies, municipalities, and organizations that agree to help Sweden become the first fossil-free country in the world (Fossil-free Sweden, 2021). More than half of the participants for the heavy-duty transport pledge are companies (Stockholm Environment Institute, 2021). The initiative is run by an administrative team that is overseen by the federal government of Sweden to ensure the actors are transitioning to fossil-free activities. They have created a fossil-free roadmap for all 22 business sectors including clear definitions of commitments the actors pledge to, as well as policy proposals (Fossil-free Sweden, 2021). The heavy-duty transport challenge has been signed by 310 actors in Sweden that have all pledged to reach fossil-free transportation by different target years spanning from 2020 up to 2030 (Fossil-free Sweden, 2022b). Transportation is considered fossil-free if there is an emissions reduction of 70% compared to its fossil fuel alternative and can be battery/fuel-cell electric trucks, biogas, acceptable biofuels (HVO-100), FAME, or ED95. The scope of the agreement includes transportation the company performs and purchases. The agreement is set on the assumption that there will be access to supply of the acceptable renewable fuels and there are no fines issued if an actor does not reach its goal (Fossil-free Sweden, 2022b).

Considering Sweden is projected to be one of the highest emitting countries in the Nordics with the heavy-duty transport sector being responsible for most of the emissions, there is a need to focus specifically on how the road transport sector in Sweden will decarbonize and reach its fossil-free goal by 2030. Furthermore, they have a unique multistakeholder agreement that is unique in that 310 actors in the country have pledged to reach fossil-free road transportation by 2030 and Sweden has the ambition to become the first fossil-free country in the world.

This multi-stakeholder approach is bringing together the largest players in the heavy-duty transport sector to move all actors in the same direction to accelerate Sweden's decarbonization transition. Although there are high level roadmaps, most of the actors are companies that face different challenges unique to their organization and there is no single solution for all manufacturing companies. From a manufacturer's perspective, decarbonization of logistics is top of their agenda as it can account for up to 35% of their total GHG emissions (Miklautsch & Woschank, 2022). Manufacturing companies are in a unique position of having the power to choose transportation providers and terms of the contracts. For a company to reach its fossil-free transportation goals, a structured sustainability strategy is a fundamental first step in understanding what to ask the transport provider for to ensure they reach their fossil-fuel free goals (Miklautsch & Woschank, 2022). A study by Dahlgren & Ammenberg (2022) explored the transport purchaser provider relationship. The impression from interviews revealed that changes in freight transport were initiated by the buyers rather than the provider, meaning that the dynamic for the providers tends to be reactive with regards to environmental issues (Dahlgren & Ammenberg, 2022). It also implies that the companies that have signed the agreement will likely be pushing for the fossil-free transportation rather than the transport providers in Sweden. There was mention of it being difficult to influence the providers to improve their environmental offerings in freight transport. Furthermore, it was found that providers could be a barrier to environmental improvements when the buyer and provider's climate ambitions are misaligned. A mitigation tactic was providing longer contracts allowing for shared risks and enabled the investments the buyer was asking for. In the Swedish context, it is common for companies to outsource the business activity to transport providers who often have contracts with freight forwarders that perform the transportation. The company, or transport purchaser, will typically purchase the transportation indirectly from a transport provider. Transport purchasers are driven to implement sustainability by initiatives such as *Fossil-Free Sweden,* consumer demand, brand-positioning as an environmentally conscious company, or internal pressure from management. There are also political factors driving transport purchasers to change such as congestion charges or air pollution policies banning fossil fuel-based transportation controlling what type of renewable fuel can be used (Dahlgren & Ammenberg, 2022). Regardless of the driver or the dynamics of transport purchaser-provider relationships there is a need for companies that have climate reduction targets in road transportation to understand the different transition pathways available and a means of assessing the feasibility of each pathway. By having this information, firms can develop a roadmap that is structured, fact-based, and realistic given the context they operate in.

Pamucar et al. (2021) studies the relationship between implementing different green supply chain management (GSCM) practices, measures, and the effect on business performance. They point out that there is a gap in the literature on research in the strategic planning aspect and lack of a holistic framework for GSCM performance assessment. They also suggest that different methods should be explored to assess GSCM performance and a framework that can create an overall performance score for the company to reveal a roadmap (Pamucar et al., 2021). Not only is this gap identified in academia but also in Nestlé Sweden who is part of one of the largest food companies in the world. They have operations in Denmark, Norway, Finland, and Sweden. In this thesis, three entities of Nestlé are mentioned; from this point forward, Nestlé Global will refer to their global business, Nestlé Nordic to their business in Finland, Denmark, Sweden, and Norway, and Nestlé Sweden to their business in Sweden. Nestlé Sweden signed the Fossil-free Sweden agreement in 2019 and pledged to reach domestic fossil-free road transportation by 2025 in Sweden. Sweden is Nestlé Global's only Nordic market in which they have signed a voluntary, multistakeholder agreement of this nature. Priority for this thesis is focused on Sweden seeing as the road transportation is a hotspot for them in the Nordics. Nestlé Nordic's Swedish transportation business provides an interesting case to explore how a company who has pledged to reach fossil-free transportation by 2025 in Sweden will navigate building a sustainability roadmap. The case study will focus on their outbound, downstream transportation and on transportation from the use phase or from tank-to-wheel. It should be noted that there will be a particular focus on decarbonization of road transport as that is their main mode of transportation in

Sweden. In other words, the focus will be on fossil-free transportation from Nestlé Sweden's manufacturing plants in Sweden, warehouses, and distribution centers to their final customers in Sweden (retailers and SMEs). The logistics department for Nestlé Nordic faces a challenge that although Nestlé Global has created a global corporate carbon strategy, they would benefit from a process to identify and assess transition pathways in Sweden to develop a roadmap to reach fossil-free transportation in Sweden. They are implementing different carbon reduction practices already in their transportation such as using electric heavy-duty trucks in Helsingborg and shifting from road to rail in Norway. The logistics and sustainability manager are aware of the different pathways and options and the general pros and cons of the alternatives. That said, the company would benefit from an analysis and more detailed plan on how to reach the fossil-free transportation agreement. Nearly all Nestlé Sweden's outbound transportation to their customers is outsourced to a freight provider, PostNord TPL, who then contracts out to freight forwarders. This adds a level of complexity for Nestlé Sweden as the transportation is not owned by themselves but by a third party. Nestlé Sweden would benefit from the process of creating a roadmap to organize, concretize, and verify what they may already see in the Swedish market.

The Paris Agreement sets out to curb global temperatures rising above 2ºC to avoid catastrophic climate change. Road transportation is a sector that has the possibility to fully decarbonize unlike other sectors. With that said, this thesis sets out to apply a theoretical framework to assess Sweden's transitional pathways for decarbonizing road transportation and provide a method for building a net-zero road map for companies. The research was conducted using a case company, Nestlé Sweden, to understand the internal scenario of a company in Sweden trying to reach fossil-free transportation.

1.1 Background

There are six identified trajectories for decarbonization in heavy duty transportation discussed in this thesis: battery electric, hydrogen, rail, transport efficiency, biofuels, and biogas. For context, these technologies will be described in this section.

Battery Electric

Electric trucks are run on batteries powered by electricity and emit zero tailpipe emissions (Ventoniemi & Vornfeld, 2023). They are charged through electric charging infrastructure connected to the electricity grid. The most common charging infrastructure is overnight charging where they are charged overnight at a distribution center. Another form is destination charging where trucks are charged during unloading and loading at logistics centers or warehouses. More recently, technology for on-the-move-charging is used for long-haul transportation where trucks are charged on the road for example through an electric road system (Ventoniemi & Vornfeld, 2023).

Hydrogen

Trucks powered by hydrogen are in the early phases of uptake in the market. It is an energy carrier but not an energy source (Ambel, 2017). It is produced by separating hydrogen from molecules such as water through different processes. It is common that hydrogen is extracted from natural gas, but the intention is to produce hydrogen from electrolysis powered by renewable electricity to produce a zero emissions fuel. From there, hydrogen can be used in fuel cell electric trucks which is a truck powered by a fuel cell and battery to make it more efficient. In theory, fuel cell electric trucks only emit water and heat but can only be considered a zero-emission vehicle if the hydrogen was produced on renewable energy (Ambel, 2017).

Rail
Over three quarters of Europe's railway freight network runs on electric traction and Sweden currently transports 33% of its freight on rail making it a useful alternative when aiming to decarbonize (Ambel, 2017). Switching from road to rail transport typically makes sense from a cost and feasibility perspective at distances greater than 200 km. Rail is less flexible to customer's needs as track access needs to be granted often months in advance whereas truck freight does not have this issue (Ambel, 2017). Research suggests that in a multimodal chain with road and rail, it makes sense when the distance is above 350 km (Björk & Vierth, 2021).

Transport efficiency
Nearly 20% of trucks used for freight are driving empty across Europe highlighting the importance of improving the efficiency of freight transport (Ambel, 2017). The price of road transport is artificially low resulting in less motivation for efficiency (Ambel, 2017). There is an opportunity to cut costs and to reduce emissions through transport efficiency.

Biofuels
Biofuels are produced from biomass and converted into "ethanol, methanol, fatty acid methyl ester (FAME), hydrotreated vegetable oil (HVO) or biomethane (compressed or liquified)" (Ambel, 2017). There are two categories; (1) first generation produced from agricultural goods such as starch crops or (2) second generation produced from waste and residue. Biofuels are positioned as a renewable fuel based on the assumption that the emissions are reabsorbed by the crop used to make the fuel. It is an attractive option as biofuels can be blended with fossil fuels without the need for investing in new trucks. Depending on the feedstock for first generation biofuel, it can have higher emissions well-to-wheel than fossil fuels due to the indirect land-use change emissions. The most used feedstock is palm oil which is linked to high rates of deforestation leading to high emissions overall. The EU has set regulations and discourages the use of feedstock with indirect land-use change emissions (Ambel, 2017). HVO100 is a commonly used biofuel in Sweden produced in Finland by Neste (Neste, 2023). This fuel can lead up to 90% less emissions compared to fossil fuels if the purest version or highest ratio of HVO to diesel is used (Neste, 2023). The feedstock for HVO100 is used from used vegetable cooking oil and residual animal fats. It can withstand colder temperatures like diesel which makes it a viable option for use in the North of Sweden and has a longer shelf life that diesel (Burbaitė, 2023). Since the feedstock is from used cooking oil it is a more sustainable option than other biofuels made from palm oil, soybean oil or other food crops with high land use change emissions (EG Fuel, 2023). HVO100 is produced through breaking down with the use of hydrogen with similar chemical makeup as diesel but is cleaner burning (Frode Laursen, 2019).

Biogas
Biogas is produced from landfill gas or anaerobic digestion of agricultural or food waste and sewage sludge (Ambel, 2017). Biogas is made of three quarters methane and around a quarter carbon dioxide which can then be upgraded to biomethane to produce a renewable natural gas (Tanigawa, 2017). The upgrading process is the removal of carbon dioxide, water vapor and other trace gases and can be distributed into natural gas pipelines. Typical feedstock is crop residue, sludge from wastewater treatment plants, livestock waste, and food waste (Tanigawa, 2017). Most of the biogas produced in Sweden is used for the transport sector and accounts for 22% of the total fuels market for road transportation (Björner Brauer & Khan, 2021). It has the potential to reduce emission up to 100% depending on the feedstock. From a well-to-tank perspective, it can lead to 80% less emissions

compared to fossil fuels. Although the savings could be even higher when considering the avoided methane emissions. The use of biogas in trucks in Sweden remains low despite it being a good option to fossil fuels. According to the Swedish Energy Agency, theoretically, the entire energy supply for road freight transportation could be serviced with biogas if the biogas production potential in Sweden was reached with the help of greater feedstock from waste in the forestry sector (Björner Brauer & Khan, 2021).

Freight transport market overview in Sweden

Emissions from freight transport are carbon dioxide, nitrous oxide, sulfur oxide, volatile organic compounds, and particulate matter (Björk & Vierth, 2021). Road transportation tends to emit higher emissions than other modes of transportation such as rail. Sweden's national freight transport strategy set a priority on modal shifting from road to rail as much as possible despite the country being dominated by heavy duty truck transportation. Road transportation is the only transport mode in the country with emissions reductions in line with their reduction targets thanks to their consumption of HVO100 (Björk & Vierth, 2021). Sweden having a long coastline makes it suitable for shipping on the sea and in the North, the higher elevations pose a challenge for rail transportation (Björk & Vierth, 2021). Road and rail are both depending on the capacity and infrastructure of the network. Some key considerations for firms when managing their transportation are cost (shipping and handling costs and insurance), transit time, and reliability of the mode of transport and now more recently, sustainability. Transit time is one of the most important factors and depends on the distance or number of transfers. Road transportation tends to have the most flexibility with timing compared to rail and has been more reliable for transportation time. Factors that can affect transit time could be maintenance, traffic, accidents, or weather events. Sweden's freight transport in Sweden follows the dynamic that most of their manufacturing industry (for products like steel and forestry) are produced in the North of the country but the consumption is mostly in the South. The long coastline makes transport by sea attractive, and Sweden is home to some of Europe's most important ports with 60% of Scandinavia's containers moving through the Port of Gothenburg. The use of rail in multimodal chains with road transportation is becoming popular in Sweden. There is an expected increase of 40% of roads in Sweden that allow for heavier and longer trucks to improve transport efficiency and reduce emissions (Björk & Vierth, 2021). Volvo trucks has increased its market share in 41 markets globally and owns 47% of the market share in Sweden for heavy duty trucks (Cision, 2022). They have the largest market share of electric heavy-duty trucks in the world with most of the volume in Switzerland, Norway, Sweden, and The Netherlands. They are a key player in Sweden and an important stakeholder for this thesis (Cision, 2022). Scania and Daimler are also large players in the truck manufacturing sector in Sweden (Panjiva, n.d.).

Nestlé Sweden

Nestlé Nordic operates in Sweden under their market specific business units (Nestlé Sverige, n.d.). Some of their strongest business units are Zoéga's coffee, Nescafé, Nescafé Dolce Gusto, and other popular brands such as Smarties, Lion, After Eight and Cheerios. They also sell to the hospitality industry through their brand Nestlé Health Science. They also have other business units such as Nespresso, Nestlé Professional, and Purina PetCare (Nestlé Sverige, n.d.). Nestlé Global is the largest food and beverage company in the world with 150 years of experience and operations in 188 countries (Nestlé, 2023a). They earned CHF 94.4 billion in sales in 2022 through their 2000 brands and have 344 factories (Nestlé, 2023a). They have set climate targets approved by the Science Based Targets Initiative of reaching net-zero by 2050 and interim goals of a 20% reduction by 2025 and 50% by 2030 (Nestlé, 2023b). They have set climate reduction targets in all business functions including transportation. In 2018, their carbon footprint was 92 million tonnes with 8% of their emissions being attributed to managing their logistics (Nestlé, 2023b). To provide context, Sweden's national carbon footprint in 2021 was 40.1 million tonnes. Therefore, Nestlé Global's total carbon footprint is twice that of Sweden (Tiseo, 2023). From the thousands of climate projects on going across the business they have managed to reach peak carbon and are now focusing on continuing to reduce their emissions in their own operations and value chain (Nestlé Global, 2023).

Nestlé Global's logistics climate target is to "reduce absolute emissions by 3.5 million tonnes of CO_2e from inbound and outbound transportation" based on 2018 emissions (Nestlé, 2021). Their general strategy to reach that goal is to focus on transport efficiency, route optimization, multi modal transportation, and electric vehicles for their short haul transportation before 2025. After 2025, they aim to focus more on hydrogen and long-haul electric trucks as well as biofuels (Nestlé, 2021). They have an overarching strategy of working with their third-party logistics partners to use more renewable fuels in their transportation (Nestlé Global, 2023). There have been great efforts across the company to integrate lower carbon emissions in their logistics activities. For example, Nestlé Global committed to investing more than CHF 100 million by 2030 into low-carbon logistics for their top three water brands. Nestlé Waters in France is working to integrate a hydrogen-powered train route expected to be ready by 2025 offering an 89% reduction in emissions. Nestlé UK & Ireland has been testing innovations in transport efficiency of rail containers that come with a raisable roof able to transport more goods in one container. Using one of these adjustable freight trains can remove 76 heavy duty trucks from the roads. Nestlé Waters has been using more biofuels and biogas with Nestlé UK and Ireland converting ¾ of their truck fleet from diesel to biogas (Nestlé Global, 2023). The fossil-free transportation agreement in Sweden is a sub-goal of Nestlé Nordic's overarching decarbonization goals and strategies linked to the Nestlé Global decarbonization roadmaps.

Defining terminology

The Swedish government states that for transportation to be considered fossil-free there should be a 70% reduction by 2030 compared to 2010 baseline levels (Fossil-free Sweden, 2022a). The fuel chosen should result in a 70% reduction compared to fossil alternatives. Acceptable fuels that meet this requirement are battery and fuel cell electric trucks, biogas, HVO, FAME, and ED95 (Fossil-free Sweden, 2022b). Net-zero is when the number of emissions produced is removed to equal zero emissions achieving a balance of zero emissions (Climate Council, n.d.). Depending on the methodology used, the lifecycle of the product or service differs and could consider the entire lifecycle or parts of it (Climate Council, n.d.). Well-to-wheel refers to the emissions from the entire life cycle of the fuel from extraction, refinement, production, transportation of the fuel to the use phase (Stokel-Walker, 2021). The two phases of well-to-wheel are well-to-tank and tank-to-wheels. Well-to-tank only includes the fuel production whereas tank-to-wheels refers to the use phase of the fuel (Stokel-Walker, 2021). Zero tailpipe or emissions free transportation refers to vehicles that do not emit any emissions during the use phase or the tank-to-wheels phase (U.S Department of Energy, n.d.). Technologies considered zero tailpipe or emissions free are battery electric trucks or fuel cell hydrogen trucks. Zero tailpipe or emissions free transportation is going one step further than fossil-free transportation which still has emissions when using renewable fuels such as biofuels (U.S Department of Energy, n.d.).

Sustainability Strategy and Roadmaps

A sustainability strategy is the foundation to a roadmap in that it establishes the vision, purpose, and mission of the firm's climate ambitions (Stena Recycling, n.d.). A roadmap is a series of steps the firm should follow to implement to reach the desired vision in the strategy (Stena Recycling, n.d.).

The strategy is where the firm defines the level of ambition of the sustainability strategy and clearly defines the desired future of the firm (Henderson, 2020). For example, Nestlé Global has created a sustainability strategy with the ambition of reaching net-zero by 2050. This strategy can be used as a guide to achieve buy-in from key stakeholders and to create a common understanding of the direction the company is going in. The roadmap is translating the vision into an implementation plan that explores a range of transition pathways and decides on the most recommended path forward (Henderson, 2020).

BCG identified common pitfalls firms confront when implementing their sustainability strategy (Cuellar et al., 2022). One of them being a weak commitment to sustainability from senior management. Another is lack of accountability to the sustainability commitments for example having executive bonuses tied to reaching sustainability goals. Another common pitfall is a coordination problem between the core sustainability team and the business unit creating a disorganized execution. For example, if roles are not clearly defined between the sustainability manager and logistics manager on who is responsible for implementing sustainability activities. Failing to embed sustainability into the business processes leads to employees being limited in being able to make decisions related to sustainability. Lastly, talent gaps relate to companies failing to build proper capabilities within their organization to have the skills to reach their sustainability goals (Cuellar et al., 2022).

Harvard Business Review identified similar pitfalls such as failing to implement proper structure and governance for sustainability (Farri et al., 2022). This relates to not having clearly defined roles for business units and the core sustainability team. Another is when firms do not connect key performance indicators in business units to their climate goals then financial performance will be prioritized over sustainability. Another important consideration is managing the culture and leadership in the organization away from profit-driven and towards an impact-driven paradigm. Lastly, ensuring that managers have sustainability decision making tools in their toolkit instead of only conventional methods for decision making (Farri et al., 2022).

1.2 Problem Definition

Thus, in essence, Nestlé Sweden faces a challenge that is two-fold; firstly, they have signed an agreement to reach fossil-free transportation in Sweden by 2025 and for this reason would benefit from a process to identify and assess available transition pathways in Sweden. Secondly, they would benefit from a roadmap that provides a more detailed action plan and understanding of how the transition pathways will develop and change in the short and long term. Echoing the concluding remarks of a study by Bauer et al (2022) on transition studies, "without direction for carbon neutrality, governance is difficult". Nestlé Sweden would benefit from a framework that identifies a geographic location's fossil-free trajectories for transportation and assess the different transition pathways to be able to develop a roadmap.

There is knowledge related to this in practice. For example, there are frameworks that can guide logistics decarbonization strategies such as Dalkmann and Brannigan's (2007) 'Avoid-Shift-Improve' (ASI) framework. The ASI framework is widely used in the logistics industry and is a high-level guidance suggesting that avoiding transportation, shifting to low-carbon modes of transportation, and improving the efficiency of current transportation will lead to decarbonization (Dalkmann and Brannigan, 2007). Another notable logistics framework is McKinnon's 'Green Logistics Framework' structuring decarbonization of freight transportation through five veins (Pinchasik, 2022). The five veins are like the ASI framework but extended with the suggestion to improve energy efficiency and switch to low-carbon energy sources (Pinchasik, 2022). These frameworks alone will not lead to firms being able to assess their market for viable transition pathways but rather supports the sustainable transport system design.

Miklautsch & Woschank (2022) developed a set of 215 measures with 27 categories, including reduction potentials, that manufacturers can use to implement sustainability into their logistics. This study identified key performance indicators manufacturers have used when building the governance for their roadmap. A limitation to this study is that it did not provide a framework for understanding the market the manufacturer operates in to ensure that the indicators used are relevant. Furthermore, key performance indicators are part of the governance structure that should be initiated after the manufacturer has a clear direction or roadmap for reaching their climate targets.

An important step is understanding why firms start to decarbonize their transportation. In terms of building corporate carbon strategies, researchers have explored this topic through understanding a firm's motivations to change. Cadez et al. (2018) rooted their study in stakeholder theory to explain the internal and external drivers underlying corporate carbon strategy. Their ambition in emissions reductions largely depends on the level of stakeholder pressure a firm is facing. In the case of Nestlé Sweden, they have signed a voluntary public pledge with Fossil-free Sweden to reach fossil-free transportation by 2025. This agreement applies stakeholder pressure on the company. Public pressure has a positive effect on a firm's corporate carbon strategy (Cadez et al., 2018).

This thesis is focusing on developing a fossil-free roadmap for road freight transportation in Sweden. There is specific examination of carbon strategies such as Almeida et al. (2021) using the natural resource-based view to develop an integrative framework defining three main activities and ten attributes to focus on in a corporate carbon strategy. For example, one of the activities is building propensity for sustainable partnerships which can be seen in Nestlé Sweden's commitment to the pledge by Fossil-free Sweden. If a firm incorporates these activities and attributes, they hold the potential to improve their sustainability performance (de Almeida et al., 2021). Similarly, Lee (2011) consolidated a list of key considerations firms can use when building a corporate carbon strategy such as setting emissions targets or product improvements. Using this framework of key considerations to assess the participating firms, Lee developed a typology of corporate carbon strategies. This is useful when a firm is aiming to benchmark themselves and understand their ambition level for their corporate carbon strategy, but this does not provide a framework for a developing a roadmap for reaching the goal of the corporate carbon strategy. Buettner (2022) uses back casting to work backwards to determine what needs to be done for a firm to reach their desired sustainability outcome. Providing a list of foundational questions that firms can use to develop their decarbonization strategy such as terminology alignment and target setting. This gives insights into the list of activities Nestlé Nordic have or can consider in their own corporate carbon strategy. Especially that these activities are proven to lead to higher sustainability performance. However, it still does not provide a concrete framework for assessing the transition pathways available in a geographic location to create action-based activities towards fossil-free transport.

One theory that seems to enfold all these theories and more is transition studies. Transition studies is used in the field of sustainability by focusing on understanding the social systems that support human needs such as transportation (de Haan et al., 2016). Rooted in theories such as Geels and Schot's (2007) sociotechnical systems, it provides a way to assess transition pathways qualitatively or quantitatively and describe changes needed in a system at specific times to reach the desired sustainable future. This was taken a step further by Turnheim & Nykvist (2019), providing a qualitative modelling framework that identifies and assesses sustainability transitions. The authors identified three facets of pathways "(i) pathways are representations of change processes that can support forward-looking evaluations; (ii) pathways are potentials in the sense of 'hopeful' new orientations providing focus to change efforts; and (iii) pathways are (sets of) conditions that can underpin the realization of such potentials in practice". Different geographies come with different political ambitions, social acceptability and infrastructure that affect the scale and speed at which a pathway will be adopted. The four identified conditions for the realization of a sustainability pathways are (1) maturity of options (2) system integration and infrastructure requirements (3) social acceptability and (4) political feasibility. This gives insights into which pathways are available to a firm given the constraints in the socio-technical system and helps firms have a realistic expectation of technology or non-technological advancements. This theoretical framework was recently operationalized by Bauer et al. (2022) at Lund University where they performed a sector-level analysis on four high emitting sectors (meat and dairy, steel, plastics, and pulp and paper) to identify transition pathways for each sector. Using the framework by Turnheim & Nykvist (2019), they assessed each pathway using the four conditions and pathways as potentials. This study was useful in that it showed that the theoretical framework is a viable method for understanding the pathways available in a market and a means of performing a system-wide assessment of each alternative to provide context specific results. From these results, they were able to develop a realistic path forward for these sectors to decarbonize. Although this study did not provide a geographically specific analysis and was not focused on the transportation sector, it does provide an opportunity to explore the applicability of this research design to other sectors and highly aligns with the needs of this thesis. Lastly, Dahlgren & Ammenberg's (2022) used a geographically specific, qualitative, and inductive approach to understanding Swedish freight buyer's sustainability work and identified drivers for implementing sustainability in transportation. They identified selection criteria and priorities that freight purchasers in Sweden consider when deciding which transport providers to work with. Finally, summarizing the respondents' thoughts on the feasibility of renewable fuels available for the transport industry. The results were summarized in a table showing the pros and cons of each renewable fuel but did not assess each trajectory using a theoretical framework.

This thesis will draw inspiration from Bauer et al. (2022)'s study that used the framework by Turnheim & Nykvist (2019) combined with Dahlgren & Ammenberg's (2022) work on Swedish freight buyer's thoughts on renewable fuels. This thesis will complement previous research by applying a system-wide approach using the theoretical framework by Turnheim & Nykvist (2019) to assess Sweden's renewable fuel transition pathways for transportation and to suggest a roadmap for reaching fossil-free transportation by 2025. Taking what Bauer et al (2022) did in a geographically agnostic way, and now testing it by applying it to a specific company, Nestlé Sweden, and country specific context, Sweden, to explore if it can produce a structured guidance on how to best reach fossil-free transportation. The aim is to provide a currently unexplored theoretical perspectives of potential value to freight purchasers in Sweden trying to reach fossil-free transportation. Hopefully closing a deficiency in knowledge, leading to freight purchasers being able to operationalize a process that will support their roadmap development. This research will ideally support companies in their transition away from fossil fuel consumption, leading to emissions reductions, and contributing to the goal attainment set out in the Paris Agreement.

1.3 Aim and Research Questions

The aim for this thesis is:
- To understand pathways that transport purchasers can pursue to reach the fossil-free transportation goals from manufacturing plant to customer.
- To develop a process for assessing a market and developing a roadmap for achieving fossil-free transportation.

Case study research focuses on *why* or *how* kinds of questions with the aim of understanding the phenomenon in greater detail and usually focus on "explain, explore, describe, understand" for their activities (Yin, 2018; Schoch, 2020). Therefore, the research questions are as follows and will be addressed through the following activities.

RQ1: How is the market transitioning to fossil-free freight transportation?
This research questions involves understanding the changes transport providers have already implemented and which transitions they are exploring to integrate or phase out in the future. The focus was understanding the transition pathways available in the market to reach fossil-free transportation by 2025.

RQ2: How do the current conditions and potentials for fossil-free transportation transition pathways compare to each other in Sweden?
This research question involves understanding the maturity of options, integration in existing systems and infrastructure, social acceptability, and political acceptability of each identified transition pathway from RQ1 based on the theory by Turnheim & Nykvist, 2019.

RQ3: How can a transport purchaser map their preferred decarbonization pathway?
This research question involves delineating a series of steps that transport purchasers can take to analyze a market to determine transition pathways and assess each alternative. It also explains how a transport purchaser can transform the findings from the analysis and contextualize those findings into their business to reach their climate target from their corporate sustainability strategy.

1.4 Scope and Delimitations

The scope of this thesis is focused on decarbonization of road-based outbound, downstream freight transport. The fossil-free transportation goal in Sweden refers to the use phase or tank-to-wheel emissions and therefore does not consider the complete lifecycle of the transportation. The freight transport is the biggest emitter of logistics and therefore will be the focus and Sweden is a priority for Nestlé Nordic as they have signed a business coalition agreement to reach fossil-free transportation by 2025 through Fossilfritt Sverige (Fossil Fritt Sverige, 2021). Furthermore, it will focus on carbon reduction strategies and transition studies to support roadmap development. The transport purchaser in this case study is Nestlé Sweden and the main transport provider is PostNord TPL. There were five participants in the thesis, and they represent the key stakeholders for Nestlé Sweden in the transition towards fossil-free transportation in Sweden. Temporally, the data's relevancy is transient as there are unexpected technological innovations, political changes, or economic activity that could change and affect the findings of this study. However, the data collected was based on today's perspective of the market's transition to fossil-free transportation. A limitation to building a roadmap is that predicting the future comes with uncertainty and inaccuracies that limit its ability to provide concrete advice for corporations. Although there are other quantitative methods that could have been chosen, due to time available and lack of access to software a qualitative theoretical framework was chosen. This was also chosen to ensure it was practical for a busy manager that may not have academic background in transition studies. The participant, Volvo, was a key stakeholder in this thesis as they are a market leader in developing low carbon transportation technologies. They were limited by the information they could share due to lack of a confidentiality agreement. They would have been able to provide more details on when certain technologies would be ready in the future. Therefore, the discussion remained more general. Among all participants, they were primarily stakeholders from the road-freight transport sector and not representing other modes of transportation such as rail or maritime. Rail was discussed as an option but was less defined, perhaps because this is not the primary business of the transportation companies that were interviewed.

1.5 Ethical considerations

This thesis has followed strict ethical considerations to maintain the integrity of the research. There was no funding provided by an external organization. In relation to researcher honesty and personal integrity, the partnership with Nestlé Nordic was a non-funded project where they provided a company laptop and connections to stakeholders for interviews. There were no participants that influenced the analysis as I led all the interviews and although a Nestlé Nordic representative was present, they did not intervene without my permission and when they did, it only added to the conversation rather than steered the conversation to their benefit.

In relation to consent and courtesy, names of participants were kept confidential, however, with their consent, their position and company name were included in this study. There was a high degree of voluntariness of participation for respondents as Nestlé Nordic would reach out to them to request if they would be willing to interview for my thesis. They all fully consented to the research and signed a consent form in which they agreed to the terms of the research and the level of confidentiality they were comfortable with. That said, there may have been a power dynamic at play having one of their customers requesting an interview for them which could be considered a disadvantage. There are no identified disadvantages or damage for the participants as most expressed they will benefit from this research. There may be a potential for biofuel and fossil-fuel providers to potentially be harmed by this research. Furthermore, the premise of the thesis is to explore pathways transitioning away from fossil fuels. This recommendation could contribute to the market shift towards other renewable options. Furthermore, if there were investments in hydrogen, the recommendations of this thesis could cause divestment in those projects and redirect those investments into battery-electric and biogas. However, none of these results would be detrimental to the participants involved in the study. All interview data is stored on a password protected laptop that only I have access to and cannot damage the participants. The thesis will be shared with all participating stakeholders at Nestlé Nordic prior to being published to ensure sensitive information is protected. The research design has been reviewed against the criteria for research requiring an ethics board review at Lund University and has been found to not require a statement from the ethics committee.

1.6 Audience

The expected audience of this study is expected to include freight purchasers in Sweden (e.g., Nestlé Sweden), freight providers in Sweden (e.g., Post Nord), companies, business coalitions on fossil-free transportation (e.g., Fossil-free Sweden), truck manufacturers (e.g., Volvo), and policy makers in the Nordics.

1.7 Disposition

Chapter 1 presents the nature of the problem addressed in this research and the specific problem(s) addressed. The content then identifies research limitations, background on renewable fuels and key definitions, scope, ethical considerations, and describes the intended audience.

Chapter 2 includes a literature review which is a more thorough analysis of corporate carbon strategy development, motivations for corporations to create roadmaps, and transition studies as a way of assessing a context to develop a roadmap are presented and the main gaps in the research field are outlined. Based on these gaps, specific research questions are developed, and a theoretical framework used for data analysis is presented.

Chapter 3 The research design presents the qualitative methods, research aims of the thesis and introduces the case of Nestlé Sweden's fossil-free transportation by 2025 goal.

Chapter 4 presents the main findings from the qualitative case study and identifies key transition pathways and recommendations for a roadmap to reach fossil-free transportation in Sweden by 2025.

Chapter 5 presents the discussion based on the two aims of the thesis and compares the findings to previous studies in this field.

Chapter 6 presents the main conclusions of the work and then provides recommendations directed to the principal audience(s). This final section then outlines areas for future research in corporate carbon strategies.

2 Literature Review

The literature review was focused on current knowledge of sustainable freight transport, motivations for corporations to change, corporate carbon strategies, and finally transition studies and how they can support roadmap development. The study grew organically therefore, this is one of two literature reviews in this thesis. The first being in this chapter and the second is embedded in the discussion chapter. The literature review in the discussion was more appropriately placed in the comparative analysis with the findings of this thesis. The literature review in the discussion chapter covers previous studies that apply theoretical frameworks rooted in transition studies that were applied to similar contexts. The previous studies apply the frameworks to different contexts within transportation, identify transition pathways in low-carbon transportation, and provide a form of analysis of different pathways that are like the assessment made in this thesis.

2.1 Current knowledge related to frameworks for sustainable logistics

The term net-zero applies to all greenhouse gases aggregated however the concept lies in net-zero carbon dioxide and is based on the Paris Agreement targets (Allen et al., 2022). Net-zero is sometimes referred to as "climate neutrality" which is "defined by the 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C (SR1.5) (10, 11) as a state in which human activities result in no net effect on the climate system" (Allen et al., 2022). Net-zero and climate neutrality is a scientifically rooted concept, a frame of reference that structures global action, and is operationalized through social, political, and economic systems (Fankhauser et al., 2021). Two frameworks that help to understand the material collected from this thesis are The Paris Agreement and the 2030 Agenda for Sustainable Development (Delafield et al., 2021). The aim of the Paris Agreement is to "keep global temperature rise this century below 2 ◦C above pre-industrial levels and to pursue efforts to limit this temperature increase to 1.5 ◦C". The 1.5 ◦C requires a global effort for a net-zero transition by 2050 to reduce our greenhouse gas emissions. The 2030 Agenda for Sustainable Development created 17 goals covering challenges such as climate change and environmental degradation to name a few. These frameworks are providing the guidance and blueprint for companies to build their decarbonization strategies including for their logistics (Delafield et al., 2021). These frameworks have been contextualized in many forms into the transportation industry and how they can achieve fossil-free or net-zero transportation. These have been transformed into performance assessments and frameworks that are used by firms to build their decarbonization roadmaps.

2.1.1 Performance Assessments of Sustainable Transportation

Trivellas et al. (2020) explains that there is increased pressure from consumers to improve the sustainability of freight transportation seeing as logistics emissions are the largest set of emissions for agri-food companies' logistics. This consumer pressure could lead back to Nestlé Sweden through demand from retailers that funnels up the supply chain. This was a case study on Greece through a questionnaire sent to 134 firms in the agri-food sector to understand the decision-making tools they used to assess decarbonization strategies. As previously mentioned, the agri-food space is unique in that they face challenges of shelf life and perishability of the transported products and the seasonality of the products they transport. The study tries to understand the interaction between green logistics activities in the agri-food firms and the green performance outcome. Based on an extensive literature review and the findings from the study, the authors created the tables as shown in Appendix 1 and 2 that describe the main areas of green logistics management that firms focus on and green logistics performance key performance indicators (KPIs) to help form a strategy. The results show managers should continue to create green logistics strategies to enhance their performance and create a resilient business (Trivellas et al., 2020). Kazancoglu et al. (2018) studies the relationship between implementing different GSCM practices and the effect it has on business performance. The study aimed to investigate environmental performance indicators as well as indicators for logistics and other areas of business. Through an extensive literature review, the authors formed a list of performance main criteria. For this report, the environmental and logistics performance (see Appendix 3) main criteria and sub-criteria (see Appendix 4) that are pertaining to carbon reductions are the most relevant. These indicators of GSCM for environmental and green logistics performance can be used by managers to assess more environmentally conscious supply chain activities. The indicators are the basis for data collection, measuring, monitoring, and evaluating performance over time (Kazancoglu et al., 2018). A limitation to these KPIs is that they do not consider the complexities of food supply chains, the political landscape, or the assessment of available infrastructure. That said, this provides inspiration for how one can develop a framework that can assess different alternatives to ultimately identify the best pathway forward.

2.1.2 Frameworks for Sustainable Transportation

There are several frameworks that can be utilized to guide managers on decarbonization in logistics. A framework that managers can utilize when making strategic decisions for their transportation is the Avoid-Shift-Improve (ASI) approach which was created by Dalkmann and Brannigan (2007) and stands for "(1) avoid transport; (2) shift it to lower-carbon modes of transport; and (3) improve the fuel efficiency of the remaining transports" (Miklautsch & Woschank, 2022). A study by Miklautsch & Woschank (2022) focused on the manufacturer's perspective and created a comprehensive framework of 215 measures with 27 categories that can be implemented in a manufacturer's logistics. They also estimated the reduction potentials of these measures. This research contributed to the decisions that manufacturers can make when trying to reduce their transport and logistics emissions (Miklautsch & Woschank, 2022). Similarly, Mak et al. (2022) did not propose a framework per se, but they did present several 'green solutions' for the logistics industry as a strategy that are like the ASI approach. They propose three approaches when decarbonizing GHGs from transportation; "(1) streamline transport activities, (2) applying technology, and (3) use lower-carbon fuels". All three steps are necessary for firms to achieve their emission reduction goals. The second proposed strategy is to implement modal shifts where possible to reduce GHG emissions. This can be for example shifting from heavy duty trucking to railway. Firms can consider their routing strategy by optimizing their delivery routes to shorten their travel time, increase the quantity of goods they transport per delivery, and reduce empty return trips. Although road-based transportation is the highest contributor of emissions in logistics, green warehousing is also important to consider (El-Berishy, 2017). Changes such as high efficiency lighting, installing solar panels, high-volume-low-speed ceiling fans, recycling programs, and apply for the Leadership in Energy and Environmental Design (LEED) certifications are all recommended (Mak et al., 2022). In a thesis by Pinchasik (2022), they identified several frameworks that can be used in green logistics management. They reference the above-mentioned ASI framework but expand this by introducing a closely related framework which is the Activity-Structure-Intensity-Fuel (ASIF) Framework created by Schipper and Marie. The Banister's 'sustainable mobility paradigm called for four types of actions: "1) reducing the number of trips by reducing the need for underlying transport; 2) encouraging modal shift; 3) reducing trip distances through targeted land-use policy; and 4) increasing transport efficiency through technological innovation". Noting that these are all frameworks for general transportation that may not be specific to road freight transport for manufacturers. A framework by McKinnon called the 'Green Logistics Framework' is specific to emission reductions from freight transport. It structures decarbonization into five veins: "1) reducing the level of freight movement; 2) shifting freight to lower-carbon modes; 3) improving vehicle utilization; 4) increasing energy efficiency; 5) switching to lower-carbon energy". This framework was used to guide a literature review by Ghisolfi et al. (2022) because the scope includes a wide range of aspects of freight transport. The authors explored the interactions between systematic external factors (e.g., behavior, technology, infrastructure, decarbonization strategies based on the framework and policy instruments used (Ghisolfi et al., 2022). Kaya and Yokobori created the "Kaya-Identify" model to analyze development in CO_2 emissions. It is a mathematical equation that can be used in many forms and in large and small segments for example, a country or a sector (Pinchasik, 2022). Another framework used to assess the potential of different decarbonization technologies (e.g., electric vehicles, hydrogen) is a SWOT and PEST analysis to understand which vehicle type the authors recommend pushing onto the market (Li et al., 2022). Hasan et al. (2019) have created the green logistics framework covering different practices under four main pillars of green logistics rather than only focusing on transportation: (1) green office, (2) inventory control and material handling, (3) green warehouse, and (4) green transport. The sub-criteria are shown in Appendix 5. A limitation of these frameworks is that they are not specific enough for a manager to create a decarbonization strategy from.

2.2 Motivations for corporations to change

Cadez et al. (2018) explores corporate GHG reduction strategies and the internal and external drivers underlying these strategies. The study was informed by stakeholder theory and the impact of internal and external stakeholders creating market pressures for the firm to reduce its emissions. The identified external stakeholders were regulatory authorities such as policy makers and market participants such as end consumers. Internal stakeholders could be board members that are motivated by carbon trading or having to pay carbon taxes due to higher GHG emissions. Despite these ever-present pressures, emissions continue to rise due to shareholders desire to continue to profit from fossil-based resources. Despite this, there is also rising market and regulatory pressure that are causing firms to have regulatory uncertainty. Literature suggests that in times of regulatory uncertainty firms tend to act more proactively and with more of a long-term oriented approach (Engau & Hoffmann, 2009; Slawinski et al., 2017; Teeter & Sandberg, 2017 in Cadez et al., 2018). Rooted in stakeholder theory, the literature suggests that a firm's corporate commitment to their emissions reductions depends upon their stakeholder pressures. This is aligned with the theory in that the more a firm aligns with the interests of its stakeholders the more success it will have in the long term. The most influential stakeholders are those able to apply direct pressure such as regulators and market actors. Regulatory pressure typically involves setting rules and setting corporate compliance processes for monitoring progress. Rules can change over time creating regulatory uncertainty for firms (Cadez et al., 2018). This will inform this thesis by focusing on how and which pressures regulators and market actors are applying. This will be explored by considering different market-based instruments that are incentivizing fossil-free transportation in Sweden as well as social acceptability of different alternatives by market actors. This study found that pressures from the market result in positive effects on a firm's corporate carbon strategy and are an important part of shaping how a firm moves forward with its environmental strategies. The stronger the pressures, the more the firm focuses on a robust carbon reduction strategy and ultimately experiences greater carbon reductions (Cadez et al., 2018). Finally, the study concludes that the more a firm implements carbon reduction strategies the better they perform on those reduction goals including GHG related costs (Cadez et al., 2018).

2.3 Corporate carbon strategy

Corporate carbon strategy is the foundational step to forming a sustainability roadmap that will provide a step-by-step guidance to reaching the ambitions of the strategy. This section of the literature review provides an overview of previous studies describing what makes a strong corporate carbon strategy that is the basis to every roadmap. These insights will be compared to the findings of this thesis in the discussion chapter. A study by de Almeida et al. (2021) identified main attributes of a successful corporate carbon strategy. The integrative framework for corporate carbon strategy was informed by relational view (RV) and natural resource-based view (NRBV) and shows that firms can achieve a collaborative capability through corporate carbon strategy and therefore sustain their competitive advantage. The relational view suggests that firms can achieve relational rents through an exchange relationship between two firms where neither firm could generate specific knowledge or achievements on their own. NRBV refers to three main activities firms should focus on for their corporate carbon strategy: (1) product stewardship, (2) pollution prevention, (3) clean technology. The ten attributes are (1) innovation towards sustainability, (2) adoption of cleaner technology, (3) absorptive capacity, (4) knowledge sharing for sustainability, (5) propensity for sustainable partnerships, (6) strategic alignment towards sustainability, (7) green development of new products, (8) sustainable operations management (9) long term relationships, (10) network structures. Innovation towards sustainability suggests that firms should observe their external environment, track innovations in sustainability and invest in new knowledge and assets to remain innovative. Adoption of cleaner technology is about firm's identifying and leveraging cleaner technologies to achieve new sustainability requirements. Absorptive capacity is about a firm's ability to absorb and process new knowledge and utilize this to develop and improve their sustainability progress. Knowledge sharing for sustainability involves exchanging knowledge to achieve relational rent. Propensity for sustainable partnerships involves the firm's ability to maintain and develop valuable partnerships as it allows a firm to improve their environmental performance. Strategic alignment towards sustainability refers to a firm's consistency with other network actors' strategies ensuring partners are selected by ensuring partner's commitment to sustainability is strategically aligned with their own. Green development for new products is about creating products that reduce a firm's environmental impacts throughout the entire value chain. Sustainable operations management involves aligning a firm's functional activities with its sustainability strategy. Long term relationships refer to a firm having informal governance mechanisms in their relationships that can reduce transaction costs through relational rents. Network structures involves a firm sharing and receiving knowledge and manage the relationships within a network. Through developing these corporate carbon strategy attributes, firms can develop relational rents according to the relationship view and can implement sustainability activities according to natural resource-based view. The study concludes that these attributes hold the potential to improve a firm's sustainability performance (de Almeida et al., 2021).

A study by Lee, (2011) performed a literature review and a list of six categories of carbon management activities that firms can prioritize to have an effective corporate carbon strategy. The first is emissions reduction commitments which refers to the act of setting carbon reduction targets with clear ways the firm will achieve them using relative and absolute indicators. The second is product improvement which refers to developing energy efficient, sustainable products across its lifecycle. Process and supply improvement refers to reducing emissions and improving energy efficiency within a firm's supply chain using cleaner fuels for example. New market and business development opportunities should be searched to gain a competitive advantage from the unique selling point of sustainability. Organizational involvement refers to a firm's commitment to increasing awareness and education among its management and employees through training programs and communication efforts. Lastly, external relationship development refers to developing partnerships such as voluntary programs with governments, carbon offset projects, and reporting standards such as Carbon Disclosure Project (CDP). The study performed a content analysis of 241 Korean companies' sustainability and CDP reports to assess their activities toward mitigating climate change. They measured how much each company was implement each of the six carbon reducing activities based on a five-point Likert scale assessing their level of proactivity. Level 1 meant that the firm had a low involvement or implementation of the activity and level 5 mean there was a high level of involvement or implementation of the activity. From this content analysis, the authors created a typology of six types of corporate carbon strategies based on their results. The first is the 'wait and see observer', these companies have a low overall score of the six activities and do not take climate mitigation activities seriously and showed a low ambition to put measures in place. Next is the 'cautious reducer' referring to when firms have set emission targets and have started to implement carbon reduction activities within their own production processes but were less focused on improving the carbon footprint of their products or exploring new markets. They were starting to explore setting emissions targets to their entire organization. 'Product enhancers' usually are solely focused on the enhancement of their products' market competitiveness through energy efficiency and products with low carbon intensity. They are motivated when the company's emissions are highest in the consumption phase versus their production process and that energy efficient products are a unique selling point for their customers. 'All round enhancers' scored the highest on carbon reducing activities except for the new market and business development attribute. They set clear emission reduction targets and measures to achieve the desired reductions as well as a dedicated department for sustainability. They actively engaged with network actors such as trade associations, sustainability reporting, and governing bodies. 'Emergent explorer' was focused on opportunities out of their own market or current scope to venture into businesses such as in renewable energy industries and investing in innovative technologies such as electric vehicles. The 'all-round explorer' is the last type and scored the highest in new market and business development and mostly had the highest scores in the other carbon activities. They prioritized their own competitiveness while exploring new business opportunities. This study created a cluster analysis of six different carbon strategies in South Korea and can be used as a reference when building the roadmap for Sweden's fossil-free transportation goals. A key limitation of this study is that the data was based on public information and may not be an accurate reflection of the real situation of Korean firms as they did not have insider information (Lee, 2011).

Back casting is defined as first defining a desired outcome and then working backwards to determine what needs to be done to achieve that desired future (Buettner, 2022). Back casting is a normative and iterative approach to building corporate decarbonization strategies and is commonly used when designing sustainability roadmaps. A limitation to back casting is that road mapping the future always comes with uncertainty and comes with inaccuracies that limit its ability to provide concrete advice for corporations. A study by Buettner (2022) was informed by back casting framework literature. The aim of the study was to determine the foundational questions firms should answer and aspects they should consider that can provide a path forward for corporate stakeholder on how to develop an effective decarbonization strategy. Through using a back casting approach, the study provided seven foundational questions that help corporations develop their decarbonization strategy. Their findings are based on interviews with manufacturing companies as well as desk research of public information on companies' decarbonization strategies. This is particularly relevant for this thesis as it is based on decarbonization strategies for manufacturing companies and not just national decarbonization plans which aligns with the target audience of this study. The answers to these seven questions allow firms to determine the ideal path forward and provides the foundation for making informed decisions on where to act. The seven identified success criterion are described as follows. The first is terminology, where firms need to create mutual understanding and clarity of terminology around decarbonization for all involved stakeholders. Optimization variable refers to firms setting their targets and determining the overarching goals of their stakeholders. For example, variables to be optimized could be the reduction in energy consumption or achieving net CO_2 neutrality. The third success criterion is the level of ambition, referring to the need for a clear timely target year and the percentage of reduction for the optimization variable to determine a firm's level of ambition. This would include interim milestones that help ensure the target achievement. The fourth success criterion is the area of observation meaning which scope will the targets be connected to base on the defined scope 1, 2, and 3 emissions by the GHG Protocol. The fifth criterion is the motivation and needs which refers to understanding the underlying motivations of the firm and its stakeholders to reach net-zero since the motivation is embedded in the overall strategy. For example, common motivators could be to meet societies' expectations or to fulfill requirements of supply chain members. The sixth criterion is priorities which refers to a firm's ranking on the decarbonization measures that determines how the roadmap will reach net-zero. The last criterion is status quo is the process of understanding where the firm stands right now. The different dimensions that should be explored are: (1) what is already being done for decarbonization in the firm and are there low hanging fruits? (2) Which changes are going to be happening anyway regardless of the roadmap (e.g., production line optimization) (3) How safe is the existing site? If a site is the target for investing in high efficiency technology but the safety of the site is questionable then the investment may not make sense. (4) What is the state of the current energy consumption and energy emissions and how do they compare to the target dimension and area of observation? This helps firms develop a baseline and help prioritize where their efforts will have the greatest impact. (5) What are the local conditions in terms of the climatic conditions, the infrastructure, the stakeholders in the surrounding area, and if there is potential for on-site electricity generation? Based on these seven-success criterion, there are several internal and external measures that firms can take to reach their net-zero targets. This study was based on manufacturing companies in Germany however the authors state that the success criterion is likely to be valid in other geographies and cultures (Buettner, 2022).

Damert et al., 2017 presents a corporate carbon strategy framework with three strategic objectives that businesses focus on when addressing climate change: "(1) carbon governance, (2) carbon reduction, (3) carbon competitiveness" (Damert et al., 2017). Each objective is connected to ten kinds of corporate activities: "organizational involvement, risk management, carbon measurement and policy, product and process improvements, carbon compensation, new markets and product development, stakeholder engagement, corporate communications and political activities". This framework can be used to assess long term effectiveness of corporate carbon strategies and its carbon reduction performance. A key limitation to this framework is that it uses voluntary disclosed corporate data and therefore it may hinder the credibility of the data especially if there is no third-party assurance on the data (Damert et al., 2017).

2.4 Transition studies

Transition studies is focused on the field of sustainability and explores the societal systems that help meet our human needs such as transportation (de Haan et al., 2016). Our mobility needs in the context of this thesis are the transportation of food items in Sweden. The system that allows transportation of food in Sweden from a company's warehouse to its final consumer is part of a societal system if referring to Rotmans' (2005) theory, a socio-technical system if referring to Geels and Schot's, (2007) theory, or a service-provision system if referring to de Haan and Rogers's (2014) theory (de Haan et al., 2016). De Haan et al. (2016) describe transitions as "processes of change that carry societal systems into a qualitatively distinct state of functioning, viz. a different way of meeting needs.". In the context of this thesis, the transition would be the transition to a fossil-free way of transporting food items around Sweden by 2025. The transition to uptake new practices such as the use of electric vehicles, trucks run on biofuels, and hydrogen trucks and phasing out trucks run on fossil fuels. The pathway itself is a description of the changes that are needed in the system at specific times (de Haan et al., 2016). Different theorists define pathways through graphs and distinct shapes with a variable on the vertical axis against time. For the case of socio-technical systems, Geels and Schot's (2007) there was an increase uptake of a certain activities while being nested in the "three levels of the niche-regime-landscape hierarchy". In nearly all cases, the curve increases to show a positive direction on the pathway to reaching the final goal (de Haan et al., 2016).

De Haan et al., (2016) model transition pathways using the Multi Pattern Approach which is a theoretical framework based on a series of inter-connected factors and determines patterns that form the prediction of possible future sustainable pathways. This approach uses a computer software written in Java to model patterns. In this case, the variables of the system are referred to as the constellation, and the changes are triggered by three conditions: (1) needs, (2) constraints, and (3) competition (de Haan et al., 2016). "*Needs* – In response to unmet or over-met needs, solutions in one or more constellations are being taken up or phased out. *Constraints* – Constrained solutions are being phased out, possibly in favor of other ones. *Competition* – Solutions are taken up or phased out because of constellations overlapping in the needs they meet. Under competition, a constellation takes up a solution at the expense of its competitors to increase its relative share in meeting the needs in question" (de Haan et al., 2016). If these three conditions take place in the constellation, then the system will either adapt or another constellation will gain power providing alternative solutions. Such as if the electric truck constellation would gain power and replace the fossil-fuel truck constellation. This leads to three patterns of the multi-pattern approach: "adaptation, empowerment (bottom-up) and reconstellation (top-down). They show the patterns, dynamics, and conditions under which they occur in Table 1 below. After the modelling is complete, there is a clustering algorithm that helps identify types of pathways for different scenarios (de Haan et al., 2016):

Pattern	Dynamics	Conditions
Adaptation 'internally induced'	A constellation takes up or phases out solutions in response to the conditions.	Needs Constraints Competition
Empowerment 'from the bottom-up'	An alternative constellation takes up (a) solution(s) at the expense of (a) solution in the constellation to which the conditions applies.	Needs Constraints Competition
Reconstellation 'top-down intervention'	An alternative constellation takes up (a) solution(s) at the expense of (a) solution in the	Needs Constraints Competition

	constellation to which the conditions applies.	

Table 1: Patterns, dynamics, and conditions under which they occur (de Haan et al., 2016).

Sustainability transition pathways require a shift from the existing trajectories of the socio-technical system it is a part of (Turnheim & Nykvist, 2019). Decarbonization involves destabilizing current socio technical systems that are in place through phasing out technologies that have been locked in and introducing new niche solutions that can help the world reach its net-zero goals by the mid-century (Rosenbloom & Rinscheid, 2020). Destabilization in the context of decarbonization has its roots in socio-technical theory as decarbonization interacts and aligns with the three dimensions of a socio-technical system: niches, regimes, and landscape developments (Geels et al., 2017). Niches are emerging innovations that challenge the current regime. The regimes involve the current dominant institutions, actor networks, infrastructure, and technologies. Once the innovation is adopted to the regime it can be path dependent and there can be a lock in effect to carbon-intensive technologies. The landscape represents are the broader aspects such as political changes that could reinforce or add pressure to the regime. "The general theory of change is that: "(a) niche-innovations build up internal momentum, through learning processes, price/performance improvements, and support from powerful groups, (b) changes at the landscape level create pressure on the regime and (c) destabilization of the regime creates windows of opportunity for niche innovations" (Geels & Schot, 2007, p. 400)." Decarbonization strategies for logistics are necessary for organizations to reach their net-zero goals but requires a strategy to ramp up the use of niches technologies to disrupt their path dependency on carbon-intensive technologies such as the use of fossil fuel-based trucks (Rosenbloom & Rinscheid, 2020). Quantitative modelling, such as the above multi pattern approach, has been used for decision making for roadmap development in decarbonization. Furthermore, it does not consider all the conditions in a socio-technical system such as policy, social feasibility, infrastructure to name a few. Furthermore, logistics managers in large corporations do not always have the capabilities to use and interpret the quantitative modelling results. They are useful when linking specific sustainability objectives to specific dimensions such as preserving certain species and translating that into a roadmap for reducing land degradation. They typically consider technical, economic, or macro-economic dimensions but risk overlooking the projections and lock-in effects of the socio-technical transitions.

A study by Buettner (2022) uses scenario-based modelling to explore pathways feasibility for reaching environmental sustainability goals. The approach was rooted in socio-technical theory, is normative, and involves back casting (Turnheim & Nykvist, 2019). Back casting is defined as first defining a desired outcome and then working backwards to determine what needs to be done to achieve that desired future (Buettner, 2022). Back casting is a normative and iterative approach to building corporate decarbonization strategies and is commonly used when designing sustainability roadmaps (Buettner, 2022). Back casting for scenario-based modelling of sustainable transition pathways have been criticized for the unpredictability of the rate at which technology will change and be adopted and that the future is always uncertain. Qualitative modelling can fill the gap that quantitative modelling does not address through pluralism. Pluralism is a form of evaluation by using different types of knowledge to create an idea of the future. Turnheim & Nykvist (2019) propose a framework that pluralizes sustainable transition pathways to address the gaps in the previous modelling methods. They identified "three 'facets' of pathways (i) pathways are representations of change processes that can support forward-looking evaluations; (ii) pathways are potentials in the sense of 'hopeful' new orientations providing focus to change efforts; and (iii) pathways are (sets of) conditions that can underpin the realization of such potentials in practice." Pathways as representations are the use of socio-technical approaches that display the actors, systems and institutions involved in a sustainable transition pathway. This can help a firm gain deeper understanding of potential delays to niche innovations and having a realistic expectation of technology or non-technological advancements. Representations can also be in the form of quantitative evaluations such as emission profiles and costs. This helps firms understand which pathways are possible given the constraints in the socio-technical system. Pathways as potentials are prioritized by pluralizing pathways to create a wider variety and reflexivity. For example, in when developed a sustainable transition pathway for mobility, it is important to consider multiple forms of production such as car sharing and working from home schemes. A second part of pathways as potentials is temporal ordering in which historical data on innovation patterns can be utilized to predict the speed at which niche innovations are adopted. These turning points all called branching points and there are two types: (1) mainstreaming of alternatives (the point when the innovation breaks out of its niche and changes the dynamics of the system) and (2) the interdependency of the innovation and the infrastructure (e.g., electric trucks and charging infrastructure). Pathways as conditions refers to the dimensions that affect a pathways feasibility and update in its specific context. For example, Norway had a rapid uptake in electric mobility due to strong stakeholder coalitions, a strategic policy mixes as compared to the slower uptake in Germany and other European countries. Different geographies come with different political ambitions, social acceptability and infrastructure that affect the scale and speed at which a pathway will be adopted. The four identified conditions for the realization of a sustainability pathways are (1) maturity of options (2) system integration and infrastructure requirements (3) social acceptability and (4) political feasibility. Maturity of options refers to how ready and commercially available an option is in a specific context. System integration and infrastructure refers to the ease in which a pathway will integrate with existing industries, systems, and infrastructures. For example, pathways that can use existing infrastructure and fit in the current systems need lower investments and can be implemented faster than pathways that do not. Societal acceptability refers to controversies or anxieties of the public with the chose option and how this would affect its adoption into the system. Finally, political feasibility refers to the likelihood of decisions that would incentivize a specific pathway forward through for example, policies, investments into infrastructure, stakeholder coalitions, or trade associations. They would either support or push for a change to implement what needs to be done for the desired outcome of the pathway (Turnheim & Nykvist, 2019).

Using the pathways as conditions from Turnheim & Nykvist, Bauer et al. (2022) performed a sector-level analysis with extensive desk research focusing on four sectors (meat and dairy, steel, plastics, and pulp and paper). They used the theory to assess the potential and conditions of the pathways through identifying the main trajectories for decarbonizing each sector. From the sector-specific trajectories, they identified five pathways that fit to all four sector that served as archetypal transition pathways to decarbonization. These were "i) production and end-use optimization, ii) electrification with carbon capture and use (CCU), iii) carbon capture and storage (CCS), iv) circular material flows, and v) diversification of bio-feedstock use". They then assessed each pathway using the four conditions for pathways of maturity of options, integration with systems, industries and infrastructure, societal acceptability, and political acceptability and delivery. In addition they assessed each pathways using the theory on pathways as potentials by considering the two main aspects that are integral in evaluating dynamic potentials and pathways which are: "i) the development of new knowledge (learning) that may strengthen or weaken the promise of pathways; ii) the possible existence of branching points in which (groups of) actors make decisions or take actions that create lock-ins to pathways (convergence) or break with them (divergence)". Learning can increase or decrease feasibility of a pathway. It can increase if for example, learning leads to process optimization which removes a bottleneck but can decrease it for example, a rapid learning curve for a competing pathway may overtake the materialization of the current pathway. Branching points are decisions that are made as a response to internal or external pressures which drive the direction of the pathway. This helps determine critical events that need to happen for the realization of different pathways. For example, the end of a subsidy for biofuels in Sweden would be branching point for the direction of the decarbonization pathway in the country. They represent a point in time or 'window of opportunity', where stakeholders either move forward or abandon pathways in favor of an alternative strategy. The two assessments are shown in Table 2 and 3 below. This study using the framework by Turnheim & Nykvist (2019) was effective in assessing the feasibility of different transition pathways that guide decision makers when developing their roadmap.

	Maturity of options	**Integration with systems, industries, and infrastructure**	**Societal (social and industrial) acceptability**	**Political acceptability and delivery**
Production and end-use optimization	Fragmented: The range from energy efficient equipment to renewable fuels/energy sources as well as integrated/shared use of products/ utilities is well developed. End-use material efficiency options are undeveloped.	Fragmented: The long-term focus on energy and resource efficiency in process industries is well developed. Materials efficiency across value chains is undeveloped.	Fragmented: Developed, although with barriers, on the production side. Acceptability on the end-use side is likely to be relatively high but it is institutionally undeveloped.	Fragmented: Energy and emissions efficiency key to EU policies and developed but the potential to deliver complete decarbonisation is limited. End-use demand management and materials efficiency is undeveloped.
Electrification with CCU	Fragmented: Technological modules are mature, but not large-scale CCU systems. Electrification and hydrogen options vary in maturity across different applications.	Limited: Electrical power systems not yet adapted for electrification, hydrogen, and variable renewables production but grid expansion, flexibility measures and storage are prepared for and evolving.	Limited: Fear for limited access to green electricity and hydrogen at low cost; potential public resistance to wind power expansion; capturing carbon most likely acceptable	Limited: Growing attention to massive electrification and use of hydrogen but hesitancy towards CCU although chemical recycling of plastics is gaining more attention.

CCS	Limited: CCS mainly developed for power generation; sequestration not implemented in full scale for industry.	Undeveloped: CCS infrastructure is lacking, and capture rates are limited when retrofitting existing plants.	Undeveloped: Long-term storage controversial; capturing carbon more likely acceptable.	Limited: Growing acceptance that CCS in industry is necessary for some emissions but so far, no delivery except R&D.
Circular material flows	Limited: High recycling of some steel and fiber qualities but can be higher, very low mechanical recycling of plastics and chemical recycling is undeveloped	Fragmented: Recycling of some materials relatively well developed but further improvement requires changes in waste handling, recycling technologies and organization of value chains.	Limited: increasing acceptability for recycling, yet limited understanding for its effects in some sectors; differences in waste handling across geographical contexts.	Limited: Acceptability well developed, but delivery limited and situation across sectors is fragmented; EU push for circular economy provides directionality but not incentives.
Diversification of bio-feedstock use	Fragmented: Some diversification but limited to few product categories (fuels and some construction materials and textile fibers)	Limited: Several projects across industries but no aggressive push; reconfiguration of clusters and infrastructure is slow.	Fragmented: Generally positive view of the bioeconomy but serious concerns about competing land uses and biodiversity	Fragmented: Support for the bioeconomy, but conflicting with concerns for land use change, biodiversity, and other environmental impacts.

Table 2: Assessment of current conditions of pathways (Bauer et al., 2022)

	Learning Increase feasibility	**Decrease feasibility**	**Branching points Increase feasibility (convergence)**	**Decrease feasibility (divergence)**
Production and end-use optimization	Continued improved efficiency of processes and equipment. Develop solutions, metrics,	Rapid learning curves for renewables leading to	Strong commitments to existing processes in business organizations (alternatives are unreliable). Policy	Unclear policy directionality may limit investments to improve efficiency

	and knowledge for materials efficiency.	decreasing energy costs.	attention to demand management.	in existing value chains.
Electrification with CCU	Innovations for efficient carbon capture or electrochemical synthesis; rapid learning curves for renewables and electrolysers leading to decreasing energy costs; increased ramping possibilities.	Limited possibilities to adapt industrial production to intermittent renewable power.	Cross-industrial commitments to investments in renewable electricity and electrification; regions with renewable electricity resources taking the lead for electrification; market demand for green materials.	Political coalition building against CCU; restrictions on expanding renewable energy production.
CCS	Adaptation of capture technologies to industrial processes; testing and establishing storage sites.	Rapid learning curves for renewables, electrification and hydrogen compete with CCS.	Establishment of industrial CCS standards; strong business associations with political support commit to CCS globally	Strict regulations on sequestration; restrictions on trading CO2 for CCS
Circular material flows	Efficient and effective material management and sorting systems; innovations in material recycling technologies (metals, fibres, plastics)	Increased diffusion of traditional waste incineration/sewage treatment systems; increased complexity of products and composites.	Regulations against virgin resource exploitation; industrial commitments and standards for recycled materials in products. New value chains and business models.	Restrictions on trading waste/ recyclates; requirements and regulation on product quality making recycled flows unreachable.
Diversification of bio-feedstock use	(Bio)technological innovations for food, feed, fibers, and energy; social acceptance for new foods and green protein.	Rapid learning curves for CCU competes with diversification of bio- feedstock use. Learning and innovation in agricultural reduces	Establishment of new value chains through collaborations/mergers; reduced restrictions against GMO. Socio-cultural shifts in diets.	Restrictions on land/bio- feedstock use for new/specific purposes. Strengthening of meat culture.

		emissions from meat and dairy production.		

Table 3: Forward looking assessment of potential to realize pathways (Bauer et al., 2022)

2.5 Theories and conceptual frameworks

The theoretical framework by Turnheim & Nykvist (2019) and the research design of Bauer et al. (2022) will inform this thesis through the research design and data analysis. With this theory, this thesis will perform a sector analysis on the transportation industry in Sweden and will determine the main decarbonization pathways. Then these trajectories will be assessed using the four conditions and the two aspects of potentials to determine the best pathways forward to reach fossil-free transportation by 2025 in Sweden.

In summary, the literature review identified a gap in research regarding frameworks that can provide an over performance assessment of different transition pathways to reveal a roadmap (Pamucar et al., 2021). Buettner pointed to a wider issue that previous studies assess national roadmaps or decarbonization for companies from a political, or technology perspective but fall short in providing concrete advice to individual company's perspective (Buettner, 2022). They indicate a gap in literature and need for frameworks that provide company-tailored advice with a roadmap that is sufficiently detailed that covers technological, social, or system level aspects. Brutschin et al. (2021) identified a similar gap in that the implementation of the transition pathways for decarbonization in the real world are challenging and they often do not consider social and institutional barriers. There are quantitative models that are used in transition studies but tend to overlook key aspects such as economic feasibility, integration with infrastructure, and social acceptability for each pathway (Loftus et al, 2015 in Turnheim & Nykvist, 2019). Turnheim & Nykvist responded to this research gap by creating a theoretical framework that can assess pathway feasibility to help reach explicitly climate goals such as fossil-free transportation by 2025. Therefore, the research gap that this thesis addresses is applying the theoretical framework to a case that aims to identify transition pathways available in a geographical specific area, Sweden, and evaluate the feasibility of each pathway. During the literature review process, there were no identified studies that applied this framework to the road-freight transportation sector, and none applied it to Sweden. Although the literature review identified many studies that apply transition theory to assess decarbonization pathways, there were no identified studies that went a step further to create a roadmap that is temporally specific to the context. This study will therefore provide an overview of the transition pathways available for a company looking to reach fossil-free transportation by 2025 in Sweden and from that, develop a realistic roadmap for reaching the climate goal.

3 Research design, materials, and methods

3.1 Research Design

The research approach for this thesis is qualitative with the aim of exploring and understanding how to reach fossil-free transportation in Sweden by 2025. The qualitative element of analyzing Nestlé Sweden and its key stakeholder's strategy is based on primary sources and triangulated by desk research. This research will take an inductive approach to identify transition pathways for decarbonizing transportation in Sweden. It will then follow a deductive approach based on a pre-existing theory by Turnheim & Nykvist (2019) to organize the data using pre-determined themes (Creswell et al., 2018). Qualitative research is useful in studies where the researcher does not have clarity on which variables to examine. It allows it to unfold throughout the research. This thesis involves qualitative research to occur in the participants' natural setting and uses interviews to collect data on the scenario under study. The researcher is the main instrument for gathering and interpreting the collected data. The philosophical worldview or epistemology proposed in the study is pragmatism. A definition of basic ideas of that worldview is that it "arises out of actions, situations, and consequences rather than antecedent conditions. There is a concern with applications—what works—and solutions to problems (Patton, 1990). Instead of focusing on methods, researchers emphasize the research problem and question and use all approaches available to understand the problem (see Rossman & Wilson, 1985)" (Creswell et al., 2018). The worldview has shaped the approach to this research as it allows for freedom to choose which methods, techniques and procedures fit best to the setting and purpose of the study.

The approach taken in the qualitative design is a case study of Nestlé Sweden's fossil-free transportation strategy to explore how a transport purchaser can develop a roadmap for fossil-free transportation in Sweden. Schoch (2020) states that the use of case study research is appropriate for studies that involve an analysis of a particular event, phenomenon, or scenario in its real-life context. Case study research can be defined as "examines, through the use of a variety of data sources, a phenomenon in its naturalistic context, with the purpose of confronting theory with the empirical world" (Pierkkari et al., 2009, p. 569; Cassel et al., 2018).

The two most popular researchers in case study methodologies are Kathleen Eisenhardt and Robert Yin (Cassel et al., 2018). Yin first published a book on case study research in 1984 and has published five others since. Eisenhardt's roadmap for case study methodology was published in 1989 followed by two other publications. Therefore, this methodological choice has been well established since the 1980s (Cassel et al., 2018).

Case studies are appropriate when the context is relevant to the phenomenon (Schoch, 2020). In this thesis, the phenomenon is the need for companies to achieve fossil-free transportation to reach their bound agreements. The context is a large transport purchaser in Sweden aiming to do just that. An advantage of a case study is the ability to focus research on a specific context and timeframe and allows the freedom to collect a variety of data such as interviews and desk research (Schoch, 2020). There is a clear timeframe in that Nestlé Sweden aims to reach their goal over the next three years making a case study approach ever more appropriate. Furthermore, direct conversations with companies allows for an in-depth insider perspective of an organization, in this case, Nestlé Sweden. Case studies allow the reader to understand a real-life scenario and apply and transfer the learning and processes to other contexts (Schoch, 2020). For example, a company aiming to reach fossil-free emissions by 2025 in Norway could apply this case study to their context to reach their roadmap development.

3.1.1 Defining the Case

An important step in a case study is to define the case and its scope. Nestlé Sweden has signed an agreement to reach fossil-free transportation by 2025. There are over 300 other actors in Sweden who have signed this agreement. Nestlé Sweden is a transport purchaser in Sweden and therefore is an appropriate company to use for the case to understand how transport purchasers can build a roadmap for reaching their fossil-free transport goals in Sweden. This is focused on carbon emission reductions and does not include other environmental issues such as noise pollution however these could be used as positive externalities or added benefit in the findings to understand why a specific alternative may be favorable over another. The emissions are focused on the use phase and tank-to-wheel of the transportation and not the complete life cycle. This is because Nestlé Sweden has signed an agreement to reach fossil-free and not emissions-free transportation. That said, this is a sub-goal of Nestlé Nordic's overarching net-zero goals and strategies linked to the Nestlé Global decarbonization roadmaps. Therefore, the fossil-free agreement is one of many decarbonization activities in the business' overall strategy. The case involved interviewing Nestlé Sweden's key stakeholders involved in the phenomenon to understand the transition pathways available and the services that will be available for Nestlé Sweden to reach fossil-free transportation by 2025. The interviews and desk research aim to provide different perspectives to give credibility to the case.

Case study research focuses on *why* or *how* kinds of questions with the aim of understanding the phenomenon in greater detail and usually focus on "explain, explore, describe, understand" for their activities (Yin, 2018; Schoch, 2020). Therefore, the research questions are as mentioned in the Aim and Research Questions section and below:

1. How is the market transitioning to fossil-free freight transportation?
2. How do the current conditions and potentials for fossil-free transportation transition pathways compare to each other in Sweden?
3. How can a transport purchaser map their preferred decarbonization pathway?

3.2 Methods used to collect data

The chosen method of data collection was semi structured interviews with open-ended questions that were transcribed and recorded using Microsoft Teams. All the interviews were online except for the interview with PostNord TPL and the workshop at PostNord TPL. The interviews followed an interview guide but were exploratory therefore although the interviews started with the guide, discussions did not explicitly follow it. This exploratory format allowed interviewees to speak freely without being confined by a theoretical framework (Creswell et al., 2018). After the thematic analysis was complete, there were some gaps in sufficient data for certain themes. In these cases, desk research was conducted to collect information on the findings. The desk research was conducted through Google searches. By triangulating the data, the findings were more robust and credible (Creswell et al., 2018).

3.3 Materials collected

The field data was collected through five interviews and one workshop on sustainability strategy. Each participant is a stakeholder in Nestlé Sweden's fossil-free logistics strategy development. The interview transcripts were used for the thematic analysis. Table 4 below contains each participant's role, company, code used for referencing in the findings chapter, and the aim of each interview.

Interviewee	Code	Aim
Logistics manager at PostNord TPL	LMP	The aim of this interview was to understand PostNord TPL's strategy for providing their customer, Nestlé Sweden, with the services they need to reach fossil-free transportation by 2025. It was helpful to understand from them what activities and strategies they are implementing to understand what is feasible to integrate in the final fossil-free roadmap for Nestlé Sweden.
Logistics Manager Nestlé Nordic	LMN	They were present in nearly all interviews and helped represent Nestlé Nordic's view on points that other stakeholders mentioned
Sustainability Logistics Manager for Nestlé EMEA	SLMN	The aim of this interview was to understand where Nestlé Global's logistics team is already working on a strategy or whether they have seen success cases in other markets outside of the Nordics.
Sustainability Consultant for Post Nord TPL and Nestlé Sweden	SCP	The aim of this interview was to gain more technical information on the fossil-free transportation strategy Post Nord TPL will be able to offer to Nestlé Sweden. This consultant is helping Post Nord TPL with their fossil-free roadmap and ultimately will be offered to Nestlé Sweden as a service.
Country Manager for Sweden who is handling the Fossil-free Sweden coalition.	CMN	The aim of this interview was to understand how Nestlé Sweden is currently engaging with the fossil-free coalition in the country and the potential for stakeholder engagement if needed for higher buying and political power in negotiations around infrastructure to decarbonize the transportation.
Environment and Innovation Director at Volvo	EDV	The aim of this interview was to understand what Volvo will be placing on the market and when they anticipate different carbon-free transport technologies to be ready in Sweden so that the roadmap for Nestlé Sweden can be realistic.

Workshop with PostNord TPL, Nestlé Sweden, Consultant	W	The aim of this workshop was to understand how Nestlé Sweden and its stakeholders are developing a roadmap and to see if their actions were aligned with the findings from this thesis.

Table 4: Participant overview

3.4 Methods used to process information

The chosen method for analyzing the interview transcripts was a thematic analysis. Thematic analysis is a method for analyzing and interpreting qualitative data to identify themes through the process of coding (Kiger & Varpio, 2020). Thematic analysis allows for flexibility to apply to many theoretical frameworks and research designs. Although some scholars argue that it falls into the category of ethnography, Braun and Clarke (2006) make the point that it is a stand-alone method despite the principles of coding in thematic analyses being similar to grounded theory and discourse analysis. Furthermore, it is a methodology that is not bound to any specific paradigmatic orientation and therefore has been judged by the author as suitable to the pragmatic worldview of this thesis. It is an appropriate method when the researcher is aiming "to understand a set of experiences, thoughts, and behaviors across a data set" (Braun and Clarke, 2012; Kiger & Varpio, 2020). The method is designed to find shared meanings that can be organized into themes from many data sets. Researchers are free to use an inductive or deductive approach when coding and developing themes in the data. Inductive approach is when the researcher identifies themes from the data whereas a deductive approach uses predetermined themes based on a pre-existing theory or framework. In the inductive approach, the analysis is exploratory of the entire data set whereas the deductive approach is focusing on specific data that fits in the predetermined themes. Either method is acceptable, but it important to specify the researcher's approach to guide readers through the result (Kiger & Varpio, 2020). This research used an inductive approach to determine the transition pathways and a deductive approach to analyze the interview data using pre-determined themes from the chosen theoretical framework.

The most widely used method for a thematic analysis by Braun and Clarke (2006) is a six-step process and is an iterative process (Kiger & Varpio, 2020). The first step involves reviewing the entire data set and becoming familiar with the data. The second step involves developing a coding framework with guidelines on what data qualifies for a specific code which in the case of this thesis will be deductive based on a theory. Once the framework is complete, the researcher can begin labelling the data with the relevant codes. Coding in the case of this thesis will be supported by a computer program called NVivo. Step three involves analyzing the coded data and organizing the extracts into themes. In a deductive analysis, the analysis is based on a predefined theory so the theme development will be focused on specific aspects of the data to develop themes. The fourth step involves reviewing the coded data and themes and asking whether each code has adequate supporting data and if the data makes sense under a certain theme. The researcher reviews the codes and themes and ensures they are all appropriately categorized. Step five involves defining and naming themes to make sure they are representative of the data it covers. Researchers should clearly define the scope of each theme and review whether all the data is appropriately placed. The scope of the predetermined themes in this thesis are clearly defined and guided based on the findings from the literature review of Turnheim & Nykvist (2019). The final step involves writing the final analysis and findings through writing a narrative description of the findings under each theme and may use appropriate data extracts such as quotes to describe the data. The data can then be linked to the research questions using clear evidence from the analysis (Kiger & Varpio, 2020).

Thematic analyses allow researchers to have flexibility in the type of research questions it can select, the type of data to code, the choice of taking an inductive or a theory-driven deductive approach to ultimately understand people's experience in a variety of contexts (Kiger & Varpio, 2020). The flexibility of the method has been critiqued as meaning it is not a rigorous method and if the researcher fails to mention the role of theory or the paradigmatic viewpoint. Some key considerations when performing a thematic analysis is to describe the assumptions throughout the analysis, ensure the data it interpreted not just paraphrased, ensure findings are backed up by legitimate data (Kiger & Varpio, 2020). The thematic analysis was used to inductively identify feasible transition pathways for decarbonizing transportation in Sweden and deductively using a thematic framework based on a pre-determined theory by Turnheim & Nykvist, 2019. The themes from the theory were: (1) the maturity of options, (2) integration in existing systems and infrastructure, (3) social acceptability, and (4) political acceptability of each alternative pathway. After the analysis, each theme is reviewed and assessed on whether there is sufficient data. Where there are themes with insufficient data, desk research was conducted to triangulate the findings for more credibility.

4 Results & Analysis

This chapter contains the findings from the data analysis of interviews triangulated with desk research. There are summary tables of the results and finally there will be a suggested roadmap for reaching fossil-free transportation in Sweden by 2025.

4.1 Introduction to stakeholders

To provide context, this section introduces each key stakeholder from the interviews.

4.1.1 Nestlé Global

Nestlé Global's approach to sustainable logistics follows the ASI framework to guide their strategy development (SLMN). The focus or first step is on optimization of logistics that results in emissions reductions and cost savings. They have goals to reduce emissions in the European zone so there is no priority between markets, but they try to adapt Nestlé Global's roadmap to the context of specific markets as much as possible. The decision to not have a roadmap specific to each individual market is to maintain standardization. Nestlé Global looks to markets to make suggestions if there are opportunities to electrify or switch to rail. They encourage markets, such as Nestlé Sweden, to identify and assess transition pathways and develop a roadmap specific to their context. The logistics teams at the market level handle outbound logistics and have better knowledge of local systems. The market needs to trigger the change. An interesting quote that is emblematic of their strategies is *"To pilot and start somewhere even if not fully optimized. We can't wait for everything to be perfect"* (SLMN).

4.1.2 Country Manager Sweden at Nestlé

Nestlé Sweden's main priority is to partner with third party logistics suppliers to shift to fossil-free transportation. They manage their fossil-free agreement with DLF which is a trade association for retailers in Sweden. The trade association and its members are part of the Fossil-free Sweden agreement. The country manager deals with DLF when managing Nestlé Sweden's pledge to become fossil-free. Through DLF, Nestlé Sweden can engage with key stakeholders in Sweden and work together to reach fossil-free transportation. Nestlé Sweden is responsible for reporting their progress towards the fossil-free goal to DLF to prove they are decreasing their emissions.

4.1.3 Environment and Innovation Director at Volvo

Volvo is a leading truck manufacturer in Sweden and Europe (EDV). The Volvo Group own half of the market share in Europe and North America for electric trucks and believe they are leading the transformation in low carbon transportation. In Sweden, Volvo and Scania share 90% of the market share so sales targets Volvo has in Sweden are an indication of how renewable fuels will materialize in the market. Volvo will likely release its hydrogen technology and infrastructure in Sweden first, making it a particularly important stakeholder to involve in this research. Volvo does not see one solution to reaching fossil-free or emissions-free transportation but a combination of transport efficiency, battery electric, fuel cell electric trucks, and biogas as complementary technology. They currently offer five electric trucks models that can cover half of the demand for freight transport in Europe. Their truck offerings have a range up to 300 km in distance and 44 tons in weight and are aiming to increase these numbers over the next decade (EDV).

4.1.4 Logistics Manager at Post Nord TPL

Post Nord TPL, headquartered in Helsingborg, is a third-party logistics provider meaning they are not a transportation company (LMP). They do not have trucks themselves or drivers but have warehouses that handle the logistics and then organize the transportation through freight companies. They take their customers' orders, in this case Nestlé Sweden, and then search for transportation companies, look for the best price and quality. They then create the contracts, oversee that Nestlé Sweden's transportation is managed, and then report back. They are purely a transport purchaser not a provider. Post Nord and Post Nord TPL are different in that Post Nord is the transportation part of the company and Post Nord TPL is the third-party logistics part of the company. Post Nord TPL was formerly a private third-party logistics company until Post Nord acquired them. Within Sweden, they use around 55 different transport providers and are one of the largest transport purchasers in Sweden, purchasing transportation worth ~ SEK 1.3 billion per year. Post Nord TPL is one of Nestlé Sweden's most important transport providers in the country. When speaking of Nestlé Sweden's pet care division, it is managed in a warehouse in Gothenburg and is handled differently but for the Nestlé Sweden food business. Post Nord TPL's largest transport providers are DSV and Post Nord. DSV is one of the largest transport providers in Sweden. They own 3000 trailers, provide the trailer but partner with a freight carrier to provide a driver for the transport. There has been a case where Post Nord TPL saw a possibility to switch to electric trucks for Nestlé Sweden, but the transport providers were not willing to switch soon enough so Post Nord TPL bought two electrical trucks and ran the trucks themselves for this specific flow to offer an emissions-free option for Nestlé Sweden (LMP).

Post Nord TPL has a goal to become fossil-free by 2030, while Nestlé Sweden has agreed to be fossil-free by 2025. This affects the relationship because Nestlé Sweden will apply pressure to change earlier than other customers to find carriers that run on renewable fuels. On the other hand, Post Nord TPL will have customers that have a later or no target to reach fossil-free transport so there is an interesting dynamic at play between the different climate targets determining who is pushing who. The business model of Post Nord TPL is an advantage because they are independent of transport freight forwarders and can use transport providers that can offer renewable fuels so Nestlé Sweden can reach their fossil-free goals. A key challenge is cost of certain transition pathways. Technically, if Nestlé Sweden asked Post Nord TPL to find all electric carriers tomorrow, they could offer this, but it would cost them double the price (LMP).

4.1.5 Sustainability Consultant for Post Nord TPL

This participant is the owner of a consulting firm that has been running for three years focused on sustainable ecommerce and logistics (SCP). The consultant previously worked for Post Nord in sustainability, so they are familiar with decarbonization and building sustainability roadmaps. They work on projects exploring how best to collaborate with stakeholders in a transportation supply chain to reach a climate goal (SCP). They are providing consulting services to Post Nord TPL that will support the roadmap development for Nestlé Sweden to achieve fossil-free transportation by 2025.

4.2 Defining terminology

During the interviews, participants were asked to define the difference between fossil-free and emissions free as it was brought to the researcher's attention that key definitions were interpreted differently. It should be noted that although there are agreed definitions of key terms in fossil-free transportation, there remained a level of misinterpretation among the key stakeholders. This pointed to a need to include a section on defining terminology in this thesis to ensure readers of this thesis understand the agreed definitions. According to Buettner (2022), defining the terminology to create mutual understanding in a corporate carbon strategy is key when working with stakeholders on decarbonization. The logistics manager of Nestlé Nordic highlighted the importance of gaining clarity on this terminology. Being a large corporation, if there is any misalignment with their claims, they face the risk of criticism from the public.

The Swedish government agrees that for transportation to be considered fossil-free there should be a 70% reduction by 2030 compared to 2010 baseline levels (Fossil-free Sweden, 2022a). Nestlé Sweden has signed the fossil-free agreement among 310 other actors in Sweden to perform or procure fossil-free domestic transport by 2025. Some actors have agreed to reaching the goal by 2025 or earlier and others by 2030 at the latest. Fossil-free Sweden's requirements for fossil-free transportation is in accordance with the EU's renewable directive. The fuel chosen should result in a 70% reduction compared to fossil alternatives. Acceptable fuels that meet this requirement are battery and fuel cell electric trucks, biogas, HVO, FAME, and ED95. Transport purchasers are advised to follow the guidance of the Swedish Procurement Authority (Fossil-free Sweden, 2022b). The Sweden Procurement Authority sets guidelines and rules for public procurement in the purchasing process (The National Agency for Public Procurement, n.d.). They have created guidelines for all sectors including road freight transport. They have defined procurement criteria split into three levels: 'basic', 'advanced', and 'cutting edge' level. All levels define renewable fuels as "bioethanol (ED95/85/75), electricity produced from green electricity, biogas, biodiesel (HVO100, RME100, or other FAME100), and hydrogen gas". The difference between the level is in the proportion of renewable fuels used from tank-to-wheel in the transportation fleet. In the basic level, at least 50% of the fleet needs to be powered by renewable fuels, in advanced at least 70% should be powered by renewable fuels tank to wheel. The remaining transportation is permitted to use a maximum of either 50% or 30% of fossil fuels. In the cutting-edge level, the entire fleet (90%) must be powered by renewable fuel with a maximum of 10% from fossil fuels tank-to-wheel (The National Agency for Public Procurement, n.d.).

During the interviews, Post Nord TPL explained that emissions free transportation requires zero emissions from well-to-wheel whereas fossil-free allows for more flexibility (LMP). Fossil-free is defined as reaching 70% emission reductions from using renewable fuels such as biofuels and electric trucks (SCP). There will always be emissions when considering well-to-wheel instead of tank-to-wheel from the extraction and production of different renewable fuels. That is why companies are focusing on fossil-free transportation, but the next step will be emissions free from well-to-wheel (SCP).

Therefore, the Fossil-free Sweden agreement is based on the advanced level and Nestlé Sweden has agreed to use the list of accepted renewable fuels for 70% of their fleet tank-to-wheel by 2025. This agreement is focused on transitioning members to renewable fuel sources that will lead to emission reductions, but they are not explicit emissions reductions targets. That said, the European Commission has set emission reduction targets for new heavy-duty vehicles from 2030 onwards (European Commission, 2023). Compared to 2019 levels, all new heavy-duty vehicles must provide a 45% emissions reduction from 2030, 65% from 2035, and 90% from 2040 to reduce the 25% emissions that come from road transport in the European transport sector (European Commission, 2023). These are requirements on truck producers and these targets are measured as an average of their yearly truck fleet production. Meaning that some will be zero-tailpipe, and some will be 100% tailpipe but on average they will result in a 45% reduction.

4.3 Transition pathways for fossil-free transportation

This section describes the identified trajectories available in Sweden for fossil-free transportation. They are organized using Dalkmann and Brannigan's (2007). The ASI Framework is used by Nestlé Global as a general framework that guides their decisions when developing their roadmap. To align with Nestlé Global general sustainable transport approach and to identify which pillars are not being explored, this section is structured using the ASI Framework. The transition pathways were identified during the interviews and these findings are from the participant's perspectives. This section corresponds to the first research question of: *How is the market transitioning to fossil-free freight transportation?*

4.3.1. Avoid Transport

Avoiding transportation overlaps with their activities in transport efficiency. A particular highlighted situation is in one of Nestlé Sweden's shared warehouses with another food company that is not a direct competitor. The other company owns an electric truck that take the same route as Nestlé Sweden, and they can add their pallets into the other company's truck. This allows Nestlé Sweden to use battery electric trucks without needing their own or lease an electric truck. Furthermore, it allows both companies to maximize pallet space in the truck (CMN). This is an example of coordinating trips with other transporters resulting in avoiding transportation.

4.3.2. Improve fuel efficiency of the remaining transport

Transport and fuel efficiency

Energy efficiency should not be forgotten even if a company electrifies their fleet. With the global energy shortage and increasing demand for clean electricity, *"even if you electrify your fleet you have to ensure your network is efficient to conserve energy"* (SCP). For example, electric trucks should still be paired with transport optimization to avoid being wasteful of energy and reduce the number of trucks on the road. The electricity that is used to charge the electric trucks should also be low carbon. There are many trucks today that are driving empty because after trucks drop off the goods and return it back to its hub empty. That is not necessarily the case for Post Nord TPL as they combine multiple customers' orders in the same truck with similar routes to be more efficient (SCP).

There is a focus at Nestlé Global and for Volvo's customers as a general strategy to optimize transportation that results in emission reductions and cost savings (SLMN, EDV). For example, customers can use heavier longer trucks if they can have two trucks that can do the same work as three trucks or changing the shapes of packaging to be able to fit more pallets on each truck (SLMN, EDV). In Sweden, there is the European Modular system that allows 25-meter trucks instead of 19-meter trucks that reduces the number of trucks on the road and improves the energy efficiency (EDV). Longer and Heavier Vehicles (LHVs) are allowed in Sweden as an exemption from the Weights and Dimensions Directive of 1996 in the EU (Ratcliff, 2017). LHVs are maximum 25 meters long and are allowed a gross weight of 64 tons as of 2015. Increasing the load capacity per truck, it can potentially lead to an emissions reduction of up to 20%. Note however that there are safety concerns for LHVs regarding overtaking and infrastructure that is not designed to handle such large vehicles (Ratcliff, 2017). Nestlé Global and Sweden use transport efficiency in all their transportation including in the example in the above "Avoid Transport" section (CMN).

4.3.3 Shift to lower-carbon modes of transport

This pillar was the pillar of the ASI framework with the most options and where the most priority was placed in the discussions with participants.

Biofuels

Sweden is a large market for biofuels (e.g., HVO-100) due to a tax relief in the country and it is one of the most widely used renewable fuels (SCP). Fuel suppliers can offer 100% HVO or a high blended biofuel that provides the highest carbon reduction possible. With the best quality of biofuels, one can reach about 90% reduction well-to-wheel in CO_2e compared to diesel. Depending on the feedstock used for the biofuels, the well-to-wheel emissions can be worse than using diesel. A common feedstock for biofuels is palm oil which results in higher emissions from the land use change from palm oil production. A preferred feedstock in Sweden are residual oil and fats such as residual cooking oil from the food industry (SCP). Volvo suggests that biofuels are one of the three technology alternatives going forward and will complement biogas, battery electric, and fuel cell electric as these technologies become more widely available (EDV).

Biogas
Biogas in compressed or liquified form is another identified option and Volvo is positioning biogas as the complementary solution to battery electric as it is good for long haul transportation (EDV).

Battery Electric Trucks
A few years ago, the industry was talking more about fuel-cell electric but now the industry is focused on battery electric trucks as it has a higher overall energy efficiency (LMP). Battery electric trucks are set to develop quickly and is likely to become the primary option for local or regional distribution in the beginning of the technology uptake (SCP). Soon, battery-electric technology and infrastructure will be widely used for long haul transportation (SCP, EDV).

Fuel Cell Electric Powered by Hydrogen Trucks
Hydrogen and battery electric trucks are the only technologies on the market that can offer emission free or zero tail pipe transportation (SCP). There are doubts on whether hydrogen will be a viable solution because it requires over two times more energy to run hydrogen trucks compared to battery electric trucks. This makes battery electric trucks two and half times more energy efficient (SCP). Despite this, Volvo is investing heavily in fuel cell electric technology for heavy duty trucks and suggests it will become a viable option for emissions-free transportation (EDV).

Rail
Rail is presented as a lower emissions mode of transportation than heavy duty trucks. Nestlé Global follows a general rule of shifting transportation modes from road to rail when the route is longer than 700 to 800 km and where the infrastructure allows (SLMN). Nestlé Sweden and Post Nord TPL are currently working on a project in the Nordics to shift from road to rail and can provide significant emissions reductions (SCP).

4.4 Assessment of pathways based on current conditions and potentials

In this section, each identified transition pathway is assessed on the four conditions for pathways (maturity of options, integration with systems, industries, and infrastructures, societal acceptability, and political acceptability and delivery) and the two potentials for pathways (learning and branching points) from Turnheim & Nykvist's (2019) theoretical framework. For some pathways, there were discussions around the costs of the different technologies. To create more realistic recommendations, it was a logical step to include economic feasibility as a fifth condition to the theoretical framework. This condition was added to the framework by the author of this thesis. This section corresponds to the second research question: *How do the current conditions and potentials for fossil-free transportation transition pathways compare to each other in Sweden?*

A summary of the findings from the current conditions and potentials for realizing the transition pathways are shown in Table 5 and 6 below followed by a detailed description of each condition and potential for all transition pathways. The scoring criteria for this theory is color based and is an added indicator added to the framework by the author of this thesis. Green indicates that this condition is fulfilled. For example, the maturity of the transition pathway is commercially available in Sweden or the pathway socially acceptable. Yellow indicates that it fulfills the requirements to be green but comes with conditions. Red indicates that this condition is not fully developed or poses a higher risk of achieving social and political acceptability. There were no scoring criteria used for the potentials to realize transition pathways as most of these factors are prediction-based and anticipatory.

Transition Pathways	Maturity of options	Integration with systems, industries, and infrastructure	Societal (social and industrial) acceptability	Political acceptability and delivery	Economic acceptability*
Battery Electric Trucks	Over the next 5 years, technology for longer haul (>300 km) will be developed. For now, can be used for shorter, local routes. Should be complemented with other options for long haul. In growth phase in Sweden, expected to be fully ready in 2024/2025. But delivery times are +1 years, limited availability for short term. Volvo currently offers a complete line of EV trucks up to 300 km driving distance and 44 tons. Aims to reach 70% sales from EV trucks in Europe by 2030. Volvo is positioning EV trucks for local, regional transportation to be complemented with biogas for longer haul.	Non-electric trucks need to be used for 10 years for logistics companies to reach ROI. Lead times for trucks are long and risk that by the time truck is delivered, better technology will be on the market. Charging infrastructure costs are on the logistics companies and government and are currently not widely available. Electric road will be ready in Sweden in 2025/2026. There is concern whether local power grids will be able to support energy supply. Volvo has a department, Volvo Energy, working with local energy companies. Volvo and two competitors are working together to build 1700	No identified concerns with the social acceptability of electric freight transport in Sweden. Therefore, social acceptability is high.	Volvo and other truck suppliers are leading the transformation and lobbying for investment support in purchasing electric trucks and infrastructure. Many cities in Sweden allow electric trucks to drive in city zones in off-peak hours. EU has set targets to build recharging stations for electric trucks every 60 km on main roads by the end of 2030.	Capex for EV is 2-3x higher than diesel but has lower Opex. Predicted Capex to fall around 2027 as demand for diesel goes down. More business due to delivery in off-peak hours in cities and presents marketing opportunity for first movers. The Swedish Energy Agency offers a climate premium covering 20% of truck's purchase. Available until 2024.

		charging points in Europe including opportunity charging. Superchargers up to 1000 kW would enable electric trucks to drive from south to north of Sweden but require energy capacity equivalent to a small community. Charging infrastructure built for long, heavy duty trucks in high traffic areas ready by end of 2023.			
Biofuels	There is limited availability and a potential supply shortage from 2023 to 2027. It is a solution for reaching fossil-free transportation fast but is not a long-term solution. Can bridge the gap until electric and hydrogen technologies are ready. Existing diesel trucks can use biofuels. HVO-100 is the third most consumed fuel type in Sweden.	Biofuels present the main strategy to reach fossil-free by 2025 because existing diesel trucks can be used for biofuels. There is no need for investment into changing the vehicle themselves.	There is a negative public perception because oftentimes, but not always, the raw materials are agricultural goods that could be used for food production. This is not the case for biofuels used for Nestlé Sweden, as they use HVO100. Poses a reputational risk for Nestlé Sweden and Nestlé Global has made a statement against the use of biofuels despite it being a widely accepted pathway in Sweden.	The EU is prioritizing biofuels supply for aviation industry through the ReFuel EU regulation leaving limited supply for road transport. Tax exemption in Sweden is set to expire at the end of 2026. There are EU policies trying to avoid using fuel that competes with food production. Although this does not affect Sweden as they use HVO100.	The energy crisis caused diesel prices to increase in 2022 this year but biofuel prices went up even higher. A supply shortage is expected to occur between 2023 and 2027.

			The feedstock is the most important to consider since some biofuels use palm oil which is connected to deforestation. There are acceptable feedstocks in Sweden (e.g., HVO 100). Yellow as it is socially acceptable in Sweden because they use feedstock unrelated to indirect land use change but not in all other countries are in the same position due to the feedstocks they use.	The EU has set limits on the use of feedstock with high risk of causing indirect land use change (does not include HVO100).	
Biogas	Biogas is widely available, and Sweden is the highest consumer of biogas for the transport sector in the world. It is expected to be a long-term solution for fossil-free transport. Long term supply of food and organic waste from households to feed biogas production. Locally produced in Sweden, safe and positive for the climate. Volvo has a sales target of 30% from biogas and position liquified biogas for longer and	At least 2000 trucks in Sweden are currently using liquified biogas and around 96% of the biogas is being used by road transport companies in the country. Other countries in Europe are not in the same scenario as biogas is difficult to find. Biogas requires investment in new infrastructure.	Biogas has a positive reputation as it utilizes food and organic waste from households. The EU supports consumption of biogas and will require EU countries to collect organic waste separately by 2024 to provide high volumes of waste for biogas production. Biogas could be encouraging the	A 10-year tax relief in Sweden for biogas was just removed by the EU Court of Justice making the full tax rate makes the price nearly 20% more expensive. RePower EU has a target to increase EU's biogas production by 10x by 2030.	A 10-year tax relief in Sweden for biogas was just removed by the EU Court of Justice making the full tax rate nearly 20% more expensive. Biogas requires investment in new infrastructure.

	heavier transport to complement electric trucks. Nearly 70% of biogas produced in Sweden is used for road transportation and holds 96% of the market share for transportation fuel in the country.	Biogas trucks can travel up to 1000 km with +600 biogas stations across Europe. 67% of biogas is consumed by the freight transport sector in Sweden proving its maturity in the market. Volvo suggests that the ideal solution will be liquified biogas for many years to come and perhaps 15 years from now battery electric or fuel cell electric would be feasible. Already 212 public and 60 non-public biogas stations in Sweden and that number is growing. The power grid for biogas in Sweden relies mainly on off-grid small, regional grids or stand-alone plants and the gas pipeline infrastructure is primarily in the south-west of Sweden.	generation of more waste solely for biogas production.		
Fuel Cell Electric (Hydrogen) Trucks	Volvo and Daimler Trucks have created their own company, Cellcentric, dedicated to developing hydrogen-based fuel cells. These are expected to be	It is likely that the hydrogen trucks produced by Volvo will be put on the market in Sweden first therefore there are many resources invested in building	Main safety hazards are flammability of fuel and electric shocks. Truck companies deign vehicles with leak detection to mitigate this risk.	EU's Alternative Fuels Infrastructure regulation aims to have hydrogen refueling stations at least every 200 km on main roads	With global energy prices on the rise and hydrogen trucks demanding 2.5 times more energy than electric, it is questionable

	ready in the second half of the decade. Truck manufacturers including Volvo and Daimler are pushing for 300 hydrogen refueling stations by 2025 and 1000 by 2030 across Europe.	infrastructure for hydrogen prioritized in Sweden. If there are superchargers available, then in theory, travelling from the South to the North of Sweden would be no problem. However, as mentioned in the battery electric section, the national grids in Sweden need the capacity to support the energy demand that will come from increased use of fuel cell electric trucks. The first public hydrogen refueling station for heavy duty trucks is set to be ready at the Port of Gothenburg in Sweden at the end of 2023. Swedish company received grant to build 15 refueling stations by the end of 2023 to develop a Swedish network for hydrogen trucks in the Värmland region between Stockholm, Gothenburg, and Karlstad.	Hydrogen should be made using renewable energy and there is concern on the sustainability of hydrogen if it's made from fossil fuels.	by the end of 2030 across Europe. Hydrogen trucks would be eligible to drive in low emission zones in Sweden.	whether this is an affordable option. Volvo says it will be a challenge to create a good business case for hydrogen and it will remain expensive for some years. The cost of electrolyzers for hydrogen trucks expected to be cut in half by 2030.
Rail	Nestlé Global's strategy is to move from road to rail when the route is higher than 700 to 800 km and the rail infrastructure is available.	As of 2014, there were 10,881 km of railway lines in Sweden of which three quarters are electrified.	Risk of goods being refused due to unreliable timing of rail. However, there were no concerns of social acceptability if	Policies are projected to raise fuel prices through fuel taxes and other market-based instruments. This could push companies	Prediction of fuel prices doubling by 2040 pushing companies to switch from road freight transport to rail.

	The planned investments in Sweden into rail infrastructure are projected to reduce road transport by one quarter of a percent and by road transport is expected to increase by the same amount. Although this option is mature in Sweden, it is unlikely that it will become the dominant mode of transportation in Sweden.	Sweden's main challenges with rail are robustness, steepness of inclines limiting speed and capacity, and frequency of delays. Investments will be used to improve these challenges.	Nestlé Sweden were to use rail.	towards alternative modes such as rail.	Sweden is investing 80% of budget towards railway networks creating improved connections from the South to the North.
Transport efficiency	Is a core strategy of Nestlé Global and most transport companies. This option is readily available. Nestlé Sweden uses transport efficiency in their one of their shared warehouses with another large food company in Sweden. The other company have electric trucks that take the same route as Nestlé Sweden, and they can add pallets into this company's truck. This works because the company is not a direct competitor but another player in the food industry. This allows Nestlé Sweden to electric without needing to own or lease an electric truck.	Volvo was involved in a project called Transformers where they were building trucks that could adapt to the size of the cargo being transported to make the trip more energy efficient.	This is already a common business practice for transportation companies.	European Modular system that allows 25-meter trucks instead of 19-meter trucks that reduces the number of trucks on the road and improves the energy efficiency which can lead to a 20% reduction in emissions.	This is a cost saving measure as well as energy efficient.

Table 5: Findings for current conditions for transition pathways

	Learning – Increase feasibility	**Learning- Decrease feasibility**	**Branching points – increase feasibility (convergence)**	**Branching Points – decrease feasibility (divergence)**
Battery Electric Trucks	Volvo has a dedicated department to working on local energy companies. As there is increased learning, more infrastructure will be available that can meet the future energy demands. Charging infrastructure such as electric road systems will enable electric trucks for long haul transportation. Increased learning in companies in Volvo and Scania, the two largest truck manufacturers in Sweden, will speed up the technological learning and improve the feasibility of electric trucks. This will be through product optimization and improvements to the charging speed leading to a higher uptake in the market and lower the prices in the market.	Swedish transport companies may sell their diesel truck fleet to other countries after 10 years of use. They are still fit for use for many years. A learning curve and capacity building in those countries could mean they start creating more stringent decarbonization goals that decreases the feasibility of this option for Swedish logistics companies.	Predicted Capex to fall around 2027 as demand for diesel goes down and EV reach economies of scale. Logistics companies may sell their existing diesel truck fleet to countries that have lower ambitions for decarbonization. As more cities allow electric trucks during off peak hours, it improves the business case for companies to switch to electric trucks.	Logistics companies that cannot resell their diesel fleet will not be able to purchase electric trucks as they have existing assets that need to be used for a total of 10 years. Lead times for electric trucks in Sweden are 1-2 years. Long wait times could decrease feasibility.

Biofuels	This technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis.	If there is a shift in views in Sweden for biofuels and society starts to push back against the use of biofuels this could raise the risk of back lash from the public in Sweden for using biofuels.	Existing trucks fleets at transportation companies can be refueled if companies decide to switch to biofuels which increases the feasibility. Swedish tax exemption that was extended until the end of December 2026 was another branching point that increased feasibility until 2026. The Swedish Democrats are pushing for cuts in the biofuel quota in Sweden to the lowest EU level. This would make it more difficult for Sweden to reach its emissions reduction targets and potentially increase the price. However, it could free up supply of biofuels from private road transportation to freight transport.	Low supply or having the EU prioritize the limited supply to the aviation industry decreases the feasibility of this as a long-term solution.
Biogas	This technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis. That said, new policies that come into place in Sweden could provide support for investment into biogas infrastructure and increased production.	If the biogas tax exemption in Sweden is approved in the future and other countries appeal the decision again then it could decrease the feasibility of the option again.	If Sweden's appeal to the EU Court of Justice is accepted, the reinstatement could lower the cost of biogas again.	The higher price for biogas in Sweden may deter companies from choosing it as an option and from moving quickly on decarbonization.
Fuel Cell Electric	As truck manufacturers improve their learning and innovation, the safety hazards for hydrogen trucks	If electricity grids in Sweden are not able to supply the electricity	If the government and companies in Sweden continue to invest in building charging infrastructure,	If energy prices remain so high, then it will be unaffordable to power hydrogen trucks and electric

(Hydrogen) Trucks	will be resolved and there will be greater social acceptability.	required to support hydrogen trucks, this will decrease feasibility.	this will increase the feasibility of hydrogen trucks. The EU's commitment to building a hydrogen refueling station every 200 km by the end of 2030 in Europe.	trucks will remain the most viable electric solution. It takes 2.5x more energy to produce hydrogen. If energy prices remain high companies may not be able to afford the amount of electricity required to charge hydrogen trucks.
Rail	This technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis.	This technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis.	If customers become flexible with delivery times when the transportation mode is rail, then it opens the possibility for more rail deliveries.	If there continues to be delays and suboptimal infrastructure for rail, it will decrease the feasibility of it becoming a viable alternative to road transport.

Table 6: Findings for current potentials to realize transition pathways

4.4.1 Pathway 1: Battery Electric Trucks

Conditions

Economic feasibility

Currently, it costs around two to three times more for a battery electric truck than for a diesel truck. Most of the additional cost lies in the initial cost of the truck (LMP). It costs around 22 million SEK for a battery electric truck and around half the price for a diesel truck (SCP). However, the fuel cost for battery electric trucks is much less therefore if Post Nord TPL can add in two shifts in a day, then the cost of the electric truck ends up being less than a diesel truck (LMP). The price for a battery electric truck is expected to decrease quite rapidly as the demand for diesel trucks decrease and the demand for battery electric trucks increase, "predictably by 2027 or so" (SCP, EDV). The difference in supply and demand will cause the capital expenditure (Capex) of the electric trucks to go down and the lower operating expenses (Opex) will remain lower for the electric versus diesel trucks (SCP). Once the volumes increase and electric trucks achieve economy of scale and at the same time the sales volumes for diesel trucks decrease then diesel trucks are expected to increase which would further decrease the volumes (EDV). To help alleviate the burden of high costs for switching to electric, The Swedish Energy Agency is distributing a climate premium to companies, municipalities and regions that purchase a heavy-duty truck over 3.5 tonnes that are powered by biogas, battery electric, or fuel cell electric (The Energy Agency, 2023). This climate premium will cover 20% of the truck's purchase and the support is available until 2024 to motivate the market to transition towards electric trucks and increase production volumes to further drive the costs down (The Energy Agency, 2023). Furthermore, electric trucks present the opportunity to make higher profits through more deliveries and through keeping business from positioning as a sustainable brand (EDV). If transportation companies cannot offer electric options, they may lose customers. Furthermore, electric trucks may be allowed to drive in cities during off-peak hours due to lower noise and emissions in the future. If a company can deliver during off-peak hours, then they can get more deliveries done during rush hour. It is important to consider maximizing the use of the truck to reduce the total cost and accelerate the payback period. As a first mover in the industry, using electric trucks presents a marketing opportunity and can be positive for the brand (EDV).

Gaining access to charging infrastructure can also be costly (LMP). The cost of charging infrastructure for freight transportation tends to fall on the transportation companies because their distribution centers are not easily accessible by the public. Governments tend to subsidize charging infrastructure that are in easily accessible areas for the public such as highways. Otherwise, they would only be providing subsidies for perhaps two transportation companies. This is where partnerships between neighboring companies should be explored to share the costs for charging infrastructure (LMP).

Maturity of options

Battery electric vehicles are starting to be grow in the Swedish market but are expected to be fully ready between 2024 to 2025 therefore it is not the primary way to reach fossil-free by 2025 (SCP). The reason is because the 2025 goal is only two years away and even if Nestlé Sweden asked its Post Nord TPL today to buy 30 electric trucks, they would only be delivered by 2024 or even 2025 due to delays in delivery time. This is why, for now, biofuels and biogas – even if they are most expensive due to changes in tax reliefs and subsidies – are the best option to reach fossil-free by 2025 for the moment (SCP). It is important to note that Post Nord TPL has confirmed that they can search for a freight company that offers transportation in electric trucks

(LMP). SCP's point is relevant for freight companies that do not already have a fleet of electric trucks but for Nestlé Sweden they have the flexibility to choose any transport company that can provide them with the fossil-free transportation they need.

Post Nord TPL stated that it would be relatively easy to convert from diesel to electric trucks once they are purchased because they are routes that they drive every single day but with a different truck (LMP). They already own a new battery electric refrigerated truck in Sweden that can run up to 200 kilometers which is almost a whole day of transport. They expect that in around five years there will be newer battery electric trucks that will be able to travel longer distances but that still won't be enough to deliver up to the Northern parts of Sweden. This means that battery electric trucks are good for shorter distances and are part of the solution but are by no means the total solution and should be complemented by other technologies for longer distances. Post Nord TPL attended a workshop with Volvo and Scania to understand the decarbonisation of the Swedish transportation market. They advised to not wait for hydrogen and battery electric is going to be very big so companies will lose out if they wait for hydrogen (LMP).

Volvo offers five different electric truck models covering around half of the freight transport market in Europe (EDV). They offer trucks that can drive up to 300 kilometers and the heaviest truck allows 44 tons. Volvo has the ambition to offer trucks that can handle even heavier loads. In terms of 'maturity of options', they have a complete offer of electric trucks ready today and they are one of the few truck manufacturers that can say that. Volvo is trying to position the electric trucks for the local and regional transportation as a complement to liquified biogas for longer and heavier transports where battery electric is not feasible today. Volvo has a sales target of 70% electric trucks in Sweden and Europe 50% electric trucks in the rest of world 50% by 2030. That would mean they would be selling more electric trucks than diesel trucks and the growth will increase in the second half of the decade. Volvo says that once their customers have converted to electric, they have not wanted to go back to diesel trucks (EDV).

Political feasibility

Volvo supplies most of the Swedish freight truck market and more than half of the European market and are leading the decarbonization transformation (EDV). They have heard from politicians and public authorities that companies are a step ahead of policies and legislation. Volvo is lobbying with the Swedish Government to ensure there is investment support for companies wanting to buy electric trucks and for charging infrastructure. Furthermore, there are political advantages to driving electric trucks because in many European cities including in Sweden there are specific times during the day that trucks are not allowed to drive in cities due to congestion, noise pollution or safety issues. Sweden has created a regulatory framework for low emission zones in eight cities: Gothenburg, Helsingborg, Lund, Malmo, Mölndal, Stockholm, Umea, and Uppsala affecting lorries and buses (Urban Access Regulations Europe, 2022). For example, Stockholm bans all heavy trucks during 10 pm and 6 am and Scania tested the transport efficiency of deliveries with low to zero emissions trucks in off peak hours (Scania, 2020). The experiment resulted in 30% faster deliveries than daytime transportation. They also result in lower emissions because there is less queuing and easier parking. The experiment used trucks that were fueled using biofuels that can provide a 90% reduction in emissions compared to diesel (Scania, 2020). This will provide electric trucks a competitive advantage as more cities implement policies that allow emission-free trucks to drive during off peak hours. If companies have electric trucks, it will allow access to city zones early in the morning or late in the evening and allows companies to do more business in a shorter amount of time. It also can help speed up the payback period if the Capex of the truck was high (EDV).

In terms of incentives for charging infrastructure, the EU has created the alternative fuels infrastructure regulation as a part of their Fit for 55 packages (European Council, 2023). The regulation sets clear targets for building recharging points and alternative fuel refueling points across the EU. The target is to have a recharging station for battery electric heavy-duty trucks every 60 km on main roads, hydrogen refueling stations and biogas refueling points at least every 200 km on main roads by the end of 2030 (European Council, 2023).

Social acceptability
There were no identified concerns with the social acceptability of electric freight transport in Sweden. However, a study exploring the drivers and barriers to implementing electric freight transport in Sweden identified branding opportunities and customer demands as drivers for businesses to use electric trucks (Melander et al., 2022). Companies can use it as a marketing tool as it is customers and policy are demanding fossil-free transport and brands that are first movers can position themselves as sustainable compared to competitors (Melander et al., 2022).

Integration with systems, industries, and infrastructure
Many companies are ordering electric trucks, however, for the shelf life of non-electric trucks is ten years to get a return on investment (LMP). There are more than one year lead times for electric trucks. This creates a risk that once the new truck is delivered, a newer model is already available on the market that can go longer distances or carry heavier loads. There is a risk of always being behind on technology (LMP). However, there are also other challenges in northern Sweden such as the cold weather that could impact feasibility of these solutions.

The limiting factor to battery electric trucks is the availability of charging infrastructure (EDV). Companies that want to have their own charging infrastructure, such as Post Nord TPL, will need to have a local power grid that can support the energy supply. There is a need for more charging infrastructure, but it is usually a question of cost and who covers it (LMP). For example, for a transport companies like Post Nord, they would need to cover the cost since it would not be accessible to the public (LMP). Volvo has teams dedicated to working with local energy companies to support companies that aim to have their charging infrastructure (EDV). Volvo is working with municipal and national governments in Sweden to communicate how they wish to grow so they know what is necessary to build into the local power grids. It's very important that the national grids in Sweden have the capacity to support the energy demand that will come from increased use of battery electric trucks. It is not possible to know exactly what year the infrastructure will be ready, but Volvo has the ambition to make sure that the infrastructure is available as the market share of electric trucks grows. They have a dedicated business area called Volvo Energy with the primary task of supporting infrastructure both for battery electric and fuel cell hydrogen trucks. They are also working with two competitors to build 1700 charging points in Europe (EDV).

Sweden's infrastructure will be ready to support battery electric trucks faster than hydrogen with the help of electric road systems and other forms of charging (SCP). Charging infrastructure will change to be 'opportunity charging' which can be done at distribution centers during loading or unloading or on electric roads along the main transport corridors in Sweden (EDV). In the proposal for investment in infrastructure for road and rail in Sweden, they state that the first electric road will be operationally ready around the first quarter of 2026 (Trafikverket, 2022). This will help allow electric trucks travel longer distances. Sweden's first electric road is being built between Hallsberg and Örebro which is in the heart of logistics traffic in Sweden between three major cities: Stockholm, Gothenburg, and Malmo (Trafikverket, 2021). Many companies use this route for their transportation. This project is a pilot to understand the benefits and feasibility of electric roads for contributing to fossil-free transportation (Trafikverket, 2021).

An identified challenge in Sweden is that the charging infrastructure for heavy duty trucks is limited and passenger car charging stations are not prepared to host these types of vehicles making a larger truck-specific charging station network is needed (Broback, 2021). There are existing public charging stations for electric heavy-duty trucks and plans to open more across the country (Broback, 2021). To respond to this challenge, Kempower is a company that provides fast charging technology for heavy duty trucks in Sweden (Kempower, 2022). They work with Nimbnet, a charging station operator and Virta a company providing a platform for electric vehicle charging are working together to build a network of refuel stations for heavy duty electric trucks in Sweden. The charging infrastructure project will incentivize logistics companies to switch their nearly 85.000 heavy duty trucks to electric. The Sweden Energy Agency has provided a grant for the first charging stations for heavy duty trucks that will be built in Gothenburg, Söderdamn, Sundsvall, and Nordmaling and will be ready by the end of 2023. The charging stations will be designed to accommodate long, heavy duty trucks. These chargers will be able to provide 350 kW of power and with the help of Nimbnet's booking system, drivers will be able to plan their delivery routes around the booked time slot for charging to reduce wait times (Kempower, 2022). Superchargers are needed to charge trucks quickly but require a lot of energy from the electricity grid (EDV). The issue with superchargers is that they will require capacity that may be equivalent to a smaller community and the higher power you want to have the higher the cost will be. The normal power of chargers are 250 kilowatts (kW) and going forward they will be 350 kW, 507 kW and then up to 1000 kW for the superchargers. When speaking about charging multiple trucks at a time, that is a lot of power needed in one place which may cause a capacity issue with the local power grids. If internal battery capacity is improved and superchargers are more widely available, then it should be possible to drive from the South to the North of Sweden without any issues (EDV).

Potentials

Branching Points: increase feasibility

Logistics companies may decide to sell their diesel trucks to countries where their decarbonization ambitions are not as high to fund the purchase of new electric trucks (LMP). This has obvious negative spillover effects but could potentially increase the feasibility of decarbonization in Sweden. Charging infrastructure such as electric road systems in Sweden could increase feasibility and improve the business case for electric trucks. It would make it possible to drive longer distances and convert from biogas and biofuels to electric (LMP, SCP). If more cities create policies for banning diesel trucks during off peak hours, this creates an incentive for choosing electric trucks and will improve the delivery efficiency for electrified businesses (EDV). If the demand increases for battery electric trucks and decreases for diesel trucks that increases the economic feasibility of purchasing electric trucks fleets (SCP).

Branching Points: decrease feasibility

Freight transportation companies with new diesel trucks need to use them for another ten years to ensure they get the most out of the asset and get a return on their investment. Therefore, if transportation companies have recently bought new diesel assets and have no resale market, the feasibility of transitioning to a emissions-free fleet will be low (LMP). That said, it is likely that freight companies have a fleet of trucks of different points of maturity (some new, some old). Another potential branching point are lead times for electric trucks in Sweden (SCP). Lead times are multiple years and as demand for electric trucks continues to rise, the long wait times could decrease the feasibility of reaching fossil-free goals and decarbonizing on time (SCP).

Learning: increase feasibility
Increased learning and innovation in Sweden's two largest truck manufacturers, Volvo and Scania, will speed up the technological learning and improve the feasibility of electric trucks (LMP). Through product optimization and improvements to charging speeds could lead to a higher uptake in the market and decrease market prices for electric trucks (LMP).

The Volvo Group has created teams that are dedicated to supporting local energy companies in developing charging infrastructure that will meet future demands (EDV). Volvo is working with municipal and national governments in Sweden to communicate how they wish to grow so they know what is necessary to build into the local power grids. It's very important that the national grids in Sweden have the capacity to support future energy demand from increased use of battery electric trucks. It currently not possible to know exactly what year the infrastructure will be ready, but Volvo has the ambition to make sure that the infrastructure is available as the market share grows for electric trucks. They have a dedicated business area called Volvo Energy with the primary task of supporting infrastructure both for battery electric and fuel cell hydrogen trucks (EDV).

Learning: decrease feasibility
Logistics companies may start selling their diesel truck fleets to countries that have less ambitious decarbonization goals to purchase more electric trucks (LMP). If those countries do not accept this, that decreases the feasibility of this option for Swedish logistics companies (LMP).

4.4.2. Pathway 2: Biofuels

Conditions

Economic feasibility
The supply issue for biofuels depends on the availability of certain feedstock used for the biofuel (International Energy Agency, 2022). A supply shortage is expected to occur between 2023 to 2027 with a 56% increase in demand for "acceptable feedstock" (waste and residue oils and fats). Biofuel from waste and residues are accepted in the EU according to their feedstock policy objectives. The United States, Europe, Brazil, and Indonesia are the main drivers for the increased demand, but Europe's consumption of biofuels will have the highest increase in demand. Based on the projected consumption of biofuels, an increase three times current rates are needed to meet the demand and climate targets of these countries (International Energy Agency, 2022). The diesel prices increased significantly in 2022 but the prices for biofuels in Sweden increased even more and if more Swedish transportation companies decide to switch to biofuels, the supply will be lower causing the price to be even higher (LMP).

Maturity of options
Biofuels are a widely considered solution to reach fossil-free transportation fast, but it is not recommended as a long-term solution (LMP). That said, biofuels will likely continue to be the main solution in Sweden until electric and hydrogen trucks are ready (SCP). Even if biofuel prices have increased it is still a viable solution for reaching fossil-free transportation (SCP). It is an attractive option because it is compatible with existing diesel trucks so there is no need to purchase new trucks for biofuels (EDV). According to CEIC Data (2023), the most widely used types of biofuels in Sweden are FAME and HVO-100 which is made from hydrogenated vegetable oils. In 2016, HVO-100 accounted for 2.7% of the fuel market for road transportation making it the third most consumed fuel type in Sweden (Sherrard, 2017). This validates the maturity of the biofuels in the Sweden fuel market.

Political feasibility

The looming supply shortage with biofuels with acceptable feedstocks such as HVO-100 in Sweden has become a political concern in the EU (LMP). The EU is responding by prioritizing biofuels supplies for the aviation industry because it is one of the harder transportation sectors to decarbonize. ReFuelEU is a fuel regulation for the aviation industry in the EU obliging jet fuel suppliers to drop-in 2% of biofuels with acceptable feed stock by 2025 and 5% by 2030 into the diesel used for airplanes. The regulation does not include crop-based biofuels (Transport & Environment, n.d.). This will leave limited supply left over for road transport (LMP). Fortunately, the Swedish tax exemption for biofuels was extended until the end of December 2026 which will help maintain its affordability until other renewable fuels are ready (Sherrard, 2022). Biofuels in Sweden are not recommended to be used alone as a long-term solution due to supply issues, political priority of biofuels for the aviation industry, and that the tax exemption is set to expire at the end of 2026 (SCP, EDV). That said, it will be a complementary solution to biogas and electric trucks likely up to 2030. The EU has set sustainability criteria for biofuels to avoid indirect land use change from the increased demand for feedstock for biofuels (European Commission, n.d.a). There is a limit on the use of feedstock with high risk of causing indirect land use change. Sweden therefore has a limit to how much it can count certain biofuels towards its overall renewable fuel targets. Countries would still be able to import the high-risk biofuels but would not be able to count them towards their national targets. An example of a high-risk biofuel is those that use palm oil as the main feedstock (European Commission, n.d.a). That said, Volvo does still support the use of high-blended, sustainable biofuels as a short-term solution (EDV). Nestlé Sweden currently only used HVO100 as their biofuel therefore is politically acceptable renewable fuel.

Social acceptability

Aside from the issue of limited availability, it is important to focus on which feedstock is going in the biofuel (EDV). Palm oil as a feedstock is an ethical issue as its connected to deforestation. For example, in Germany, palm oil as a feedstock for biofuels is not an accepted feedstock. Biofuels have a negative perception because the raw materials are agricultural goods that could be used for food production (EDV, LMN). With Nestlé Global being a food company, this poses a risk of receiving negative backlash from the public. Nestlé Global has made a statement against the use of biofuels as to not use agricultural land that could be used for food production. In Sweden, the use of biofuels is a very commonly used pathway and is widely used and accepted. They had many internal discussions on this topic and found that it is socially acceptable in Sweden and by competitors in the market. They made the argument to the Global office that although that might be the global strategy, from the local perspective, it is an acceptable option and there is a low risk of receiving negative media attention. They have chosen to not advertise their use of biofuels and is an important pathway to reaching fossil-free transportation (LMN). Therefore, biofuels, namely HVO100, are socially acceptable in the Swedish context.

System integration and infrastructure requirements

Biofuels are one of the main strategies to reach fossil-free transportation by 2025 because existing diesel trucks can be refueled with biofuels. There is no investment change in the vehicles themselves (LMP). This means that the switch to biofuels can be done today if there is access to biofuels and use an acceptable feedstock (EDV).

Potentials

Branching Points: increase feasibility

Existing trucks fleets at transportation companies can be refueled if companies decide to switch to biofuels which increases the feasibility. Furthermore, the Swedish tax exemption that was extended until the end of December 2026 was another branching point that increased feasibility until 2026 (Sherrard, 2022).

Branching Points: decrease feasibility
With the new ReFuel EU regulation in the aviation industry, there will be an even lower supply of biofuels available in the EU which leaves limited supply for road transport (LMP). This low supply decreases the feasibility of biofuels as a long-term solution. The uncertainty of whether the tax exemption will be renewed after 2026 decreases the feasibility of biofuels as a renewable fuel. Additionally, The Swedish Democrats are pushing for cuts in the biofuel quota in Sweden to the lowest EU level instead of the previous quota of nearly half biofuels blended into petrol and diesel (The Local Sweden, 2023). The decision is intended to lower the cost of fuel, but it would make it more difficult for Sweden to reach its emissions reduction targets. If this decision is accepted, it could free up supply of biofuels from private road transportation to freight transport.

Learning: increase feasibility
The technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis.

Learning: decrease feasibility
If there is a shift in views in Sweden for biofuels and society starts to push back against the use of biofuels this could raise the risk of backlash from the public in Sweden for using biofuels.

4.4.3 Pathway 3: Biogas

Conditions

Economic feasibility
A 10-year tax relief for biogas in Sweden was just removed (Bioenergi, 2023). Since the tax relief in Sweden was removed, the price for biogas has risen by 20% (W)._For a transportation company with 150 biogas trucks this increase could lead to an additional SEK 30 million per year (Bioenergi, 2023). This creates uncertainty for the future of biogas as a viable solution for decarbonization (Bioenergi, 2023). The sustainability consultant from Post Nord TPL suggested that Sweden will reapply for the tax relief, and this is likely to be approved. They described this scenario as a "*bump in the road"* however this is not confounded in concrete evidence and biogas remains at a higher price than before (W).

Maturity of options
Sweden is the highest consumer of biogas for the transport sector in the world (European Biogas Association, 2023). Biogas is widely available in Sweden and is expected to continue to be a viable option for reaching fossil-free transportation in the long term (SCP). There is expected to be a continuous supply of food and organic waste from households in the long term and there is a need to treat that waste. Biogas converts waste into energy in the form of biogas. It is locally produced in Sweden, safe, and positive for the climate (SCP).

Volvo is a strong believer in compressed and liquified biogas as a solution for reaching fossil-free transport (EDV). Biogas powered trucks can travel up to 1000 km and there are over 600 biogas stations across Europe making it a good option for long haul transportation (Mårtensson, 2023). As a result, they have set sales target for reaching 30% of their sales from liquified biogas by 2030. They are then aiming to position electric trucks for local and regional transportation and liquified biogas for longer and heavier transport where the battery electric trucks are not feasible yet. In Sweden, biogas makes up around 21% of the total energy consumption with the rest being fossil-based fuels (Klackenberg, 2019). Most of the biogas (67%) is used for the freight transport sector and the market is quite developed in Sweden (Klackenberg, 2019). Other countries in Europe are not in the same scenario as biogas is difficult to find, making natural gas the most available gas in those countries. Since Volvo has a goal of reaching 70% of their sales from electric vehicles and 30% from biogas by 2030, then it will most likely steer the Swedish market in the same direction. Volvo is one of the largest truck manufacturers in Sweden, so they are setting the direction for the market. Volvo suggests that the ideal solution will be liquified biogas for many years to come and perhaps 15 years from now battery electric or fuel cell electric would be feasible for long transportation (EDV).

Political feasibility

With the 10-year tax relief in Sweden for biogas, the market was historically quite stable with a lot of investment into new biogas plants and vehicles (SCP). There were complaints about the tax relief in Sweden from other European countries stating it goes against fair competition. The case was taken to the EU Court of Justice and now the tax relief is removed so now there is full tax on biofuels. The removal of the tax relief makes the price nearly 20% more expensive. Such a quick change in the market has caused instability and the price to go up significantly for biofuels (SCP). Despite this, the RePower EU plan has set a target increase the EU's biogas production ten times by 2030 (Volvo Trucks, 2023).

Social acceptability

Biogas has a positive reputation as it makes energy out of food and organic waste from households (SCP). Biogas is made from food waste and animal manure and captures the methane emissions and turns it into renewable fuel for transportation (Juliani, 2020). The benefit is that biogas makes use of waste, prevents nitrogen runoff into water resources, and captures methane gas that would otherwise be emitted into our atmosphere. Although it provides many benefits, biogas could be encouraging the generation of more waste solely for biogas production (Juliani, 2020). There is open support from the EU for the use of biogas as a means of reaching net-zero targets (European Commission, n.d.b). It is preferred over biofuels as it uses waste and residues instead of food and feed feedstocks. This means biogas does not lead to land use change and turns waste into energy. Under the RePowerEU Plan, EU countries will be required to collect organic waste separately by 2024 to provide higher volumes for biogas production and a revenue stream for farmers and foresters (European Commission, n.d.b).

System integration and infrastructure requirements

As mentioned in the maturity of options section, in Sweden, biogas makes up around 21% of the total national energy consumption with the rest being fossil-based fuels (Klackenberg, 2019). Most of the biogas (67%) is used for the freight transport sector and the market is quite developed in Sweden. Other countries in Europe are not in the same scenario as biogas is difficult to find, making natural gas the most available gas in those countries. The power grid for biogas in Sweden relies mainly on off-grid small, regional grids or stand-alone plants and the gas pipeline infrastructure is primarily in the south-west of Sweden. Although there is a regional gas pipeline network in Stockholm, there is limited infrastructure in the north of Sweden. There are around 212 public and 60 non-public biogas stations in Sweden. That said, the number of gas filling stations and heavy-duty trucks that run on biogas is increasing quickly (Klackenberg, 2019).

Potentials

Branching Points: increase feasibility

Sweden has sent an appeal on the decision to remove the tax relief on biogas and if the EU

Court of Justice decides to reinstate the tax relief it would lower the cost for fuel and increase its feasibility as a long-term solution for decarbonization (SCP).

Branching Points: decrease feasibility
With the removal of the 10-year tax relief, the higher price for biogas may deter companies from choosing this as a viable option for decarbonization reducing the feasibility of it as an option (SCP). If the price is too high, it removes biogas as a viable option for fossil-free transportation.

Learning: increase feasibility
The technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis. That said, new policies that come into place in Sweden could provide support for investment into biogas infrastructure and increased production.

Learning: decrease feasibility
If the biogas tax exemption in Sweden is approved in the future and other countries appeal the decision again then it could decrease the feasibility of the option again.

4.4.4 Pathway 4: Hydrogen Trucks

Conditions

Economic feasibility
Hydrogen trucks requires 2.5 times more energy to power than a battery electric truck (SCP). Therefore, it is questionable, with global energy prices on the rise, whether it will be an affordable option anytime soon. It may be feasible to use hydrogen in other transportation sectors but perhaps not for the transport sector initially (SCP). Having said that, Fossil Fritt Sverige identifies hydrogen plays an important role in reaching fossil-free transportation. The cost of electrolysers used for hydrogen trucks is expected to be cut in half by 2030 (Fossil-free Sweden, 2021). This highlights the challenge to create a good business case for hydrogen now because it is and will remain expensive for some years (EDV).

Maturity of options
Volvo and Daimler have created their own company, Cellcentric, where they develop and produce hydrogen-based fuel cells for use in hydrogen trucks (EDV). They expect to have these trucks ready on the market in the second half of the decade (EDV). Truck manufacturers including Volvo and Daimler are pushing for 300 hydrogen refueling stations by 2025 and 1000 by 2030 across Europe (Volvo, 2021). The higher cost of hydrogen should be supported by policy frameworks to make sure the pathway remains affordable (Volvo, 2021).

Political feasibility
Same as for battery electric trucks, the EU has created the alternative fuels infrastructure regulation as a part of their Fit for 55 package (European Council, 2023). The plan has a target to have recharging stations to have hydrogen refueling stations and biogas refueling points at least every 200 km on main roads by the end of 2030 (European Council, 2023). Hydrogen trucks would also be able to benefit from access to low emission zones in Sweden. Deliveries in off-peak hours are more time and cost efficient (Urban Access Regulations Europe, 2022).

Social acceptability
The challenge for hydrogen is to make it efficient as possible but also secure the safety demands

(EDV). The main safety hazards with hydrogen vehicles are the risk of electrical shock and the flammability of the fuel (The Minnesota Department of Public Safety, n.d.). Hydrogen vehicles need a much higher voltage to power electric motors. The standard voltage in the automobile industry is 42V, 50V can stop a human heart and yet some fuel cell motors run on voltages that are 350V. Electric shocks would pose a great risk to human health (The Minnesota Department of Public Safety, n.d.). Hydrogen requires less energy to ignite when it meets air or oxygen compared to other fuels making it more flammable (FuelCellsWorks, 2022). Truck companies ensure that hydrogen tanks in the vehicle are designed with leak detection and strong enough material to mitigate this risk. In contrast, hydrogen dissipates in a leak quickly as its lighter than air so there is a smaller time window for ignition than with fossil fuels (FuelCellsWorks, 2022).

System integration and infrastructure requirements
It is likely that the hydrogen trucks produced from Volvo will be put on the market in Sweden first. Therefore, there are many resources invested in building infrastructure for hydrogen in Sweden (EDV). The first public hydrogen refueling station for heavy duty trucks is set to be ready at the Port of Gothenburg in Sweden at the end of 2023 (Heavy Duty Trucking, 2022). A company in Sweden named Everfuel was granted a SEK 45 million grant from the Swedish Environmental Protection Agency to fund two hydrogen refuel stations for heavy duty trucks in Sweden (Nordic Hydrogen Corridor, 2022). This is part of a plan to build 15 refueling stations by the end of 2023 to develop a Swedish network for hydrogen trucks. The stations will be in the Värmland region between Stockholm, Gothenburg, and Karlstad (Nordic Hydrogen Corridor, 2022). If there are superchargers available, then in theory, travelling from the South to the North of Sweden would be no problem. However, as mentioned in the battery electric section, the national grids in Sweden need the capacity to support the energy demand that will come from increased use of fuel cell electric trucks (EDV).

Potentials

Branching Points: increase feasibility
If the government and companies in Sweden continue to invest in building charging infrastructure, this will increase the feasibility of hydrogen trucks. The EU's commitment to building a hydrogen refueling station every 200 km by the end of 2030 in Europe will also increase feasibility.

Branching Points: decrease feasibility
If energy prices remain so high then it will be unaffordable to power hydrogen trucks and electric trucks will remain the most viable electric solution (SCP). It takes two and half times more energy to produce hydrogen. If energy prices remain high companies may not be able to afford the amount of electricity required to charge hydrogen trucks (SCP).

Learning: increase feasibility
As truck manufacturers improve their learning and innovation, the safety hazards for hydrogen trucks will be resolved and there will be greater social acceptability.

Learning: decrease feasibility
If electricity grids in Sweden are not able to supply the electricity required to support hydrogen trucks, this will decrease feasibility.

4.4.5 Pathway 5: Rail

Conditions

Economic feasibility

The Swedish Transport has forecasts that fuel prices will double by 2040 due to fuel taxes and emission reduction obligations (Trafikverket, 2022). This will likely transfer road traffic to rail traffic, increasing the market share for rail freight transport. In Sweden, more than 80% of the investments in road and rail infrastructure are made towards the railway network. The investments will be made in four main transport corridors that span from the South to the North of Sweden. The conditions of the lines are projected to ameliorate to reduce the risk of disruptions and delays (Trafikverket, 2022).

Maturity of options

Nestlé Global has a strategy to move from road to rail when the route is higher than 700 to 800 km and the rail infrastructure is available (SLMN). In the proposal for the Swedish National Plan for transport infrastructure for 2022 to 2023, there is information regarding investments in rail freight infrastructure (Trafikverket, 2022). The proposal focuses on the maintenance and investment plans for road and rail infrastructure in Sweden. Sweden's transport sector has the goal of reducing emissions by 70% compared to 2010 by 2030 and nearly all the emissions come from road traffic. Rail poses a viable solution to reducing the number of vehicles on the road to contribute to emissions reductions. The planned investments in Sweden into rail infrastructure are projected to reduce road transport by one quarter of a percent and by road transport is expected to increase by the same amount. Even a larger uptake of rail freight transport will lead to an insignificant reduction in road transport because there will be less substitution of road and rail. It is more likely that there will be new rail traffic rather than a transfer from road (Trafikverket, 2022). Although this option is mature in Sweden, it is unlikely that it will become the dominant mode of transportation in Sweden.

Political feasibility

The Swedish Transport has forecasts that fuel prices doubling by 2040 due to fuel taxes and emission reduction obligations (Trafikverket, 2022). There will be less road traffic and more rail traffic increasing the market share for rail freight transport making investments more profitable (Trafikverket, 2022).

Social acceptability

Rail is a method of fossil-free transportation, but it comes with the risk of more delays and missing delivery timeslots with customers (W). In Nestlé Sweden's pilot test for switching from road to rail they faced several issues with delays and being late for their delivery times with customers. Although they did not receive complaints from customers, there is a risk of goods being refused due to unreliable timing of rail (W).

System integration and infrastructure requirements

As of 2014, there were 10,881 km of railway lines in Sweden of which three quarters are electrified (European Parliament, 2017). The main challenges of the Swedish railway infrastructure are robustness and frequency of delays, especially in severe weather conditions. Sweden has the highest number of competitors in rail freight in the EU. Sweden is home to a core railway network that has links from east to west and north to south of the country. The links contribute to a wider network that connects the Nordics to Russia. Part of this rail network faces challenges due to steep inclines limiting the speed and weight of the cargo and insufficient carrying capacity. The investments from the Swedish National Plan aim to improve on these challenges (European Parliament, 2017).

Potentials

Branching Points: increase feasibility
If customers become flexible with delivery times when the transportation mode is rail then it opens the possibility for more rail deliveries (W).

Branching Points: decrease feasibility
If there continues to be delays and suboptimal infrastructure for rail, it will decrease the feasibility of it becoming a viable alternative to road transport.

Learning: increase feasibility and decrease feasibility
The technology is mature and has limited learning left and therefore was left out of scope for this part of the analysis.

4.4.6 Pathway 6: Transport Efficiency

Conditions

Economic feasibility
Transport efficiency is seen as a fundamental step to reducing emissions, increase efficiency of transportation and typically is paired with cost reductions (SLMN).

Maturity of options
Transport efficiency should not be forgotten and is normally the core strategy for transport companies (EDV). Heavier and longer vehicles are more efficient than two trucks that are lighter and shorter. In Sweden, there are already policies that incentivize transport efficiency mentioned the in the below sub section (EDV). The logistics managers from Nestlé Nordic, Post Nord, and Nestlé Global all confirmed this is a common practice in transportation planning (SLMN, LMP, LMN).

Political feasibility
Transport efficiency is typically the core focus for Volvo's customers (EDV). For example, customers can use heavier longer trucks if they can have two trucks that can do the same work as three trucks (EDV). In Sweden, they are part of a European Modular system that allows 25-meter trucks instead of 19-meter trucks that reduces the number of trucks on the road and improves the energy efficiency which can lead to a 20% reduction in emissions (EDV, SCP).

Social acceptability
There were no foreseen concerns regarding social acceptability of transport efficiency. This could be because this is primarily a business-to-business activity that is not visible to the consumer.

System integration and infrastructure requirements
As mentioned, this is already a common business practice for transportation companies. An example is that Nestlé Sweden uses transport efficiency in their one of their shared warehouses with another large food company in Sweden (CMN). The other company own electric trucks that take the same route as Nestlé Sweden, and they can add pallets into this company's truck (CMN). This works because the company is not a direct competitor but another player in the food industry. This allows Nestlé Sweden to go electric without needing to own or lease an electric truck (CMN).

Potentials

Transport efficiency was excluded from the study on potentials as it is already a widely used practice in Nestlé Global and not a specific technology. This was left out of the scope of this part of the thesis.

4.5 Suggested roadmap for reaching fossil-free transportation by 2025 in Sweden

This section corresponds to the third research question*: How can a transport purchaser map their sustainability roadmap?* Based on the above findings, to reach fossil-free transportation by 2025 in Sweden it is recommended to use readily available solutions due to time constraints for Nestlé Sweden. The available options are biofuels, biogas, battery electric trucks, rail, and transport efficiency. Transport efficiency is already being deployed by Nestlé Sweden. Biofuel is the "quick and easy" solution since Post Nord TPL could use existing diesel trucks without further investment needed. The downside is that there are upcoming supply issues and the Swedish tax exemption for biofuels is set to expire at the end of 2026. It is recommended that biofuels be used to reach the agreed fossil-free target by 2025 but in the meantime, Nestlé Sweden could benefit from focusing on building capacity for other transition pathways. The largest truck producer in Sweden, Volvo, is positioning biogas as the complementary solution to be used with battery electric trucks. Biogas is widely available in Sweden and there is already system integration and infrastructure available. The tax relief for biogas in Sweden was just removed but it remains a viable option for long haul transportation. So much so, that Volvo has set a sales target of 30% for biogas and 70% for battery electric trucks by 2030 in Europe. That said, biogas requires an investment into new biogas trucks unlike biofuels that can be a drop-in fuel to existing diesel trucks. Electric trucks are available and, on the market, as of today, however, they remain more expensive than diesel trucks and the charging infrastructure needs to be further developed for long haul transportation (>300 km). There is expected to be growth in the market for electric truck production and is expected to reach economies of scale in the second half of the decade. It is recommended for Nestlé Sweden, where possible, to integrate electric trucks for short-haul transportation and for the long-haul transportation use a combination of biogas, biofuels, rail, and transport efficiency to reach fossil-free transportation by 2025 in Sweden. From 2023 to 2025, it is recommended for Nestlé Sweden to focus on preparing for an increased use of biogas, battery electric trucks, and rail transportation which can support moving from fossil-free to emission-free transportation. There are hydrogen trucks available on the market, however, it is not recommended as a transition pathway for reaching fossil-free transportation for 2025. This is due to charging infrastructure and economic acceptability constraints. It is recommended to continue using biofuels after 2025 but to prepare for the phasing out of biofuels as the supply shortage resulting in limited availability and higher prices due to the subsidy in Sweden expiring. That said, it will remain an important transition pathway likely until 2030.

The roadmap is summarized in Table 7 below and follows a similar scoring criteria to the above tables. The roadmap table was innovated by the author of this thesis and can be used as a template for organizing the conditions and potentials temporally and to understand the feasibility of each transition pathway. This provides an overview of when each pathway will be ready in the short-term and long-term view to support the roadmap development for 2025 and provides a long-term horizon to future roadmap developments. Green indicates that the transition pathways is likely to be ready to use for reaching fossil-free transportation. Yellow indicates that it fulfills the requirements to be green but comes with conditions. Red indicates that it is not a recommended option.

Pathway	Today - 2023	2024 - Later
Battery Electric Trucks	EV's are being used for short, local routes. Volvo offers trucks that can drive up to 300 km / 44 tons. Complete offer of EV trucks available and ready today. Swedish cities, such as Stockholm, allows electric trucks to drive in off-peak hours. Charging infrastructure expected to be ready by end of 2023. The Swedish Energy Agency offers a climate premium covering 20% of truck's purchase. Available until 2024.	*2024:* - Last year to receive climate premium of 20%. *2025:* - Nestlé Sweden reaches fossil-free transportation. - Growth phase for EV in Sweden begins, expected exponential growth later. 2026: - Electric road in Sweden will be ready. *2027:* - Price expected to fall, technological improvements for longer haul. *2030:* - Volvo reaches 70% sales target for EV and hydrogen trucks in Sweden and Europe. - Recharging station available every 60 km on main roads.
Biofuels	All diesel trucks can use biofuels today. No need for further investment of assets. ReFuelEU prioritizes biofuels for the aviation industry in EU. Expected supply shortage that will likely last until 2027.	2024: - Supply shortage potentially worsens. 2026: - Tax exemption expires in Sweden.
Biogas	A tax relief was just removed, and it is now 20% more expensive. Already 212 public charging stations, 67% of biogas used for freight transport and range of 1000 km.	*2030:* - Volvo reaches 30% sales target for EV and hydrogen trucks in Sweden and Europe.

	Requires investment into new biogas trucks.	- EU biogas production increased by 10x its 2023 production rate.
Fuel Cell Electric (Hydrogen) Trucks	The technology and infrastructure are not developed to be able to be a viable pathway until the second half of the decade. Hydrogen refueling station for heavy duty trucks opens in Port of Gothenburg by end of this year.	"Second half of decade" - Volvo and Daimler Trucks have created their own company, Cellcentric, dedicated to have hydrogen trucks market ready. 2025: - 300 hydrogen refueling stations across Europe. 2030: - 1000 hydrogen refueling stations at least every 200 km on main roads across Europe. - Cost of electrolysers for hydrogen trucks expected to be cut in half.
Rail	This option is readily available today if there are viable options for Nestlé Sweden's routes. Sweden investing in maintenance of railway networks.	2040: - Higher demand for rail as fuel prices expected to double in cost.
Transport efficiency	This is already being implemented by Nestlé Sweden. European Modular system that allows 25-meter trucks instead of 19-meter trucks leading to 20% emissions reductions.	

Table 7: Sustainability Roadmap for reaching fossil-free transportation by 2025 in Sweden.

5 Discussion

This chapter will perform a comparative analysis between the findings of previous studies and the findings from this thesis.

5.1 Transition pathways for transport purchasers in Sweden

The first aim of this thesis set out to understand pathways that transport purchasers can pursue to reach the fossil-free transportation from manufacturing plant to customer. The findings in this thesis confirms biofuels as a readily available pathway to reaching fossil-free transportation by 2025. It is currently compatible with existing infrastructure but comes with supply constraints and an end date to a subsidy in Sweden. Biogas is identified as a complementary solution to biofuels but requires different infrastructure and is not a drop-in fuel like biofuels. That said, the infrastructure is widely available in Sweden, can be used for long haul transportation, and comes with a continuous supply. The status of battery-electric trucks is that they are available but are positioned for short-haul transportation and can be complemented with biogas or biofuel for longer routes. Hydrogen technology is not developed enough to use for reaching fossil-free transportation by 2025 or potentially even 2030, and rail and transport efficiency is an attractive option to use where possible to reduce emissions. These findings are aligned with the literature. Dahlgren & Ammenberg concluded that, although HVO100 is the cheapest and most compatible renewable fuel in Sweden, it faces a supply shortage. Only when the transport purchaser added specific contract requirements, the transport providers used other options than biofuel such as biogas and electric vehicles. Similarly, a study by Lindfeldt et al. where they explored different strategies for the road transport sector in Sweden to reduce its dependency on imported fossil fuels. They concluded biofuels could cover one fifth of the energy demand in the road transport system but is not enough to meet the future energy demands. They concluded that renewable electric trucks, biogas, and hydrogen trucks (when the technology is available) are the main complementary solutions to biofuels (Lindfeldt et al., 2010). In public transportation, Xylia & Silveira (2017) aimed to develop a decarbonization strategy to help public road transportation in Sweden become fossil-free by 2030. They also concluded that biofuels are the leading renewable fuel in Sweden based on its compatibility with existing infrastructure and biogas where there is sufficient production capacity and availability. Electricity is another viable option for fossil-free transportation so long as it is produced from renewable sources. The main barriers are economic, political factors (e.g., taxation), and infrastructure ownership (Xylia & Silveira, 2017). Echoing this, a study in public procurement for transportation in Sweden found that biofuels, biogas, and electric buses are the recommended renewable fuels for fossil-free transport (Aldenius et al., 2021). Findings in this study and by Dahlgren & Ammenberg, point to biofuels being the easiest, most compatible, and widely used renewable fuel in the road transport market. Dahlgren & Ammenberg's (2022) state that if transport purchasers seek that their providers use other renewable fuels such as biogas or battery-electric truck, the best way to achieve this is by setting specific requirements in the contract. As biofuels continue to be perceived as a short-term solution due to potential supply issues it may lead to increased demand for biogas and battery electric trucks leading to greater uptake of other transition pathways. Another study by Breuer et al., (2022) used a method called 'technology readiness level' to assess the readiness of different fossil-free transportation technologies developed by the National Aeronautics and Space Administration (NASA) using Germany as a case study. Their conclusion found that the most promising technologies are battery-electric and hydrogen fuel-cell trucks, natural gas, biogas, and biofuels (e.g., HVO). That said, drop-in fuels such as biofuels that can be mixed with diesel are highly compatible with existing trucks. Battery-electric trucks are unlikely to be used for long-distance heavy-duty transportation before 2025. Currently, the lower production cost of hydrogen is cancelled out by the higher cost for infrastructure making it unlikely to be a solution for reaching fossil fuel free transportation by 2025. They also found a similar issue with biogas that there is currently a lack of infrastructure (Breuer et al., 2022). The case study of this thesis included a temporal aspect that the other studies did not explicitly address. In the case of Nestlé Sweden, they have pledged to reaching fossil-free transportation by 2025 which requires a relatively quick shift by the company's transportation. The recommendations and conclusions of this thesis may differ from other studies seeing as the case company has a time constraint. For example, the transition pathways were judged based on their readiness as of today's scenario that do not meet the timeline of emerging emissions-free solutions such as electric trucks. The literature on transition pathways in Sweden in road freight transportation aligns with the findings of this study.

5.2 Process for roadmap development

The second aim of this thesis set out to develop a process for assessing a market and developing a roadmap for reaching fossil-free transportation by 2025. The literature identified a gap in research regarding frameworks that can support the process to provide a performance assessment of different transition pathways to reveal a roadmap (Pamucar et al., 2021). Buettner pointed to a wider issue that previous studies assess national roadmaps or decarbonization for companies from a political, or technology perspective but fall short in providing concrete advice that address individual company's perspective (Buettner, 2022). They indicate a gap in literature and need for frameworks that provide company-tailored advice with a roadmap that is sufficiently detailed that covers technological, social, or system level aspects. There are quantitative models that are used in transition studies but tend to overlook key aspects such as economic feasibility, integration with infrastructure, and social acceptability for each pathway (Loftus et al, 2015 in Turnheim & Nykvist, 2019). Turnheim & Nykvist responded to this research gap by creating a theoretical framework that can assess pathway feasibility to help reach climate goals such as fossil-free transportation by 2025. The theoretical framework provides a qualitative modelling framework that identifies three facets of pathways with the two that were particularly important in this thesis: (1) pathways as conditions underpinning the realization of the pathway; (2) pathways as potentials or 'hopeful' orientations that lead to a change in efforts towards or away from a pathway. The theoretical framework was recently operationalized by Bauer et al. (2022) at Lund University where they performed a sector-level analysis on four high emitting sectors (meat and dairy, steel, plastics, and pulp and paper) to identify transition pathways for each sector. Building upon the framework by Turnheim & Nykvist (2019), they assessed each pathway using the four conditions and pathways as potentials. This study was useful in that it showed that the theoretical framework is a viable method for understanding the pathways available in a market and a means of performing a system-wide assessment of each alternative to provide context specific results. From these results, they were able to describe a realistic path forward for these sectors to decarbonize. Although this study did not provide a geographically specific analysis and was not focused on the transportation sector, it does provide an opportunity to explore the applicability of this research design to other sectors and highly aligns with the needs of this thesis. Dahlgren & Ammenberg's (2022) used a geographically specific, qualitative, and inductive approach to understanding Swedish freight buyer's sustainability work and identified drivers for implementing sustainability in transportation. They identified selection criteria and priorities that freight purchasers in Sweden consider when deciding which transport providers to work with. Finally, summarizing the respondents' thoughts on the feasibility of renewable fuels available for the transport industry. The results were summarized in a table showing the pros and cons of each renewable fuel but did not assess each trajectory using a theoretical framework.

Another study by Bergek et al. (2021) applied Turnheim & Nykvist's framework in the Norwegian maritime shipping sector to assess the uptake of a specific pathway of battery-electric energy storage solutions in different user segments. They introduce a concept of recognizing sub-regimes arguing that although regimes have tended to be considered homogenous in previous studies, this is not nuanced enough to understand the underlying sociotechnical systems. For example, previous studies assume that actors in the same sector or geography follow a similar logic whereby the transportation regime could consist of a road and rail sub regimes which could be further broken down into passenger and freight sub regimes. They adapted the framework to include another theoretical framework and used it to assess how different transition conditions change between sub-regimes within maritime transport. This displays another use of the theoretical framework and validates the applicability and flexibility of the framework to be applied to the context of decarbonization of transportation (Bergek et al., 2021).

A study by Espegren et al. (2021) focused on assessing one transition pathway, hydrogen, for decarbonization of Norway's energy system. They focused on three analytical perspectives, two of which were scenario modelling to address economic and its role in energy markets. The last was a socio-technical qualitative case study to identify key drivers and barriers for this transition pathway. The third analytical method is closest to the research design of this thesis in that it was grounded in socio-technical transition theory by applying the multi-level perspective analytical framework developed by Geels (2011). They collected data through studying key documents from hydrogen production initiatives, conducting stakeholder interviews, and observing workshops. In their final model, they indicated that by 2030 most of the energy system will mostly rely on renewable electricity with support from fossil fuels and biofuels with hydrogen still being a very small portion of the energy supply. The hydrogen demand in the land-based freight transport sector will increase by 2050 in their scenario model. They identify two options for decarbonization of road transportation and they are biofuels and hydrogen. They identify biofuels as a "transient" renewable fuel although the supply is limited its convenient to use with existing infrastructure and a cost-effective way to transition away from fossil fuels. Their analysis predicts a significant share of biofuels by 2030 followed by a steep reduction towards 2050 in Norway once hydrogen technology is mature enough. It is important to note that although this may be the Norwegian scenario, it is unclear whether that would apply to other geographic locations. They identify four transition pathways for road-freight transportation by 2030. The scenario predicts that by towards 2030, the highest share for energy supply in Norwegian freight transport will be fossil fuels, biofuels, electricity, and then hydrogen. Towards 2050, the model predicts mostly hydrogen complemented by electric. The socio-technical case study assessed the three levels of the multi-level perspective: landscape, regime, and niche level. They identify windows of opportunity at a landscape level from ambitious EU legislation for hydrogen. At a regime level, they identify a potential lock-in effect to battery-electric trucks and charging infrastructure from heavy investments that may prevent the rapid uptake of hydrogen. They also identify a similar finding from this study of a question of safety and limited social acceptance due to skepticism of overall sustainability depending on whether it is produced from renewable energy or not. On the niche level, they identified a similar finding to this thesis in that the cost for hydrogen is expected to reduce towards 2030. There are barriers to storage and distribution among others (Espegren et al., 2021). While they used qualitative systems modelling, the use of the socio-technical perspective allowed the researchers to understand the system interactions at different levels to understand "non-economic barriers and areas of uncertainty" from previous research. Although this study did not aim to create a roadmap, the analysis of transition pathways for hydrogen in Norway using transition studies was like the research design of this thesis. The results of this study align with this thesis in that transition studies provide a tool to analyze the sociotechnical system in a geographical context to identify and assess transition pathways to support in roadmap development.

Brutschin et al. (2021) identified a similar gap to this thesis in that the implementation of the transition pathways for decarbonization in the real world are challenging and they often do not consider social and institutional barriers. The researchers proposed a multidimensional framework to evaluate and compare decarbonization pathways that "enables to assess the timing, disruptiveness and scale of feasibility concerns, and to identify trade-offs across different feasibility dimensions". There are 24 quantitative indicators and feasibility thresholds based on a literature review and collected data. To evaluate the feasibility of each transition pathway, they built a series of four steps that make up their framework as seen in Appendix 6. They assigned low, medium, and high feasibility concern levels for each indicator which resembles the same color categorization as this thesis. They applied the framework to evaluate the set of scenarios by the 2018 IPCC Special Report on 1.5°C. The quantitative indicators of the framework evaluated the feasibility framework based on a series of conditions like that of Turnheim & Nykvist (2019). The high-level concept of developing a step-by-step approach to assess the feasibility of transition pathways is highly aligned with this thesis. The researchers developed a quantitative framework and did not apply it to a regional level however, it confirms the value in creating evaluation frameworks to create a practical roadmap. They also identified a gap needed in performing feasibility evaluations of pathways at a regional level making this thesis ever more important (Brutschin et al., 2021).

When viewed as a whole, it is deemed that the findings of these studies align and validate the transition pathways identified for Sweden's road transportation fossil-free journey. Table 7 in the findings chapter organize the data for each transition pathway and organize it based on a before and after 2025 scenario. The table then is categorized by a color to understand whether the pathway is 'ready for use' before or after the deadline. This thesis took the theoretical framework a step further by organizing the data on a timing perspective to understand which pathways are feasible to include in the roadmap towards fossil-free transportation by 2025. This complements the findings on conditions and potentials for pathways by adding the time component and operationalizes the findings in a tangible decarbonization roadmap.

5.3 Additional Insights

When performing a comparative analysis with the findings from the literature review and results of this thesis, there are some additional insights beyond the aim of this thesis that are interesting to discuss.

The ASI framework by Dalkmann and Brannigan (2007) was referenced by previous studies and another important framework by McKinnon called the 'Green Logistics Framework' and is operationalized by Nestlé Global. The three pillars of the ASI framework are "(1) avoid transport; (2) shift it to lower-carbon modes of transport; and (3) improve the fuel efficiency of the remaining transports" and the five veins of the Green Logistics Framework are "1) reducing the level of freight movement; 2) shifting freight to lower-carbon modes; 3) improving vehicle utilization; 4) increasing energy efficiency; 5) switching to lower-carbon energy". All of which are included in the recommended roadmap for fossil-free transportation in Sweden. For example, reducing the level of freight movement, improving vehicle utilization, and avoiding transportation and improving fuel efficiency are all part of the transition pathway of transport efficiency. Shifting freight to lower-carbon modes from the Green Logistics Framework or shift it to lower-carbon modes of transport from the ASI Framework are both covered by the transition pathways of biofuels, electric or hydrogen trucks, rail, or biogas. Therefore, these frameworks help to cross reference and guide whether a sustainability roadmap is fulfilling the overarching pillars of higher-level green logistics frameworks.

In terms of motivations for corporations to change, Cadez et al. (2018) point to regulatory and stakeholder pressure that can result in positive effects on a firm's corporate carbon strategy and carbon reductions. In this thesis, the stakeholder pressure from the public agreement through Fossil-free Sweden has led to Nestlé Sweden defining a roadmap on how to achieve the agreed upon target by 2025. This is further motivated by the upcoming regulatory changes to market-based incentives for biofuel and biogas in Sweden. These pressures are part of what is motivating Nestlé Sweden and will contribute to the positive performance of the company in reaching the ambitions of their local sustainability strategy.

Regarding previous studies on corporate carbon strategy, Almeida et al. (2021) identified three main activities and ten attributes that firms should focus on in their corporate carbon strategy. They are (1) product stewardship, (2) pollution prevention, (3) clean technology. The ten attributes are (1) innovation towards sustainability, (2) adoption of cleaner technology, (3) absorptive capacity, (4) knowledge sharing for sustainability, (5) propensity for sustainable partnerships, (6) strategic alignment towards sustainability, (7) green development of new products, (8) sustainable operations management (9) long term relationships, (10) network structures. Through the suggested roadmap for fossil-free transportation, Nestlé Sweden is engaging in all activities and attributes. For example, they are engaging in propensity for sustainable partnerships as they are maintaining and developing valuable partnerships with Post Nord TPL to improve their sustainability performance. They have strategic alignment through consistency with other network actors' by ensuring their partner's commitment to sustainability is strategically aligned with their own. For example, through the interviews Post Nord TPL and their sustainability consultant was explaining how their activities will align with Nestlé Sweden's ambition for fossil-free transportation by 2025 and strategically aligns with Post Nord TPL's own ambition of reaching fossil-free transportation. Based on Lee's (2011) typology for describing different levels of ambitions of corporate carbon strategies, Nestlé Sweden falls under the 'all-round explorer' level which is the most ambitious. They engage in trade associations such as DLF and engage with governing bodies such as setting climate goals aligned with the Science Based Targets Initiative. They are also exploring investing in new technologies such as when Nestlé Global committed to investing more than CHF 100 million by 2030 into low-carbon logistics for their top three water brands. This is not necessarily connected to the aim of this thesis but a way for the reader to understand the level of ambition of Nestlé Global and Sweden's corporate carbon strategy.

Finally, Buettner (2022) suggested seven success criteria to consider when building a corporate carbon strategy. The first is creating a mutual understanding and clarity of terminology around decarbonization for all involved stakeholders. Interestingly, there was a lack of clarity among stakeholders in this case study around terms such as fossil-free and how it is defined in Sweden. This was why there were two sections in this thesis addressing the terminology for the reader audience of this thesis. Nestlé Sweden has set their targets with overarching goals, set their level of ambition of reaching fossil-free transportation by 2025, scope of their target, the understanding of the motivations of the firm to reach said target, defining a roadmap to reach the target, and understanding where they stand right now. This added value to the thesis in cross references the success criterion. Nestlé Sweden had addressed five of six of the success criteria and an inductive finding from this thesis was that the mutual understanding and clarity of terminology is an area of improvement for Nestlé Sweden is an integral part of implementing the roadmap.

5.4 Reflecting on the results of this thesis

In terms of the choice of methods and theories, there are several means of assessing transition pathways that are both qualitative and quantitative. Quantitative modelling would have required access to specific software that was not available due to limited resources for this thesis. However, an alternative theoretical framework that could have applied was Geels' (2011) multi-level perspective analytical framework. Both Turnheim & Nykvist's and Geels' frameworks are rooted in socio-technical transition theory and are both proven methods in assessing decarbonization transition pathways. Considering that one key audience member for this thesis is logistics managers in companies, the Turnheim & Nykvist framework is simpler to use. Logistics managers are busy and are required to juggle multiple tasks at once. Furthermore, sustainability is one of many objectives they are aiming to reach. Therefore, the simpler and more user friendly a tool is, the quicker they will be able to operationalize it and uptrain other stakeholders to use. This makes it relatively straightforward to implement for a professional without a background in transition theories.

In terms of the legitimacy of this thesis, there is a clear identified research gap in that there is a lack of studies that evaluate the feasibility of decarbonization transition pathways that are sector specific. With the results from this thesis, any Swedish company with road transportation will be able to understand the different pathways they can choose and when. This thesis has also shown that it is feasible to make transition studies useful with a sectoral and geographic focus. The results from the first aim of this thesis are generalizable to any actor that pledged to the Fossil-free Sweden agreement. That is because the transition pathways explored were geographically and temporally specific to the Swedish context. In different geographic and cultural contexts there is expected to be different transition pathways, potentials, and conditions. The results from the second aim of the thesis are generalizable to any actor that seeks a way to assess transition pathways and build a realistic decarbonization roadmap. The frameworks are context agnostic and therefore are flexible to be applied to nearly any geographic, temporal, or cultural context. The applied theoretical and roadmap framework can, for example, be used by Nestlé Nordic to be applied to the rest of the Nordics to make market specific roadmap.

6 Conclusion

With the heavy-duty transport sector in Sweden accounting for most of the emissions and considering Sweden one of the highest emitting countries in the Nordics, there is a clear need for sustainability roadmaps to support reaching fossil-free transportation swiftly. Not only will reaching fossil-free transportation be an important step in reducing emissions but will bring actors closer to emissions-free transportation and fulfilling their commitments to net-zero goals and support national agreements such as the Paris Agreement. Considering this, transport purchasers need a framework that is flexible to apply to different sectoral and geographical contexts that can support the roadmap development process and lead to the achievement of their ambitions set out in their corporate carbon strategy. For this, three research questions were defined that identify transition pathways for fossil-free transportation in Sweden, how they compare to each other based on an applied theoretical framework, a framework and process that can be applied in other markets.

The first research question is: How is the market transitioning to fossil-free freight transportation? The market is transitioning to fossil-free freight transportation by exploring transition pathways such as biofuels, battery-electric trucks, hydrogen trucks, biogas as well as continuing to implement multi modal shifts to rail and transport efficiency wherever possible.

The second research question is: How do the current conditions and potentials for fossil-free transportation transition pathways compare to each other in Sweden? Based on the data analysis, biofuels are a highly compatible, 'transient' transition pathway but is recommended to be complemented by biogas and electric trucks as they become more mature and affordable. If companies decide to move beyond fossil-free transportation into emissions-free or net-zero transportation, transitioning away from biofuels can support achieving these goals. Electric trucks require a higher investment, but the technology is ready, and the infrastructure and initial investment is expected to fall towards 2030. For now, electric trucks are positioned as a transition pathway for short haul transportation and the market is complementing this with biogas and biofuels for long haul transportation. Both biogas and electric trucks require a higher investment to biofuels however are recommended options for phasing out fossil-fuels. Lastly, although the market is discussing hydrogen, the infrastructure and technology is expected to be ready closer to 2030 and therefore would not be a recommended transition pathway for reaching fossil-free transportation by 2025.

The third research question is: How can a transport purchaser map their preferred decarbonization pathway? Transport purchasers can apply the process used in this thesis of applying the theoretical framework by Turnheim & Nykvist (2019) along with Table 7 to create a temporal, geographically specific evaluation of transition pathways and derive roadmap for reaching fossil-free transportation. This thesis has shown that it is feasible to apply the framework to a specific sector and geographic context.

My contribution to research can be summarized in three succinct points. Firstly, this thesis provides a process for transport purchasers to understand a specific sectoral and geographic context to develop, identify, and assess transition pathways and support the development of a sustainability roadmap. Although previous studies had used similar approaches to applying the theoretical framework, this is the first study to apply the framework developed by Turnheim & Nykvist (2019) to a geographical context of Sweden and sectoral context of road freight transportation.

Secondly, this thesis adapted the framework in two distinct ways to better align with the needs of transport purchasers. Firstly, through adding the economic acceptability to the pathways as conditions. This was a logical step that provided a more holistic view on each transition pathway. For example, electric vehicles are on the market and ready in present day, but they are nearly double the cost of a diesel truck providing a lower economic acceptability than biofuels. The additional conditions have led to a more realistic overview of the feasibility of each transition pathway. The second way in which the framework from adapted was through adding a color-coding system to Table 5 and Table 7. The color system of green, yellow, and red was used to have a clear visual representation of the transition pathways. Logistics managers are busy and are juggling many tasks at once, this visual representation makes it quick to judge each transition pathway. For example, at first glance at Table 5 on current conditions for transition pathways, one can derive that rail and transport efficiency are transition pathways that can be implemented today without issues and that biofuels and biogas are also ready to implement today but there are certain considerations.

Lastly, following Buettner's (2022) recommendation of creating a mutual understanding and clarity of terminology is an important success criterion for all involved stakeholders. Although this was not part of the aim of this thesis, it was an additional insight worth mentioning. Part of the final recommendations provided were to create clarity around terminology as not all stakeholders were able to define terminology related to fossil-free transportation.

6.1 Practical implications and recommendations for non-academic audiences

When the findings were presented to the logistics manager and sustainability manager at Nestlé Sweden, they provided feedback that they find these insights help concretize what they were already seeing in the Swedish context. In most cases, managers have worked on various projects with stakeholders and have a solid understanding of the available transition pathways and their pros and cons, but the process used in this thesis provides a way to organize, concretize, and verify what they may already know. This is important for two reasons: (1) it helps with organizing and creating a holistic assessment of the market (2) it helps as a communication tool to relevant stakeholders and to achieve buy-in for support for the roadmap. Nestlé Sweden provided feedback that this process is useful for them, and they foresee operationalizing it in their business to apply to other Nordic markets.

This process can be applied to any sector or geography in sustainability roadmap development. For example, logistics managers who have signed the fossil-free Sweden agreement for 2025 in Sweden and or sustainability managers who have decarbonisation goals for their warehouses can benefit from this thesis. They can use the thesis to understand the sectoral and geographic context and how best to create a sustainability roadmap.

6.2 Recommendations for future research

Although previous literature has used varying qualitative and quantitative methods to assess transition pathways, they did not translate them into a roadmap towards a climate target. This thesis has contributed to filling this research gap by providing an evaluation of transition pathways in Sweden for fossil-free road transportation by 2025 and provide a process that can be used by the public or private sector to develop a realistic sustainability roadmap. There are a few recommendations for future researchers regarding this thesis. Firstly, future researchers are recommended to set more extensive thresholds for the color-coded system. For example, what indicators need to be fulfilled for a condition to achieve green. This may be context specific but could strengthen the tool. As of now, the color-coded system is based on if there are considerations and how risky those considerations are. This could be further developed to strengthen the assessment. The economic acceptability condition could be explored further to provide a more comprehensive overview of the actual costs of each technology and how they compare to each other. A more technical financial analysis could be included in the methodology of the framework that could strengthen the assessment. Similarly, future researchers could add another condition to the framework on the emissions reduction potential of each transition pathway. This was not in the scope of this thesis due to resource constraints but would prove valuable when estimating the reduction capacity of each pathway. It is also recommended that future researchers apply the framework to other geographies and sectors to see whether this process is helpful in other contexts to develop sustainability roadmaps. Lastly, it is recommended to perform a case study on a company that is operationalizing this process in their roadmap development to understand how a company may adapt it and use it in practice.

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8 Appendix

Green Logistics Management Items (Drivers)	Items Group
1. Green Packaging Materials	Packing
2. Packaging Material amount	
3. Information sharing with manufacturing firms and retailers	Information sharing
4. Efficient and accurate ordering system	
5. Reduction of warehouse fee	Warehouse
6. Location selection of warehouse	
7. Greenhouse gas (GHG)	Logistics emissions
8. Adoption of green technologies to save resources	
9. Pollution emissions in logistics activities	
10. Standardization of transport	Logistics networking and transportation
11. Optimization of vehicles' routing	
12. Greener vehicles – transport modes	
13. Loading and unloading safety	
14. Unit load to improve efficiency	
15. Logistics networking	
16. Information technology design and use of logistics network	

Appendix 1: Green logistics management items and groups (Trivellas et al., 2020).

Green Performance KPIs	KPI Group
1. Energy consumption	Resources usage and safety
2. Water consumption	
3. Restrain usage of dangerous/hazardous materials	
4. Environmental accidents	
5. Carbon dioxide emissions	
6. Novelty in environmental issues relative to competitors	Environmental Process management performance
7. Waste management	
8. Environmental performance in transportation process (e.g., lower fuel consumption	

Appendix 2: Green performance KPIs (Trivellas et al., 2020).

Environmental Performance	
Decreasing emissions	Decreasing energy consumption
Greenhouse gas emissions Air emissions	Energy utilization ratio Usage of green fuels

Carbon emissions	Less consumption Usage of alternative energy sources

Appendix 3: Sub-criteria for environmental performance main criteria (Kazancoglu et al., 2018).

Logistics Performance
Improving green logistics
- On time delivery - Eco-driving to decrease fuel consumption. - Just in time for logistics - Order cycle time - Environmentally friendly transportation - Recyclable or reusable packaging/containers in logistics - Order fulfillment - Delivery dependability - Modal split (weight of goals transported by road) - Average handling factor (road tons lifted) - Average length of haul (tons-km) - Average load on laden trip (weight/volume) - Average percentage of empty running - A recycling system for used and defective products - Products with take-back policies - Mode of transport - Greener vehicles - Route optimization - Vehicle utilization - Fuel efficiency

Appendix 4: Sub-criteria for logistics performance main criteria (Kazancoglu et al., 2018)

Green Office	Inventory Control and Material Handling	Green Warehouse	Green Transport
- Reducing papers materials, excess usage of water and electricity - Green recycling for office waste materials - Implementing environment-based training and activities	- Using barcode inventory systems & radio frequency identification (RFID) inventory systems (Pontius, 2018) - Using technology for control inventory wastage - Proceed automatic material handling systems	- Lessening usage of paper materials, water, and electricity - Reuse the reusable materials. - Reducing and managing warehouse wastage - Green recycling for warehouse waste materials	- Using technologically advanced transport that emits low carbon dioxide. - Following green transportation strategies - Promoting eco-driving training - Processing low-viscosity lubricant oil engine

Appendix 5: Green logistics framework (Hasan et al., 2019)

Step 1	Step 2	Step 3	Step 4
Feasibility dimensions	**Indicators**	**Levels of concern & thresholds**	**Aggregation (geometric mean) & assessment**
9 Geophysical 10 Technological 11 Economic 12 Institutional 13 Socio-cultural	For each dimension, selection of relevant indicators measuring decadal changes	Categorization of level of feasibility concern for each indicator in each decade based on thresholds from the literature and available empirical data. 14 low (1) 15 medium(2) 16 high (3)	Aggregation within each dimension → To assess trade-offs among feasibility dimensions. Aggregation across dimensions at different points in time → To assess the timing and disruptiveness of the transformation. Aggregation across dimensions and across time → To assess the scale of the transformation.

Appendix 6: Steps and details of Brutschin et al.'s general framework for scenario evaluation (Brutschin et al. 2021)