ARCADA

# The future of new green technologies in sustainable road logistics

## The challenges and opportunities

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The future of new green technologies in sustainable road logistics, the challenges and possibilities

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## Abstract:

Transport over road is what keeps the world running and supplied. Without transport, the society as we all know it today simply would not exist. Transport is a great thing in that way considering how efficiently it all works and how much it is integrated into our daily lives. However, in this society where we buy more and more and where we rely more and more on transport, causes issues that have a major influence on our surroundings. The aim of this thesis is to discover what the challenges but also opportunities will be when we develop and employ new technologies for transport over roads. In this work, documents from manufacturers were analysed together with EU legislation to get an accurate view of what the possibilities are, what needs to be done and what we already have. Until we have a way of replacing the benefits of fossil fuels, companies are focussing mostly on electricity, but is that truly the way to go? While the industry is trying its best to transition to green alternatives, items like range and reliability are causes of concern.

## Keywords:

Green road transport, green technologies, road transport, sustainability, sustainable road logistics

# Contents

# 1 INTRODUCTION

When we take a short look at the news nowadays, it is very clear that the climate is struggling. Some talk about a climate trend, others call it a planet-wide disaster. No matter what one calls it, nature is showing that we cannot continue the way we are doing right now. Yet over the years, transport in the European Union has only gone upwards (EU Transport in figures, 2022). This means that even though we know something must change in how we live, it is not the biggest and most important item on our to-do list.

This study figures out what technologies exist to make road transport greener and more sustainable. Electric vehicles are growing in numbers but there is still an array of teething issues with them. Think about not enough charging points, not as reliable as conventional petrol/diesel engines, fire hazards, etc. (*Electric cars* 2017). So, the question is, how can we transit to a green fleet of trucks without impeding any of our own operations?

First some background information: what exactly is climate change and what makes climate change happen? In the end, we cannot give solutions if we do not understand the causes of the issue. Climate change, as defined by the United Nations, is the process of changing weather patterns in the long run (United Nations). We have seen natural climate change like the Ice Age and right now we are in a so-called interglacial period. Interglacial means that the earth is in between 2 Ice Ages. This is normal, the earth heating up and cooling down are natural processes and usually take a very long time (University of Calgary). The problem however is that since the Industrial Revolution, this natural cycle has been interrupted and accelerated by human activity because of our factories and new ways of producing (AdaptNSW, n.d.).

Now we are in the year 2023 and we are starting to see the full extent of consequences regarding the philosophy of just letting all this CO2 and other pollutants in the air. Companies are working tirelessly to produce and develop new kinds of engines that do not rely on fossil fuels to work. The only two questions right now are: are those new green alternatives really as green and is it not too late already? Because yes, batteries have no emissions on paper but is it truly like that? And if the green alternatives are not implemented enough yet, why change considering how reliable fossil fuel engines are?

## 1.1 Problem statement

According to the statistics of the European Union, transport over road counts for 77% of the total transport emissions in the EU (EEA, 2022). This means that even though it is not the most popular mode of transport (maritime transport rules the statistics by far), it has the biggest impact on the environment (Eurostat, 2023). The switch from fossil fuels onto renewable or zero-emission ones is not easy. It needs a legal framework, infrastructure and it needs to be reliable and "cheap", especially in professional driving.

## 1.2 Aim of the study

The aim of this study is to get a better understanding of what technologies are being developed as alternatives for fossil fuels. This way it is easier to understand why certain technologies work better for this purpose (being road logistics) and which do not. It is important to understand what the pros and cons and more importantly, what else is needed to implement in order to get everything working smoothly. In the end, you cannot have electric trucks when there are not enough charging places for truck drivers to charge their vehicles for example.

The study poses the following research question:
**What are the strengths, weaknesses, opportunities and threats of the new green technologies being developed as an alternative to the current fossil technologies in scheduled road transport?**

## 1.3 Demarcation

This study only covers the challenges and opportunities of green alternatives to the fossil fuels we utilize nowadays. And to narrow it down even more, research is only conducted about scheduled transport over road. As it is easier to talk about the European Union information wise, the focus of this research is on the EU.

## 1.4 Definitions

**SSTPA:** Safe and Secure Truck Parking Areas (IRU, 2018)
**TEN-T:** Trans-European Transport Network, is an EU policy that aims to develop high-quality and efficient transport infrastructure across the Union. (European Commission, n.d.)
**EV:** Electric Vehicle, as defined by the US government is "a vehicle that can be powered by an electric motor that draws electricity from a battery and is capable of being charged from an external source". (U.S. Department of Energy, n.d.)
**Well-to-wheel emissions:** as defined by the US government are "all emissions related to fuel production, processing, distribution, and use." (U.S. Department of Energy, n.d.)

# 2 THEORY

This section that follows is the theoretical background of the study which focusses about the different pros and cons of new green technologies in trucks, legal framework, why the switch needs to happen and required infrastructure. The main base for this research has been found by the European Union, Volvo and Scania. These two companies have been chosen because they main leading companies in these technologies.

## 2.1 Climate change

According to the United Nations, climate change is the biggest and largest threat that our world has ever faced (Fry, 2022). Since 1970, the average global temperature has increased about 0.2 degrees every decade. It does not sound that much, but this increase in a timespan of 50 years is the biggest measured in the last 200 years. Members countries of the UNFCCC (United Nations Framework Convention on Climate Change) have agreed on the Paris agreement to keep the increase in global temperature under 2 degrees Celsius. The 2-degree limit is in relation to the pre-industrial average temperature. (EEA, 2023)

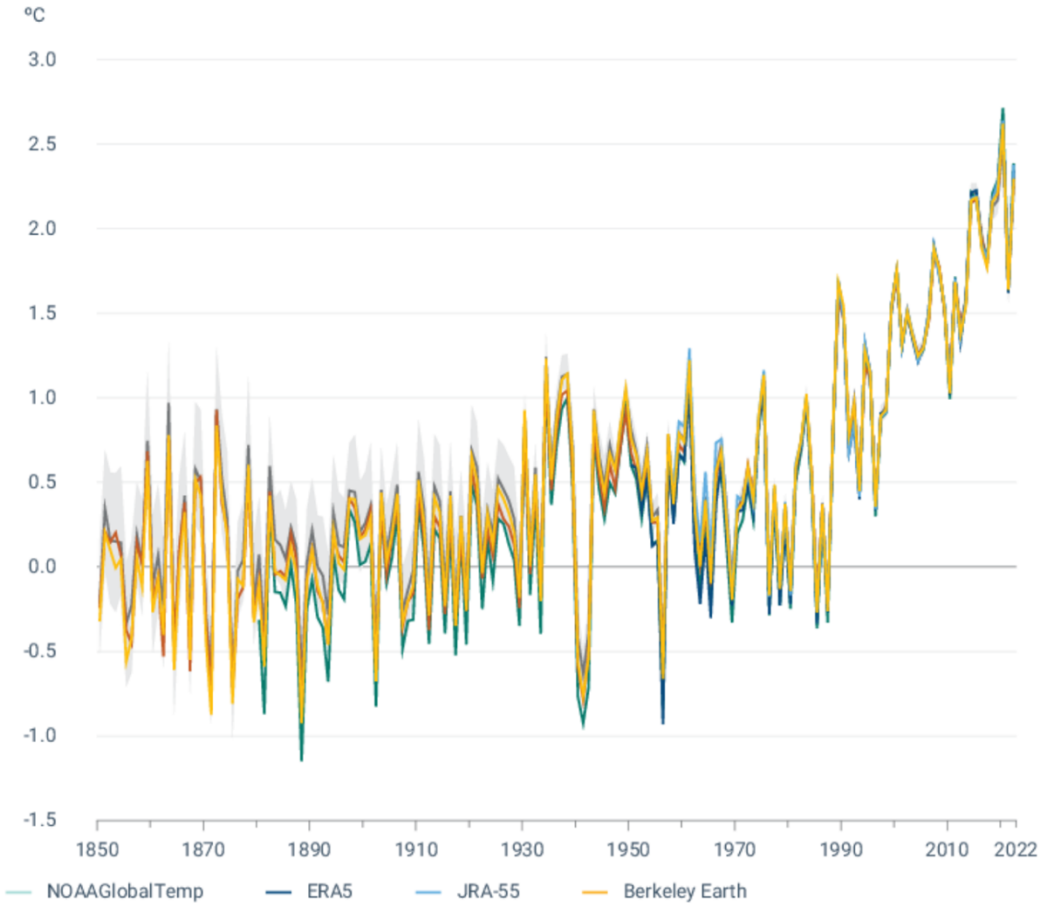


*Figure 1 European annual average near-surface temperature anomalies relative to the pre-industrial period 1850-1900 (data by EEA 2022)*

The main item on the list that causes global warming is the emission of greenhouse gasses. These gasses are the result of burning fossil fuels like petrol, diesel, coal etc. These five greenhouse gasses are CO2, Methane, Nitrous Oxide, Chlorofluorocarbons and water vapor. Out of these five, CO2 is the biggest problem. While we need greenhouse gasses for our planet (they trap the sun's energy, so the warmth does not get lost into space), we are producing way too much of it. This means that the earth's atmosphere traps way too much heat, causing global increase in temperatures. (NASA, n.d.)

### 2.1.1 Kyoto protocol

The Kyoto protocol came into effect on the 16th of February 2005 even though it was already formally adopted on the 11th of December 1997. This was possible due to the difficult ratification process. As of 2023, 192 different parties participate in the protocol, meaning a big chunk of the countries are in on the program. In essence, the protocol serves

as an enforcing measure to transform the agreed upon measures into reality. This is done by mandating that industrialized countries should limit their greenhouse emissions. Same thing counts for transitioning economies. These countries should be able to meet certain targets set by the protocol. Reporting is done on a periodical base. (UNFCCC, n.d.)

Developed countries bear the most weight in climate change so that is why the protocol places binding commitments on them. The idea behind this is that those countries have more capabilities to combat climate change than developing economies and countries. In this situation these are 37 industrialized countries and the European Union. The first commitment period was from 2008-2012 and these targets should have made (on average) a five percent reduction in the emissions of greenhouse gasses. It is to note that this is in comparison to the 1990 levels of emissions. (UNFCCC, n.d.)

Nowadays in 2023, the Kyoto protocol is not in use anymore. At the 18th Conference of the Parties in 2012, it was agreed upon to prolong the protocol until 2020. After this, the protocol would be replaced by another treaty developed in 2015. This new treaty is also known as the Paris agreement and is in effect right now. (Encyclopaedia Britannica, 2023)

### 2.1.2 Paris agreement

The Paris agreement is a binding agreement between 194 nations of the United Nations. These consist of 193 nations and the European Union. As mentioned before, the main aim is to make sure that global temperature does not exceed two degrees compared to the pre-industrial average temperature. In the meantime, this two-degree limit has been adjusted to one and a half degrees Celsius. (UNFCCC, n.d.) As the name implies, the agreement was signed in Paris, France. It got signed on the 12th of December 2015 and entered into force on the fourth of November 2016. (Marjo Nummelin, n.d.) The Paris agreement is the successor to the Kyoto protocol.

The agreement itself is historic because for the first time it was able to bring together all nations to reach a solution when it comes to climate change. These long-term goals include items like funding poorer countries to help them combat climate change, to significantly reduce greenhouse emission and to review what has been done every five years. The treaty is legally binding which means that all countries that signed it have a

legal obligation to also put the treaty into effect and to reach the set targets. (United Nations, n.d.)

The first time one of these review points was held, was in 2023. It is meant to see how much progress has been made and to encourage the people to continue improving. Anyway, not only is the agreement a deal on reducing emissions, but also to help adapt to the effects of climate change and to increase the efforts of reducing emissions. This is done in a progressive way. The treaty is a first step towards a zero-emission world, and it should be able to help us navigate the transition for years to come. (United Nations, n.d.)

## 2.2 Available alternatives

### 2.2.1 Electricity

Electricity is the main technology companies and scientists are developing. Electricity powered vehicles have been around for decades, but usually those are used in short distance deliveries. Think about postal vans for example. If the source of the electricity is clean, then the vehicle is clean as well. This means that for a vehicle to be fully climate neutral, the electricity needs to come from a renewable source. Because the batteries are so heavy, fully electric heavy vehicles are not popular yet as the weight has an impact on range. For this reason, the main chunk of electric vehicles are still hybrids. (McKinnon et al., 2015, p. 282-283) However, development is happening at rapid speeds. Not only charging docks can be used to recharge electric trucks. Some manufacturers of trucks have developed a system called regenerative braking. This basically means that the energy released during braking gets recycled into the truck's electrical system and powering them. (McKinnon et al., 2015, p. 282) Electricity can be sourced from a variety of places, making it very useful.

### 2.2.2 Diesel, synthetic diesel, biodiesel, HVO and electrofuel

Diesel is the most used fuel in the transport industry. B0 being the standard version of this fuel. B0, B7 and B10 stand for the percentage of biodiesel used in the diesel blend. B0 has 0%, B7 has 7% etc. (European Commission, 2018) Biodiesel is the result of the trans-esterification process. Oil (rapeseed, soybean oil etc. it depends on location) reacts with alcohol and produces biodiesel. A catalyst is needed for this process. (McKinnon et

al., 2015, p. 279-280) Synthetic diesel is available as well now, this fuel relies on the Fischer-Tropsch process. Basically, gas is used to convert “a mix of hydrogen and carbon monoxide into a diesel-like fuel.” (Volvo Trucks, 2020)

HVO is a second-generation of biodiesel. By adding hydrogen to vegetable oil (used in the kitchen) it is possible to end up with a fuel that is alike to diesel. (Volvo Trucks, 2020)

Electrofuel relies on a chemical process that involves electrolysing water. By doing this, a diesel-like fuel can be obtained. According to Volvo, this technology can be carbon-neutral and limitless. However, the source of the electricity needs to be climate-neutral in that case. This technology is still in its early development. (Volvo Trucks, 2020)

### 2.2.3 Bioethanol, biomethane and dimethyl ether

Bioethanol can be produced from any organic material that contains sugar or starch. (McKinnon et al., 2015, p. 280) Chemically speaking, it is the same alcohol that is found in our alcoholic beverages. Biomethane is a biogas that can be extracted from organic materials. Compared to diesel, emissions can be reduced by 60%. (McKinnon et al., 2015, p. 280) DME is produced from biomass or fossil resources. The end-product is a fuel that resembles diesel. It has the same performance and efficiency. (Volvo Trucks, 2020)

### 2.2.4 LNG and green hydrogen

LNG or liquefied natural gas is natural gas that has been chilled to a liquid form. This makes it still a fossil fuel, but it has 1/5 less emissions than diesel. Bio-LNG fuel also in development. This uses organic waste in contrary to fossil resources. (Volvo Trucks, 2020) Green hydrogen fuel is a fuel in early development that relies on electrolysis. This chemical reaction is obtained by breaking down water molecules into oxygen and hydrogen by using an electric current. By pumping this hydrogen into a fuel cell, it gets combined with oxygen. This in turn produces electricity. (Acciona, n.d.) This chemical reaction only produces by-products are warm air and water vapor (McKinnon et al., 2015, p. 281-282). As nothing gets burned, it is a 100% emission free fuel. Considering the electricity used for the process comes from a renewable source of course.

## 2.3 EU and road transport

### 2.3.1 EU legislation and vision

As everything in the EU, legislation around transport is very well worked out. Items like emission standards, truck measurements and weight, driving times etc. are all European laws. This makes international transport way easier but above all, standardized. When everything is standardized, the flow of traffic throughout the supply chain goes faster. (European Commission, n.d.) Border crossings and filling out papers go easier when everyone has the same papers for example. Another focus area of European laws is to make transport more sustainable and safer. That is why the so-called Euro standards exist for example but also standardized driving times. (Rijksoverheid, 2022) Back in the day, drivers could drive as long as they felt like driving and that caused horrible accidents. Thanks to the tachograph, these accidents have been reduced. (European Commission, n.d.) However, this is not the only reason. Quality driving lessons, safety equipment, road infrastructure etc. are all European requirements.

Now, to come back to the Euro standards: Euro standards are a set of rules that regulate emissions. The main emissions they target are carbon monoxide, nitrogen oxides, carbon dioxide, hydrocarbons and particulate matter. As mentioned above, these have an incredible influence on the climate. Euro standards have been around since 1992 when EURO 1 was adopted. Since 1992, these rules have been tightened and have gotten new numbers. EURO 2,3,4 etc. Nowadays, EURO 6 is the norm and this one has the tightest emission norms. (ACEA, 2022)

EU vision has a big impact on the legislation and the other way around. Since the European Union wants as many standardized procedures and vehicles as possible, it is not hard to say that this is why the laws and vision are closely related. As mentioned above: safety, sustainability and harmony are the main ideas of the EU. Since the Schengen zone got founded, it has never been easier to travel within the Union. This is also a big reason why the EU is putting so much effort on getting rules standardized. There are 27 member states that would otherwise all have their own rules and customs and that does not have a good impact of getting products from Finland to Belgium fluently for example. (European Commission, n.d.)

### 2.3.2 Green Deal

The Green Deal is a law adopted on the 24th of June 2021, with the goal of reducing emissions 55% by 2030 and to be climate neutral by 2050. (European Commission, n.d.) While the Paris agreement is a global treaty, the European Green Deal is a European Union policy. The main aim is to prove that being climate neutral does necessarily mean that economic growth is impeded, that is also why the EU vows to leave no country behind in its transition. Some of these "sub policies" include circular economy, improving biodiversity, sustainable agriculture and of course clean transport. Even though this policy is very ambitious, the EU is already on track to exceed the targets set for 2030. (European Commission, n.d.)

### 2.3.3 Trucking industry in Europe

The trucking industry in Europe employs 3,204,468 people in total and they have 6.2 million trucks to their disposal. When looking at the statistics provided by the European Automobile Manufacturers Association, these trucks have an average age of 13.9 years. Which is starting to be old for a vehicle in terms of technology and environmental standards. Additionally, 95.8% of trucks in circulation in the EU is powered by a diesel engine. Petrol engines count for 0.1% of the total amount. Hybrid/ fully electric trucks only count for 0.2% of the 6.2 million trucks on the roads today. The other 4% are powered by alternative fuels. When buying a new truck, companies still go for the fossil fuel engines as electric trucks only represent 0.5% of recent sales. Considering the agreements made in terms of the climate, this is a rather bad number. (ACEA, 2022)

### 2.3.4 Truck manufacturers

When looking at Volvo, they believe that electric engines and hydrogen fuel are the two future power plants. Of course, these technologies are both still in their testing phases. On the other hand, Volvo has managed to create a 74 tonnes truck that drives completely on electricity. This type of truck is the FH model, their flagship model. According to Jan-Olof Mattsson, this electric truck can drive 12 hours a day, and take as much cargo as regular trucks. (Volvo Trucks, 2023) Additionally, the work environment is way quieter, so it is better for the driver. Volvo also managed to increase the range of their FL Electric trucks up to 450 km. (Volvo Trucks, 2023) The FL trucks however are mainly used for

the last-mile deliveries so not relevant for this study, yet it does show how the technology in improving.

Hydrogen fuel cells is another route that Volvo is exploring in their quest to find zero-emission fuels. However, this technology is still in development so lots of questions are still unanswered. Volvo has started with public road tests in May of 2023, and they expect that it should be commercially available at the end of the 2020'ies. (Mårtensson, 2023)

Scania on the other hand mainly believes in fully electric and hybrid engines. With the hybrid engines being a mix of biofuels and electricity. The company has been developing these alternative biofuels for the last 25 years. (Scania, 2023) Their main goal now is to reduce the emissions and not completely get rid of them like Volvo is aiming at. However, just like Volvo, Scania has made a fully electric truck that can pull a maximum of 64 tonnes. Additionally, Scania has been experimenting with a truck powered by solar power. The trailer of that truck has been filled up with solar panels so there is no need of charging the truck at a charging dock. It is to note however that this truck is not fully electric, but a hybrid (Scania, 2023).

Mercedes, just like Volvo, is working hard on fully electrifying their trucks. (Daimler Truck, 2023) Additionally, also like Volvo, hydrogen is also the route they are exploring. (Daimler Truck, 2023) MAN is doing the exact same thing even though their focus is electricity. Hydrogen power seems less important to them for now. (Christian Jeß, 2022)

### 2.3.5 Production emissions

When looking at the available technologies today, Volvo has given its customers an amazing tool that instantly shows the difference between different engine options for the truck. Here it is very easy to find out what truck is the best option environmentally speaking. To get a good comparison that made the most sense, Volvo FH, Volvo FH Electric and Volvo FH LNG were chosen. As mentioned above, The FH series is the flagship of Volvo and ideal for both regional and long-haul driving. Both FH LNG and FH comply to the latest EURO 6 standards of the European Union. The EURO 6 standard is the latest emission standard set out by the Union and its focus is to reduce the emissions of Nitrogen Oxide in comparison to the older EURO standards. (Motus commercials, n.d.)

The Electric FH uses the average EU hydro power in this simulation. The FH has standard B0 fuel, the FH LNG runs on LNG. More on this later. The annual mileage was set at 100,000 kilometres per year. (Volvo Trucks, n.d.) The results of this comparison can be found in the results chapter.

When looking at the results, it is very noticeable that the electric truck by far is the worst one when it comes to production. 5,990 kg of CO2 emissions, while the LNG version only has 2,030 and the regular FH needs 2,1 tonnes of CO2 to be manufactured. However, during one year of using the trucks, the electrical variant wins by a landslide. It only emits 1,090 kilogrammes of CO2; the LNG emits 64,200 kilos and the regular FH emits a whopping 71,700 kilogrammes. This goes to show that even with the production emissions being higher for the electric truck, the overall emissions during its lifetime make up for it more than enough. These emissions of course depend on driving style, environment, weight and lots of other factors (Volvo Trucks, n.d.).

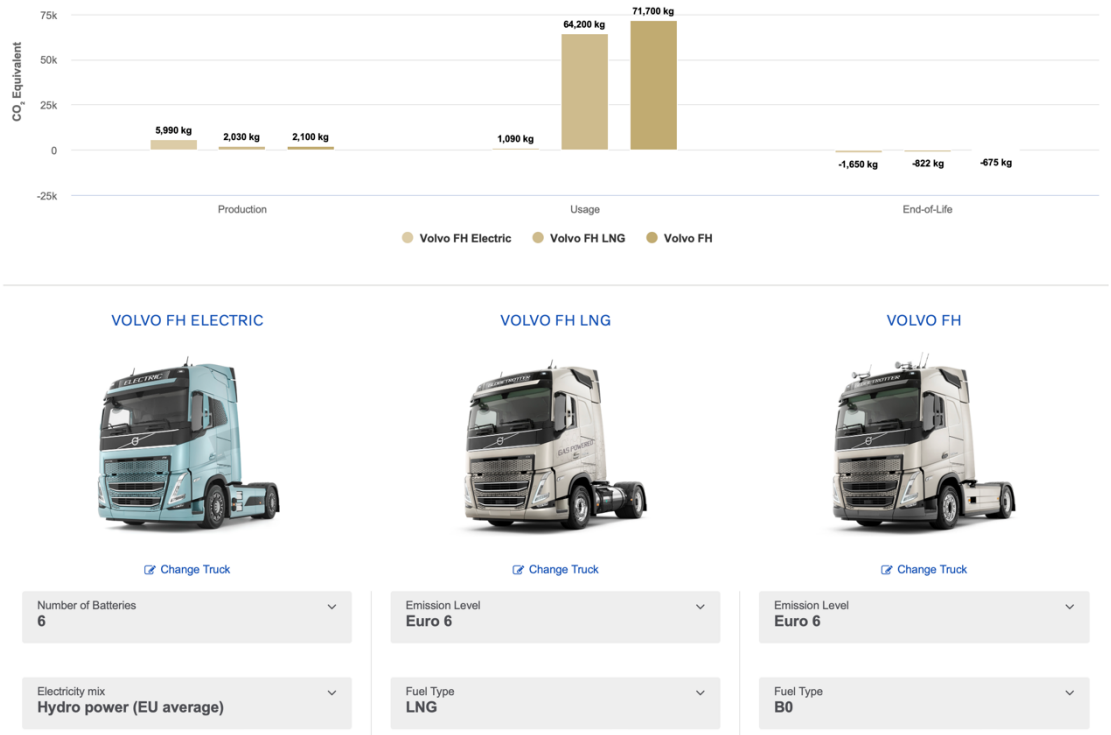


*Figure 2 Comparison between Volvo FH ELECTRIC, Volvo FH LNG and Volvo FH*

## 2.4 Infrastructure

If our society wants EV's to be truly environmentally friendly, our sources for our electricity need to be clean too. According to the European Union, about 40% of the total electricity comes from renewable sources. Another 22% originates from nuclear sources and he last 38% is from fossil resources. This means that about 2/3 of our total energy production has a neutral impact on the climate emission wise. When looking at the statistics, pure green energy has increased from 16% up to the about 40% we have today since 2004. Great steps have been taken and the European Union has committed to become climate neutral by 2050. This means that the share of renewable energy will only increase until it is our only and main source of energy (European Council, 2023).

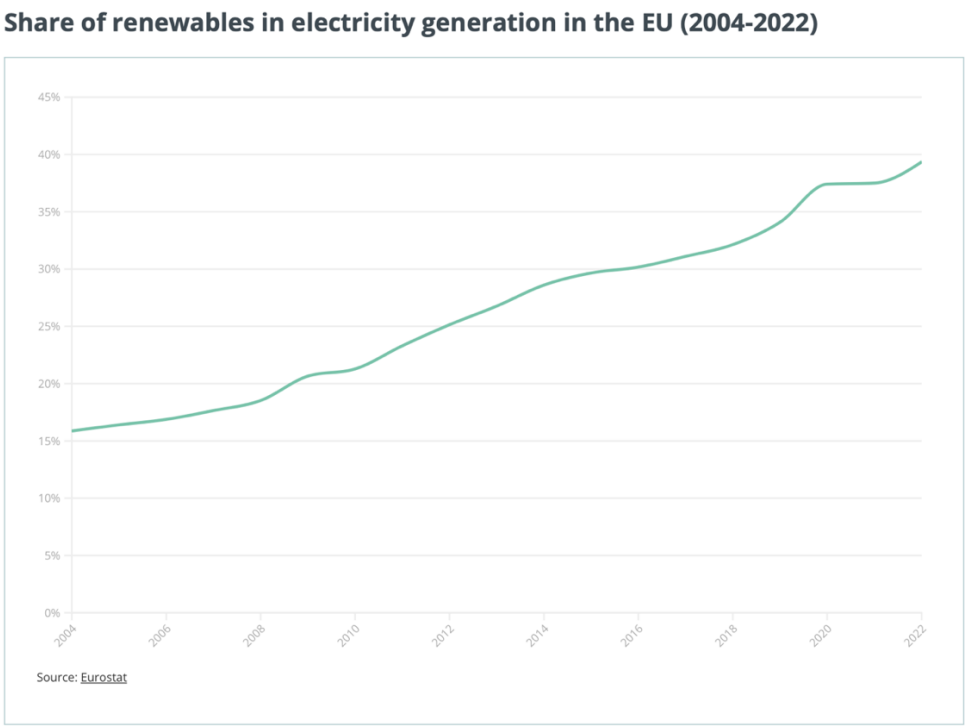


*Figure 3 Share of renewables in electricity generation in the EU (2004-2022) (European Council, 2023)*

Then there is also the issue on transporting and storing of energy.

To solve the problem on the charging docks, Volvo has recently launched a service in cooperation with other companies. This app will show truckdrivers where the closest charging docks are, and they will be able to prebook timeslots. For now, this app only works within Sweden, but plans are to deploy the app in the rest of Europe as well. This

app, in combination with building 130 new charging points in Sweden will make electrical transport way easier and reliable (Volvo, 2023).

The main issue with switching to green trucks is that the hydrogen fuel cells are hard to transport and charging an Electric Vehicle takes quite a long time. Additionally, the EV's have a limited range meaning they need to stop more often than trucks with conventional engines. For example: Scania made an EV with a range of about 350km depending on weight. This is the main breaking point for many drivers and company owners. The steep price of an electric truck in combination with the limited range and limited charging points and long charging times make it not financially interesting for now. (Yle Svenska, 2023) On top of that, truck drivers are legally allowed to drive four and a half hours before they need to take a 45-minute break (Rijksoverheid, 2022). It makes the whole situation very complicated for company owners when deciding on what new truck to buy (Yle Svenska, 2023).

According to the IRU, the European Union is short of 100,000 parking spots to meet the demand of how the current situation is. At this moment, there are "only" 300,000 parking spots across the entire Union. To make the situation even worse, only 7,000 of those areas are considered safe. That is less than 3%. (IRU, 2022) To counter this problem, the European Commission has approved 100 million euros in CEF funding. CEF is the "Connecting Europe Facility" program that aims to give Europe better and more infrastructure. The idea is that about every 100 km there should be at least one SSTPA along the TEN-T road networks. When this project is fully finished is not clear at this moment (IRU, 2021). To solve the problem on the charging docks, Volvo has recently launched a service in cooperation with other companies. This app is supposed to show truckdrivers where the closest charging docks are, and they can prebook timeslots. For now, this app only works within Sweden, but plans are to deploy the app in the rest of Europe as well. This app, in combination with building 130 new charging points in Sweden makes electrical transport way easier and reliable (Volvo, 2023).

# 3 METHOD

In the following part, the method used for this study is covered. There is a wide array of different research methods available to conduct a well-executed study. These can range

from interviews to case studies and just document analysis. It is up to the researcher to determine what method to use as they all have their pros and cons. Regardless of that, some methods just do not fit completely with the specific research conducted. (Bryman & Bell, 2011) For example: an interview in this paper was not optimal so that is why different methods were employed.

The main purpose of this work is to how the different possibilities we have as a society. That is why the chosen method is the qualitative one. Analysis has been based on available documentation provided by the European Union and Volvo. To get an even better understanding of the found information and results, a swot analysis has been chosen to get a more detailed answer to the research question.

## 3.1 Choice of method

This whole study has been conducted by doing research using secondary research on existing sources, this is in combination with the SWOT analysis, makes it multimethod research. (Bryman & Bell, 2011) This research is done inductive: meaning that a search for patterns has been conducted (Bryman & Bell, 2011). These patterns open the door to understand and create theories and conclusions. Considering that this study's aim is to get a better understanding in what options we have and what each of those pros and cons are, this is the best approach to this specific study. An interview was considered in the early stages of this research but was abandoned as there was enough information to be found. Meaning that the interview was not necessary.

While the study has been done in a qualitative setting, there are some quantitative elements that have been studied. These include emission standards and production numbers etc. However, this study still focusses on the events and is aimed at answering the "what, why and how" questions of the change towards green technologies and getting the climate carbon neutral.

## 3.2 Data sources

The data that has been chosen for this study comes from three main sides: manufacturers, EU legislation and academic sources. This was done as it gives a good mix to answer the research question to the fullest: academic sources set the theoretical framework, EU sets

the legal framework and the manufacturers put these two into reality. As mentioned before, this study is done using secondary research.

The main form of documentation in this case are public records. Public records are documents published by organizations such as reports, plans etc. The advantage of these records is that they are public as the name implies; meaning they are not confidential and thus easy to have access to. (Cornell Law School, 2022) The records used for this study include reports, laws, press publications and road maps made by the truck manufacturers and the European Union. While these organizations publish a big amount of these documents, useable data was relatively easy to find. This is mainly because of the organization within these institutes. Regardless of anything, the sources that are useable for this study must comply to four different criteria. This is to make sure that they are relevant. These criteria are as follows (Ahmed, 2010):

**Authenticity:** The documents need to be real, not manipulated and truthful.

**Representativeness:** The documents need to be representative for the study. This means that the evidence that can be gathered from the original source, should contain relevant information that is also typical for its kind.

**Meaning:** The sources should be clear to understand and comprehensible. This is important because the researcher needs to be able to understand what the sources say. The same counts for the people who read this study.

**Credibility:** The documents need to be from a credible source, meaning they should be trustworthy and be follow the standards set for neutral academic research.

In this case, following these four criteria was relatively easy. While searching for documents, the main manner of working went like this: check webpage or book, check date, check content, check author. Taking the example of EU legislation, it would have been like this:

Webpage: Is this an official website of the European Union or an institution of the EU?

Meaning: is what is being said easy to understand? Does the researcher know and understand the content?

Content/relevance: Does this page answer the research question? Is the information relevant?

Author: European Commission, is the website a secure and is it the website official?

If these four criteria get four yesses, then it is good to use as a source for this study. The same idea goes for academic sources and/or books. To get sources of even better quality, a fifth criteria was handed as well: date.
Date: Is there a date and if yes, is this the most recent one? If no, is this a page that gets updated frequently?

The data sources used for the study are presented down below:

*Table 1: Data Sources*

| # | Doc name | Doc type | Author | Relevance | Obtained from |
|---|---|---|---|---|---|
| 1 | Alternative fuels for trucks: A guide to the pros and cons. | Guide | Volvo Trucks | Truck manufacturer | https://www.volvotrucks.com/content/dam/volvo-trucks/markets/master/home/news/insights/articles/pdfs/2020/hydrogen-fuel-cells-all-your-questions-answered/Alternative-fuels-for-trucks-A-guide-to-the-pros-and-cons.pdf |
| 2 | Breakthrough for fast charging of electric trucks – Volvo trucks launches new service. | Article | Volvo Trucks | Truck manufacturer | https://www.volvotrucks.com/en-en/news-stories/press-releases/2023/oct/breakthrough-for-fast-charging-of-electric-trucks-volvo-trucks-l.html |
| 3 | Different routes to a fossil fuel-free future for trucks. | Article | Mårtensson, L | Truck manufacturer | https://www.volvotrucks.com/en-en/news-stories/insights/articles/2023/may/different-routes-to-a-fossil-fuel-free-future-for-trucks.html |
| 4 | Electric trucks - a complete solution. | Article | Scania | Truck manufacturer | https://www.scania.com/group/en/home/products-and-services/trucks/battery-electric-truck.html |
| 5 | Environment footprint calculator. | Calculator tool | Volvo Trucks | Truck manufacturer | https://www.volvotrucks.com/en-en/trucks/renewable-fuels/environmental-footprint/environment-footprint-calculator.html |
| 6 | First test for new solar-powered hybrid Scania truck. | Article | Scania | Truck manufacturer | https://www.scania.com/group/en/home/newsroom/press-releases/press-release-detail-page.html/4616759-first-test-for-new-solar-powered-hybrid-scania-truck |
| 7 | Green logistics: Improving the environmental sustainability of logistics (3rd ed.). | Book | McKinnon, A. C., Browne, M., Whiteing, A., & Piecyk, M. | Professor Logistics Kühne University | / |
| 8 | New Fuels SWOT Analysis | Analysis | International Chamber of Shipping | Shipping organisation | International Chamber of Shipping. (n.d.). New Fuels SWOT analysis. https://www.ics-shipping.org/wp-content/uploads/2022/01/New-Fuels-SWOT-analysis.pdf |
| 9 | Renewable fuels. | Article | Scania | Truck manufacturer | https://www.scania.com/group/en/home/innovation/technology/renewable-fuels.html |
| 10 | Volvo delivers 74-tonne electric truck. | Article | Volvo Trucks | Truck manufacturer | https://www.volvotrucks.com/en-en/news-stories/press-releases/2023/jun/volvo-delivers-74-tonne-electric-truck.html |
| 11 | Volvo presents electric trucks with longer range. | Article | Volvo Trucks | Truck manufacturer | https://www.volvotrucks.com/en-en/news-stories/press-releases/2023/jun/volvo-presents-electric-trucks-with-longer-range.html |

## 3.3 Research approach

After having found suitable sources, they were analysed in terms of topics and keywords that were relevant to the study. The results that came forth out of these sources were then compared to each other, trying to find out what the general trends were in terms of approaches taken by the manufacturers. Not only the general trends were analysed, also the different approaches between manufacturers were part of this research. Additionally, legislation and infrastructure were taken into consideration. It was important for this study to make sense, that the info gathered from truck builders was in accordance with the legislation that is current today.

When it comes to the SWOT analysis, multiple tables have been created corresponding to each alternative to fossil fuels. This gives an open and clear view of the strengths, weaknesses, opportunities and threats of these new fuels. The information for both approaches were sourced from manufacturers' reports, press articles and technical data sheets. Besides those, sources from the European Union were utilized in this study as well. For reliability's sake, the chosen sources are always the most up to date ones. This

is incredibly important as the material covers new technologies and laws etc. These tend to change easily.

## 3.4 Analysis of the data

Analysis of the data is done by a qualitative thematic analysis approach. This method is chosen as it was the purpose of the analysis is to discover trends and patterns within the documentation. (Bryman & Bell, 2011)

The chosen approach is the template analysis. The first stage of this approach is the coding stage. In this stage, themes that could be relevant for the study are examined and analysed. This can be adjusted later if needs be. The second stage is when similar themes get grouped. These groups get related to each other. Out of this work so far, it is possible to make a first template. Now that the template has been designed, it is possible to expand on it with more data. As long as the study is ongoing, it constantly gets revised and changed. This is a process that keeps repeating itself. The last phase of this approach is finishing up. Technically speaking this template can constantly get changed as previously stated so this part is up to the researcher. The most important part however is that the study the template covers, has enough and correct information. Meaning that the researcher should have enough info and cannot just call it a day halfway through. (University of Huddersfield, n.d.) To get to the actual analysing part, a table was used to be able to get a good overview of the available information that was gathered. This first glance of the available data was good first step into expanding on that information and eventually the study as well. The thematic analysis can be found at the end of this study as Appendix 1.

The second method used in this study is the SWOT analysis. This method is used to visualise the results that found using the thematic analysis. A SWOT analysis is a method that relies on a table that shows the strengths, weaknesses, opportunities and threats of the chosen topic. (Queensland Government, 2022) Via this way, a plan of action can be made for the future. Plans to minimise weaknesses etc. can be made early on enough as well (Queensland Government, 2022). In this case, this table shows all the different aspects to alternative fuels.

## 3.5 Validity and reliability

Validity and reliability in studies likes these are of incredible importance. Validity in short is that a measurement of a concept should really measures that concept. This means that data should answer the research question and provide the information asked for by the study. (Bryman & Bell, 2011)

Reliability, while it almost sounds like a synonym of validity, is something different. Reliability is the idea that a well performed study should be able to be recreated with similar results in the future with a similar methodology. If this is the case, then a design of the study can be considered as being reliable. (Bryman & Bell, 2011)

There could be some issues that might arise using this method and criteria. While it is easy to see when a document has been published and by who, it might be harder to ensure their credibility. In the end these kind of documents (from manufacturers and the government) can show a better situation than reality really is. Car manufacturers, in this case truck manufacturers, have the tendency to put the lowest emissions on their vehicles for example. And while they most likely are not lying, those emissions are achieved in very specific circumstances. The same counts for the electric vehicles' range, this is also often the "record" range. So yes, while they are not lying, there is some kind of bias going on towards their own product. The numbers on paper are not always the same in practice. When talking about relevancy, these technologies and legislature tend to change rather quickly. This means that something that could be "it" last week, could already be out of date next week. Considering this, it can be hard to find the latest info that complies to the latest rules.

## 3.6 Ethics

Ethics, as defined by Merriam-Webster, "are a set of moral principles". (Merriam-Webster, 2023) This means that these define what is "good and bad". If these are transferred to research, they refer to the ethical principles that should be used when conducting research (University of Stirling, n.d.). For example, interviews need to be taken with consent, you cannot let personal bias come through etc.

The main issue that could have arisen during this study was influence from the manufacturers or being biased towards certain aspects of this work. The way results are presented could favour one company over the other or anything related. This however would be highly unethical and is not the case. When talking about the issues presented in this work, none of the companies mentioned has had an influence on this study. Everything that has been covered was found in the public domain and analysed without help from who published said documents. This study is the effort of objective research without any form of personal opinions.

# 4 RESULTS

In this chapter, the results of the research done beforehand is analysed and grouped into their corresponding SWOT analyses. These tables give a throughout idea of the pros and cons of the above-mentioned alternative fuels for trucks in existence.

## 4.1 SWOT analyses on green technologies

To answer the research question stated above, different SWOT tables were used to give an as accurate as possible view of the different alternatives mentioned in the theory chapter. Additionally, their different strengths, weaknesses, opportunities and threats are examined. By using a SWOT table, the results are structured in a transparent and open way.

### 4.1.1 Electricity

The first SWOT table that has been examined is about electricity. This is also the main route that the majority of truck manufacturers take. The reasoning behind this is that electric vehicles can offer a sustainable choice. This is a combination of zero emissions, quiet trucks and cost-effectiveness throughout their lifetime. Additionally, there is the fact that electrical trucks need less maintenance than diesel trucks.

However, they also face some challenges in terms of implementation. For example, electric vehicles are heavier than regular diesel vehicles are because their batteries are so heavy. Talking about batteries, the production is incredibly bad for the environment. Batteries require minerals like for example lithium and nickel and these can only be

mined. Anyway, this increase in weight also influences the tires as they wear out faster. Another problem that the current generation of batteries have is that their range is limited, and this is a big downside when doing long distance transport. This being said, an EV is only truly electric when the origin of the electricity is generated from a green source. Other issues are that EV's have a decreased efficiency during winter times and charging the trucks can take quite a long time even though improvements have been made. These are all challenges that can made companies think twice before buying electric trucks.

When it comes to the opportunities, the technology is only improving year by year, just like the needed infrastructure (charging docks, etc.) is being rolled out continuously. While the production might not be entirely carbon-neutral, the overall lifecycle of electric vehicles emits considerably lower emissions than regular vehicles. In that way, electric trucks certainly are an improvement when it comes to climate change.

The main threat for electric vehicles is the range, as it is just not commercially viable nowadays. Trucks need to get recharged every 350-450 km (depending on weight, drive style, etc) or so. Additionally, there is the issue that electric vehicles can be a fire hazard and when they catch fire, they are incredibly hard to extinguish. Another problem is limited availability of charging points for trucks. Even though the network is expanding, there are still too little charging points for all trucks and regular transport to effectively charge them all. Moreover, electricity is often produced offshore and/or in remote areas. This means that electricity can have the disadvantage of having to travel long distances to the end-consumer. Storing electricity for longer periods of time is also quite hard.

*Table 2: SWOT electricity*

| **Strengths** | **Weaknesses** |
|---|---|
| - Zero emissions<br>- Quiet<br>- Lower costs during lifetime<br>- Less maintenance | - Heavy batteries<br>- Production of batteries is not sustainable.<br>- Limited range<br>- Green sourced electricity<br>- Reduced efficiency during winter<br>- Longer charging times<br>- Tires wear out faster<br>- Hard to store for longer times |
| **Opportunities** | **Threats** |
| - Technology is only getting better.<br>- More charging points are being build.<br>- Production of energy is not carbon-neutral, but lifecycle is. | - Needs recharging every 350-450 km.<br>- Not enough charging points<br>- Fire hazards<br>- Needs transport infrastructure (high voltage lines etc) |

### 4.1.2 Green hydrogen and LNG

Two other alternatives that can be used for trucks are green hydrogen and LNG. Green hydrogen has the big advantage that it exists of one the elements which is most common, and it produces no CO2 or NOx. Additionally, there is the fact that it has the same benefits as electricity-based trucks. In contrary to electricity however, green hydrogen just like regular hydrogen does not have the same big impact on the power grid as electricity does. Another advantage is that green hydrogen is not toxic. On the other hand, green hydrogen is incredibly expensive and the infrastructure to produce green hydrogen is not developed at all. Countries are investing in this infrastructure, but it will take quite a long time still. This in combination with the new technology needed to produce it, explains the price tag. Trucks that are fitted with hydrogen fuel cells cost about 800,000 to 1 million euros for example, a way steeper price tag than conventional trucks. This means that it is not commercially viable to invest in new infrastructure now. In comparison to other fuels or LNG, green hydrogen has less energy stored yet it requires more volume to store it. This makes it even harder to make it commercially viable as one needs more space. Regardless of all this, green hydrogen is also incredibly flammable so it is possible that the public opinion views it as dangerous, meaning it will be hard to convince people and step over onto green hydrogen completely.

When looking at LNG, it is also widely available, but it is also a fossil fuel. However, LNG has less emissions than diesel has. In order for trucks to be LNG compatible, they need to have special tanks installed to store it. While it is not a difficult modification, it is of course additional money for the owners. Nowadays, the LNG network is still quite limited, but it is growing and being developed at fast rates. The biggest advantage however over electricity driven vehicles is that LNG powered vehicles can travel farther.

*Table 3: SWOT Green hydrogen and LNG*

| **Strengths** | **Weaknesses** |
|---|---|
| Green hydrogen<br>- Fully carbon free<br>- No emissions<br>- Most abundant chemical substance<br>- Not toxic<br>LNG<br>- Widely available<br>- Lower emissions than diesel | Green hydrogen<br>- Explosive<br>- Lower energy in comparison to LNG<br>- Higher storage volume<br>- High cost<br>- Very new technology so no experience with it yet<br>LNG<br>- Is a fossil fuel.<br>- Additional tanks needed for storage |
| **Opportunities** | **Threats** |
| Green hydrogen<br>- No well-to-wheel emissions<br>- Endless applications<br>LNG<br>- Trucks can travel further than EV.<br>- Network growing quickly | Green hydrogen<br>- Expensive infrastructure<br>- Early stages of development<br>- Safety concerns<br>LNG<br>- Limited network<br>- Expensive infrastructure |

### 4.1.3 Synthetic Diesel and Biodiesel

The following table goes into more detail about synthetic diesel and biodiesels. Synthetic diesel has the strength of being a direct alternative to traditional diesel, requiring no adjustments to existing infrastructure. Meanwhile, biodiesel offers a great eco-friendly option, creating a 65% reduction in CO2 emissions while maintaining the same performance that regular diesel has. Additionally, it is compatible with current infrastructure.

However, these strengths also come with their own weaknesses. Synthetic diesel main drawbacks are high costs, significant energy intensity and still has emissions of NOx.

Additionally, its production still relies on fossil resources. Biodiesel faces challenges when it comes to cold climates and it poses environmental issues, as it can degrade land and water over time.

Synthetic diesel offers low well-to-wheel emissions when the gas comes from green sources and its adoption requires no modifications to existing trucks. Biodiesel presents a cost advantage due to possible tax reductions and can be produced from readily available biowaste, making it a financially attractive and environmentally friendly option.

The threats for each are that synthetic diesel's emissions are influenced by the source of the gas and for synthetic diesel to be economical, one needs a balance of low gas prices and high oil prices. Biodiesel on the other hand has the threat that if one uses 100% biodiesel, vehicle costs become way higher than usual.

*Table 4: SWOT synthetic diesel and biodiesel*

| **Strengths** | **Weaknesses** |
|---|---|
| *Synthetic Diesel*<br>- Can be a direct alternative to diesel.<br>- No changes needed to infrastructure for storage etc.<br>*Biodiesel*<br>- 65% less CO2<br>- Same performance as diesel<br>- Works with existing infrastructure | *Synthetic Diesel*<br>- Expensive and Energy intensive<br>- Still emits NOx.<br>- Relies on fossil resources.<br>*Biodiesel*<br>- Incompatible with cold regions<br>- Degrades water and lands. |
| **Opportunities** | **Threats** |
| *Synthetic Diesel*<br>- Low well-to-wheel emissions if gas is from green source.<br>- No changes needed to truck.<br>*Biodiesel*<br>- Cheaper because tax reductions<br>- Can be made from regular biowaste | *Synthetic Diesel*<br>- Origin of gas influences emissions<br>- Relies on low gas prices and high oil prices to be viable.<br>*Biodiesel*<br>- 100% biodiesel = higher vehicle costs<br>- Expensive |

### 4.1.4 Bioethanol, Biomethane and Dimethyl Ether

Bioethanol is a fuel that can be derived from anything that contains sugar, and its production technology has been in existence since the 1930s. Biomethane is generated from organic waste as can achieve a reduction of 60% when it comes to CO2 emissions. Dimethyl Ether, while having only 8-10% less emissions than diesel, has low levels of NOx and particles.

While these are some good strengths to have, there are of course some weaknesses as well. Bioethanol for example needs significant amounts of land to produce the resources needed. This in turn creates high CO2 emissions during the production. Additionally, bioethanol is hard to use in cold climates. Biomethane is highly explosive and demands substantial organic material for production as well. Dimethyl Ether has a lower energy density than diesel has, requiring trucks to carry double the quantity if one would like to get the same performance.

Bioethanol presents significant growth opportunities and possible economic profitability through innovations. These in turn contribute to emission reductions. Biomethane, with emission reductions and growth possibilities also aligns with the environmental goals set. DME stands out for its potential to achieve the lowest well-to-wheel CO2 emissions and compatibility with diesel engines. This makes it a promising choice for cleaner transport. Bioethanol's use for more land can divert resources from food production away to fuel production. This combined with its low energy output compared to diesel/petrol engines and lack of needed infrastructure threatens its potential. Biomethane faces higher vehicle costs, limited electricity production and the need for extra infrastructure. DME's main threats are the limited infrastructure as well and its production capabilities.

*Table 5: SWOT Bioethanol, Biomethane and Dimethyl Ether*

| **Strengths** | **Weaknesses** |
|---|---|
| *Bioethanol*<br>- Can be made from anything that contains sugar.<br>- Technology has been around since the 1930s.<br>*Biomethane*<br>- Generated from organic waste.<br>- Reduction of 60% in CO2.<br>*Dimethyl Ether*<br>- 8-10% lower emissions than diesel<br>- Low emissions of NOx and particles | *Bioethanol*<br>- Needs a lot of arable lands.<br>- Production emits high numbers of CO2.<br>- Hard to use in cold climates.<br>*Biomethane*<br>- Highly explosive<br>- Needs a lot of organic material.<br>*Dimethyl Ether*<br>- Has only half the energy diesel has, so trucks need to take double the quantity |
| **Opportunities** | **Threats** |
| *Bioethanol*<br>- Large opportunities for growth<br>- Innovations = possible economic profitability<br>- Reduction of emissions<br>*Biomethane*<br>- Reduction of emissions<br>- Growth possibilities<br>*Dimethyl Ether*<br>- Can have lowest well-to-wheel CO2 emissions.<br>- Compatible with diesel engines | *Bioethanol*<br>- More lands used for fuel = less lands for food<br>- Produces less energy than regular petrol/diesel.<br>- Needs extra infrastructure.<br>*Biomethane*<br>- Higher prices for the vehicles<br>- Limited electricity production<br>- Needs extra infrastructure.<br>*Dimethyl Ether*<br>- Limited infrastructure and production |

# 5 DISCUSSION

The chapter discusses, examines, evaluates and presents the study's outcomes. The discoveries made during the research and their connections to both each other and the existing theoretical framework are shown. On top of that, the methodology is explored, considering its strengths and weaknesses along with considerations for alternative research methods that could provide more targeted results.

## 5.1 Discussion of results

With regards to the results, it became very clear that most manufacturers chose the path of electricity, even though electricity has a very limited range. Currently, the range is about 250-450 kilometres depending on load and driving style, etc. This means that range wise, electricity could work fine but charging the truck to full range again takes about an hour to 90 minutes. As a result, on a 9-hour workday, the driver loses about half an hour just waiting. The driver wastes time, and the company wastes money because a truck that is standing still does not generate revenue. 350km is about the same distance from Helsinki to Seinäjoki, or about a four-hour drive so it is just not worth the effort right now. Charging for an hour gives another issue: the truck is not alone on the road. According to the European Commission there are 6.2 million trucks in Europe, and they all need to get recharged at some point. Refuelling is easy and goes quickly so that is not really a problem. But if every truck needs to recharge for an hour, traffic might start to pile up quickly. In combination with the fact that there are too few parking spots for truck drivers and charging points are not available in big numbers for the thousands of trucks that pass by on a daily base, sounds like a perfect recipe for chaos.

The other alternatives seem to be having the same issues. These are not just limited to the electrical trucks. Either the truck has limited range but is emits lower or no emissions, or the range is there but then there are emissions. Of course, these are still lower emissions than driving with regular diesel. Then there is also the fact that some alternatives are either higher in costs and/or do not work as well in colder climates. These are all factors that are more or less important depending on the company. Additionally, a lot of the infrastructure is still lacking. Green hydrogen for example needs specialized infrastructure in order to work, it is not compatible with existing "fuel pumps". Trucks

need to get modified with the hydrogen fuel cells (either from the factory or afterwards) which increases the cost once again. Plus, as mentioned in the results chapter, one needs more hydrogen to get the same energy output than other fuels. Volume/energy output wise this is not great either. LNG is an example on how precious space on board a vehicle can be wasted: LNG canisters usually fill up most, if not all, space in the trunk of a car. Electricity is probably the easiest to transport as it is just connected to the power grid and does not necessarily need huge adjustments. However, this is for short distances, electricity transport over longer distances is a bit harder to organise. That is where the high voltage lines come in. The main problem with electricity is storing it however, and that is a question that engineers have been trying to solve for years now. It is possible to store electricity of course, it is just hard to store it for a longer time. Biodiesels are the easiest in terms of storage and transport: no modifications need to be made and they are compatible with existing infrastructure. Anyway, these kinds of factors are incredibly important when buying a new truck and it is most likely just easier and cheaper to buy a truck on fossil fuels now. Regardless of anything, what alternative green fuel to choose from depends on available capital and what the company needs in terms of performance etc.

Another issue that still needs to be tackled is the production of energy. The majority of the alternative fuels presented in this study are only green fuels when the production of their respective resources is green as well. Think about electricity production, right now 40% of the total energy production is actually green (European Council, 2023). So, while EV's and green hydrogen powered vehicles are green on paper, they are not necessarily so in reality. However, the production of energy is also in a transitional phase and the share of renewable sources is increasing.

One thing is clear: the CO2 levels need to get drastically reduced in order to avoid exceeding the 2-degree mark and, according to the report of the EU in the theory chapter (EEA,2022), the trucking industry in Europe is the biggest polluter when it comes to transport. This means that if there are ways to make scheduled transport over road greener and sustainable, we could already solve a part of the problem. While efforts are being made and alternatives are being rolled out, we are not there yet. However, these alternatives are being refined and perfected on a daily base so the problems they have right now will most likely get solved within a reasonable time.

Overall, the different manufacturers of trucks are working intensely to be able to meet the climate regulations set out by the EU. Making engines that are as efficient as possible was already a priority for them, but for different reasons. The main reasons were economical ones in the past: more efficient engines mean less fuel burn which in turn means more profit for the owner of the truck. While that is still the case, being climate-neutral is now a big priority as well. Anyway, this specific industry is highly interlinked with numerous factors. Think about lawmakers, manufacturers, clients, energy providers, resources, etc. While it is hard to make the whole supple chain climate-neutral at this point, efforts are being made from everyone involved.

## 5.2 Discussion of method

The method used for this study, secondary analysis of documents, worked really well. Documents were readily available and overall easy to find, and more importantly easy to understand. The sources used showed clearly what the current issues are, what needs to be done and what possibilities we have towards the future.

However, while the analysis of the available documentation surely was appropriate, it was probably also a good idea to have done some interviews. By conducting interviews with people who are experts on this matter, and who are in close relation to the actors investigated in this study, more results would probably have been found. Not only this but the theory would have had to possibility to be better understood on a deeper level. On the other hand, it is fair to assume that the information that is not readily available is most likely confidential.

Another approach that could have been a good track to follow, was to get in touch with trucking companies themselves. This could have given more insight and understanding in why they would opt for one alternative but not for the other. This could also be an interview, or a survey could work as well.

# 6 CONCLUSIONS

The original aim of this study was to understand what technologies are being developed in terms of alternative green fuels and what their strengths and weaknesses are. This aim was achieved by asking the following research question **"What are the strengths, weaknesses, opportunities and threats of the new green technologies being developed as an alternative to the current fossil technologies in scheduled road transport?"** To get these results, documents by law-making bodies and manufacturers were obtained and analysed. By analysing these documents, it was possible to deduct an answer to the stated research question and the aim of this study was achieved.

Research has shown that manufacturers of trucks are actively working on innovating and electrifying their vehicles. If electrification is not an option, then they are working hard on finding alternatives. As the EU updates the law around emissions frequently with new, tighter regulations, this could be hard to do. However, the studied manufacturers have shown that they are able to meet EU regulations time and time again, sometimes even exceeding EU regulations. This means that overall, these EU laws do not seem to be unreasonable to achieve.

Every alternative that has been presented in this study has its own limitations and opportunities. However, the main issues that keep returning with these alternatives are reliability issues, range issues, costs and infrastructure issues. Electricity for example has a limited range and green hydrogen is both expensive and needs extra infrastructure. There are also other perspectives of the alternative fuels to keep into consideration. Most alternative fuels are not 100% climate-neutral but just emit a smaller fraction of emissions in comparison to diesel. Additionally, the production of electricity is not always from a green source either, making it also not climate neutral.

Now, those teething problems are worked hard on by the manufacturers, and they keep improving the technology for the presented alternatives. All in all, the different players in this field are all working closely together on the road towards sustainability and climate neutral fuels. Considering how big of an industry this is, and how much needs to be developed, the transition is going relatively fast with new technologies and breakthroughs emerging quickly.

## 6.1 Limitations of the study

The whole study is an ever-changing one, meaning that this study could be out-of-date quite quickly. Some technologies are being developed right now and are yet too "young" to be relevant, yet this all evolves very quickly. Additionally, it could be that the results are limited by the author's own expertise on the matter. This whole work is based on multiple areas like laws, technology, manufacturers, etc. Additionally, the work is mainly based on information provided by truck manufacturers, meaning that it is possible that in-depth information was withheld as those could be company secrets. They decide what information is public and what information is not. The reason why the author chose to pick these sources, and not academic sources, is because the manufacturer's information is being updated almost daily and it thus the most up to date.

## 6.2 Suggestions for further studies

Considering how this is an ever-changing topic that gets updated almost daily, it would most likely make sense to redo this study after certain periods of time. During the study itself, new technologies emerged. This in combination with newly designed laws, makes it almost a necessity to redo this study every six months to keep up with the latest data and evolutions.

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# Appendix 1: Thematic analysis

| # | Title | Author | Year | Source type | Keywords | Results |
|---|---|---|---|---|---|---|
| 1 | Alternative fuels for trucks: A guide to the pros and cons | Volvo Trucks | 2020 | Guide | Alternative fuels, electricity, hydrogen, LNG, pros, cons, biodiesel, bioethanol, synthetic diesel, dimethyl ether | Pros and cons of each alternative fuel were covered. |
| 2 | Breakthrough for fast charging of electric trucks - Volvo trucks launches new service | Volvo Trucks | 2023 | Article by manufacturer | Electricity, range, recharging, charging docks, app, customer satisfaction | Volvo created an app that helps truck drivers locate charging docks. Helps with changing to electric trucks |
| 3 | Different routes to a fossil-free future for trucks. | Volvo Trucks / Mårtensson L | 2023 | Article by manufacturer | Electricity, hydrogen, alternatives, sustainability | Both electricity and hydrogen fuel cells are good alternatives to combustion engines and a great opportunity towards the future. |
| 4 | Electric trucks - a complete solution | Scania | Not determined | Article by manufacturer | Electricity, solution, regional transport, tailoring, emission-free | Technical details like range (370km at 40 tonnes and 260km at 64 tonnes) and power (270 to 450 kW) were covered. |
| 5 | Environment footprint calculator | Volvo Trucks | Not determined | Wheel-to-well emissions calculator | Emissions, electricity, hydrogen, diesel, wheel-to-well | Calculator showed the diffferences in production and lifetime emissions. |
| 6 | First test for new solar-powered hybrid Scania truck. | Scania | 2023 | Article by manufacturer | Hybrid, electricity, solar-powered, regional transport | Scania started testing this new truck that should be able to add another annual 5,000 kilometers on electricity, op top of the regular range on fuel. |
| 7 | Green logistics: Improving the environmental sustainability of logistics (3rd ed. | McKinnon, A. C., Browne, M., Whiteing, A., & Piecyk, M. | 2015 | Academic book | Green logistics, alternative fuels, electricity, sustainability, LNG, hydrogen, biodiesel, diesel, transport | Alternative fuels were mentioned, each with pros and cons, and explained in detail what they are. |
| 8 | New Fuels SWOT analysis | International Chamber of Shipping | Not determined | Analysis | Green hydrogen, SWOT | Analysis made by ICS about green hydrogen. |
| 9 | Renewable fuels | Scania | Not determined | Article by manufacturer | Renewable fuels, alternative fuels, biodiesel, hybrid, biomethane, electricity | Article shows different alternatives and how Scania develops the biggest range of engines that are compatible with alternative fuels. |
| 10 | Volvo delivers 74-tonne electric truck. | Volvo Trucks | 2023 | Article by manufacturer | Electricity, range, High-capacity transport | Volvo developed a 74-tonne truck that only needs one recharge and can run 12 hours a day. |
| 11 | Volvo presents Electric truck with longer range. | Volvo Trucks | 2023 | Article by manufacturer | Electricity, range, extra energy capability | Volvo developed a more powerful FL truck with a range up to 450 km by implementing new batteries with 42% extra energy capacity. |