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# **Cleaning and reuse of engine oil**

Assessing Waste Engine Oil Management: Exploring the Potential of Re-Refined Base Oil (RRBO) for Enhanced Sustainability at Volvo Trucks

Thesis within the bachelor's program Mechanical Engineering

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DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

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CHALMERS UNIVERSITY OF TECHNOLOGY  
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## **Abstract**

In the context of increasing environmental concerns, this thesis explores the management of waste engine oil at Volvo Trucks and evaluates the potential for implementing more sustainable practices, particularly through the adoption of re-refined base oil (RRBO). The study identifies significant gaps in the current management practices, including a lack of clarity regarding contracts with recycling companies and the fate of waste oil post-collection. Data was collected through surveys and field visits to workshops across Europe, revealing diverse waste oil handling practices. While many workshops demonstrate effective management, inconsistencies in procedures and financial arrangements raise concerns about the overall efficiency of waste oil recycling efforts. The findings emphasize the environmental advantages of utilizing RRBO, which can lead to a substantial reduction in carbon emissions compared to traditional incineration methods. However, the integration of RRBO into new engine oil formulations is contingent upon the practices of oil producers, necessitating further testing to ensure compliance with quality standards. This thesis contributes to the understanding of waste engine oil management within the automotive industry and provides actionable recommendations for Volvo Trucks to enhance its sustainability initiatives. By standardizing waste oil handling practices and exploring the use of RRBO, Volvo can lower its environmental impact and strengthen its reputation in a competitive market.

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## Table of Contents

<b>1. Introduction and background</b> .....	2
1.1 Problem description.....	1
1.2 The edge of knowledge.....	1
1.3 Expanding the edge of knowledge.....	1
1.4 Deliverables.....	2
1.5 Purpose and questions in focus.....	2
1.6 Limitations.....	2
1.7 Company Introduction.....	2
<b>2. Literature review</b> .....	4
2.1 Engine oil.....	3
2.2 Additives.....	4
2.3 Oil refining .....	4
2.4 Waste oil.....	5
2.5 Re-refined base oil (RRBO) .....	6
2.6 How waste oil is managed today by private owners .....	7
2.7 EU legislation regarding waste oil .....	7
<b>3. Method</b> .....	11
3.1 Survey.....	10
3.2 Field visits.....	10
3.3 Oil samples.....	11
3.4 Recycling companies.....	11
3.5 Re-refined base oil (RRBO) .....	12
3.5.1 Meeting with and RRBO Company 1.....	12
3.5.2 Meeting with Oil Company B and RRBO Company 2.....	12
3.6 Carbon footprint calculations.....	13
<b>4 Results</b> .....	15
4.1 Survey results.....	14
4.1.1 Survey results compiled from all markets.....	14
4.1.2 Survey results from Austria.....	16
4.1.3 Survey results from Denmark.....	16
4.1.4 Survey results from Finland.....	17
4.1.5 Survey results from France.....	17
4.1.6 Survey results from Germany.....	18
4.1.7 Survey results from Italy.....	18
4.1.8 Survey results from Norway.....	18
4.1.9 Survey results from Poland.....	19
4.1.10 Survey results from Sweden.....	19
4.1.11 Survey results from Switzerland.....	20
4.1.12 Survey results from United Kingdom.....	20
4.2 Waste oil management at workshops.....	21
4.2.1 Rejmes Lastvagnar.....	21
4.2.2 Borås Bil Lastvagnar.....	21
4.2.3 Volvo Truck Center Stora Höga.....	23
4.3 Results from oil samples.....	24
4.4 Meeting with Stena Recycling.....	24
4.5 Amount of waste oil.....	25
4.6 Carbon footprint.....	26
4.7 Total Energies and Tecoil.....	27
4.8 Oil Company B and RRBO Company 2.....	27

- 5 Discussion .....29**
  - 5.1 Reliability of survey.....29
  - 5.2 Total amount of waste oil.....29
  - 5.3 Carbon footprint analysis.....29
  - 5.4 Limit to group 3 RRBO.....30
  - 5.5 EPR framework.....30
  
- 6 Conclusion .....31**
  - 6.1 Evaluation.....31
  - 6.2 Recommendations.....32
    - 6.2.1 Waste management.....32
    - 6.2.2 RRBO implementation.....32
    - 6.2.3 Further investigations.....33

## **Executive Summary**

This thesis investigates the management of waste oil at Volvo Trucks and evaluates the potential of adopting more sustainable practices, particularly through use of re-refined base oil (RRBO). As sustainability becomes increasingly critical in the automotive industry, the effective handling of waste materials, such as engine oil, is essential for both environmental responsibility and cost-effectiveness. The current management practices at Volvo Trucks reveal a significant gap in knowledge regarding the fate of waste oil after collection. Workshops often lack clarity in their contracts with recycling companies and the following processing of the oil.

This thesis aims to broaden the understanding of waste oil management practices, regulatory frameworks, and the potential for integrating RRBO into new engine oil formulations. Through surveys and field visits to various workshops across Europe, data was collected on waste oil storage, collection practices, and financial arrangements with recycling companies. The findings indicate a diverse range of practices, with many workshops demonstrating a commitment to proper waste oil management, while others exhibit inconsistencies that could hinder recycling efforts.

The analysis highlights the environmental benefits of utilizing RRBO, which can significantly reduce carbon emissions compared to incineration. However, the ability to incorporate RRBO into Volvo's products depends on the practices of oil producers, necessitating further testing and validation.

In conclusion, this thesis provides valuable insights into the current state of waste engine oil management at Volvo Trucks and outlines actionable recommendations for enhancing sustainability practices. By standardizing procedures and exploring the integration of RRBO, Volvo can strengthen its commitment to environmental responsibility and improve its market reputation.

# 1. Introduction and background

In an era where sustainability and environmental responsibility are crucial, the management of waste materials has become a focus for industries worldwide. This thesis aims to explore the current management of waste engine oil within Volvo Trucks and the recycling processes employed by external companies. The primary objective is to evaluate whether Volvo Trucks can adopt more effective and sustainable solutions for handling waste engine oil, partially through the potential method of re-refined base oil (RRBO). In the following subchapter, the purpose, problem description, deliverables and limitations are presented.

## 1.1 Problem description

In today's society, the reuse of raw materials is extremely important. Therefore, Volvo Trucks wants to ensure that their waste engine oil is reused in the best possible way. In the current situation, a recycling/waste company collects the waste engine oil from the workshops. It is unclear if the workshops have a contract from Volvo or their own contract with the recycling/waste company. Volvo Trucks also does not know what happens to the waste oil after it has been collected. This might not be cost-effective, nor does Volvo Trucks know if this is good for the environment.

What Volvo Trucks know today is that the waste oil is being collected from their workshops by a recycling company. The new engine oil that Volvo sells is not recycled and that is also the case for most new engine oils on the market. This means that the information that Volvo Trucks currently have is extremely limited, and with this thesis some light will be shed in this area.

The ideal future would be that all the base oil, about 80% of the engine oil would come from RRBO. This would mean that all the oil that can be recycled would be recycled. It would also be ideal if this process was cost-effective. Another ideal scenario is that the RRBO process would be environmentally friendly and lower the carbon emissions compared to the current process.

The value of getting these questions answered will be huge as there could potentially be another solution which could be a lot better for the environment and/or cheaper. Even if there is no better solution available, the information could still be very useful as their current information about how the oil is handled is extremely limited. As Volvo Trucks workshops handle a lot of waste oil, a small amount of saving per liter could lead to a big saving in the end. For Volvo as a brand, it is also important to have a good reputation, and the increasing pressure of contributing to the environment is extremely important to the reputation of the brand. This means that even if the RRBO is more expensive it might be worth it anyway as the savings in carbon emissions could make up for the increased cost.

## 1.2 The edge of knowledge

In the current situation, a recycling/waste company collects the waste engine oil from the workshops. It is unclear if the workshops have a contract from Volvo or their own contract with the recycling/waste company. Volvo Trucks does not know what happens with the waste oil after being collected, whether it's good for the environment or if it's cost effective.

## 1.3 Expanding the edge of knowledge

With the current knowledge about how waste oil is handled today (see chapter 1.2), it is important that the knowledge is broadened for Volvo Trucks, as the current knowledge in this area is very

limited. There is also an opportunity that with new information a better decision of how the waste oil is handled could be made. The main goal of this thesis is to broaden the horizon for Volvo regarding their waste oil and how it could be handled. This includes finding out how the waste oil is handled at the workshops today, if there are any regulations that dictate how waste oil can be handled, approximately how much waste oil Volvo produces and what is needed to re-refine waste oil. Therefore, a big part of the thesis will be put into research and data collection.

## **1.4 Deliverables**

The deliverables will consist of different tasks that are important or have a set due date. These are but not limited to the planning report, literature review, summarization of the collected data from the workshops, summarization of the data collected from the current recycling/waste companies, analysis of RRBO, first draft of final report, completed presentation and completed final report. These deliveries will be important to follow so that the project will be completed smoothly and on time.

## **1.5 Purpose and questions in focus**

The purpose of the thesis is to study how the workshops handle waste engine oil today and how the waste oil is managed by the recycling company, to identify if Volvo Trucks can implement a solution with lower carbon footprint. Also to analyze if the waste engine oil Volvo's workshops handle can be used to make RRBO and if that's the case, if Volvo Trucks can implement some of the RRBO in their brand-new engine oil, mainly to make a more sustainable oil with the same quality as it has today.

## **1.6 Limitations**

Limits were set due to time restrictions and thus narrowing down the scope of the thesis. The following limitations were set for this thesis.

- The thesis will only consider Volvo Trucks.
- The thesis is limited to study waste oil management in Europe.
- The thesis will only involve evaluating the RRBO process as an alternative method within the context of sustainability and cost.
- The thesis will only discuss advantages and disadvantages with the solution.
- The thesis will use data provided by Volvo Trucks and Volvo Trucks workshops, complemented with data from other sources.
- Outside of the public report, a confidential report will be produced, providing Volvo with insights and recommendations.

## **1.7 Company introduction**

Volvo Trucks AB is a leading global manufacturer of heavy-duty trucks and commercial vehicles. They have built a reputation for innovation, safety and sustainability in the transportation industry. With their commitment to deliver high quality products they operate on more than 140 markets worldwide, providing solutions that meet customer needs. Volvo Trucks offers a wide range of vehicles designed for applications such as long-haul transport, regional distribution, construction and urban delivery.

## 2. Literature review

The literature that was reviewed mostly came from Volvo, but some other sources were also used.

### 2.1 Engine oil

Engine oil serves several critical purposes in the functioning of an engine. The primary function of engine oil is to lubricate moving parts in the engine. The purpose is to reduce friction between components, to prevent wear and to ensure smoother operation, to extend the engine's lifetime. Engine oil consists of 80% base oil and 20% additives, where the base oil comes from crude oil and the additives come from either organic or inorganic compounds. The additives are added to enhance the oil's performance and properties (see chapter 2.2)

The base oil is differentiated into five different categories. These are called group one, two, three, four and five. According to Noria Corporation (2021) the first three groups are refined from petroleum crude oil and are the main oils when talking about commercial grade engine oil. Group four base oils are full synthetic oils while group five includes all other base oils that are not included in the other groups. In this thesis group four and five will not be considered. Table 1 shows the different base oil groups and how they are divided into different groups. This shows for example that if a base oil is less than 90% saturated it is a group one base oil. Of the base oil that is made from crude oil, group three is the best due to it being the cleanest but also that it has the lowest viscosity. This means that it flows easier making it more fuel efficient in an engine, but it is also the most expensive. Group one is the worst oil since this has more contaminants and higher viscosity. This is due to group two and three having an extra refinement step, and for group three the extra refinement step is more complex.

Table 1: Table over the requirements for classification of base oil

Group	Saturates	(% Wt)	Sulphur		VI
			(% Wt)		
I	<90	and/or	>0.03	and	$80 \leq VI < 120$
II	$\geq 90$	and	$\leq 0.03$	and	$80 \leq VI < 120$
III	$\geq 90$	and	$\leq 0.03$	and	$\geq 120$
IV	PAO (Polyalphaolefins)				
V	All stocks not included in Groups I-IV and VI				

In this thesis the focus will be the engine oils VDS-4.5 and VDS-5 that are mainly used in the engines of Volvo Trucks. From a lecture given by an expert in engine oil at Volvo Trucks C. Frennfelt (personal communication, 22 January 2025) in Engine oil at Volvo Trucks, it's described that VDS-4.5 is classified 15W-40 or 10W-30 and is a multigrade oil that works well in both cold and warm temperatures. In 15W the "W" stands for "Winter" and number 15 indicates the oils viscosity at low temperatures, the lower the number the better the oil operates in cold temperatures. The 15W oil is suitable for cold climates because it can still flow well at low temperatures. The number "40" in 15W-40 indicates the oils viscosity at higher temperatures, meaning that the oil is thick enough to provide good lubrication at higher operating temperatures. The engine oil VDS-5 is classified with 5W-30, meaning that it can perform even better in cold climates in comparison

with VDS-4.5 and it's also thinner, which can lead to better fuel efficiency and lower engine drag. However, it may provide less protection under high temperature conditions.

## 2.2 Additives

Additives in engine oil play a crucial role in improving the performance and protecting properties of the oil. Their inclusion is important for ensuring optimal engine function and lifespan. The additives that play a key role in engine oil are as follows.

- *Detergents*: Detergents are additives that help the engine parts be kept clean by preventing formation of deposits.
- *Dispersants*: Dispersants are similar to detergents but are specifically designed to keep soot suspended in the oil.
- *Anti-wear*: Anti-wear additives form a protective film on the metal surfaces in the engine to reduce friction and wear during operation.
- *Extreme pressure (EP)*: Extreme pressure additives are used to prevent metal-to-metal contact by forming a protective layer on the surfaces.
- *Antioxidants*: Antioxidants prevent oxidation of engine oil and help to extend the life of the oil by inhibiting the chemical reactions that occur when oil is exposed to oxygen and heat.
- *Rust and corrosion additives*: Rust and corrosion additives protect the metal from rust and corrosion by forming a protective barrier on the metal surfaces, preventing rust from forming.
- *Friction modifiers*: The friction modifiers are used to reduce friction between moving parts, which improves fuel efficiency and reduces wear and tear.
- *Viscosity modifiers*: Viscosity modifiers help maintain the viscosity of the oil across a range of temperatures. It makes sure that the oil remains thick enough to perform well under different operating temperatures.
- *Anti-foam agents*: Anti-foam agents are used to reduce foam in oil that can lead to reduced lubrication efficiency.
- *Pour Point depressants*: Pour point depressants lower the temperature at which the oil becomes too viscous to flow, which is important in cold temperature.

Each of these additives plays a crucial role in ensuring the efficiency and performance of the engine oil (Pirro et al. 2016).

## 2.3 Oil refining

In engine oil, the base oil is primarily made by oil refining, the process goes as follows, an illustration of the path is seen in figure 1. The source of base oil is crude oil which is extracted from the Earth's crust. The crude oil is entered into an atmospheric tower that is used to separate crude oil into different fractions, based on boiling point. When the crude oil is heated it vaporizes and enters the tower, where it cools down and condenses. The base oil that is used in engine oil is a heavier fraction that is collected in the lower part of the tower. After the atmospheric tower the base oil undergoes further separation in a vacuum tower, this process allows distillation of the heavier fractions that couldn't be effectively separated in the atmospheric tower. The process in the vacuum tower results in high-quality base oil with specific viscosity grades. After the vacuum tower the base oil is transferred to an extraction process that removes undesirable components from the base oil. The next step is dewaxing, in this step the oil is cooled so that it crystallizes, and waxes can be removed which would otherwise affect the oil's performance at low temperatures, which in terms results in a fluid-based oil that is more suitable for cold weather. The last step in the refining

process is hydrofinishing, which improves the performance of the oil and ensures that the base oil meets the requirements for engine oil applications (Frennfelt, 2024).

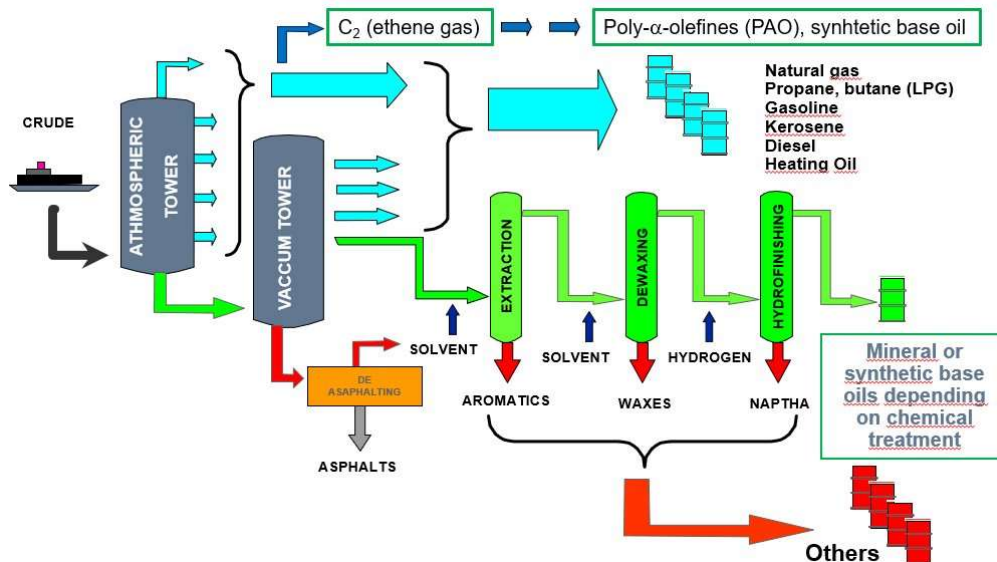


Figure 1: The path of oil manufacturing.

## 2.4 Waste oil

Waste oil is considered as hazardous waste because, in the long term it can cause harm too humans, animals and ecosystems. According to an article at Stena Recycling, a large portion of hazardous waste is used for energy recovery or waste disposal, but waste oil can be recycled into lubricating oil and fuel products (Stena Recycling, n.d).

In a publication from The Swedish Civil Contringencies Agency, waste oil is often an unknown mixture of different fluids (The Swedish Civil Contringencies Agency [MSB], 2013). This means that engine oil often is stored in a tank together with coolants, fuels and other kinds of oils, which makes it more difficult to recycle and reuse.

According to Vbolt Maskiner used engine oil contains toxic substances as polycyclic aromatic hydrocarbons that are carcinogenic, it also contains metal residues that come from wear in the engine. Waste engine oil has a different chemical composition than new engine oil, which makes it heavier (Vbolt Maskiner, 2020). Due to the pollution of waste engine oil it's even more important that it's handled correctly.

According to Gulf (Gulf, n.d) engine oil can be contaminated in two different ways. These are external and internal motor oil contamination.

Gulf (n.d) states that external motor oil contamination can be things like dirt and debris, water or incorrect oil. As the engine is well sealed off from the outside world it is not easy for dirt and debris to make its way into the engine. However, dirt and debris could enter the engine when the engine oil is changed, or the oil level is checked via the dipstick. It could also make its way into the engine from the air if the air filter is particularly dirty. Water vapor on the other hand is generated in the engine during the combustion process and can condense in the engine. This often happens in colder temperatures and if the engine is not allowed to heat up properly, for example if someone only takes short trips. Refilling the

engine with the incorrect oil is also a type of external motor oil contamination which could lead to a complete engine failure in the worst case. This can be refilling the engine with too low or high viscosity oil or the wrong quality of oil. Driving around with a for example to thin oil can badly damage the engine and lead to an engine failure if not addressed according to Gulf (n.d). Therefore, it is important to check that the right type of oil is used.

Internal motor oil contamination can be things like engine wear, fuel or coolant leak Gulf (n.d). Engine wear is hard to do anything about. Engine wear will always happen in an engine, and it is normal. However, it can be accelerated by not following the maintenance tasks like changing oil. Fuel can in some cases seep past the piston rings and make its way into the engine oil. This reduces the engine oils' viscosity which makes it less protective. If your head gasket is broken it can lead to coolant making its way into the engine oil. This then mixes with the engine oil and produces a thick sludgy mix. This can severely damage the engine so if a coolant leak is suspected it is important to fix the issue and change the oil afterwards.

For most cases the engine oil will be contaminated from mostly engine wear. This makes it important to regularly change the engine oil so that it still protects the engine as it should.

## **2.5 Re-refined base oil RRBO**

According to Lubrication Explained (2020) re-refined base oil refers to used lubricants/oils that have been processed to restore their properties so that a base oil is extracted and can be used again for its intended purpose. A used lubricant/oil is often extremely contaminated, and these contaminants change the properties of the base oil. Therefore, an oil refinement process needs to take place to make sure that the base oil is brought back to its original state. Today the technology to process lubricants/oils and make RRBO is better than ever. This means that the quality of RRBO is often just as good or even better than brand-new oil (Noria Corporation, n.d). According to Noria Corporation (n.d) tests were done with both RRBO and virgin oil and concluded that both oils were satisfactory and could be considered substantially equivalent.

The use of RRBO is very fairly limited today. Although, the use of RRBO is increasing due to both companies and consumers caring about environmentally friendly alternatives. This means that there is a big push towards expanding the refinement of RRBO.

The re-refining process is similar to the process of making base oil from crude oil. Although the starting point is not the same, the same goes for the process. The process usually consists of collecting waste oil. According to Lubrication Explained (2020) the cleaner and more consistent the oil is, the better. So ideally you would only collect engine oil or gearbox oil for a batch of RRBO. The next step is pre-treatment. Here the oil will undergo a process to remove large contaminants. Distillation is the next step which separates the oil into different fractions based on boiling points. The step after is hydrotreating which removes sulfur, nitrogen and other impurities as well as saturating the oil. The final step is finishing where the process depends on who is doing the re-refining and what the new oil will be used for. With these steps the oil goes from contaminated waste oil to a brand-new base oil that can be used for new lubricant/oils. A general cycle of RRBO is illustrated in figure 2.

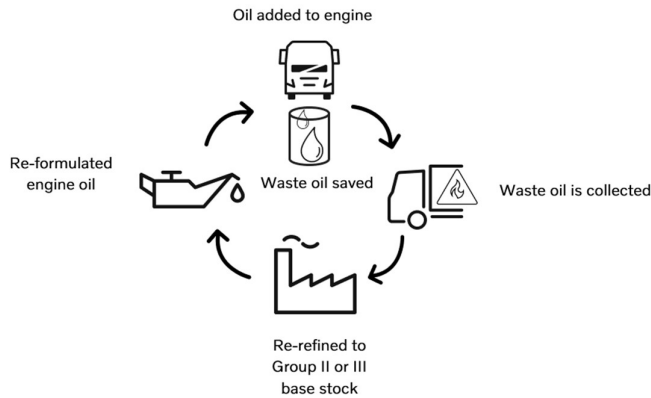


Figure 2: A general cycle of RRBO.

## 2.6 How waste oil is managed today by private owners

According to AutoZone (n.d) they state that waste engine oil is classified as dangerous waste. This in terms means that it needs to be disposed of in the right way. Their recommendation is that it should be put in a sealed package, preferably the original package. They also state that it is important to use a container that is made from polyethylene or another plastic that is suitable for containing the oil if the original packaging can't be used. After that, it should be handed in to a recycling center in the dangerous waste section. They also state the importance of not getting rid of the oil in an improper manner as this according to them could destroy million gallons of water. According to Stena Recycling (SR, n.d) and their article "Trygg återvinning av farligt avfall" it is important that as much waste as possible is reused. One of these waste products is waste oil. According to them it is important that the oil is not burnt but recycled and reused. According to them they also make sure that this waste oil is recycled, which is better for the environment.

## 2.7 EU legislation regarding waste oil

The Waste Framework Directive is the main law regarding waste oil and handling of waste oil (European commission [EU], 2008). According to EU the objectives in this law are the following: "The Waste Framework Directive requires EU countries to take measures to

- Treat waste oils in accordance with the waste hierarchy to protect human health and the environment
- Ensure waste oils are collected separately
- Ensure that waste oils with different characteristics are not mixed, and that waste oils are not mixed with other kinds of waste or substances that would impede their treatment" (EU, 2008).

The waste hierarchy, illustrated in figure 3, is a framework for waste management that prioritizes methods to minimize environmental impact and promote sustainability. It consists of five levels ranked from the most to the least desirable approach.



Figure 3: An illustration of the waste hierarchy.

*Level 1: Prevention.*

The best way to manage waste is to prevent it from being created in the first place.

*Level 2: Reuse.*

If waste cannot be avoided, the next option is to reuse items without processing them.

*Level 3: Recycling.*

When reuse is not possible, materials should be recycled.

*Level 4: Energy generation.*

If recycling is not feasible, waste can be burnt to generate energy.

*Level 5: Disposal.*

The least preferred option is disposing of waste, which in this case means burning the waste oil without energy recovery.

Everyone, including customers, industries, workshops, bears a responsibility to follow the waste hierarchy in waste management.

The waste oil that are relevant for the study (engine oil, rear axle oil, hydraulic oil and transmission oil) are allowed to be mixed if it doesn't impede their regeneration, but waste oil should always be separated from other hazardous waste such as coolant and fuel.

Waste oils are classified as hazardous waste, which means that they pose a greater risk to both the environment and to human health and therefore it requires a stricter control regime. To ensure safe management of waste oil the Waste Framework Directive provider record keeping, monitoring and control obligations and it bans hazardous waste to be mixed with other hazardous waste categories and with non-hazardous waste (EU, 2008).

EU countries have a responsibility for waste management and should take necessary measures to ensure that the companies collecting or transporting the waste oil delivers it

to appropriate treatment installations (EU, 2008). Extended Producer Responsibility (EPR) is a policy approach that holds producers responsible for the entire lifecycle of their products, including waste management. According to EPR, producers of oil products are required to manage the waste generated from their products, including financing the collection and recycling processes. Producers must establish or participate in collection systems that facilitate the return of used oil. This can involve collaborations with retailers or working with waste management companies to ensure that customers can easily dispose waste oil. The collected waste oil must be treated and recycled properly. This can involve re-refining the oil. Producers are then required to report on the quantities of oil they place on the market and the amount collected and recycled. Compliance with these regulations is monitored by national authorities, and failure to comply can result in penalties. The EU's EPR framework is intended to apply to all member states, the implementation and application of these rules have varied. Some countries have already established EPR systems and have active programs for managing producer responsibility, while others are still working to adapt their national laws and systems to meet EU requirements. The EU has set guidelines and goals to ensure that all member states eventually implement EPR principles, but the timelines and details may differ. Countries that have established EPR-systems is Germany, France, Sweden, the Netherlands and Belgium, but none of the countries have waste oil as a part of their EPR framework. The EU is continuously updating its waste management directives, and future revisions may include specific provisions for waste oil under EPR.

## 3. Method

A survey was conducted (see chapter 3.1) and was sent out to 14 markets in Europe, to be able to map out how the waste engine oil is currently handled. Simultaneously an interview with Rejmes ses chapter 3.2.1 took place. This was to ensure that the survey is not misunderstood. Two field visits took place se chapter 3.2.2 and 3.2.3. This was to get an understanding of how waste oil is handled at workshops today. The same questions were asked on these visits as with the survey, however, there were more detailed follow-up questions. When a sufficient number of answers had been collected from the survey, the answers were summarized and compiled. Next a meeting with the companies that currently handle the waste oil took place, which can be found in chapter 3.3.1. After this information was collected a research study took place to evaluate if it is possible to implement RRBO from Volvo's waste oil. Thereafter a carbon footprint calculation was made to compare the current solution to a solution with RRBO oil.

### 3.1 Survey

Since there was a strict time limit, a survey was conducted to get more information about waste oil management without making a lot of field visits. The survey was conducted with the purpose of collecting data from different Volvo Trucks workshops around Europe. It was sent to both Volvo Trucks centers and private workshops to see if the management differ in different type of workshops and in different countries. The following questions were asked.

- Please select the country your workshop is located in
- Please specify the workshop type
- How does your workshop store the waste oil?
- Is the workshop using the same container for all waste oil/fluids?
- What setup do you have with the waste/recycling company, collecting the waste oil from your workshop?
- Please provide the name of the company collecting the waste oil from your workshop.
- How often is the waste oil collected?
- How many liters of waste oil are collected each time?
- Do you get paid for every liter of waste oil collected?
- What happens with the waste oil collected from your workshop by a waste/recycling company?
- Do you agree to be contacted personally with additional questions?
- If yes on the previous question, please provide your email address.

The purpose of the questions was to get a clear picture of how the waste engine oil is managed from the moment it has been drained from the engine until it has been picked up by the recycling company.

### 3.2 Field visits

The field visits took place at three workshops. One Volvo Trucks center and two private owned workshops. The workshops were Volvo Truck Center Stora Höga, Rejmes Lastvagnar and Borås Bil Lastvagnar. With Rejmes Lastvagnar, there was first a Teams meeting and then a visit. These visits took place to see how they manage the waste oil and ask them questions similar to the questions in the survey. However, these visits serve the purpose of getting a good understanding of how they manage the waste oil in "real life" and to be able to ask more site specific questions.

At a few of the locations an oil sample was taken.

### 3.3 Oil samples

Two oil samples were collected, one at a private owned workshop and one a Volvo Truck center. This was to ensure that Volvo's waste oil meets the requirements. These oil samples were then handed over to Claes Frennfelt, oil specialist at Volvo who then passed the oil tests to a lab who conducted tests on them. With a hose attached to the pump used to suck up the oil see figure 4, it managed to extract the oil, and an oil sample was collected see figure 5.



Figure 4: Picture of the pump used to extract the oil.



Figure 5: Picture of the oil sample collected.

### 3.4 Recycling company

To evaluate the waste oil management after the waste oil is collected from a workshop a meeting with a hazardous waste specialist at Stena Recycling took place. Stena Recycling is a company specializing in waste management and recycling services. They are based in Sweden and are focusing on sustainable solution for recycling materials.

In the meeting the following questions were discussed:

- What methods do you use to collect oil from the workshops?
- How is the waste oil transported from the workshops to your facilities?
- What does the specific process of waste oil management look like?
- What steps are included in the process?
- Do you have a contract with a vacuum service?
- How is the waste oil stored at your facility before it is processed?
- Do you have any specific agreements/routines with Volvo workshops?
- Do you use specific systems/containers to facilitate the collection of oil?
- What is the risk of the waste oil mixing with other substances?

- Do you use the same tank when emptying drains as when collecting waste oil?
- If only half of the tank is filled at the workshop, is there a risk that the other half will be filled with something else before it is delivered to Stena?
- What methods are used to recycle the oil?
- Do you recycle the oil?
- Where do you recycle the oil?
- Is the oil you send for recycling mixed with other oil beforehand?
- How much oil do you send for recycling?
- How much of the oil can be recycled?
- What checks are made to ensure that the collected waste oil is of the right quality for recycling?
- What happens with the recycled oil?
- How do you handle waste oil that cannot be recycled?

### **3.5 Oil and Re-refined base oil companies**

The main goal with this subchapter is to identify the required quality of waste oil to make RRBO and to get a picture of what is required to implement RRBO into Volvo Trucks.

#### **3.5.1 Meeting with Oil company A and RRBO company 1**

The collaboration between Oil company A and RRBO company 1 in the production and re-refining of oil, is specifically focusing on the process of creating group 3 RRBO. Oil company A prominent global energy company dedicated to provide sustainable energy solutions. It is recognized as one of the leading companies in liquefied natural gas. RRBO company 1, a subsidiary of Oil company A, specializes in the production and re-refining of oil. RRBO company 1 is one of only two companies worldwide that produces group 3 RRBO. To gain insight into requirements and processes involved in the production of RRBO, a meeting was conducted with representatives from both Oil company A and RRBO company 1. This meeting provided valuable information regarding specifications that waste oil must meet to be eligible for re-refining.

#### **3.5.2 Meeting with Oil Company B and RRBO Company 2**

To gain a deeper understanding of the production process of re-refined base oil and the implementation of RRBO in feedstock by oil companies, meetings were conducted with representatives from oil company B and RRBO company 1. The discussions with these companies aimed to explore their respective approaches to integrating RRBO into their operations, as well as the challenges and opportunities they encounter in the process. Insights gained from these meetings contribute to a comprehensive understanding of the industry's practices regarding RRBO.

### **3.6 Carbon footprint calculations**

A carbon footprint calculation was conducted to compare the environmental impacts of re-refined base oil versus oil designated for incineration. This analysis involved several approximations necessary for a comprehensive evaluation. The processes for both scenarios were largely similar, with the exception of the final step. Re-refining established a circular process, allowing the same oil to be reused multiple times. However, it is important to note that losses occur during both utilization and re-refinement of engine oil. For instance, in the Volvo D13 engine, which contains 35 liters of engine oil, approximately 0,03% of oil is consumed per liter of diesel burned, leading to a loss of around 29% of oil with each use. This necessitates the addition of approximately 10 liters of oil between service intervals. Figures 6 and 7

illustrate the block schematics of the carbon footprint lifecycle for both re-refined and incinerated oil.

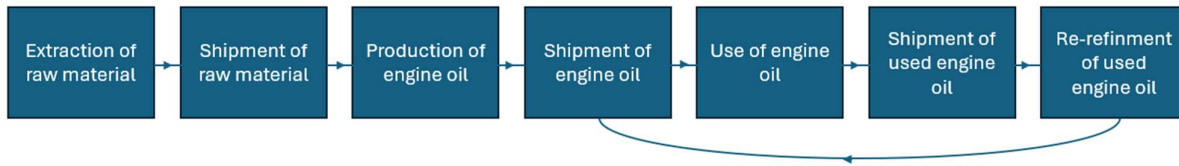


Figure 6: Block schematic of what is included in carbon footprint calculation of oil that is re-refined.

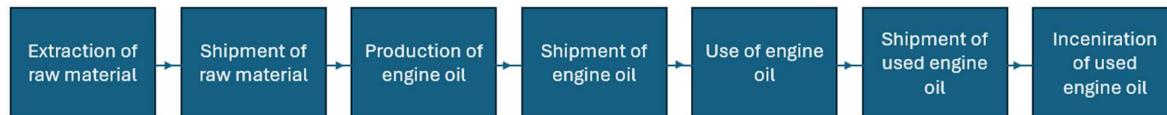


Figure 7: Block schematic of what is included in carbon footprint calculation of oil that is incinerated.

The initial components in the carbon footprint schematic are the same for both pathways, specifically from the extraction of raw materials to the refining process. To calculate the mean value of emissions during phase, data from figure 1 in the report by the International Council on Clean Transportation (2010), which analyzes crude oil supply and demand in Europe, was used. It involves three distinct categories, each characterized by a specific emission factor and corresponding volume. The emission factors considered are 6.5 g CO<sub>2</sub> eq./MJ, 14 g CO<sub>2</sub> eq./MJ, and 34.5 g CO<sub>2</sub> eq./MJ. The respective volumes for these categories are 6.4 million barrels per day (MMbbl/d), 6.4 MMbbl/d, and 0.3 MMbbl/d. The mean value was calculated as follows:

$$emissions = \frac{6.5 \cdot 6.4 + 14 \cdot 6.4 + 34.5 \cdot 0.3}{6.4 + 6.4 + 0.3} = \frac{41.6 + 89.6 + 10.39}{13.1} = \frac{141.55}{13.1} = 10.8 \text{ gCO}_2/\text{MJ}$$

Next, this value was converted from grams of CO<sub>2</sub> per megajoule ( $gCO_2/MJ$ ) to grams of CO<sub>2</sub> per liter ( $gCO_2/L$ ). This conversion began by calculating the energy value of crude oil per liter. The energy value of crude oil is approximately 35 MJ/kg, and its density is 0.9 g/L. Therefore, the energy value per liter is calculated as 31.5 MJ/L. To find the carbon dioxide emissions per liter, the energy value per liter was multiplied by the emission value, resulting in 315  $gCO_2/L$ .

EFDB (2025) shows that for incineration of waste oil an emission factor of 1024 kg CO<sub>2</sub> foss/ton can be expected. 1042 kg CO<sub>2</sub> foss/ton translates to 900 g CO<sub>2</sub>/L. This step will only apply to oil that is incinerated.

In a meeting with RRBO specialists at RRBO company 2 it was known that the process of RRBO saves approximately 30% of carbon emissions in comparison to incineration. That means that the process of RRBO saves 270  $gCO_2/L$ .

## 4 Results

A lot of data has been collected during this thesis and therefore there are also a lot of results. Firstly, the results of the survey that was sent out to workshops in Europe are presented. After that a value of how much oil Volvo handles are presented as well as calculated from the results of the survey.

### 4.1 Survey results

The Survey was sent to fourteen markets around Europe and resulted in 237 answers.

#### 4.1.1 Survey result compiled from all markets

The 237 answers that were collected is presented per country in Figure 8

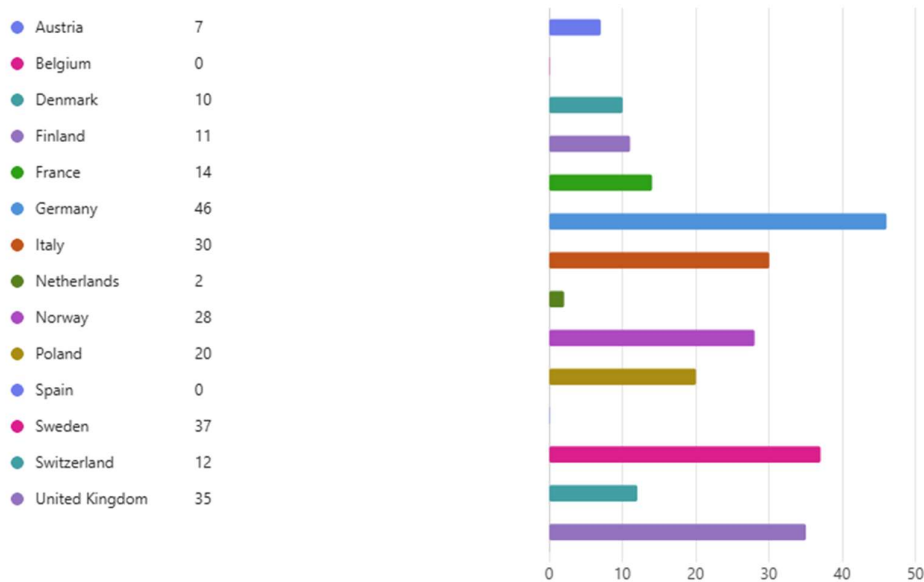


Figure 8: Diagram of how many answers from each county were collected

Of the workshops that answered the survey 84 of them were Volvo Trucks Centers and 153 of the respondents were privately owned workshops.

How the workshops store waste oil varies a bit, but 90% store it in a tank, 5% in a drum, 3% in an IBC and 2% has answered “Other”. Two of the workshops that answered “Other” store the waste oil in an underground tank which can be classified as a tank. One has answered that they store in a cistern which also is classified as a tank, and one has answered plastic tank that is classified as an IBC. The result of these answers is that many of the workshops store waste oil in tanks of different types.

On the question “Is the workshop using the same container for all waste oil/fluids?” 45% have answered that they store all waste oil in one container and that it is separated from other fluids, but 40% have answered that they store all waste oil and all waste fluids in the same container. 14% have answered that they separate waste engine oil from other waste oils and waste fluids and 1% have answered “Other”.

From the survey, it can be inferred that 67% have an own contract with a recycle company that collects the waste oil and waste fluids, 22% have a contract through Volvo

Trucks, 6% of the workshops that have answered the survey don't have a contract and the rest 3% don't know if they have a contract with a recycling company or what type of contract they have.

How often the waste oils are collected varies a lot, but mainly it gets collected once a month. This depends on the size of the container that the waste oil is stored in and how many oil changes that are made by the workshops, see the answers in figure 9.

7. How often is the waste oil collected?

[More details](#)

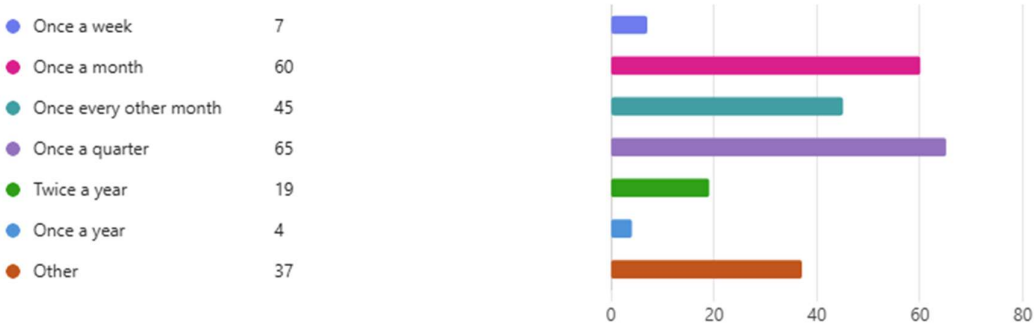


Figure 9: Survey answers of how often the waste oil is collected.

The amount of waste oil that is collected each time also varies, but the majority have answered that it is 1,000 – 2,000 liters or 2,000 – 4,000 liters, the result on the question is presented in figure 10.

8. How many liters waste oil are collected each time?

[More details](#)

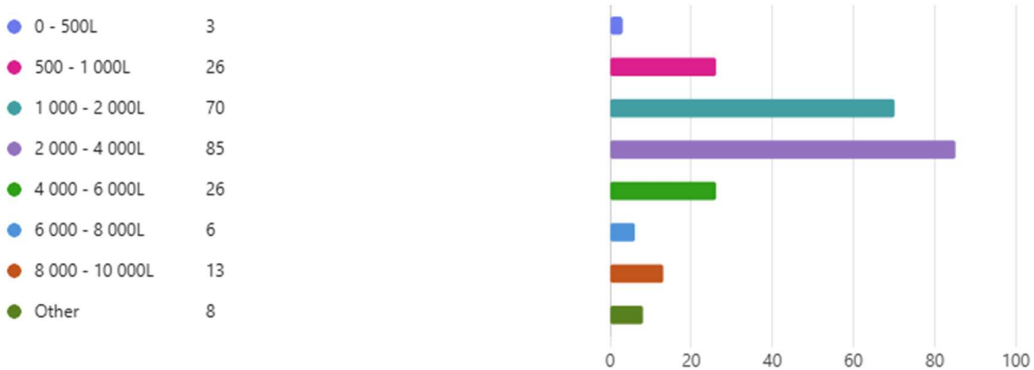


Figure 10: Survey answer of how many liters of waste oil that is collected each time.

If the workshops get paid for every liter of waste oil is also varying, see figure 11. There is no pattern in if they get paid or not, except for Poland. Every workshop in Poland gets paid for their waste oil even if they mix the waste oil with other fluids. From these results it is calculated that 38% of the workshops that separate the oil from other fluids must pay for it, 26% of those who separate the oil from other fluids get paid for it and the rest neither get paid nor have to pay. For the workshops that mix all fluids in the same container, 32% get paid for the waste when it is collected.

9. Do you get paid for every liter of waste oil collected?

[More details](#)

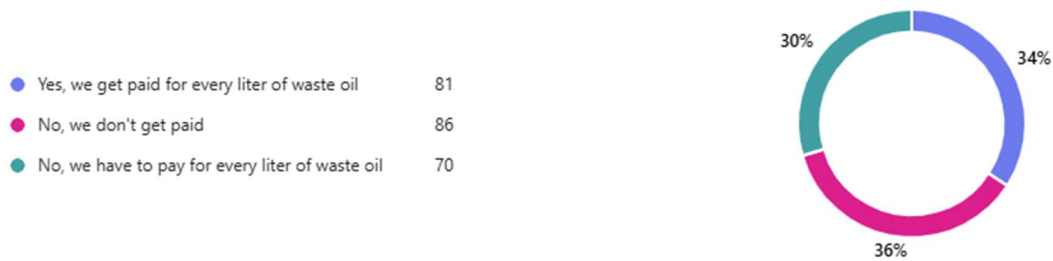


Figure 11: Survey answers of if the workshop get paid for every liter of waste oil collected.

### 4.1.2 Survey result from Austria

The survey conducted in Austria received seven responses, comprising four from Volvo Trucks Centers and three from privately owned workshops. All participating workshops reported storing their waste oil and fluids in designated tanks. When asked about the use of containers, three workshops indicated that they combine all waste in a single container, while four confirmed that they separate waste oil from other fluids. The arrangements with recycling companies vary, with some workshops lacking contracts, others having established their own contracts, and one workshop having a contract facilitated through Volvo Trucks.

The frequency and volume of waste oil collection differ among the respondents. Four workshops have their waste oil collected quarterly, with one workshop collecting a larger volume of mixed waste oil and fluids, while the others collect smaller amounts. One workshop reported biannual collections of a significant volume, another indicated bi-monthly collections, and the final workshop collects a smaller volume monthly. Notably, one privately owned workshop that mixes waste oil with other fluids reported receiving payment for every liter collected, while the remaining workshops incur costs for the collection of their waste oil and fluids.

### 4.1.3 Survey result from Denmark

The survey conducted in Denmark yielded a total of 10 responses, evenly split between five Volvo Trucks Centers and five privately owned workshops. All participating workshops reported storing waste oil in designated tanks. Among the respondents, most workshops have established contracts with recycling companies, while a few have contracts facilitated through Volvo Trucks. One workshop expressed uncertainty regarding their contractual arrangements.

The privately owned workshops reported the following practices: one workshop separates waste oil from other fluids, collecting a moderate volume quarterly without compensation. Another workshop combines all waste oil and fluids in a single tank, with bi-monthly collections of a similar volume, also without receiving payment. A third workshop separates waste oil, collecting a moderate volume each time the tank is full and receiving payment for every liter collected. Another workshop separates waste oil, with quarterly collections of a smaller volume without compensation. The final workshop separates waste oil, collecting a moderate volume monthly without receiving payment.

Regarding the Volvo Trucks Centers, one center stores all waste oil and fluids in a single tank, collecting a larger volume monthly without compensation. Another center collects a moderate volume every other month but incurs costs for disposal. A third center reports quarterly collections of a smaller volume without payment, while another center collects a moderate volume monthly without compensation. The final center separates engine oil from other fluids, collecting a specific volume when the tank is full, also without payment.

Most of the waste oil collected from workshops in Denmark is sent to Avista Oil for re-refining into Group 2 base oil.

#### **4.1.4 Survey result from Finland**

The survey conducted in Finland received a total of 11 responses, consisting of four Volvo Trucks Centers and seven privately owned workshops. Among these, most workshops reported storing waste oil in tanks, while one workshop utilizes an Intermediate Bulk Container (IBC). Several workshops have established their own contracts with recycling companies, while others have contracts facilitated through Volvo Trucks.

The Volvo Trucks Centers reported that they separate waste oil from other fluids. One center collects waste oil bi-monthly, with collections ranging from a few thousand liters, and receives payment for the waste oil. Another center also separates waste oil, collecting a smaller volume monthly but does not receive payment. A third center separates waste oil, with quarterly collections of a few thousand liters, receiving payment for the collected waste oil. The fourth center separates waste oil and collects a larger volume every few weeks, receiving payment for the waste oil.

Among the privately owned workshops, one workshop separates waste oil from other fluids, collecting a small volume monthly without payment. Another workshop collects a similar volume, with their tank emptied every other month, without receiving payment. A third workshop collects a larger volume quarterly and incurs costs for the waste oil collection. Additionally, two workshops separate waste engine oil from other fluids, collecting a small volume monthly and every other month, respectively, without receiving payment.

#### **4.1.5 Survey result from France**

A total of 14 responses were collected from France, consisting of 13 from privately owned workshops and one from a Volvo Trucks Center.

Most privately owned workshops either store all waste oil and fluids together or separate waste oil from other fluids. Notably, some workshops utilize IBCs for storage.

The workshops have contracts with recycling companies, with collection frequencies ranging from monthly to quarterly, and some even bi-monthly. A few workshops operate without any contracts. The volume of waste oil collected varies, typically ranging from 500 to 4,000 liters per collection, depending on the workshop's practices.

Payment structures differ significantly. Some workshops receive payment for every liter of waste oil collected, while others incur costs or do not receive any payment at all. Workshops that separate waste oil generally have more favorable financial arrangements.

In France, most waste oil is directed towards either re-refining into base oil or incineration for heat recovery.

#### **4.1.6 Survey results from Germany**

The data collected from various workshops and Volvo Trucks Centers in Germany reveals diverse practices regarding waste oil management and is summarized below.

Many private workshops store all waste oil and fluids in the same tank, while others separate waste engine oil from other fluids. The separation practices vary, with some workshops using dedicated containers for different types of waste oil.

Most workshops have their own contracts with recycling companies, with collection frequencies ranging from monthly to quarterly, and some even bi-monthly or twice a year. A few workshops do not have contracts at all.

The volume of waste oil collected varies significantly, typically ranging from 500 to 6,000 liters per collection, depending on the workshop's capacity and practices.

Payment structures differ among workshops. Some receive payment for every liter of waste oil collected, while others incur costs or do not receive any payment. Notably, workshops that separate waste oil often have better financial arrangements.

Several workshops engage in recycling practices, including re-refining and incineration for heat recovery. The methods of disposal and recycling are crucial for environmental compliance and economic viability.

#### **4.1.7 Survey result from Italy**

The survey conducted in Italy received responses from various workshops, including both privately owned workshops and Volvo Trucks Centers. All participating workshops reported storing their waste oil and fluids in designated containers. Among the workshops, some combine all waste oil and fluids in a single container, while others separate waste oil from other fluids. The arrangements with recycling companies vary, with some workshops having their own contracts, while others have contracts facilitated through Volvo Trucks.

The frequency and volume of waste oil collection differ among the respondents. Some workshops collect waste oil monthly, while others have collections every other month, quarterly, or even weekly. The volumes collected range from smaller amounts to larger quantities, with a few workshops receiving payment for every liter of waste oil collected. However, many workshops incur costs for the collection of their waste oil and fluids.

Notably, a few privately owned workshops that separate waste oil from other fluids reported receiving payment for their collected waste oil, while the majority do not receive compensation and instead face costs associated with waste oil disposal. The recycling methods employed by these workshops primarily focus on re-refining used oil.

#### **4.1.8 Survey results from Norway**

The survey conducted in Norway included responses from various Volvo Trucks Centers and privately owned workshops. All participating centers and workshops reported storing their waste oil in designated containers. Most workshops separate waste oil from other

fluids, while some combine all waste oil and fluids in a single container. The arrangements with recycling companies vary, with many workshops having their own contracts, while others have contracts facilitated through Volvo Trucks.

The frequency and volume of waste oil collection differ among the respondents. Some workshops collect waste oil monthly, while others have collections every other month, quarterly, or even twice a year. The volumes collected range from smaller amounts to larger quantities, with several workshops receiving payment for every liter of waste oil collected. However, many workshops incur costs for the collection of their waste oil and fluids.

Notably, a few privately owned workshops that separate waste oil from other fluids reported receiving payment for their collected waste oil, while the majority do not receive compensation and instead face costs associated with waste oil disposal. The recycling methods employed by these workshops primarily focus on re-refining used oil, with some workshops also utilizing incineration for heat recovery.

#### **4.1.9 Survey results from Poland**

The survey conducted in Poland included responses from various Volvo Trucks Centers and privately owned workshops. All participating centers and workshops reported storing their waste oil in designated containers. Most workshops separate waste oil from other fluids, while some combine all waste oil and fluids in a single container. The arrangements with recycling companies vary, with many workshops having their own contracts, while others have contracts facilitated through Volvo Trucks.

The frequency and volume of waste oil collection differ among the respondents. Some workshops collect waste oil monthly, while others have collections every two weeks, quarterly, or every other month. The volumes collected range from smaller amounts to larger quantities, with several workshops receiving payment for every liter of waste oil collected. Notably, many workshops reported receiving compensation for their collected waste oil, indicating a favorable financial arrangement.

The recycling methods employed by these workshops primarily focus on re-refining used oil, with several workshops actively participating in this process. Overall, the survey highlights a mix of practices regarding waste oil management among the Volvo Trucks Centers and privately owned workshops in Poland.

#### **4.1.10 Survey results from Sweden**

The survey conducted in Sweden included responses from various Volvo Trucks Centers and privately owned workshops. All participating centers and workshops reported storing their waste oil in designated containers. Most workshops separate waste oil from other fluids, while some combine all waste oil and fluids in a single container. The arrangements with recycling companies vary, with many workshops having their own contracts, while others have contracts facilitated through Volvo Trucks.

The frequency and volume of waste oil collection differ among the respondents. Some workshops collect waste oil monthly, while others have collections every two weeks, quarterly, or based on need. The volumes collected range from smaller amounts to larger quantities, with several workshops receiving payment for every liter of waste oil

collected. Notably, many workshops reported having to pay for the disposal of their waste oil, indicating a less favorable financial arrangement.

The recycling methods employed by these workshops primarily focus on re-refining used oil, with several workshops actively participating in this process. Overall, the survey highlights a mix of practices regarding waste oil management among the Volvo Trucks Centers and privately owned workshops in Sweden.

#### **4.1.11 Survey results from Switzerland**

The data collected from privately owned workshops and Volvo Trucks Centers in Switzerland reveals a diverse range of practices regarding the storage of waste oil. Most of these facilities utilize tanks for storage, although drums and IBCs are also employed in smaller workshops. Notably, five out of twelve workshops consolidate all fluids in a single tank, while the remainder separates oil from other fluids.

All workshops, except for two that are unaware of their arrangements and one that has an independent contract, maintain contracts with a recycling company through Volvo Trucks. The frequency of waste oil collection predominantly occurs quarterly, although one workshop schedules collections monthly, and two others do so every other month. The volume of waste oil collected varies significantly, ranging from 500 to 14,000 liters. The amount of waste oil present in the tank at the time of collection fluctuates considerably, with 2,000 to 4,000 liters being the most common volume.

Only two workshops receive compensation for their waste oil, and both of these facilities store all their waste fluids in a single tank. The remaining workshops do not receive payment for their waste oil, and two of them incur costs for its collection. Most workshops lack knowledge regarding the fate of the oil post-collection, with only four workshops being informed about its subsequent handling. Among these, three are aware of that the oil is recycled, while one workshop understands that it is utilized for incineration.

#### **4.1.12 Survey results from United Kingdom**

The data collected from privately owned workshops and Volvo Trucks Centers in the United Kingdom indicates that all facilities store their waste oil in tanks. Furthermore, it reveals that nearly all these workshops store their waste oil separately from other fluids, although all oils are stored within the same container.

All privately owned workshops have established their own contracts with recycling companies, while most Volvo Trucks Centers operate under contracts facilitated by Volvo Trucks. The frequency of waste oil collection is predominantly monthly, with a few workshops scheduling collections biannually or annually. The volume of waste oil collected varies between 500 and 10,000 liters, with most workshops providing the recycling company with approximately 2,000 to 4,000 liters.

Only four workshops receive compensation for their waste oil, while the majority do not, and a few even incur costs for its disposal. Notably, there appears to be no correlation between the practice of keeping oil separate and receiving payment for it. Approximately half of the workshops have their oil recycled, while the remaining facilities are uncertain about the fate of the oil after collection.

## **4.2 Waste oil management at workshops**

The workshops observed during field visits employ systematic procedures for managing waste oil.

### **4.2.1 Rejmes Lastvagnar**

Rejmes is an independent company having three workshops that are placed in Halmstad, Varberg and Falkenberg. At the workshop the waste oil is stored in a tank that holds approximately three cubic meters of fluid. In this tank they store engine oil, rear axle oil, gear oil and a small amount of hydraulic oil, but engine oil stands for approximately 90% of the volume. They keep fluids like coolant and brake fluid separate to the oil. They also keep fluids like diesel separated thanks to an old diesel tank from a truck that they use to store diesel in while they do the work. This means that they can empty the diesel into the old tank and keep it there while they work. When finished with the work, they can pour the diesel back into the tank of the truck which means that they don't have to waste any diesel.

They have a contract with Stena Recycling that manages the handling of the waste oil. This is regulated through a level sensor that is connected to the tank, where the data is sent to Stena Recycling, which in turn hires a vacuum service when the tank needs to be emptied. The amount of waste oil that is collected at a time is approximately 1500 liters, once a month. When the waste oil is collected at the workshop it is transported to Denmark where its taken care of.

### **4.2.2 Borås Bil Lastvagnar**

Borås Bil Lastvagnar is an independent workshop located in Borås, and with a new facility where the focus has been on fluid management, when the facility was designed and built. The engine oil is emptied from the engine to an oil barrel, see figure 12, it is then sucked up through an arrangement of pipes on the wall, see figure 13, to a cistern that can carry 8 cubic meter oil, see figure 14. A level sensor is connected to the cistern and is regulated by a panel on the wall, see figure 15. When the cistern needs to be emptied the workshop contacts a vacuum service company called "Lastbilscentralen" that collects the waste oil and deliver it to Stena Recycling that recycle the oil. The vacuum service collects 4,000 liters of oil every other month in a tank truck. Borås Bil Lastvagnar gets paid for the waste oil but in the end the collecting service and the management costs the company which means that it results in a cost for them.

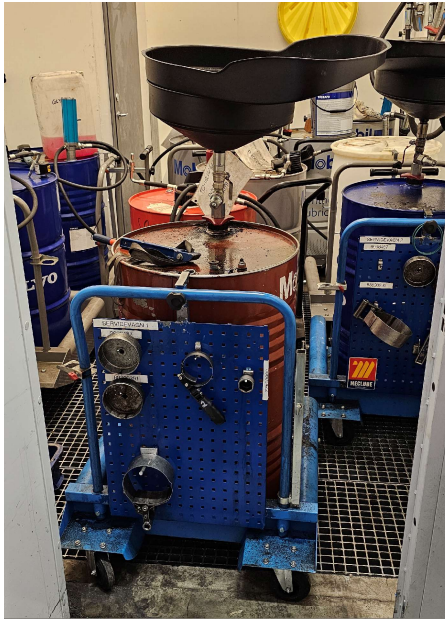


Figure 12: Oil barrel where the engine oil is collected after being emptied from the engine.



Figure 13: Arrangement on the wall where the engine oil is sucked up to the cistern.



Figure 14: Cistern where the waste oil is collected.



Figure 15: Panel where the level sensors are connected to.

### 4.2.3 Volvo Trucks Center Stora Höga

Volvo Trucks Center Stora Höga is a Volvo owned workshop located in Stora Höga. This workshop was built in 2014 which means it has modern equipment. They store all the waste oil in a tank that is about 8 cubic meters se figure 16. However, they do keep all other fluids like coolant in a separate container. To empty the truck of the oil, a movable oil barrel is moved under the truck so that the oil can be emptied into the barrel se figure 17. After this the oil is sucked from the barrel into the big tank. A level sensor is connected to the tank se figure 18. When this shows that the tank is starting to get full, they order for a pickup of the waste oil in the tank. The tank is emptied around 3 times per year, and it is often around 6-7,5 cubic meters of waste oil in the tank at that point. A rough estimate was given that it is around 60% of engine oil in the total amount of waste oil. Renova picks up the oil and manages everything from the pickup to the environmental report for them. The only thing that Renova does not pick up is the oil filters which Ragn-sells picks up. Volvo Trucks Center Stora Höga has their own contract with which company that picks up the oil and the other liquids. They also pay for the waste oil, pickup, and emptying of the truck that collects the oil as well as the environmental report which in turn means that it is a fairly big cost for them.

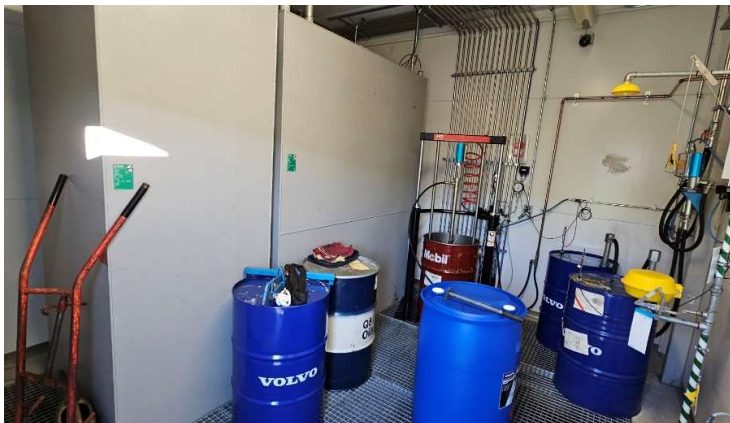


Figure 16: Tank where all the waste oil is collected.



Figure 17: Movable oil barrel.



Figure 18: Level sensors that inform when the tank is almost full.

### 4.3 Results from oil samples

The results from the oil samples, are highly favorable. All requirements are met, with most parameters exceeding the specified limits, with the exception of one criterion. The only parameter that does not meet the specification is the phosphorus content. The phosphorus value was too high. The diesel value was also very high but it is unclear if this is a problem.

### 4.4 Meeting with Stena Recycling

In a meeting with Dan-Inge Andersson, Product Specialist hazardous waste at Stena Recycling, he explained that waste oil is a great re-refine product because it's easy to re-refine if the waste oil is clean and not mixed with other waste fluids. A mix of different oils is not a problem since they are created from almost the same base oil and fulfill the same purpose of lubricating. These oils can be engine oil, gearbox oil, rear axle oil and hydraulic oil. However, some fluids will make the waste oil very hard to re-refine if there is even a small quantity of them in the oil. These fluids are brake fluid, washer fluid and glycol. Some fluids that make it harder to refine the waste oil but are not a big problem if there isn't a large amount of them, are diesel and gasoline.

It is common that there is a small amount of water in the oil, usually under five percent, since among other things condensation can occur in the engine. Hower, D-I. Andersson (personal communication, 28 February 2025) said that this is not a problem since Stena has their own way of getting rid of any water from the waste oil. This process includes letting the oil be in a container and letting the oil separate from the water. Since the oil has lower density, it will flow to the top which allows the water to be drained from the container.

D-I. Andersson also explained that Stena Recycling has four places in Sweden where they can store and remove the water from the waste oil. These places are in Gothenburg, Halmstad, Köping and Luleå.

D-I. Andersson explains that Stena Recycling quality tests all their deliveries of oil for water contamination to ensure that the oil is in an acceptable condition regarding how much water it is contaminated with. They do not do any further quality tests unless they suspect they received worse than usual contaminated waste oil. Since they can pick up oil from different workshops in the same drive the oil could be mixed before the oil reaches one of Stena Recycling facilities, that is why they ensure that the driver takes a sample of each waste oil they pick up. This way they can go back and see which workshop has delivered contaminated waste oil.

D-I. Andersson explains that Stena Recycling sends all their collected waste oil to Avista in Denmark. Avista then pays Stena Recycling for the waste oil and re-refines it to new base oil. The expert did not know more about what happened to the oil after it had been re-refined at Avista. Another interesting point the expert explained is that they get paid for the waste oil from Avista, but they would get more if they were to sell the waste oil as fuel oil for incineration. However, they do not do this with the oil that can be re-refined as they both have directions from the EU to recycle as much as possible and that it is worse for the environment. However, the oil that can't be re-refined is sold as fuel oil to cement companies.

#### **4.5 Amount of waste oil**

The volume of waste oil sold by Volvo was provided by M. Emanuelsson (personal communication, March 14, 2025). He detailed the quantities of various oils sold by Volvo across different regions in Europe during 2024, encompassing both buses and trucks. Given that most trucks and buses utilize similar engine types, they will be considered collectively. The total volume of oil sold by Volvo amounts to 25 million liters, which is categorized into engine oil, gearbox oil, and axle oil. Specifically, Volvo sells 17 million liters of engine oil, 5.2 million liters of gearbox oil, and 1.8 million liters of axle oil.

An assumption made in this analysis is that each engine undergoes a top-up of 10 liters of oil between oil changes, as some oil is consumed during operation. Additionally, it is assumed that 50% of customers opt for Volvo-branded engine oil for these top-ups. If we consider that a truck requires 35 liters of oil for filling and that the same amount is drained, it follows that Volvo generates an equivalent volume of waste engine oil to what it sells. However, not all of this waste oil will be from Volvo-branded products. Based on the earlier assumptions and the fact that the most common engine offered by Volvo is the 13-liter diesel engine, which contains 35 liters of engine oil, calculations can be performed to determine the proportion of waste oil attributable to Volvo-branded oil. The calculations are as follows:  $[\frac{17,000,000}{35} = 485,714, \frac{485,714}{2} = 242,857, 242,857 * 10 = 2,428,571]$ .

17,000,000 comes from the amount of engine oil Volvo sells in Europe and half of the calculated value is divided by two since an assumption is made that half of all the oil that is topped up is non Volvo oil. The calculations indicates that approximately 2.4 million liters of waste oil collected by Volvo's workshops is non Volvo-branded oil. Consequently, this implies that 14.6 million liters of waste engine oil will be classified as Volvo-branded waste oil.

K. Andersson (personal communication, April 9, 2025) provided insights regarding the production of engines in Skövde, where 3.1 million liters of engine oil are utilized to fill new engines. While Volvo is expected to have around 25 million liters of waste oil, it is important to note that there may be some loss of oil at various stages. Although each engine is filled with 35 liters of oil and topped up once between services, it is possible that not all 35 liters are drained into the waste oil container at the workshops. Some oil may be consumed during operation without triggering a warning light, potentially resulting in only 34 liters being emptied into the waste oil tank. Additional losses may occur during the collection process and through the pipes used for oil transfer. Furthermore, it is acknowledged that not all trucks are serviced at Volvo-authorized dealers; however, it is estimated that approximately 85% of Volvo trucks do utilize these services. Therefore, it is assumed that Volvo's workshops collect 75% of all waste oil, equating to 18.75 million liters of waste oil. This volume is sufficient to meet the initial fill requirements for the Skövde production facility.

From the survey conducted, the average amount of waste oil generated per workshop was calculated to be 25,426 liters per year. With 1,036 dealers in Europe, including 253 Volvo Truck Centers, this results in an estimated total of 26,341,336 liters of waste oil generated annually from dealers, of which 6,432,778 liters per year is sourced from Volvo Truck workshops.

#### **4.6 Carbon footprint**

The results indicate that while re-refinement can be performed multiple times, it is not an indefinite process due to inherent losses. According to an expert at RRBO company 1 71.4% of the oil sent to a re-refinery can be successfully re-refined, resulting in a loss of 28.6% during the refinement process. The initial components in the carbon footprint schematic for both re-refined and incinerated oil are identical, covering the extraction of raw materials to the refining process. By utilizing re-refined base oil, significant savings are achieved in terms of resource extraction and environmental impact. The re-refinement process reduces the need to extract new raw materials from the earth, thereby conserving natural resources and minimizing the ecological footprint associated with oil production. This circular approach not only decreases the carbon emissions related to extraction and refining but also contributes to a more sustainable lifecycle for engine oil. According to EFDB (2025), the incineration of waste oil results in an emission factor of 1,024 kg CO<sub>2</sub> foss/ton, which translates to 900 g CO<sub>2</sub>/L. However, discussions with RRBO specialists at RRBO company 2 revealed that the RRBO process saves approximately 30% of carbon emissions compared to incineration. This equates to a reduction of 270 gCO<sub>2</sub>/L, underscoring the environmental benefits of opting for re-refinement over incineration. The calculated carbon dioxide emissions per liter of crude oil were found to be 315 gCO<sub>2</sub>/L.

#### **4.7 Oil company A and RRBO company 1**

In the meeting with Oil company A and RRBO company 1, it was clarified that RRBO company 1, a subsidiary of Oil company A, specializes in the production of Group 3 Re-Refined Base Oil (RRBO). RRBO company 1 is one of only two companies globally that manufactures Group 3 RRBO, utilizing advanced technology. During the discussion, it was noted that the same waste oil can be processed to produce both Group 2 and Group 3 RRBO; however, the distinction lies in the production process. The manufacturing of Group 3 RRBO is more costly than that of Group 2 and necessitates the use of newer technology. Consequently, the limited number of companies producing Group 3 RRBO is attributed to the sustained demand for Group 2 RRBO. For Volvo Trucks, the demand for Group 2 RRBO is insufficient, as their products are formulated using Group 3 base oil.

A significant point discussed during the meeting was RRBO company 1 willingness to offer a premium for cleaner, less contaminated waste oil. There is a perception that Volvo's waste oil is of high quality, which is a promising indication that RRBO company 1 may be inclined to pay more for it. This suggests that if all workshops adopt a similar practice of segregating oil from other fluids, as seen in Finland, the waste oil from all Volvo vehicles could potentially be re-refined effectively. Notably, the oil used in the engines remains consistent across different countries. Additionally, it was noted that the combination of gearbox, hydraulic, automatic transmission, and engine oils does not pose a challenge for re-refining. RRBO company 1 reported achieving a high yield from the waste oil they process, with a yield rate of 71.4%. Given that engine oil comprises approximately 80% base oil and only the base oil can be re-refined, a yield rate of 71.4% is exceptionally high.

#### **4.8 Oil Company B and RRBO company 2**

During the meeting with Re-Refined Base Oil (RRBO) specialists at oil company B, it was discussed that oil company B is actively investing in RRBO production and operates its own facility. The specialists provided valuable insights into the operations of RRBO company 2. It was explained that RRBO company 2 sources its waste oil from various collectors. These collectors typically gather waste oil from workshops and transport it to refineries. In regions near the refinery, larger companies such as RRBO company 2 may establish their own collection networks to facilitate the acquisition of waste oil. Notably, these collectors do not perform any pre-cleaning of the waste oil, delivering it in its original state directly to the refinery.

RRBO company 2 tries to buy as high-quality waste oil as possible so that the cleaning process is as simple as possible. This means that they are willing to pay more for high-quality waste oil. A high-quality waste oil is a waste oil that does not have large amounts of contaminants in it like brake fluid, coolant and water. Preferably the oil should also be of group 3 base oil since this is the highest quality base oil. A high-water content is not a big deal in terms of re-refining however it significantly lowers the value of the waste oil RRBO company 2 does not want to pay for the water and therefore they will pay less if the waste oil contains a lot of water. To ensure that the waste oil they receive is of good quality they test the oil from each truck that delivers waste oil. Another aspect that determines the price is the competitions. And in the waste oil market there is quite a high competition since concrete businesses and other businesses want the waste oil as cheap fuel. The waste oil that RRBO company 2 receives comes mostly from workshops where 80- 90 percent of all oil they receive comes from oil that has a lifespan of around 6-12 months in use.

## 5 Discussion

The survey results reveal discrepancies in waste oil storage practices, highlighting potential misunderstandings due to language barriers. This necessitates clearer communication in future surveys. Additionally, the analysis emphasizes the environmental benefits of re-refined base oil over incineration, despite limitations in refinery capacity. The role of regulatory frameworks like the Waste Framework Directive and EPR is crucial, though inconsistencies in implementation persist.

### 5.1 Reliability of survey

The results of the survey reveal a significant discrepancy in responses to the question regarding: Is the workshop using the same container for all waste oil/fluids? A further investigation regarding some of the people who answered that they mix all fluids in the same container reveals that they separate the oil from other liquids like coolant. This means that it's very likely a lot more people that have misunderstood the question and have provided the wrong answer. It is essential to analyze the factors contributing to this misunderstanding, as they may have profound implications for the interpretation of the survey results. Possible reasons for the misjudgment could be wording of the answers and language barrier. For instance, these wordings and that the survey was only provided in English may have led respondents to interpret the question differently than intended, resulting in skewed data that does not accurately reflect the true sentiments or behaviors of the target population. Furthermore, the implications of these inaccuracies extend beyond mere data collection; they can affect decision-making processes, policy formulation, and the overall validity of the research findings. Therefore, it is crucial to address these issues and consider how they might be mitigated in future surveys.

### 5.2 Total amount of waste oil

The elevated calculations derived from the survey results may be attributed to several factors. Firstly, the survey collected responses from only 237 participants, which suggests that larger workshops may have disproportionately contributed to the results, potentially inflating the mean value. Secondly, it is possible that drivers are using non-Volvo oil in their engines, leading to workshops receiving oil that is not oil that is sold by Volvo. Lastly, the responses were provided within a range, and the calculations were based on the upper limit of that range, which could further contribute to the higher mean value.

### 5.3 Carbon footprint analysis

The analysis of re-refinement versus incineration of waste oil reveals important insights into the sustainability and efficiency of these processes. While re-refinement offers the advantage of multiple cycles of reuse, it is not without limitations. The process inherently results in losses, with 71.4% of the oil being successfully re-refined and a notable 28.6% loss during the refinement process. This highlights the need for continuous improvement in re-refinement technologies to maximize oil recovery and minimize waste. The carbon footprint schematic for both re-refined and incinerated oil shares common initial stages, from raw material extraction to refining. However, the environmental benefits of re-refined base oil are significant. By reducing the need for new raw material extraction, re-refinement conserves natural resources and minimizes the carbon footprint associated with oil production. This circular approach not only reduces carbon emissions related to extraction and refining but also supports a more sustainable lifecycle for engine oil. Comparatively, incineration of waste oil results in an emission factor of 1,024 kg CO<sub>2</sub> foss/ton, translating to 900 g CO<sub>2</sub>/L, according to EFDB. In contrast, insights from RRBO specialists at RRBO company 2 indicate that the RRBO process can save approximately 30% of carbon emissions compared to incineration, equating to a reduction of 270 gCO<sub>2</sub>/L. This

substantial decrease underscores the environmental advantages of re-refinement over incineration, making it a preferable option for waste oil management. Furthermore, the calculated carbon dioxide emissions per liter of crude oil stand at 315 gCO<sub>2</sub>/L, emphasizing the need for effective waste oil management strategies to mitigate environmental impact. The discussion highlights the importance of adopting re-refinement practices to achieve significant carbon savings and promote sustainability in the oil industry.

#### **5.4 Limit to group 3 RRBO**

An essential consideration for Volvo is the constraints affecting the production of Group 3 Refined Renewable Base Oils (RRBO). During the meeting with Oil company A and RRBO company 2, it was identified that the primary limiting factor is the availability of refineries. There are currently very few refineries globally capable of producing Group 3 RRBO. Consequently, a significant portion of the oil that could be utilized to produce Group 3 RRBO is instead allocated to the production of Group 2 RRBO and incineration. However, why more group 3 RRBO refineries are not built is unclear. What seems to be the main factor is economics. A refinery is a huge investment but the bigger the refinery the more sense it makes according to RRBO company 2. At the moment, some companies might not think it is worth the investment either upgrading their refineries or building a new one to produce group 3 RRBO.

#### **5.5 EPR Framework**

The waste framework directive serves as a base for waste management legislation within EU. By mandating that waste oils be treated according to the waste hierarchy, the directive safeguards the environment from the hazardous effects of improperly managed waste oils. The directive's requirements for separate collection and treatment of waste oil are vital in preventing contamination and ensuring an effective recycling process. The prohibition against mixing waste oils with other hazardous or non-hazardous wastes is particularly significant, as it helps maintain the integrity of the waste management process and enhances the potential for recycling.

Extended Producer Responsibility (EPR) is another critical aspect of the waste framework directive placing the onus of waste management on producers throughout the lifecycle of their products. This policy approach encourages manufacturers to take responsibility for the waste generated by their products, including financing collection and recycling efforts. The requirement for producers to establish collection systems and report on their waste management encourage proactive measures in waste oil management. However, the implementation of EPR principles has been inconsistent across EU member states, with some countries leading the way while others lag behind. The ongoing updates to the EU's waste management directives signal a commitment to improving waste oil management, and future revisions may further enhance the role of EPR in this context. In conclusion, the waste framework directive plays a crucial role in shaping waste oil management practices across the EU. By enforcing the waste hierarchy and promoting EPR, the directive aims to reduce the environmental and health risks associated with waste oils.

## 6 Conclusions

The conclusion seeks to offer a comprehensive summary of the work conducted and the findings obtained. It includes a thorough analysis, along with evaluations and recommendations for Volvo, aimed at guiding the company in making informed decisions for its future.

### 6.1 Evaluation

To summarize the data a recap of what the purpose of this thesis was all about is needed. In chapter 1.5 it is stated that the purpose of the thesis is to study how the workshops handle waste engine oil today and how the waste oil is managed by the recycling company, to find out if Volvo Trucks can implement a better solution. Also to analyze if the waste engine oil Volvo produces can be used to make RRBO and if that's the case, if Volvo Trucks can implement some of the RRBO in their brand-new engine oil, mainly to make a more sustainable oil with the same quality as it is today.

Through the survey and visits to various workshops, a comprehensive understanding of how waste oil is managed has been achieved. While some questions in the survey were not optimal, as discussed in Chapter 5.1, the overall insights gathered were valuable. Additionally, a meeting with Stena Recycling, detailed in Chapter 4.3, provided further clarity on the waste oil handling processes employed by the recycling company. This information serves as a solid foundation for evaluating future waste oil management strategies. Meetings with oil company B and RRBO company 2, and Oil company A, referenced in Chapters 4.5 and 4.6, revealed that Volvo's waste oil is regarded as being of very high quality for the production of Re-Refined Base Oil (RRBO). This assertion is further supported by oil samples collected from one private owned workshop and one Volvo Truck center. The high diesel value and phosphorus valued does need to be investigated. Phosphorus exists in the new engine oil, however, there is more phosphorus in older formulas engine oil. Diesel most likely makes its way into the oil tank when the mechanics replace the fuel filters. This mean that phosphorus might not be possible to do anything about while for diesel some training for the mechanics regarding contamination of waste oil could be a good option. However, there remains some uncertainty regarding Volvo's ability to incorporate RRBO into their newly manufactured oil. Since Volvo does not produce the oil themselves, the decision to implement a higher percentage of RRBO does not rest solely with them. Nevertheless, there appears to be a consensus that RRBO is comparable in quality to virgin oil, which is encouraging. It is important to note that extensive testing must be conducted to confirm that RRBO meets the same standards as virgin base oil, a responsibility that primarily lies with the oil producers.

The evaluation of waste oil management at Volvo Trucks reveals critical insights into current practices and potential improvements. The findings from the survey and the field visits indicate a diverse range of waste oil handling methods across various workshops in Europe. While many workshops demonstrate a commitment to proper waste oil storage and management, inconsistencies in practices and lack of standardized procedures raise concerns about the overall effectiveness of current systems. The survey result highlights that a significant portion of workshops utilize designated tanks for waste oil storage, yet notable percentage still mix waste oil with other fluids, with a suspicion that the survey questions may have been misunderstood by the respondents. The mixing can complicate recycling efforts and diminish the quality of the waste oil, making it less suitable for re-refining. Furthermore, the financial arrangements regarding waste oil collection vary widely, with some workshops incurring costs while others receive compensation. One conclusion is that his disparity suggests a need for clearer contractual agreements and better

communication between Volvo Trucks and its workshops to ensure that waste oil is managed sustainably.

The analysis of the RRBO process indicates that Volvo Trucks has a unique opportunity to enhance their sustainability efforts. The meetings with experts from Oil company A, RRBO company 1, oil company B and RRBO company 2 confirm that Volvo's waste oil is of high quality, which is essential for producing RRBO. However, the ability to incorporate RRBO into new engine oil formulations is contingent upon the practices of oil producers, as Volvo does not manufacture the oil itself. This presents as a challenge, as extensive testing and validation are required to ensure that RRBO meets the quality standards expected of virgin base oil.

Moreover, the carbon footprint analysis demonstrates the environmental benefits of adopting RRBO over incineration. The potential reduction in carbon emissions by approximately 30% when utilizing RRBO underscores the importance of transitioning to more sustainable waste oil management practices. This shift not only aligns with Volvo Trucks commitment to sustainability but also enhances the company's reputation in an increasingly eco-conscious market.

## **6.2 Recommendations**

To address evolving market demands, the following are the key recommendations for Volvo Trucks.

### **6.2.1 Waste management**

To enhance waste oil management practices across workshops, it is crucial to implement a structural approach that aligns with the waste framework directive and promotes sustainability. Given that 90% of the workshops currently store waste oil in tanks, it is recommended that all workshops adopt standardized storage solutions to ensure proper separation of waste oil from other waste fluids. This will facilitate recycling efforts and minimize contamination risks. Furthermore, it is concerning that 40% of the workshops have answered in the survey that waste oil is mixed with other fluids. If that's the case, workshops should be encouraged to separate waste oil from other waste fluids, such as coolants. Training sessions on proper waste handling should be provided to workshop staff to raise awareness of the environmental impacts of improper waste management. Additionally, the implementation of extended producer responsibility (EPR) should be prioritized. It is recommended that Volvo Trucks establish contracts with recycling companies for the workshops to ensure that the waste oil is collected and treated appropriately. The collaboration with oil producers is also important to maintain, to create efficient collection systems will also enhance the recycling process to ensure compliance with EU regulations.

### **6.2.2 RRBO implementation**

Based on the data collected, a strategic recommendation for Volvo would be to establish a centralized contract directly with the re-refinery for all Volvo Truck centers, as well as for privately owned workshops that wish to participate. Both Oil company A and RRBO company 2 have demonstrated interest in Volvo's oil and currently maintain contracts with various companies, making this approach a viable option. Both entities are willing to pay a premium for high-quality oil and have indicated that they consider Volvo's oil to be of high standard. Additionally, securing a larger volume of oil could lead to more favorable pricing, thus it would be

advantageous to include privately owned workshops in the contract. Another compelling advantage for Volvo is that these workshops are capable of consistently delivering high-quality oil. While there may be fluctuations in supply at certain times of the year, they generally maintain a reliable volume of oil provision.

### **6.2.3 Further investigations**

To enhance the management of waste engine oil and explore the potential benefits of re-refined base oil (RRBO), several key areas warrant further investigation. Firstly, it is crucial to assess how RRBO compares to virgin oil in terms of performance and quality. A detailed comparative analysis should be conducted to evaluate the performance characteristics of RRBO, including its viscosity, lubrication properties, and overall engine performance. This investigation will help determine whether RRBO meets or exceeds the quality standards set for virgin oil, particularly for the specific engine oils used in Volvo Trucks. Additionally, understanding the long-term effects of using RRBO on engine wear and maintenance requirements will provide valuable insights into its viability as a sustainable alternative.

Secondly, it is important to investigate the practices of workshops regarding the mixing of oil with coolant and other fluids. This can be achieved through targeted surveys and interviews with workshop personnel to gather data on their oil handling practices. Understanding whether workshops mix waste oil with coolant will help identify potential contamination risks that could affect recycling processes and the quality of the resulting waste oil. Analyzing these practices will also inform the best practices for waste oil storage and handling.

Lastly, exploring the feasibility of a unified contract for waste oil management across all Volvo workshops could streamline operations and enhance cost-effectiveness. A thorough cost-benefit analysis should be conducted to determine the financial implications of implementing such a contract, including potential savings from bulk collection and processing. Engaging with workshop managers and recycling companies will provide insights into their experiences with current contracts and the desirability of a unified approach. Furthermore, it is essential to investigate any regulatory implications of a unified contract to ensure compliance with local waste management laws and the Waste Framework Directive. By pursuing further investigations, Volvo Trucks can gain a deeper understanding of the current landscape of waste engine oil management and the potential benefits of adopting RRBO. This proactive approach will not only enhance sustainability efforts but also position Volvo as a leader in responsible waste management practices within the automotive industry.

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