CHALMERS

# Investigation of food losses in cold cargo transports

## A case study of cold cargo chain supply chains of fresh foodstuff to Sweden

Bachelor thesis for International Logistics Program

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CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2024

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# PREFACE

This bachelor thesis was conducted during the spring semester and is compulsory to receive a bachelor's degree in International logistics from Chalmers University of Technology. The thesis is written for 15 ects and is therefore studied at 50% during the semester. We would like to give thanks to our supervisor Lena Granhag for the guidance.

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# SAMMANDRAG (in Swedish)

Transport av färskvaror inom kalla leveranskedjor är viktigt för att upprätthålla livsmedelskvalitet och minimera matförluster. Trots tekniska framsteg inom kylkedjelogistik kan utmaningar kopplade till temperaturavvikelser uppstå. Denna rapport undersöker logistiken inom livsmedelstransporter till och inom Sverige, med ett primärt fokus på operativa, tekniska och reglerande utmaningar relaterade till matförluster. Rapporten fokuserade enbart på färskvaror som livsmedel och tog inte hänsyn till returförsörjningskedjor eller andra, icke ätbara varor inom kyltransporter.

Rapporten har baserats på en fallstudieanalys med perspektiv från olika företag som verkar inom kylkedjan. Forskningsfrågor handlar om företags anpassning till hållbar utvecklingsmål och regelverk, operativa aspekter av kyllasthantering och initiativ för bättre energieffektivitet i kyltransporter. Fynden visar att företagen är kompatibla med regelverk, trots detta har det funnits återkommande bevis som visar på mänskliga fel som bidrar till matförlust, främst relaterade till temperaturavvikelser. Operationella förbättringar diskuteras i befintlig litteratur, men operationella aspekter hindrar implementering. Initiativ för energieffektivisering diskuteras, främst relaterade till bränsleförbrukningen vid utförda transporter och inte nödvändigtvis till kylaggregatets förbrukning.

Sammanfattningsvis, även om företag efterlever regelverk, finns det ett behov av kontinuerliga lagstiftningsförbättringar från beslutsfattare för att minimera matförluster. Operativa utmaningar, särskilt mänskliga fel, kräver ständig förbättring och innovativa lösningar för att minimera matförluster. Initiativ för energieffektivisering visas av alla intervjuade företag men har varierande fokuspunkter relaterade till företagens respektive verksamhet.

**Nyckelord:** Reefer, kylaggregat, matförluster, matavfall, utsläpp, energiförbrukning, transporter

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# ABSTRACT

The transportation of perishable goods within cold supply chains is important for maintaining food quality and minimizing food losses. Despite technological advancements in cold chain logistics, challenges connected to temperature deviations may occur. This report investigates the cold supply chain logistics of food transports to and in Sweden, with a primary focus on operational, technical, and regulatory challenges with food losses. The report solely focused on perishable goods such as food stuff and did not take return supply chains into account, or other, non-edible goods in cold transports.

The report has been based on a case study analysis, incorporating perspectives from different companies operating within the cold chain supply. Research questions address companies' alignment with Sustainable Development Goals and regulations, operational aspects of refrigerated cargo handling, and initiatives for better energy efficiency in refrigerated transportations. Findings show that the companies are compatible with regulatory frameworks, despite this there has been recurring evidence which shows human errors contributing to food loss, primarily related to temperature deviations. Operational improvements are discussed in existing literature, but operational aspects hinder implementation. Initiatives for energy efficiency are discussed, primarily related to the fuel consumption of performed transports and not necessarily of the cooling unit’s consumption.

In conclusion, although companies show compliance with regulatory frameworks, there exists a need for continuous legislative improvement from the decision makers, in order to minimize food loss. Operational challenges, particularly human errors, require attention and innovative solutions to minimize food losses. Initiatives for energy efficiency are shown by all interviewed companies but are varying in regard to different focus points related to the companies’ respective activities.

**Keywords:** Reefer, refrigerated unit, food losses, food waste, emission, energy consumption, transportation

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# ACRONYMS AND TERMINOLOGY

| | |
|---|---|
| TEU | Twenty foot Equivalent Unit |
| FEU | Forty foot Equivalent Unit |
| MRU | Mechanical Refrigeration Unit |
| T-Floor | Section of the reefer floor, in the shape of the letter T. |
| GHG | Greenhouse Gas |
| Reefer | Refrigerated container |
| SDG | Sustainable Development Goals |
| Dry container | ISO shipping containers used for cargo transport of dry goods |
| PTI | Pre Trip Inspection |
| FCR | Freezer Classed Units |
| FIFO | First In First Out |

# 1. INTRODUCTION

In the 19th century the steam engine was invented and revolutionized the transportation industry. The engine was installed in both trains and boats making it possible to travel longer distances with larger quantities (Robert de Vries & Torbjörn Nilsson, 2010). The concept of supply and demand was invented in 1776 by Adam Smith, but was created by humans demanding certain goods (Pinkasovitch, 2023). With the steam engine connecting the world, the consumers started to demand perishable goods from other continents than their own. The reefer ship came in the middle of the 19th century and made its first attempt to sail across the pacific ocean from Australia to the UK in 1876. The cold cargo transportation has later evolved massively today's supply chains cold cargo is mostly carried in refrigerated containers known as reefers. These container vessels are usually equipped with allocated spots for refrigerated containers, where the units are connected to an electrical power supply and can keep cargo cool at a pre-set temperature (Lukasse et al., 2023a).

In 2023 it was estimated that one third of the food that is produced is thrown away and all energy used to produce this food has been wasted. The cold supply chain plays a crucial role in minimizing both food waste and food loss. The cold chain refers to perishable goods that must be transported at a decided temperature all the way from harvest to the end customer to not be damaged (Hundy et al., 2016). The difference between food losses and food waste is that food loss is defined as the reduction of food quantity and quality due to decisions made by the food supplier, therefore the households, retailers or food services is not included in this definition. All food lost at production, post-harvest, in food processes and transportation that does not reach its end customer is defined as food loss. Food waste on the other hand is food that arrives fresh at the final destination but because of e.g wrongful First In First Out (FIFO) principle has to be discarded. Food waste is also the food that is thrown out by household consumers (WWF, 2021a).

To understand how large quantities of food could be lost during transport it is relevant to start looking at the origin countries. Much of the food sold in European markets is produced and harvested in other countries and even other continents. The intercontinental transport of perishable goods has historically been shipped via sea (Arduino et al., 2015a). Sea transports enable the highest loading utilization of all conventional modes of transport; thus it leads to a lower total transport cost per unit and increases the economy of scale (Jansson & Shneerson, 1987).

As we enter the year of 2024 the world has only six years to meet the 2030 Sustainable Development Goal (SDG 12) of halving the food waste per capita (FAO, 2023a). The global issue of food loss is on top of the UN committee's agenda as the latest Food loss index report shows there is no growing improvement on this goal. According to Food and Agriculture Organization, in 2022 a mid-range of 737 million people were faced with hunger and food insecurity. A large portion of the work performed by FAO is related to creating sustainable agricultural practices to mitigate food insecurity and food losses, however the global food losses is seemingly a multifaceted issue with several aspects. Such as the food lost after the production level, according to FAO the amount of food losses after harvest during transports, storage and wholesale handling was estimated to be 13,2% of the global food supply lost in 2021. This report will primarily focus on the food lost within the cold supply chain, meaning the supply chain of perishable goods transported at cold temperatures (FAO, 2023b).

## 1.1 Background

Investigating the transportation of perishable goods in the context of food losses, is of relevance due to its profound impact on both economic sustainability and global food security. As our world population burgeons and consumption patterns evolve, efficient transportation systems play a pivotal role in ensuring that perishable foods reach consumers in a timely manner and retain their quality throughout the supply chain (Arduino et al., 2015b). The global market value of cold chain logistics was in 2023 $292.89 billion and is estimated to grow beyond $400 billion over the coming five years (Statista, 2024). In the cold supply chain, reefer containers are being used to transport 0,1 billion tons of food across the globe annually (Lukasse et al., 2023b). The transportation of perishable goods such as fruits and vegetables from other continents to Europe in cold supply chains has been a daily business for over a century. Even with the long experience of fruit transportation, there is still a large number of e.g. bananas arriving in poor condition due to temperature deviations faced during transportation (Jedermann et al., 2013a). Temperature deviations in perishable goods transportation leads to food losses and by that negative externalities.

The European market and especially Northern Europe has a high demand for perishable goods from other continents where the climate is more appropriate for farming of fruits and vegetables. The high demand for other fruits and vegetables than what can be grown domestically makes northern Europe not self-sufficient, increasing the importance of well working cold supply chains to maintain the quality of the produce (van Duin et al., 2018a). Some perishable foods are most often cheaper to import from other continents than to grow domestically and it can therefore be seen that northern Europe imports these foods instead (Török et al., 2023).

The cold supply chain faces a big challenge handling the perishable goods being transported between continents. Perishable goods as foods are sensitive to change in temperature and in the transportation with reefers, trucks and trailers it is a crucial part to maintain the correct temperature. If temperature during transport deviates too much it would increase the amount of food loss and thus the energy consumed by the refrigeration unit during transportation is wasted. By allowing food to go to waste due to incorrect handling, the resources used to produce the food must also be considered lost when estimating the total environmental impact of food losses. Resources used in agriculture such as water, soil, energy, capital negatively contribute to greenhouse gas emissions and are lost when food is thrown away (UN, 2023).

Before the modern reefer was first used in the 1970s, refrigerated goods were solely transported with refrigerated cargo ships (Castelein et al., 2020a). After the invention of the reefers, technological advancements have been made regarding the cooling unit systems in the transportation units. The fleet market has since then been growing rapidly and tenfold during 30 years from 294 000 TEUs in 1990 to. 3.2 million in 2019 (Lukasse et al., 2023c). The first reefers did not have an integrated cooling unit but instead were insulated and connected to air ducts. According to the modern ISO standard these reefers would today be referred to as thermal containers. In the 1970s the reefer advanced to integral reefers with advanced cooling systems. The reefer slots on board of the top 10 container carriers occupy 15-25% of the total slots on board the vessel. As it is more prevalent for food to be shipped on container vessels rather than bulk or pure reefer vessels, full ship utilization cannot be reached for the transport of these reefer units. The use of reefers is primarily used as the cargo does not need to have the same

temperature cargo, smaller quantities can be shipped, and the frequency of container vessels is higher than reefer vessels.

The purpose of this report is to study the cold supply chain logistics of food transports to European ports. Different companies' views will be taken into account to reach an extensive overview of this market segment and its current challenges with sustainability issues in regard to food losses. These views and standard operational procedures will be combined with results gathered from past literature published on the subject.

## 1.2 Aim of the study

The aim of this report is to conduct a case study analysis on the cold supply chain imports of perishable foods to Sweden. Focus will be on the operational, technical and regulatory challenges of refrigerated transport to minimize food spoilage and losses within the supply chain. The research questions will be answered by a case study method conducted in this report.

## 1.3 Research questions

1. How do companies within the cold chain supply work with the **different Sustainable Development Goals and other regulations related to food transports?**
2. What are the operational aspects of refrigerated cargo handling during transports of foodstuff to minimize losses?
3. What initiatives on energy efficiency regarding refrigerated food transports **is used and planned by companies in the cold supply chain?**

## 1.4 Delimitations

This report will solely focus on perishable goods as fresh produce food transported in refrigerated units, such as containers or trailers. Regarding food losses, household waste, cross contamination, dropping cargo or other food waste that is not connected to temperature deviations are not considered. What will be described as food loss henceforth is fresh foodstuff grown or raised in farms across the globe, and later lost or spoiled from harvest to arriving at wholesalers' distribution center (WWF, 2021b). The supply chain that is analyzed in this report does not take return supply chains into consideration, only transportation from produce to end customer is analyzed. The focus will only be on cold supply chain's within Sweden or imports to Sweden.

When gathering information from different sustainability reports some delimitations are made, especially in reports from companies whose main focus is not necessarily refrigerated transports. There might be sustainability work presented by the companies that are non-related to the focus of this report which will therefore be disregarded.

# 2. THEORY

The theory part of the rapport will focus on the literature to pick out what is relevant to answer the research questions.

## 2.1 Regulatory frameworks

There are several legislative measures on the national level which both transport companies and transport buyers must relate to. The Swedish national, European Union and The United Nations legal requirements on transporting refrigerated perishable goods.

The (EC) No 853/2004 regulation on hygiene of foodstuffs regulates the general requirements for all hygiene aspects for all food business operators including transporters. This regulates temperature control, cleanliness and hygiene practices during transportation on foodstuff. CHAPTER IV is the most relevant for this report since it regulates the transport part. Seven points (EC) No 853/2004, 2004):

*"1.*
*Conveyances and/or containers used for transporting foodstuffs are to be kept clean and maintained in good repair and condition to protect foodstuffs from contamination and are, where necessary, to be designed and constructed to permit adequate cleaning and/or disinfection.*
*2.*
*Receptacles in vehicles and/or containers are not to be used for transporting anything other than foodstuffs where this may result in contamination.*
*3.*
*Where conveyances and/or containers are used for transporting anything in addition to foodstuffs or for transporting different foodstuffs at the same time, there is, where necessary, to be effective separation of products.*
*4.*
*Bulk foodstuffs in liquid, granulate or powder form are to be transported in receptacles and/or containers/tankers reserved for the transport of foodstuffs. Such containers are to be marked in a clearly visible and indelible fashion, in one or more Community languages, to show that they are used for the transport of foodstuffs, or are to be marked "for foodstuffs only".*
*5.*
*Where conveyances and/or containers have been used for transporting anything other than foodstuffs or for transporting different foodstuffs, there is to be effective cleaning between loads to avoid the risk of contamination.*
*6.*
*Foodstuffs in conveyances and/or containers are to be so placed and protected as to minimize the risk of contamination.*
*7.*
*Where necessary, conveyances and/or containers used for transporting foodstuffs are to be capable of maintaining foodstuffs at appropriate temperatures and allow those temperatures to be monitored."*

The European Union has a regulation ((EC) No 178/2002, 2002) that must be implemented and accepted into the Swedish law as Sweden is a part of the European Union:

The Swedish law Livsmedelslagen (Livsmedelslag (2006:804), 2006) with the complementary regulation Livsmedelshygienförordningen (EG) nr 853/2004 has the intention to control that perishable goods being transported are handled in the correct way. The purpose is to regulate disinfection of the transportation unit as well as temperature control to avoid viruses and bacterias spreading. These laws and regulations have an impact on all haulagers and container carriers' transport operations. They have to adapt this into their operations both to please the customers' demand for fresh and uncontaminated fruit and vegetables, but also to avoid lawsuits.

Found in the Swedish law (SFS (2017:1201) on reduction of greenhouse gas emissions from certain fossil fuels there are regulations on the reporting of companies' obligation to report the work to minimize GHG emissions from fuel consumption. According to paragraph 5§ the one with reduction duty for petrol or diesel should for every year make sure that the amount of energy by using these types of fuels falls below the limit from the corresponding energy amount of fossil patrol or diesel.

The Paris agreement was signed by 196 countries in 2015 and is, when ratified, a legally binding legislative measure to defeat climate change (UNFCCC, 2024). The goal is to keep the rising temperature to 2 degrees celsius and to minimize GHG emissions by 2030. Countries are obliged from 2020 to hand in a report on what environmental actions have been implemented. In the Swedish law on annual reporting "Årsredovisningslag" (SFS: 1995:1554, 1995) 6th chapter 1§ it is mentioned that the companies are required by law to be transparent with their sustainability work that are important to understand the companies work and position. Companies are required to leave this information in their sustainability report about their businesses activities and their impacts on the environment. To understand how the different companies are working towards the respective SDG goals it is helpful to provide information through the sustainability reports which includes information and numbers on annual achieved sustainability goals set. According to the Swedish Companies Registration Office (Bolagsverket, 2019), which is a Swedish government agency on business management and registration, companies who fulfills two or three of the following requirements during both of the last two financial years shall conduct a sustainability report with the the average number of employees has been 250 or more. The report must also be conducted if the balance sheet resulted in more than 175 mkr SEK and net turnover of more than 350 mkr SEK.

Legislations and policies set by organizations such as the United Nations play a vital role in improving the food supply chain in regards to minimizing food losses (Herzberg et al., 2023). The SDGs are goals set by the United Nations to minimize the urgent environmental, political and social challenges which need to be addressed by all member nations. For Swedish law this is ratified through the EU and is therefore mandatory legislation which companies has to comply with. The SDGs that would benefit from a cold supply chain without food loss and environmental impact would be 7, 12 and 13. Brief explanations on the chosen SDG's for this report are shown in Table 1:

Table 1. Table over Sustainable Development Goals specifically selected for this report.

| SDG Goal and respective subcategories. | Aim |
|---|---|
| **Number 7: Affordable and clean energy** | Ensure access to affordable, reliable, sustainable, and modern energy. |
| Target 7.3 | By 2030, double the global rate of improvement in energy efficiency. |
| **Number 12: Responsible consumption and production** | SDG number 12 aims to ensure consumption and production patterns. |
| Target 12.2 | The subcategory that is relevant for refrigerated transportation and food loss. Target 12.2 aims for efficient use of natural resources. |
| 12.3 | Aims to By 2030 the food loss both by the supply chain including post-harvest has to be cut in half. |
| **Number 13: Climate action** | aims to take urgent action to combat climate change and its impacts. |
| 13.2 | Integrate climate change measures into national policies, strategies and planning. |
| 13.2.2 | 13.2.2: Reduce total greenhouse gas emissions per year |

## 2.2 Technical requirements, capabilities and dimensions of reefer containers, trucks and trailers

### Standards and requirements set by ISO:

The refrigerated shipping container, more commonly known as the “reefer container”, was implemented in the late 20th century as an insulated freight container with capacities to keep cargo at cooler temperatures (Lukasse et al., 2023d). Since the first reefer container, several technological advancements have been made to further enhance the qualities of the freight unit. Presented below are several ISO standards related to the transportation units within the cold supply chain. The purpose of this is to illustrate the standardized quality requirements companies must comply with.

The ISO standard (ISO 1396-2: 2018) sets the dimensions of the standard Twenty-Foot-Equivalent freight container of 20’ x 8x 8’6’’ in imperial feet (6.1 m x 2.4m x 2.6m), in addition to this the standard also regulates the larger 40ft units which is significantly more prevalent in the market. This dimensions standard is set for the external parts of regular dry containers as well as thermal containers (ISO 1496-2:2018). It is important to make a distinction between “thermal”- and “refrigeration” containers as the definition is not the same. All refrigeration containers are thermal containers but not all thermal containers are

refrigeration containers. The definition of a thermal container is a freight container with insulating walls, doors, floor and roof to delay the heating time on the inside. While the definition for a refrigeration container is a thermal container using a means of cooling as for example liquefied gasses (ISO 1496-2:2018).

Furthermore the ISO standard 1496-2:2018 for thermal freight containers sets reefer container design requirements which all units must comply with. In Table 2 these requirements are present:

Table 2. ISO standard 1496-2:2018 design requirements for thermal freight containers.

| **Requirement** | **Description** |
|---|---|
| Corner Fittings support | Containers should be able to be solely supported by the corner fittings. |
| Door opening | Each reefer should have at least one door opening at the end part of the unit. These openings shall have practical width in regards to the given dimensions of the unit. |
| Sanitation | Containers shall be made up of proper material suitable for refrigeration which will not have any negative impacts on the cargo, with an emphasis on foodstuff. Also the material should be easily cleaned, without crevices which cannot be reached during cleaning by normal cleaning procedures. |
| Fork-lift capabilities | Each reefer shall be provided with fork-lift capabilities by operational reasons as to ensure correct handling. |
| Drainage | Drains shall be constructed in such manner that water used for cleaning can easily be drained from the inside. These drains shall during transports be protected by fittings with sealing mechanisms. |
| Extra water management | In units which use additional water for humidity control, there shall be extra cleaning instructions to ensure removal and disinfection of extra water. |
| Air circulation | All integrated air circulation systems should be provided with a marked load line to ensure airflow to the MRU (Mechanical Refrigeration Unit). Reefer containers with integrated air circulation systems should be provided with methods for airflow to the floor (e.g. T-floor but not a requirement). |
| Handling Air Changing | In regards to air circulation, units should be able to handle 50 container volume air changes per hour while operating on 50 Hz power supply. |

In addition to the requirements related to the design of refrigeration units, the units shall be able to withstand various tests further stated in the same document of ISO standard 1496-2:2018. First there are general structural tests on the strength and functionality of the containers main parts, such as stacking and lifting capabilities. This to ensure that the unit can be properly stacked and lifted in terminal operations, also weatherproofness, and the overall strength of the walls and roof.

Further tests are carried out after the aforementioned structural tests have been completed. These tests consist of:

- Airtightness, where the container is fully closed and in its operative mode. Then the air supply shall be tested by a manometer.
- Heat leakage
- Test of the performance of a container under refrigeration by a mechanical refrigeration unit MRU, where the unit is required to maintain a set temperature for a period of at least 8 hours.
- Functional test of a thermal container at high ambient temperatures while being cooled by a mechanical refrigeration unit MRU.
- Energy consumption of a thermal container at defined ambient temperatures while being cooled by a mechanical refrigeration unit MRU. There is no requirement for energy consumption, the test is for comparative purposes only.

In addition to the above presented general requirements on thermal containers there is also an ISO standard for the remote condition monitoring of freight thermal containers (ISO 10368:2006). In this standard there are requirements described regarding the temperature control systems for products sensitive to temperatures, such as perishable goods as foodstuff. The requirements of monitoring systems for thermal freight containers are illustrated in Table 3:

Table 3. ISO standard 10368:2006 requirements of monitoring systems for thermal freight containers.

| **Requirement** | **Description** |
|---|---|
| **Temperature monitoring** | Requirement which states that there should be some variant of a temperature monitoring device in the transport unit during transport which needs to be accurate and calibrated. |
| **Temperature control** | There should be some sort of control equipment to regulate and adjust the set temperature within the transport unit. |
| **Temperature recording and reporting** | There should be procedures for recording temperature data during transports, for traceability reasons. |
| **Temperature alarm systems** | An alarm system should be installed to alert personnel in case of a significant temperature deviation. |
| **Quality management system** | A quality management system needs to be implemented to ensure that temperature control systems are efficient. Such as maintenance, personnel training, and a continuous improvement of procedures. |

To summarize this comprehensive part on the extensive technical requirements of thermal containers: these requirements are stated here to illustrate the importance of creating a

standardized unit for transportation of perishable goods. All in all, to minimize operations failures and minimize food losses.

## 2.3 Energy consumption of refrigerated units

There are ways of reducing the energy consumption of reefers. It is possible to save up to 17% of the total electronic energy consumption when a reefer is placed under a sun roof rather than placed under direct sunlight (Vichos et al., 2022). At terminals, reefers are responsible for 30-35% of the total electric energy consumption(Geerlings & van Duin, 2011).

The reason energy-saving is so important is connected to the environmental impact that the consumption of energy causes. Spoilage of energy causes negative environmental impact. It is possible to reduce energy consumption by planning the stacking of reefers. When a reefer is placed: top layer inside the stack, top layer corner setting, middle layer inside the stack, middle layer corner setting. It is possible to save power consumption of 7% when stacking the containers in one of these positions (Filina-Dawidowicz et al., 2022a).

Another important factor to consider is how driving patterns and driving behavior affect fuel consumption. Fuel is an energy source for vehicles so it is important with eco-driving to ensure optimal energy efficiency and minimize energy consumption. According to recent literature it is possible, with the correct truck driver training, to minimize the fuel consumption with 5.2-9% (Pinchasik et al., 2021). The education of professional drivers is usually theory based but could also include practical training. The purpose of eco-driving is to minimize the consumed fuel whilst driving. The equivalence of eco-driving within the shipping industry would be “slow steaming”, it is possible for shipping vessels to slow steam, meaning that the vessel decreases its speed to save bunker fuel and thus lower their GHG emissions. Slow steaming has a great impact on the transit time and is therefore not always an option for the shipping lines. (Maloni et al., 2013)

## 2.4 Handling of perishable food

The position of the pallet is important as there could be an temperature deviation of 5 degrees celsius in the reefer transportation depending on where in the reefer the pallet is placed (Jedermann et al., 2014a). A deviation of 5 degrees is considered a high temperature deviation of refrigerated goods and will be damaging to the product. As the temperature in the air inside the reefer decreases, the relative humidity increases, thus often resulting in high humidity content inside reefers (Lukasse et al., 2023e). Consequences of high humidity could be frosting or condensation on foods products, causing shrinkage in especially fruit and vegetables. To mitigate such losses some reefer containers are installed with the capability of controlled atmospheres, to lower respiration of fresh food. One issue with too high or too low temperatures during transportation is that the problem of food loss may not occur until the next step in the supply chain, in cases of undesirably hastened ripening processes. Some foodstuffs are more sensitive to changes in temperature than others. Minced meat is more sensitive to temperature deviations than a steak as there is more air in the packaging and therefore changes temperature faster.

If a reefer or trailer is packed with gaps between the pallets the air stream will flow differently in the transport unit than if the pallets were packed close together. When the air stream pressure and volume differences the cooling system can not perform as it should, and the cargo temperature can not be guaranteed (Jedermann et al., 2013b). Perishable goods have a high sensitivity towards temperature changes and it is therefore important that the supply chain is properly planned to minimize deviation from the preferred temperature.
Bananas  internal temperature for example should be maintained at 13.6 to 16 degrees celsius to avoid freezing or maturing before arrival at its destination (Arduino et al., 2015c). If a deviation in temperature of the goods is too high or low the risk for food losses increases drastically.

It is important that each part of the cold supply chain takes responsibility for their part and that the delivery of goods between the transportation moods is done in the most efficient way to minimize food loss. When food is lost or wasted, the whole supply chain of natural resources is wasted, such as water, power consumption, GHG emissions, phosphorus, eutrophication and the effects on biodiversity (WWF, 2021). Having a high amount of food loss will increase energy consumption as the customer still demands to receive their selected quantity and the food has to be produced a second time. A high energy consumption leads to increased emissions that will have a negative impact on the environment (Axfood, 2024b).

# 3. METHODS

In this chapter the approach to the rapport will be described.

## 3.1 Chosen methods

The method that was chosen to conduct the report was a case study, with the cold supply chain as the chosen case to perform an in-depth analysis on (Höst et al., 2006a). Facts and knowledge from both engineering and operational aspects were collected to conduct this report, primarily information was collected by conducting interviews. The method was chosen as it gives a complete overview of the refrigerated transportation cold supply chain and the issues and challenges that come with it.

## 3.2 Sample and data collection

To get a complete overview of how the rapport was written, the description of the collection of data will follow.

### 3.2.1 Literature search

The literature was mainly found on databases provided by Chalmer library such as: Scopus and Google Scholar. Some statistical sources were also used in the report for highlighting relevance of different market segments and export/import values. These statistics were found by using another database provided by Chalmers library: Statista.

When searching for literature these primary keywords as reefer container, refrigerated unit, food losses, emissions, energy consumption and transportation were used. These keywords provided relevant results which then were filtered to get the most cited works to primarily use established publications. The literature was then studied and relevant conclusions were saved with an intention to use and compare in the results of this report.

The selected companies sustainability reports were analyzed to compare the answers from the interviewee's, but also to add additional results s to support the relevance of some aspects towards the research questions.

### 3.2.2 Interviews

A total of six interviews were held with actors within the cold food supply chain: one wholesaler, two shipping companies, one hauler and one manufacturer. The interview questions were formed after what type of company and field the interviewed person works in but with the same focus on refrigerated transportation of fresh produce. The questions both referred to operational aspects of food handling, technical and regulatory aspects of reefers and cold trailers. These questions varied a bit depending on company type and therefore the interviews were held semi structured, with room for follow-up questions. Primarily the interviews were based on these main questions which were founded in regard to the research questions:

- How much food losses are you estimating yearly per transport unit?
- How do you ensure correct temperature during transports?
- Do you have a monitoring system to monitor temperatures inside transports? Alternatively a routine to manually check temperatures?
- How do you ensure that your suppliers minimize the risk of food losses?

- What precautions do you take to increase the energy efficiency of your refrigeration units?
- What is your biggest focus on to keep the temperature constant?
- How does your routines look for maintenance of your cooling units, to ensure optimal performance and minimized emissions?
- What actions do you take if a temperature deviation occurs during transport?
- What are your largest challenges in regards to food losses?
- What are your routines during deliveries of goods? To keep temperatures?
- How much electricity per distance does your refrigeration units consume? Minimum and maximum. And how do you work to decrease the maximum?

The initial target was to make at least five interviews consisting of at least three different shipping companies with reefer transports to Sweden, one wholesaler with fresh produce, and one company with cold transports on road. Additional companies relevant for the case study were also contacted, such as port companies or manufacturing companies of cooling systems. Several fruit and vegetable companies and freight forwarders were reached out too but did not respond. A total of six different shipping companies operating within Sweden were contacted via either a standardized form on their website or by an employee on at least manager-level by contacts to the report writers. Out of six shipping companies three answered and two finally participated in the interview. One CEO of a hauler company participated in the interview. Two different managers at large wholesalers participated in the interviews. A manager at a manufacturer of cold units was reached out to and interviewed. Furthermore, several fruit companies were unsuccessfully contacted to perform interviews. Some companies referred to their sustainability report and this was therefore read to complement the interviews.

The interviews were conducted in a semi-structured manner with prepared questions to the interviewees (Höst et al., 2006b)so that the persons being interviewed could answer freely with room for follow-up questions. Since the interviewees had different backgrounds the questions brought up varied slightly depending on relevance for the interviewed person. The questions were formed in a standardized manner and then further questions were developed with regards to the specific expertise of the interviewee.

The results from the interviews were then processed to understand how standard operational procedures relate to the literature. The interviewed people were asked if they wished to be kept anonymous and if it is the meeting could be recorded and later transcribed.

When the interviews were finished the collection answers were chosen based on relevance of the answer towards the research questions. The interviewees' answers sometimes did not have relevance towards the research questions and was therefore not selected to be part of the report. As the companies were interviewed during a 3-month period, questions did change or vary under the progress of the work as the knowledge of what to asked developed (Höst et al., 2006c).

## 3.3 The study focus

Since the primary focus was to conduct a case study analysis on the cold supply chain logistics part, the research questions had to be divided into three main categories, technical, operational and strategic. After delving into the existing literature, it was made clear that a great deal of publications on reefer containers were strictly engineering articles on how to

optimize the containers airflow and cooling systems. Thus an initial main research question was put: How does the reefer handling challenges look today in regards to minimizing losses of perishable goods and what initiatives are taken to further optimize this for the future? Eventually this question was divided into two.

## 3.4 Ethics

The report does not only present facts that support the research questions but multiple sides of the cold supply chain to give the reader a more complete overview of the industry. All sources were reviewed by the CRAAP test so that the rapport maintains its scientific standard. A result not intended when searching for interviewee's was that all interviews were held with men. Several women of comparable positions were contacted without success.

# 4. RESULTS

The results are from both interviews and selected literature connected to the research questions.

## 4.1 Regulatory aspects

When presenting the results of laws and regulations it will be possible to analyze companies behavior in the discussion.

### 4.1.1 Regulations and legislation in the interviews

All of the interviewed companies who are responsible for stowing the transportation units themself, stated that when loading pallets into a refrigerated transport unit, leave room so the pallets are not stacked to the ceiling to ensure airflow is working well. There is no specific law for the stacking pallets but according to (EG) nr 852/2004, Chapter IV, Point 7 ratified by Swedish law that transported food should be handled in such a manner that it is not subject to deterioration or spoilage. No interviewed person mentioned pallet stacking as an issue when discussing operational challenges in regards to food waste. All interviewees also mentioned at least some insights regarding their respective monitoring systems, To provide monitoring of temperatures during transports is in compliance with (EC) No 852/2004, Chapter IV, Point 7. Furthermore the monitoring system provides traceability along the transport of the chilled goods, to provide security in regards to their customers (Regulation (EC) No 178/2002).

During the semi-structured interviews there were no specific questions regarding regulations, however during the interviews the operational aspects were clearly connected to the legislative and regulatory frameworks.

The CEO of a Swedish haulage company stated that their routine ensures that the receiver of goods makes a sample check on the temperature of the delivered goods. According to the svenska dagligvaruhandel report it is the responsibility of the receiver to perform a sample check of the temperature of the cargo (Svensk Dagligvaruhandel, 2018).

Furthermore, the haulage company mentioned that the transport units used for transportation have an annual routine regarding quality control, which could be interpreted as the company is working in compliance with (EC) No 852/2004, Chapter IV, Point 1. This states that containers used for transporting foodstuffs are to be kept clean and in good condition. The haulage company claims that all refrigerated transport units are FCR which is not a compulsory class to have but he claims it is to increase energy efficiency as it consumes less fuel to keep the goods cool.

A global cooling unit manufacturers Scandinavian Product & Development Manager stated that Scandinavia stands out with its special demands with exceptionally cold temperatures. It was stated that they provide an extensive temperature monitoring system in all their cooling units on the market with advanced alarm systems in case of temperature deviations.The company mentioned that they yearly do check-ups on their cooling units as this is regulated by law. This must be done at a certified service station, or the carrier receives a driving ban. He also stated that their equipment should be sustainable and that they also have to scrap their products in a sustainable manner. The company is continuously working on bringing their carbon footprint down, their goal is to save 1 gigatonne of CO2 by 2030, and when asked what their largest challenge is in regards to reaching the climate goals the answer was:

"*Urgency at the decision makers level, we as a manufacturer are a bit ahead in the development of energy efficient fuels. We need legislative measures, we can provide climate neutral products to our customers but we need legal measures to be able to deliver them, these products are significantly more expensive. Globally the largest challenge is that the legislations differ between continents, which is a problem for companies with operations in many countries.*"

The Chief Commercial Officer of a large shipping company was interviewed:
*"We as a shipping company make sure to have as many new reefers as possible, i.e invest in the latest technology available. In addition to that we put a large emphasis on what fuels our ships run on, we are the market leader on alternative fuels with great reductions of emissions. This is really important as the reefers are primarily active during ocean transport where the electricity to the reefers is supplied from the ships energy production".* The interviewee continues to state that their primary focus to keep temperatures within the reefer unit is to perform a PTI check in the container depot.

The head of sales of another shipping company mentioned that they, in collaboration with the reefer manufacturers, ensure to improve energy efficiency of their reefer containers. When asked about their biggest challenges in regards climate work around reefer transport the interviewee did not want to give a specific challenge but it was stated that there is a bigger picture and more emphasis was put on alternative fuels of the ships.

One of the interviewees at the wholesale company was a quality coordinator, responsible for ensuring the operational procedures are in line with Swedish legislation for handling of foodstuff. This involves routines of keeping temperatures in the terminal, cleaning transport units and how they educate staff, drivers and receivers of goods at destination. This is done to minimize food losses resulted from operational faults. This allegedly largely involves working with managers to make sure they are following routines for temperatures. One method to make sure the staff is up to date in their knowledge on operational routines is that the quality coordinator has a yearly course for the drivers, regardless of how long they have been working for the company. According to EU legislation (EC) No 852/2004, Chapter XII, Point 1 which is ratified by swedish law in Livsmedelslagen, "food business operators are to ensure: that food handlers are supervised and instructed and/or trained in food hygiene matters commensurate with their work activity".

The vehicle coordinator of the same wholesale company mostly referred to the legislations regarding vehicle conditions set by the Swedish Transport Agency. They mostly relate to the climate targets by investing in electric vehicles and battery driven cooling units. In addition to this as the company is of a larger magnitude they have received opportunities to participate in several pilot projects regarding electric vehicles and alternative fuels. More than investing in these types of vehicles they are allegedly only acquiring cooling units which are FRC-classed, which he claims is not compulsory in Swedish but is EU-legislation.

### 4.1.2 The different companies approach to the Paris agreement

The interwieved companies had different approces to how they choose to align with the paris agreement.

#### 4.1.2.1 CEO at Haulage company

As the haulage company is not subject to the rules set by the Swedish Companies Registration Office on providing sustainability reports there is no report to be found, however the company has provided an environmental policy. According to the haulage's environmental policy the shall to the greatest extent possible take action to minimize the environmental impact caused by their performed operations. This is actively being worked on by: efficient route planning, driving behavior, usage of environmentally cleaning materials, recycling and proper waste management, at procurement of new transport units, to wager in environmental aspects such as; fuel, load capacity.

#### 4.1.2.2 Product & Development Manager at manufacturing company

The Product & Development Manager at a manufacturing company of cooling units mentioned that food losses are an important part of their work, that humans waste $3.3 billions worth of food and approximately one third of all harvest is lossed. Continuously, it is mentioned that this company has done several projects related to providing infrastructure and cooling units to developing countries with an aim to educate and thus decrease the rate of food losses on a global scale. The interviewee states that there is an explosive demand for development of renewable energy in the products. Furthermore, the cooling units use a patented technology which removes mechanical transmissions which is used in traditional belt-driven technology and instead with the help of a generator transforms engine power into electricity. It is stated that this technology is used to primarily decrease the total amount of moving parts which eventually will require service, but also to decrease carbon footprint by reducing refrigeration leakage by 50%. This is regulated in Agenda 2030 and is signed by the Swedish government. This company provides a sustainability report, where there is among other initiatives an extensive food programme which the company participated with along other leading companies and the UN world food programme to advance the cold supply chains, reduce hunger and food insecurity (Carrier, 2024). In table 4 the Environmental Social and Governance (ESG) report of the manufacturing company is presented, containing different categories of which the company is doing some sort of work with and their respective related SDGs:

Table 4. Summarized table of manufacturing company's sustainability report 2023 in regards to the scope of this study:

| Presented category in report:<br>Description in report. | Related SDGs |
|---|---|
| Financial implications and other risks and opportunities due to climate change | SDG 13 |
| Energy consumption within the organization. | SDG 7, SDG 12, SDG 13 |
| Energy intensity. | SDG 7, SDG 12, SDG 13 |
| Reduction of energy consumption | SDG 12, SDG 13 |
| Reductions in energy requirements of products and services. | SDG 7, SDG 12, SDG 13 |
| Interactions with water as a shared resource | SDG 12 |
| Direct scope 1 GHG emissions | SDG 12, SDG 13 |
| Energy indirect scope 2 GHG emissions | SDG 12, SDG 13 |
| Other indirect scope 3 GHG emissions | SDG 12, SDG 13 |
| GHG emissions intensity | SDG 13 |
| Redcution of GHG emissions | SDG 13 |
| Waste generation and significant waste-related impacts | SDG 12 |
| Management of significant waste-related impacts | SDG 12 |
| Waste generated | SDG 12 |
| Waste diverted from disposal | SDG 12 |

#### 4.1.2.3 Commercial Manager of shipping company 1

The first shipping company is a major factor within the liner shipping industry and a large international company they are subject to the Swedish sustainability regulations related to the Paris agreement:
One important factor to consider is a delimitation mentioned in the shipping company's sustainability report (CMA CGM, 2024).
"*We consider the following information to be outside the scope of the Group's activities:*
- *Fighting food insecurity*
- *Preventing food waste;*
- *Protecting animal welfare;*
- *Responsible, equitable and sustainable food.* "

As this is a shipping company with a main focus on performing ocean transports globally of both dry and reefer containers it is stated that the most important focus regarding

sustainability work is related to fuel consumption and derived GHG emissions from fuel consumption. It is stated briefly in the introduction to the report that the company intends to respond to the global challenges set out by the UN (SDGs), further than that there is no specific SDG addressed and it is therefore no table for this company.

Moving on, the specific work regarding reefer containers is mentioned a few times in the report:

- To reduce the indirect impact of reefer containers by design-improvement and maintenance the company is working with alternative paints and insulations.
- In-depth analyses have been conducted in regards to energy consumption to invest only in high-performance, low-consuming cooling units.
- Analyzing energy management of reefer containers on board of ships.
- The company states it is taking part of a pilot project to recycle refrigerant gasses, refrigerant gasses are after cleaning & filtering reused in other reefer containers.

#### 4.1.2.4 Head of Sales of shipping company 2

In the sustainability report of shipping company 2 there is information that the company has successfully completed early tests of re-usage of refrigerants from reefer containers (ONE, 2024). The refrigerants were in these tests cleaned and re-processed before being used again in the containers. It is furtherly stated that the re-usage of refrigerants has the possibility to reduce emissions from reefers up to 4,000kg CO2 per reefer per year. Moving on, it is stated in the report that the SDGs considered relevant for the company's sustainability work is SDG 4, 5, 7, 8, 9, 12, 13, 14, 16, 17, with a priority on SDG 7, 9, 13, 14 of which there is capabilities to positively contribute to. The sustainability report of shipping company 2 is presented in table 5:

Table 5. Summarized table of Shipping company's (no 2) sustainability report 2023 in regards to the scope of this study:

| **Presented SDG and (underlying targets in report):** | **Presented work and initiatives** | comments? |
|---|---|---|
| SDG 7 (7.2 and 7.3) | Implemented a green strategy, involving development of alternative fuels to decrease GHG emissions. | |
| SDG 13 (13.1 and 13.3) | In 2021 signed the Call to Action for Shipping Decarbonisation, meaning commitment to reach net zero emissions by 2050. Five key factors have been targeted to reach this: investing in green solutions, exploring alternative fuels, managing carbon emissions, optimizing operations, collaboration with industry partners. | |

#### 4.1.2.5 Logistics company within wholesale group

The wholesale company has provided a sustainability report where it is reported what internal goals and work they are doing to obtain these goals (Axfood, 2024a). This report was created by the core company of the wholesaler group, therefore the following findings will solely be

sourced from the company within the group whose focus is the transport and logistics activities. As described in the report, the logistics company within the group is responsible for the quality and effectiveness for the goods flow between all companies and external customers related to the group. The top priorities for 2024 related to the aforementioned company is to further develop the layout of storage- & terminal facilities, effectivize terminal operations, and to effectivize and furtherly develop sustainable transport solutions.

It is also stated that large adjustments in regards to transports have been made in an effort to reduce climate impact, as transports between warehouses and stores is reported to be the largest climate impact from the whole group. Allegedly all trucks owned by the group are possible to run on fossil free fuel since extensive investments have been made in different vehicle-types. The targeted goal is to go over to solely renewable fuels, in order to achieve this an electrification plan has been implemented.

Beyond investing in renewable fuels and electrified transport units the company is monitoring fuel consumption to optimize cargo loading and driving within the distribution network. By using this monitoring system, loading of the transportation unit can be effected and routes optimized, which in the long turn could reduce fuel consumption. In addition to route optimizing, the company is actively working with eco-driving i.e. educating drivers to a more efficient driving behavior. The results from above mentioned initiatives are followed up by measuring the amount of CO2 relative to delivered tonnes of goods between warehouse and stores.

Carefully selected targets with regards to the transport and logistics part. The group as a whole has 30+ different internal environmental targets presented. In table 6 the wholesaler's sustainability report is presented, where only targets related to logistics and transports will be presented:

Table 6. Summarized table of Wholesaler's sustainability report 2023 in *regard to the scope of this study:*

| Presented sustainability goal | Presented SDG and (underlying targets in report): | Comments |
|---|---|---|
| The total food losses from all stores and the logistics company shall be halved by 2025, related to the base year 2015 of 1,7% food losses. | SDG 12 | |
| Net zero emissions by 2030 | SDG 12 | |
| "Axfood shall work for a more sustainable production and consumption of food by annually reducing the climate impact per kilogram of food sold through a changed sales mix, work for a fossil-free Swedish agriculture by 2030 and influence the industry, authorities and politics to contribute to a reduced climate impact from food production." | SDG 12 | |
| Electric consumption in warehouses shall decrease by at least 10 percent in relation to revenues by 2025 with base year 2020. | SDG 7 | -9% 2023 |
| Fleet of logistics company shall be differentiated in regards to sustainable fuels. By 2025 should no single type of transport unit accord for more than half of the fleet. | SDG 13 | "The vehicle fleet is differentiated and contains a number of different vehicle types that can run on different fuels. No vehicle type makes up more than half of the total." |
| Logistics company shall decrease GHG emissions from owned truck by 30 percent by year 2025, with base year 2020. | SDG 13 | -23% 2023 |
| Reports regarding transport into the warehouses of the logistics company shall be conducted in regards to climate impact. | 13 | |

## 4.2 Operational aspects

The results of operational aspects come from interviews to understand how the companies actually operate so that it later can be compared to the literature in the discussion.

### 4.2.1 Standard operational procedures

From the semi-structured interviews both shipping companies stated that before each trip, the reefer unit undergoes a Pre Trip Inspection (PTI) control that checks the whole unit to make sure it is functional and appropriate for transportation of temperature sensitive cargo. The Pre Trip Inspection, which is done before release to shippers, ensures that no damages have been found, that the cooling unit is properly working and that the genset is working. All interviewed companies agreed that the transportation unit must be pre cooled. What was different between the companies was how much they worked with or were aware of pallet placement in the transportation unit.

The CEO of a haulage company stated that when the trailer was to be loaded the goods that were most temperature sensitive were placed closest to the cooling unit as he claimed this was the coldest place in the transportation unit. The drivers are informed to keep the pallets close together so that the airflow is not blocked or disturbed. It is also mentioned that when transporting different goods, the cargo which is most sensitive towards high temperature is the guideline for what temperature the transportation unit is set to. The haulage company continued to state that the company has an annual routine regarding quality control. This is done in April before the summer months to ensure the cooling units are properly working before the operationally tough summer period. Every vehicle and refrigerated transport unit is thoroughly inspected with pressure tests, oil is changed etc.

The wholesaler company's vehicle coordinator mentioned that they have a so-called gold service agreement with their supplier on cooling units to make sure that they perform at the optimal level required for the cargo. In the gold service contracts it is included maintenance of their cooling units two times per year. In addition to this, once per year there is an inspection of the cooling unit to make sure that there is no risk for refrigerant leakage.

The wholesaler company loads two pallets on top of eachother but makes sure not to stack the pallets all the way to the ceiling as it would stop the airflow. They try to separate different types of cargo from each other in different trailers but sometimes they have to be packed together with freezed goods with a foldable temperature-separating wall between them. The vehicle coordinator of one of Swedens largest wholesalers was interviewed and mentioned that before loading a transportation unit, the unit was pre cooled to the desired temperature. The company did not have a timeline for when the unit was to be pre cooled but the interviewee appreciated that this was done 3 hours before loading.

#### 4.2.1.1 Standard operational procedures literature

According to literature it is important to perform a PTI and install data loggers to log temperature in the transportation unit to avoid failure that leads to cargo loss.

The literature specifies the importance of closed packed pallets in refrigerated units. If the unit is not closely packed together the air flow will be interrupted and the unit will therefore not hold the set temperature. (Jedermann et al., 2013b). When the cooling unit is not switched on the temperature rises the fastest the closest to the doors, cooling units and the top layer of the pallet stack than other positions.

### 4.2.2 Temperature monitoring

Although the different companies are using a variety of different cooling units from several manufacturers and different levels of monitoring, all interviewed companies routinely monitor

the temperature of the cargo. This could be done both live and by collecting documated data of the temperature if the customer claimed that the cargo did not hold the temperature upon arrival. The chief commercial officer at shipping company 1 mentioned that they have a temperature monitor system but also do physical inspection of the reefer where they open the doors and check the temperature manually. The head of sales at shipping company 2 states that they have invested in new technology making it possible to read the reefers temperature from the office. All of their reefers are not able to be monitored from the office so for now they prioritize the customers who need it, the goal is to equip all reefers with this technology

The CEO of a haulage company states that their routine of monitoring the temperature of the cooling unit is by a monitoring system that makes it possible to see the temperature of the truck and trailer units in the cabin of the truck, as well as in the office.

The manufacturer of cooling units mentioned that the company has invented a temperature controlling system making it possible to change the temperature from the office, e.g. if the temperature had been set to the wrong temperature. This has been developed to meet some customers' demand to minimize the amount of cargo loss due to temperature deviations.

The wholesaler company also has small monitoring devices that are randomly placed on transport going to five different customers per week to monitor specific pallet temperature. From the administrative level in the office they also have routines to manually check the temperature of outgoing trucks and trailers to make sure that there are no deviations in temperature.

### 4.2.3 Failure of the cooling unit

Operational aspects of cooling units failure on the road, there are some similarities between the haulage and wholesales companies. Both of them pointed out that if close enough to the customer, the transportation of the goods continues. If too far from the customer, the unit is kept close and repaired, they later inform the customer of the incident and if the cargo is damaged the customer starts a claim.  Both shipping companies stated that if the reefer unit breaks on the ship, there are some possibilities to repair on board as there are some spare parts and technical knowledge. If there are no spare parts on board they claim that there is nothing else to do but to inform the customer that their cargo is damaged.

### 4.2.4 Delivery of goods

The haulage company mentioned that when the goods were to be delivered, the customer is according to protocol supposed to measure the temperature of the goods directly after the transportations units doors are opened to avoid the influence of external temperature. The haulage company mentioned that the biggest challenge was the milk round delivery during April to September due to the high temperature and the high frequency of opening doors. It is therefore very important that the customer takes the temperature on the trailer and not on the dock, to avoid wrongful temperature measures. The haulage company uses refrigerated foldable walls to keep the temperature inside the transportation unit as the trailer is being unloaded for other customers. The haulage company emphasizes the importance of having easy access to the producers refrigerated room when collecting the goods, as it is their responsibility that the cargo holds a decided temperature and the haulegers responsibility that the truck is set to the correct temperature as the transportation unit holds the cargos temperature but does not cool the cargo down.

One shipping company mentioned that when the reefer is discharged off the ship, it is disconnected from the electric supply and optimally picked up straight away by truck or plugged in again at quay. Whether the reefer is plugged in on the trailer or not is dependent on how sensitive the cargo is, a disconnected reefer generally decreases 1 degree celsius per day. The other shipping company mentioned that they always keep the reefers plugged into an outlet and that the customer then comes and collects their cargo in the harbor.

The wholesalers company mentioned that when receiving pallets from the producers they measure the temperature of the first pallet and then assume that the rest of the pallets also hold temperature. The rest of the operational aspects when delivering to customers was the same as the haulage company.

#### 4.2.4.1 Temperature of goods literature

The cargo inside a refrigerated transportation unit could have a temperature deviation of 5 degrees celsius depending on where in the unit it is placed. Therefore variations on quality of fresh food of the same origin could solely be explained by temperature deviations encountered inside the refrigerated transportation unit. Such deviations can only be mitigated by better quality monitoring systems to ensure sufficient conditions inside the reefer. (Jedermann et al., 2014b). Other issues that may occur is that if the cargo is loaded with the wrong temperature, the refrigerated transportation unit will not cool down the cargo, but only keep the temperature the cargo already has been pre-cooled to (Castelein et al., 2020b). The most common cause of damaged goods in reefers is failure of the cooling unit (Kan et al., 2021). Such failures are reported to be caused by damage to the compressor, power failure, or damage to other parts inside the reefer unit. When the cooling unit is damaged in such manners, the temperature of the cargo will rise due to the damage not being detected in time and thus necessary actions not being taken in time, which is a common issue in maritime transport (Kan et al., 2021). However timing of detection may not be the sole necessity to prevent total cargo loss of reefer containers. Even though damage of the reefer unit might be detected in time, repairment might not be possible due to lack of either expertise and/or spare parts (Castelein et al., 2020b).

### 4.2.5 Food losses

The haulage company mentioned an incident where it was over 30 degrees outside and the truck and trailer carried 18 customers' cargo for a milk round. When opening the doors to unload cargo at each destination it became a challenge to keep the temperature at the last customer's pallets. The cargo was heat damaged and had to be wasted. This was a distribution fault as there were too many deliveries going out from the same truck to safely ensure to keep the temperature static. There has been no change in routines as the haulage company means that this was a one time error. When asked if it would be a solution to do two milk rounds instead of one the answer was that there is not enough economy or personnel enough for this. Furthermore he mentioned that temperature damage to the cargo is the absolute biggest challenge as broken cargo rarely happens.

The wholesalers company mentioned that they have about 10 incidents per year connected to wrong temperature on cargo that has to be returned to the warehouse and wasted. Most food

losses accrued due to human error i.e the temperature was set to the wrong degree from start. Sometimes the temperature was set to the wrong degree and the cargo became damaged. He further stated that this was to be called a human error and the only routine to make sure that this do not happen was to inform the staff of the degrees to be set and continue with the yearly quality course. The wholesalers company mentioned that if a deviation in temperature is discovered during transportation, the cargo is not delivered to customers but instead returned to the wholesalers warehouse to check if there is some cargo that can be saved and returned into stock.

## 4.3 Technical aspects

The technical results show how the company works with the transportation unit and cooling unit to minimize energy consumption.

### 4.3.1 Energy Efficiency

The CEO of one haulage company that only drives fresh produce mentioned that to save energy and increase energy efficiency he invests in freezer classed units (FCR) with thicker insulation in the walls than normal refrigerated classed units to keep the temperature levels better. Furthermore the transportation unit needs to use its cooling unit less since the walls are able to keep the temperature better than refrigerated classed units, therefore less fuel or energy is used. The company has some cooling units still running on diesel, but focuses on investing in cooling units that are connected to the cars engine. The haulage company also discuss eco-driving with the professional driver so that they are aware of both environmental and economical aspects of fuel consumption.

The Product and Development Manager of a company that manufacturers cooling units mentioned that to increase energy efficiency they have worked a lot with integrating the cooling unit with the engine of the vehicle instead of the cooling unit having its own engine. This makes it possible to decrease fuel consumption, and by that CO2 emissions. Furthermore the manager mentioned that if you have a belt drive it is harder to turn the cooling unit off than with electric power, not being able to turn off the belt drive results in big energy losses. Today they only produce cooling units with electric power.

The chief commercial officer of  shipping company 1 mentioned that to increase the energy efficiency of the reefer the company always invests in the newest technology, but did not specify what kind of technology this is or how it would help the decrease of energy use. They have no set working routine to minimize the energy use of reefers as they claim that reefers have a consistent consumption of energy.

Head of sales at a shipping company 2 stated that they collaborate with the company that constructs the reefers and are able to specify to the manufacturer what kind of specifics they need. They have invested in reefers with two zones, making it possible to carry one zone with one temperature and the other zone with another temperature in the same transportation unit. This saves energy as it is possible for the buyer to buy smaller batches. One reefer unit transported from Hamburg to Singapore emits 2100 kg CO2compared to a TEU that only emits 900 kg CO2 on the same journey.

The vehicle coordinator of a wholesalers company mentioned that they have a contract with the seller for 8 years, where the maintenance work is performed by the seller to make sure that the cooling unit has the best performance and therefore not increasing the energy consumption. Their cooling unit is connected to the engine of the vehicle and their 154 trailers cooling unit is run by diesel fuel, but are investing in electrical batteries for their cooling unit, and have as of now 3 battery driven trailers. The wholesaler company uses two different car and trailer manufacturers, the first option uses 17 KwH and the second option uses 20 Kwh. And says that the only factor that they assume affects the energy use is the weight of the cargo, and mentioned that they do not have the knowledge of other aspects. The company yearly has education of eco-driving to ensure that the fuel consumption is minimized and optimized.

The manufacturer of cooling units mentioned the company had a policy that the new unit had to be four times as energy efficient as the previous release. 10 years ago their alarms had 10-20 different alarms, as today the unit reacts to 250-300 different deviations. Their cooling units use about 3-4 Kwh but could use more depending on the quality of the truck and trailer.

#### 4.3.1.1 Energy efficiency literature

Up to 17% of a refrigerated unit's total electronic energy consumption could be saved if it would be placed under a sunroof during sunny days. (van Duin et al., 2018b). It would also be possible to save energy while stacking them onboard on a vessel, when a reefer is placed: top layer inside the stack, top layer corner setting, middle layer inside the stack, middle layer corner setting. It is possible to save power consumption of 7% when stacking the containers in one of these positions. (Filina-Dawidowicz et al., 2022b). The wrong mix of cargo or wrong placement in the transportation unit may also lead to lost goods. Eco-driving could minimize the energy use on up to 9%.

To summarize the results gathered from interviews and the respective reports on sustainability work from each company the key takeaway’s is presented in table 7:

Table 7. Summarized table of primary work presented by interviewed companies in regard to to their work with SDSs, operational cause of food loss and energy efficiency alternatives.

| **Company** | **SDGS brought up in sustainability report** | **Stated most common operational cause of food losses** | **Initiatives on energy efficiency in regards to food losses in transports** |
|---|---|---|---|
| **Haulage** | N/A (Not obliged to conduct sustainability report due to company size) | Human error | Investing in FCR-classed refrigerated transport units. |
| **Shipping company 1** | None specific mentioned | Technical issues of the cooling unit. | Investing in high-performance, low-consuming cooling units. In addition to that a large emphasis on what fuels the ships run on. |
| **Shipping company 2** | SDG 7, 12, 13. | Technical issues of the cooling unit. | Investing in energy efficient reefers. |
| **Manufacturer** | SDG 7, 12 and 13. | Lack of well functioning monitoring systems. | Development of better technology to keep temperature |
| **Wholesaler** | SDG 7, 12, 13. | Human error | Educate staff and invest in renewable fuels and vehicles. |

# 5. DISCUSSION

In the discussion the literature will be compared to the interviews to answer the research questions.

## 5.1 Legislative aspects

As mentioned in the theory part, there are several regulations from ISO regarding cooling units and transportation units used within the cold supply chain, which sets a standard for the equipment. This is not mentioned much by the companies, perhaps as these companies take the standardized qualities of their equipment as a given factor which cannot be compromised with. However some emphasis was put on further enhancements of the different companies' transportation unit, to illustrate how they are working beyond the minimum requirements set by the International Organization of Standardization.

None of the interviewed companies claim to have any issues regarding compliance with current legislations on food transports. Even if such direct questions would have been asked during interviews surely no sufficient answers would have been supplied regardless of anonymity granted for interviewees. However, as companies claim to have issues with temperature settings and some manual procedures this could be interpreted as occasional non-compliance with legislations on safe food handling. Although these miss happenings have not been reported as problems of larger magnitude which happens often, seemingly the companies have mandatory educational courses on safe food handling to mitigate such human errors mentioned. As these courses and their content have not been analyzed in-depth but merely mentioned briefly it is not possible to determine whether the companies education on safe food handling is inadequate or if these minor issues just are purely human errors.

The wholesaler and haulage mentioned the yearly routine of checking for refrigerant leakage to make sure that the cooling unit is working properly. This is done in line with the Swedish legislation as the vehicles are prohibited to drive otherwise. This is due to the tremendous risks of refrigerated leakages and its contributions to global warming and is therefore connected to SDG 12 in the companies' sustainability reports.

One company's sustainability report mentioned that preventing food waste is outside the scope of the activities of the group. At first this might raise several questions and doubts, however this is a shipping company with a primary focus to transport containers, therefore mitigating food losses might not be possible for this company to have an impact on. However, there should be no reason to believe that this company would have no interest in keeping food losses at a minimum within their own transport network.

All analyzed companies seemingly have strategies on how they should be addressing agenda 2030 and working toward more sustainable business practices. The companies differ slightly in their interpretations on what is relevant to be addressing, especially regarding minimizing food losses. It seems that most emphasis are being put on reducing GHG emissions from transports and not too much specific strategies are described on mitigating food losses within the transports. Perhaps as none of the companies in this report claim to have any larger issues with food losses this could be representative for the companies, and more focus are being put on the emissions of the transports themselves.

## 5.2 Operational aspects

Following the operational aspects of cold supply chain is discussed and compared to the literature.

### 5.2.1 Standard operational procedure

To minimize food loss caused by cooling unit failure the shipping companies mentioned PTI routine to minimize the amount of food loss as it makes sure that the transportation and cooling unit is well working and capable of carrying perishable goods.

The haulage company mentioned that the most fragile period was during summer as the temperature rises and it was hard to keep the temperature in the transportation unit during milk rounds as it had to be opened to deliver all the time. The manufacturers way of reducing food loss was to ensure that their cooling units were as technically advanced as possible. The wholesaler company's main focus to minimize food loss is to properly load the transportation unit to make sure that the air is flowing sufficiently to minimize the risk of temperature deviations, in addition to proper stuffing they claimed educating personnel was of high importance. It can be assumed that the company works with minimizing food loss both for environmental purposes but also for the own companies' economic benefits as food losses in the cold supply chain will have to be replaced by the company.

### 5.2.2 Cargo temperature

The wholesaler mentioned that when receiving goods from the producers the routine is to check the first two pallets' temperature. The literature on cargo temperature mentioned that pallets traveled in the same refrigerated transportation unit could have a deviation of up to 5 degrees celsius. As not every single pallet is checked it could lead to pallets being brought into stock which have been exposed to different temperatures during transport, thus possibly creating a risk of accepting damaged cargo. The wholesaler's producer's transport comes with approximately 30-40 pallets per transportation unit; it would therefore not be possible to temperature check all pallets since there is a flow of about 10-20 units of transportation per day. It can therefore be assumed that the company does not expand the amount of personnel to check every single pallet as this would be a major cost for the company. As this may cause problems further ahead when the wholesaler assembles together their own pallets to send out to their customer. Here an assumption can be made that it is cheaper for the wholesaler to discover temperature deviations on goods when picking the pallets than checking the temperature of every single pallet upon arrival.

One shipping company mentioned that when unloading a vessel, it might happen that a reefer stands unplugged in the terminal for a few hours if the unit is supposed to be picked up. Furthermore the company mentioned that it does not do any severe harm to the goods as the reefer loses 1 degree celsius per day. The literature shows that the temperature closest to the cooling unit, door and roof rises in temperature rapidly. To minimize food loss and waste it would be theoretically optimal if the refrigerated unit is constantly plugged in. However, it would be hard to keep the reefer plugged in at all time regarding the operational aspects as a vessel can carry up to 20 000 TEU of various container types that has to be unloaded.

### 5.2.3 Delivery of goods

Both the wholesaler and haulage company mentioned that to minimize the food loss it is important, and especially during summer periods, to keep the doors closed of the transportation unit for as long as possible. When the operational obstacles are having a lot of customers on both truck and trailer it is a challenge to keep the doors closed. It is therefore important that the chauffeur follows routine calls the customer 10 minutes upon arrival to have easy and direct access to the customers cooling rooms.

### 5.2.4 Load planning

The haulage company mentioned that when very temperature sensitive goods were transported with normal sensitive goods in the same unit without foldable walls, there was a plan on where to place the goods in the transportation unit to make sure that all the cargo kept its temperature.

As the literature is very clear on the importance of close packed pallets and pre-cooled transportation units. The operational part of the wholesalers are aware of the importance but do not have a clear routine on when the transportation unit should be cooled or how close the pallets should be packed together. The overall one thing that is communicated to the loaders is to not load too close to the ceiling, some companies mentioned that they are aware that the pallets need to be close together, but it was understood that the important part was that the pallets were not too close to the ceiling.

When asked how the interviewees work with load planning of the transportation unit to minimize food loss, only the haulage company planned how to load extra temperature sensitive goods so that it would not be damaged. The wholesaler company mentioned that their focus is to not load too close to the ceiling. However, if the cooling unit would stop working the pallets closest to the door, unit and the top layer of the stack would increase faster in temperature than cargo placed in other positions. It would therefore be beneficial to place the extra sensitive cargo in the middle bottom layer in case of cooling unit failure. It can be assumed that it would have operational obstacles to be able to load the transportation unit perfectly, it would take more logistical resources in terms of planning and making sure that the pallets are picked and placed in the warehouse in correct order for the loader.

## 5.3 Energy efficiency initiatives

Energy efficiency methods used by the interviewed companies are compared to the facts in the literature.

### 5.3.1 Energy consumption

All of the companies interviewed had some way of trying to lower their energy consumption on their refrigerated units. Not one company mentioned sunroofs as a way of keeping the reefer out of direct sunlight and therefore avoid the cooling unit having energy peaks. The wholesales company also had an unclear routine on how far ahead the unit should be pre-cooled and how this would differ during the different seasons. Not having a clear routine could decrease the energy consumption of the unit as there is no strategy in place to know how long it takes to actually cool down the unit. At terminals, reefers are responsible for 30-35% of the total electric energy consumption. (van Duin et al., 2018b). So it could be considered a high priority to try to minimize the consumption of energy. According to the

findings in current literature, a method of minimizing the energy consumption of reefer containers could be to use sunroofs over the units, as the unit would not heat up to the same extent and overclock the cooling unit and could therefore save energy. Perhaps it is unrealistic however to put every single reefer container under a sunroof as this surely would increase the total loading and unloading time of vessels, which in turn could pose a risk for food losses of fresh foodstuff.

The literature shows that it would be possible to save up to 7% energy if the reefers would be loaded onto the vessel in a specific order (Filina-Dawidowicz et al., 2022b). The shipping companies were asked how they worked with minimizing their energy consumption but did not mention any routines or operational aspects regarding the literature. So it would be possible to save up to 7% energy from stowage planning, however it can be assumed that this would add a high logistical cost. It would take a lot more personnel to make sure the pallets are not only stacked close to outlets, but also stacked correctly in the stack. This would most likely be logistical impossible as the consequences would be that the lay time for the vessel would increase dramatically.

The haulage and wholesaler company, which are of the companies operating on roads of the companies interviewed. Both mentioned that they yearly educated their staff of eco-driving and the benefits of this. This goes well with the literature that states that it is possible to reduce energy consumption up to 9%.

## 5.4 Method Discussion

Initially this report was intended to be based on quantitative data on emissions derived from seaborne reefer transports regarding food losses. The intention was to gather AIS-data from ships transporting reefer cargo, to analyze emissions from these transports which could help bring up to an answer on how emissions from international food transports look. But since most food related reefer transports are shipped on large container vessels it would be hard to only pick out data from these vessels. This led to us realizing perhaps this report should be based on more qualitative information, as operational management in daily routines is most in line with the preferred research topics for the report.

A great variety of companies were contacted to conduct interviews with. No freight forwarding companies contacted chose to participate in any interviews. The preference was to get freight forwarding companies specialized in cold cargo transports with reefer containers to participate, as these companies surely would have operational expertise and in-depth knowledge about common problems with food transports between countries. About 25 different companies were contacted but finally six quality interviews of about 45 minutes each were held. Almost all the interviewees recommended us to read their respective sustainability reports from their websites, especially when asked questions they claimed they could not confidently answer. Therefore we also analyzed different sustainability and compared the information gathered from the reports with the answers from the interviews, to see if the information from the interviews could be representative for the whole companies' activities.

A large emphasis in the theory part of the report was put on ISO standards, the purpose of this was as previously mentioned to illustrate the standardized quality requirements companies have to comply with. With this information presented the conclusion that companies' transportation units have more or less the same basic requirements and starting position, what

separates them is their routines and daily operations. Companies of course can invest in higher quality cooling systems but a larger emphasis in this report has been taken on loading operations and related work.

This method was representative for the industry as most part of actors of the supply chain was covered to get a complete overlook of the process. No personal opinions were added to the report to maintain objective during the process of the work. It is possible that preferable results could have been accumulated with more interviews performed as well as quantitative data to support the research questions. Perhaps more interviews on the same type of companies could provide further operational aspects. To gather any data related to food losses occurred during the cold supply chain is hard due to some interviewed companies state the routines they implemented regarding vehicle inspections related to the rules stipulated by the Swedish Transport Agency.

# 6. CONCLUSION

How do companies within the cold chain supply work with the different Sustainable Development Goals and other regulations related to food transports? The regulatory frameworks are clearly stated in Swedish and EU legislations and the different actors who participated in the report claim to be following these regulations by the book. Although the most common cause for improper operations leading to food waste seems to be caused by human errors, such as improper temperature settings. It is clear that the companies follow and adjust their operations in accordance with current legislations, therefore it is important that legislators continuously make new and improve laws and regulations to minimize food loss.

What are the operational aspects of refrigerated cargo handling during transports of foodstuff to minimize losses? The studied companies have reported various operational procedures that could be improved to minimize the amount of food loss. All companies stated that the most common cause for food loss related to transports was human errors, such as setting the wrong temperature in the transport unit from start, or not properly cooling down transport units during warmer months where cold transports are put more at risk to temperature deviations. Although human errors have been identified as the most common operational issue it was not necessarily seen as a large issue in need of a change. When asked about possible improvements and solutions to mitigate human errors there was no real solution to this other than to keep personnel updated on the standardized routines. From the literature on this area there are suggestions on how to further optimize the operations of cold chain supply logistics. However, when delving in more into the daily operations of such related companies there seems to be little applicableness of these academically brought out procedures into the real world.

What initiatives on energy efficiency regarding refrigerated food transports is used and planned by companies in the cold supply chain? It was easier to discuss energy efficiency with the companies as this is something that is regulated by law and had to be followed rather than operational aspects that are regulated within the company. All companies have ways of minimizing their energy consumption and are aware of the importance of minimizing emission. But these companies also claim that there is still ways to improve the cold supply chain to minimize energy consumption further, especially in regards to fuel consumption.

# 7. RECOMMENDATIONS FOR FURTHER RESEARCH

To further investigate the problems with food loss that occur during the cold supply chain it would be recommended to further interview specialized wholesalers and quay terminals. Since a common answer from transporters and wholesalers dealing with fresh food is that dairy and meat products are the most sensitive there is a lack of information about other operational issues regarding other food categories such as fruits or vegetables. Surely a specialized wholesaler as a company dealing only with transports of different types of fruit will provide a nuanced answer about the operational challenges to minimize loss of fruit cargo. It would also be important to interview quay terminals as the insight could lead to a larger understanding of reefer handling on shore.

As human errors seem to be the most common cause for food loss from operational faults it tells us that there are a lot of manual operations related to the stuffing and transports of refrigerated cargo. Perhaps an interesting field of study would be to analyze how automatization of such operations could help reduce food loss.

One finding which finally was chosen to be excluded from this report is the fact that several companies studied reported in their sustainability report on different charity projects they are doing. Such as donating money or resources to struggling communities in especially developing countries, primarily to help minimize food security. These projects are of course great acts of humanitarian aid that should not be neglected. It would however be interesting to understand how the daily operations of the same companies are being improved to help minimize the same goal as food insecurity. As for example how does a large shipping company help minimize food losses occurring in their own operated reefer containers to reduce food security and starvation across the globe.

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