The carbon footprint of an oil product terminal

Kristian Pettersson

Master’s thesis
Supervisors: Prof. Margareta Björklund-Sänkiaho, Åbo Akademi
Master mariner Kimmo Vahanto, Neste Oyj
Examinator: Prof. Margareta Björklund-Sänkiaho
Energy Technology, Vasa
Study programme in Chemical Engineering
Faculty of Science and Engineering
Åbo Akademi University
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ABSTRAKT

Strävan mot kolneutralitet är starkare än någonsin och alla företag över hela världen söker nya metoder och energikällor för att minska sina växthusgasutsläpp. I takt med att utsläpp av växthusgaser begränsas ökar intresset att göra ändringar inom företagen. Dessa ändringar kräver dock ofta stora investeringar och har ibland långa implementeringstider. För att veta vad som måste göras och vad som är de viktigaste områdena att förbättra bör företagen känna till sin nuvarande situation.

I detta arbete undersöks nuläget vid hamnen och tågterminalen i Sköldvik, Borgå. Målet var att beräkna kolavtrycket med fokus på direkta utsläpp och utsläpp som uppstått vid produktionen av köpt energi, alltså utsläpp av omfattningarna 1 och 2. Genom att kartlägga utsläppen för området i fokus kan företaget i ett senare skede använda sig av detta arbete för att kartlägga kolavtrycket för hela sin verksamhet. Källor till utsläpp av omfattningarna 1 och 2 inom det analyserade området är företagsägda fordon, facklor som används vid lastningsoperationer samt som säkerhetsanordningar, och användning av elektricitet och processånga.

Kolavtrycket sammanställdes med hjälp av data insamlad från flera olika källor, både interna och externa. Bränsleåtgången för fordonen samlades från kreditkort och bränsleleveranser till en tank i hamnen. Utsläppen för facklorna samlades i ett övervakningssystem där data från olika mätpunkter samlas. I systemet lagras också användningen av elektricitet och processånga som kunde användas i kombination med utsläppsfaktorer för att beräkna utsläppen.

Resultatet och jämförelsen med tidigare år visar att företaget redan kommit långt med att nå sitt mål att ha kolneutral produktion år 2035. Det finns fortfarande mycket att förbättra, men för att uppnå någon märkvärdig reducering av kolavtrycket krävs stora investeringar och omfattande ändringar av speciellt rörledningsuppvärmningen.

Nyckelord: kolavtryck, utsläpp, kolneutralitet, hållbarhet

ABSTRACT

The strive for carbon neutrality is stronger than ever and companies the world over are searching for new methods and energy sources to reduce their greenhouse gas emissions. As emission restrictions are getting ever stricter, changes in ways of working within companies are gaining more interest. However, large scale changes require large budgets and often have long implementing times. Knowing what has to be done and which the most significant areas of improvement are, the present situation has to be analysed.

In this work the present situation at the harbour and train discharge terminal in Kilpilahti, Porvoo is investigated. The goal was to calculate the carbon footprint with focus on direct emissions and emissions arising from the production of purchased energy, scope 1 and 2 emissions. By identifying the carbon footprint for the area in focus the company is able to make use of the findings of this work to identify the carbon footprint of the whole company in future investigations. Sources of scope 1 and 2 emissions in the analysed area are company owned vehicles, flares used for loading operations and as a safety measure, and the use of electricity and process steam.

The carbon footprint was calculated from data compiled from several sources, both internal and external. The fuel consumption of the vehicles was gathered from vehicle-specific credit card histories as well as receipts of fuel deliveries to a bunker tank in the harbour. The emissions from the flares are calculated automatically in a utility management system that gathers data from several sources. Data about the use of electricity and steam is also stored in the system, which could be used in combination with emission factors in carbon footprint calculations.

The result and comparison with previous years shows that the company is already well on its way toward its goal of having a carbon neutral production by 2035. There is still much to improve. To achieve any significant reductions of the carbon footprint substantial and costly changes must be made, especially the pipeline heating solution at present.

Key words: carbon footprint, emissions, carbon neutrality, sustainability

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This thesis has been written for Åbo Akademi University and is a part of Neste Oyj's strategy of achieving a carbon neutral production, regarding scope 1 and 2 emissions, by 2035. The project consisted of performing a carbon footprint analysis at the harbour and train discharge terminal in Kilpilahti, Porvoo. This work is also meant to function as a template for analyses carried out for other Neste terminals.

I would like to thank Neste Oyj for giving me the opportunity to perform this interesting analysis of the emissions at the company premises. I would also like to thank Kimmo Vahanto, Miikka Vanhanen, Nora Saarinen, and all other personnel at Neste Oyj that have been involved in this work by providing information and giving me guidance and support along the way. Additionally, I would like to thank Margareta Björklund-Sänkiaho at Åbo Akademi University for guidance during the work, and especially for giving excellent feedback during the final stages of writing.

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Kristian Pettersson

1 INTRODUCTION

Technologically advanced is a term that could well be used to describe today's world. With technology comes a need for energy to power it. The energy must come from somewhere, and fossil fuels have provided a large part of the energy required to power the developing modern society. Fossil fuels are a dense energy source, with regrettably high emissions as a by-product. However, in recent years the trend of moving away from high-emission sources has accelerated. This trend is the result of a rising awareness of anthropological emissions being the main contributor towards global warming. According to a special report on global warming by the Intergovernmental Panel on Climate Change (IPCC) published in 2018, we are already seeing the effects of a 1 °C increase in global temperature, for example, in the form of extreme weather and rising sea levels (IPCC, 2018). To limit the rise in temperature as much as possible, aggressive steps must be taken to combat the anthropological emissions.

More and more companies release statements about joining the battle against global warming by moving to greener energy options, and Neste Oyj is one of them. Neste is committed to achieving a carbon neutral production by 2035, and one step in the process is analysing the current situation which can be done by calculating the carbon footprint (Neste, 2022a). A carbon footprint analysis takes all emissions flows into account, both release and capture, to present a total emission value over a predefined period of time for the analysed system (Muthu, 2016). The carbon footprint concept could be thought of as a sub-set of a life cycle assessment because of the similarities of the process. Both concepts use the same four-step framework of goal and scope, inventory analysis, impact assessment, and interpretation (Muthu, 2015).

The goal of this thesis was to calculate the carbon footprint of the harbour and train discharge terminal at Neste's refinery in Porvoo, Finland. Furthermore, the work was to be made in such a way that it could be used as a template for carbon footprint analyses at Neste's other terminals in Finland. The scope of the analysis was to calculate the total scope 1 and 2 emissions, as well as the scope 3 emissions relating to the production and transport of fuel used by company-owned vehicles.

2 THEORY

The world today is constantly changing, and with change comes both positive and negative aspects. On the one hand, ever-evolving technology allows for higher efficiency. On the other, the polluting is sustained due to old technology still being used to power the new, more demanding technology. By choosing to use alternative energy sources, we can lower the emissions arising from the energy we consume. Analysing the impact we have on the environment is called *carbon footprint analysis*. This chapter presents the theory of carbon footprint analysis, beginning with sustainability and global warming, and continuing with the theory of performing a carbon footprint analysis.

2.1 Sustainability

Sustainability is difficult to describe in just one way. The term is described by Gulliksson & Holmgren (2018) as meeting today's demand without venturing the future of the world we, and those after us, live in. This definition is also the one most agreed upon, called the Brundtland definition, although it has been criticised because *development* cannot be sustained with a finite resource pool (Franchetti & Apul, 2012). Gulliksson & Holmgren (2018) discuss four alternative definitions for sustainable development: quality of life does not decline over time, natural resources cannot decrease over time, maintaining resources to ensure a sustainable yield of goods and services, and maintaining the resilience of the socioecological systems over time. These four definitions rely on being able to accurately measure quality of life, strict management of natural resources, and understanding how social and ecological systems are connected and how to predict when they are at risk of collapsing.

Some of the most prominent threats to achieving sustainable development are the booming population, the global warming effect, overconsumption, the size of the ecological footprint, and possible depletion of resources such as oil and minerals (Gulliksson & Holmgren, 2018). Actions have been taken to combat these problems in the past. According to Gulliksson & Holmgren (2018), a suitable starting point for the move towards a sustainable society is the United Nations' Universal Declaration of Human Rights, signed in 1948, which has provided the foundation for more than 70 human rights treaties and has set the development of a sustainable social society in motion (United Nations, 2022a). Other United Nations' declarations and targets that guide the way to a more sustainable future are Agenda 21 (1992), the millennium goals (2000), and the UN's sustainable development goals (2015) (Gulliksson and Holmgren, 2018). In addition to the UN's efforts, there are some important international environmental agreements, such as the Kyoto Protocol in 1997, binding all countries that signed to decrease their CO_2 emissions, and the Paris agreement in 2015, aiming to limit global warming to 2 °C.

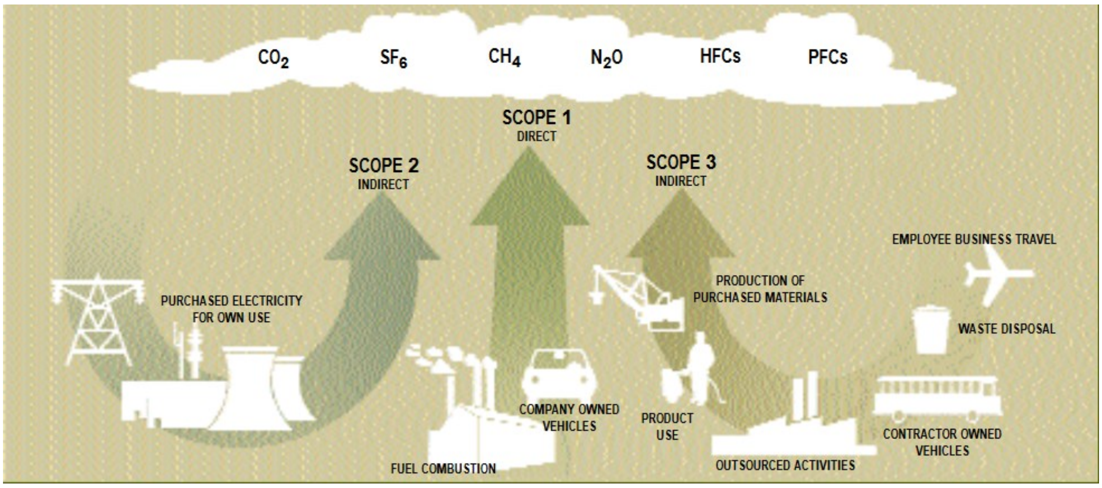
2.2 Global warming and greenhouse gases

The term *global warming* is used as an expression for the rise in average temperature caused mainly by carbon dioxide (CO_2) in the earth's atmosphere. The rise in CO_2 has the effect of letting solar radiation through the atmosphere while limiting the outflow of radiation from the atmosphere, raising the temperature within the atmosphere (Bogren, Gustavsson & Loman, 2006). There is a natural fluctuation in the earth's average temperature, each period spanning millions of years, but in the past few hundred years there has been a significant acceleration of the global warming effect. In addition to the natural global warming, mankind causes an anthropogenic global warming effect due to the emissions arising from our industrialised civilisation, mainly the release of fossilised CO_2. According to the IPCC (2015), it is with 95 percent certainty human activities that are the cause of the recent global warming effect. Greenhouse gas concentrations in the atmosphere are at the highest level in at least the past 800 000 years, and in the last 40 years around half of the total cumulative anthropogenic CO_2 emissions since 1750 have occurred. In the past 40-year period, there has been an approximately 40% increase in CO_2 emissions from burning of fossil fuels, cement production, forestry and other land use (IPCC, 2015; Muthu, 2016).

A greenhouse gas (GHG) is a gas that absorbs and emits radiation and the presence of GHGs in the atmosphere is what causes the greenhouse effect that warms the earth (Franchetti and Apul, 2012). Water vapour, CO_2, methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) are GHGs that exist naturally in the atmosphere. Without them the earth would be around 30 °C colder (Bogren, Gustavsson and Loman, 2006). It is the increased anthropogenic pollution that is worrying, and what is causing an unnatural rise in the earth's average temperature. Human activities have increased the concentrations of CO_2, CH_4, N_2O, and anthropogenic gases such as sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) in the atmosphere (Bogren, Gustavsson and Loman, 2006; Franchetti and Apul, 2012). Each of these gases has a different impact on the climate over a certain period expressed as the global warming potential (GWP), relating to the impact of CO_2 (Bogren, Gustavsson and Loman, 2006; IPCC, 2015). To be able to comprehensively compare these gases their impacts are converted to a common unit of measurement: tonnes of CO_2-equivalent, or tCO_2eq abbreviated (Brohé, 2017).

As seen in figure 1, there are three different categories of GHG emissions when analysing a anthropogenic emissions relating to a company: scope 1, 2, and 3. Scope 1 includes the direct emissions from sources owned or controlled by the company (GHG Protocol, 2015). Some examples of scope 1 sources are electricity or heat generation by the company itself, physical or chemical processing, transportation of any kind with company-owned or -controlled vehicles. Scope 2 emissions are defined as purchased energy, or energy brought into the organisational boundary. For many processes and companies, purchased electricity is often the main scope 2 emission. Scope 3 includes all other indirect emissions apart from purchased energy.

Figure 1 A summary of the different emissions relating to emission analysis (GHG Protocol, 2015)



2.3 Environmental goals and strategies

As a measure to counteract global climate change, the European Union (EU) has set goals for reducing the greenhouse gas emissions. These goals are the 2020 climate and energy package (European Commission, 2022a), and the 2030 climate and energy framework (European Commission, 2022b). The 2020 goal was to reduce GHG emissions by 20% compared to 1990 levels, that 20% of energy within the EU would come from renewables, and that there would be a 20% improvement in energy efficiency (European Commission, 2022a). The 2030 goals are to further reduce GHG emissions by another 20% to a total reduction of 40% compared to 1990 levels, to increase the share of renewable energy to at least 32%, and to further improve energy efficiency by at least 32.5% compared to projections of the estimated energy use in 2030 (European Commission, 2022b).

Neste Oyj actively works to improve sustainability and combat climate change. This is done by continuously searching for better solutions and methods and striving for a transformation to a carbon neutral value chain. The company has set specific goals to achieve this. The goals directly targeting climate change are to reach a carbon neutral production by 2035 regarding scope 1 and 2 emissions, and reducing scope 3 emissions by 50% by 2040 compared to 2020 levels (Neste, 2022a). The company is also providing solutions that have comparably lower emissions, aiming to reduce their customers' emissions by at least 20 million tCO_2eq by 2030 (Neste, 2022b). These solutions largely consist of renewable fuels for both road transportation and the aviation industry.

The United Nations and all member states have agreed on 17 global goals, known as the 2030 agenda for sustainable development, providing a shared method of working toward global peace and prosperity (United Nations, 2022b). Of the 17 global sustainable development goals (SDGs) identified by the UN, the company studied has nine SDGs as priority goals which are most relevant to the company's operations (Neste, 2022b). Some of these nine SDGs relating directly to emissions and the climate are clean energy, sustainable cities and communities, climate action, and life on land. The company is working toward these goals by, for example, producing renewable fuels from waste and by aiming toward the use of 100% renewable electricity by 2023

(Neste, 2022b).

2.4 Life cycle analysis

The purpose of a life cycle analysis (LCA) is to identify the environmental impact, and transfer of the impact to other mediums, of a product or a process over its life-span (Curran, 2015). A life cycle analysis can be split into four steps: goal and scope, inventory analysis, impact assessment, and interpretation and presentation of the result (Muralikrishna & Manickam, 2017). Each of the first three steps is always followed by an interpretation of the results of the step, with the presentation of the results following the completion of the analysis.

It is important to set a clear goal and scope when performing an LCA. The outcome of the analysis strongly depends on the goal and scope of the project, which can be adjusted if needed during the analysis (Curran, 2015). The type of LCA conducted may also vary between internal or external use of the results and analysis of a single system or a comparison between different designs, depending on the intended use of the analysis. Parameters that should be clearly defined when setting the scope is the functional unit, the system boundaries, allocation procedures, impact assessment methodology and interpretation approach, the functions of the system, and the data needs. The goal and scope could be specified in a separate document, which could also include a background to the study. This document is rarely made available to the public, as the sole purpose is to help with the analysis.

The inventory analysis, also called life cycle inventory (LCI), begins with the collection of data. This is the most demanding task of the LCA. The types of data can be split into two categories: foreground data, which is specific data for modelling the system; and background data, which is general data for materials, energy, and transport (Muralikrishna & Manickam, 2017). When a conventional inventory analysis is performed, the system studied is split into unit processes. A unit process is described by Curran (2015) as the smallest element that is considered when compiling data for inputs and outputs within the system. During the LCI, a unit process is considered as a black box where the process of converting input elements into output elements is not analysed in detail. This method of looking at the system as a series of processes is the earliest, and most commonly used, method for compiling the inventory data of an LCA (Suh & Huppes, 2005).

Another approach to the inventory analysis is the input-output (IO) method, which utilizes the input-output concept of the economic sector (Leontief, 1970). In this approach it is assumed that each industry, or step, consumes some of the outputs of other industries to produce its own product (Suh & Huppes, 2005). This method utilises matrices to process inputs and outputs to and from the system, and can further be expanded to take environmental impact into account by assuming that the magnitude and type of the impact has a fixed ratio with the amount of output from the process analysed (Suh & Huppes, 2005). The IO method is less prone to truncation errors and is cheaper than the process-based method, but it is also less accurate and less detailed. This has sparked the development of hybrid methods where the IO analysis complements the process analysis to varying degrees, with varying results (Crawford *et al.*, 2018).

A life cycle impact assessment (LCIA) processes the results of the inventory analysis and describes the potential impact on the environment of every unit process in the system. The main part of an LCIA is the impact category, which should be well defined in the goal and scope part of the analysis (Curran, 2015). Some examples of categories are climate change, depletion of fossil energy sources, and toxicity. The result of an LCIA is reported as an impact indicator which is chosen depending on the approach of the analysis. There are typically two approaches: the classical approach that aims to present the impact at a mid-point (e.g., global warming potential), and a damage-oriented approach which aims to present the impact as an ultimate societal concern (e.g., impact on human health).

After both the inventory analysis and impact assessment, the results are to be interpreted and reported. In this phase of the LCA, the observations of both the LCI and LCIA are evaluated in relation to the goal and scope of the project. This should be done with transparency, meaning the methods and calculations used should be clearly documented (Curran, 2015). Transparency is achieved by stating all methods, assumptions, and value choices, in the final report.

The LCA approach to analyse energy use and pollution is well established and practiced widely all over the world. There are, however, some drawbacks with the concept. It is considered impractical due to the amount of data needed, the time needed to analyse and implement the concept, the expense, and the uncertainty regarding the results due to estimations in the calculations (Muralikrishna & Manickam, 2017).

2.5 Carbon footprint

Increased human activity releases GHGs that cause a global warming effect, which in turn triggers climate change (Franchetti & Apul, 2012). Carbon footprint is a measure of how much greenhouse gases are produced by the system observed (Franchetti & Apul, 2012; Muthu, 2016). The carbon footprint concept can be defined as a sub-set of an LCA with focus only on the emission part because the carbon footprint process is similar to the LCA, as mentioned earlier, in that it uses the same four-step framework: goal and scope, inventory analysis, impact assessment, and interpretation (Muthu, 2015).

The term *carbon footprint* could also be described as *greenhouse gas inventory* (Franchetti & Apul, 2012). When calculating a carbon footprint, the rate of removal should also be included, i.e., carbon sinks. Thus, the carbon footprint is the sum of the total amount of CO_2 released and captured, directly or indirectly, over the lifetime or a predefined time period of a product or process (Muthu, 2016). A large part of a carbon footprint analysis (CFA) is calculating the global warming effect of greenhouse gases (GHGs). Many gases have GHG properties, but typically only six are accounted for according to the Kyoto Protocol (UNFCC, 2008; Franchetti & Apul, 2012). These are: carbon dioxide (CO_2), Methane (CH_2), Nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Each of the gases are inventoried in metric tons and then converted into CO_2-equivalent units (Franchetti & Apul, 2012). The conversion to one common measurement unit is done because each gas impacts the environment with a different magnitude, depending mainly on the absorption of solar radiation and residence time in the atmosphere (Bogren, Gustavsson & Loman, 2006). Using only one unit simplifies the carbon footprint calculations.

As for an LCA, the goal and scope of a CFA should be clearly defined and include the boundaries, the intended audience, the intent of the study, and the functional unit (Muthu, 2015). The system boundaries consist of the organisational boundary and the operational boundary. The organisational boundary is defined as the boundary on the economic and business grounds where the organisation is located, and the operational boundary consists of direct and indirect emissions from the process (Muthu, 2016). These boundaries must be clearly defined and followed throughout the analysis. A thing to consider when stating the intent and intended audience of the study is the approach. Muthu (2015) states that there are two possible approaches, namely an attributional or consequential approach. The attributional approach describes what the carbon footprint of a product or system is, while the consequential describes how the carbon footprint could change if the surrounding systems were altered. For example, the attributional approach may be chosen if the public is the intended audience, and the consequential if it is intended for internal use when considering a change in the process.

The inventory analysis is most time-consuming involving examining every element of the system in detail (Muthu, 2015). By utilising the LCA framework, the inventory analysis can be performed using the process analysis or input-output method. Process analysis has mainly been used for assessing a single product or systems in smaller scale, while the IO method has been used regionally or nationally (Muthu, 2015). When compiling data using the IO method, one of the main complications are the estimations based on emission factors for certain processes and the verification of the collected data (Muthu, 2015; 2016). While the IO method is less time consuming, it often underestimates the worst pollutions because of estimations and use of average emissions within the system (Muthu, 2015). In some cases a hybrid approach may be used for more accuracy, using process analysis for more important elements of the system and IO analysis for the supporting systems. Some things to take into consideration and to be certain of is that the data for the foreground system is of high quality, and that all relevant GHG emissions are included in the analysis.

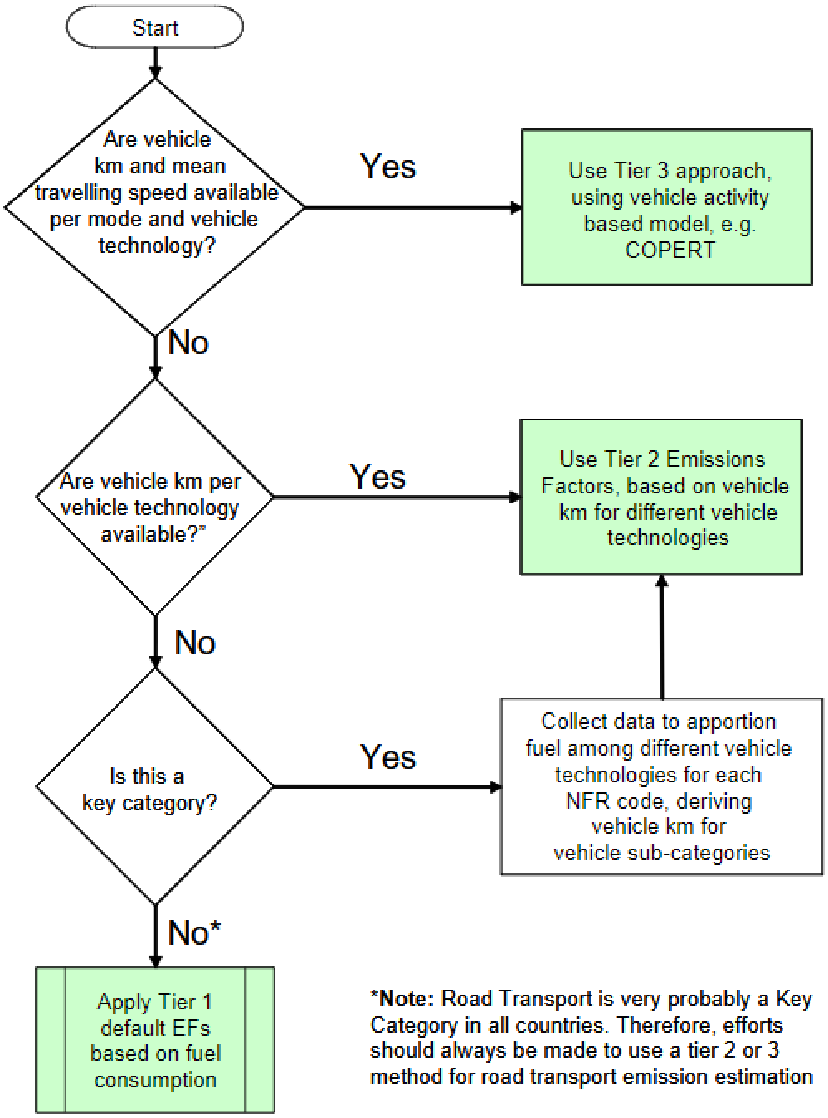
The impact assessment phase of the CFA focuses only on the environmental impact of the released GHGs. The impact of the GHGs is expressed as a global warming potential (GWP). This impact is usually assessed over a 100-year period, abbreviated to GWP_{100} (Muthu, 2015). Other commonly used time-perspectives are a 20 years and 500 years. All the perspectives yield different results for the environmental impacts (Brohé, 2017). The 100-year perspective is based on the notion that a 100 years from now the problems of today should be resolved and the GHG emissions under control, while the 20-year perspective better addresses problems in the near future and the 500-year perspective takes the distant future into account (Muthu, 2015). For example, the GWP_{20} of methane in IPCC's assessment report from 2014 is 84, while the GWP_{100} is 28 (IPCC, 2015). In contrast, the GWP_{20} for perfluoromethane (CF_4) is 4 880 and the GWP_{100} is 6 630 (IPCC, 2015). This sheds some light on why it is important to consider the choice of time-perspective carefully, even choosing to evaluate all of them to get the full picture of the environmental impact.

2.6 Vehicle emissions

We use vehicles daily in our modern society, from driving ourselves to transporting personnel and materials. In 2018 there were 120 505 new vehicles registered in Finland with a combined carbon dioxide emission figure of 117.4 g/km for all fuels considered (Tilastokeskus, 2022a). As our vehicles run mainly on fossil fuels, they generate emissions which should be accounted for if vehicles are used on-site where a carbon footprint analysis is performed. The International Energy Agency estimate that 27% of the global emissions are accounted for by the transport sector (IEA, 2022). In a report from the European Parliament (2019) it was estimated that 72% of transport emissions within the EU in 2016 came from road transportation, with 60.7% of the emissions from this sector coming from cars. Automotive emissions may be a significant part of the total emissions of a company, depending on how the company operates of course. There is an established term of well-to-wheel emissions, which accounts for all of the emissions arising from the use of fuels (Zemo Partnership, 2022). The well-to-wheel definition can be divided into 2 sub-parts of well-to-tank and tank-to-wheel (Chocholac *et al.*, 2019). Well-to-tank consists of the emissions arising from the production and transport of the fuel, and tank-to-wheel consists of emissions arising from the use of fuel by the end-user.

The European Environment Agency (2022) states there are three methods for calculating vehicle emissions, varying in the amount of data and situations analysed which in turn affects accuracy. The three methods are assigned as tiers in order of accuracy: 1, 2, and 3, with tier 3 being the most exact and tier 1 being the least exact. The tier 3 method would be applicable if vehicle type, mileage, and mean travelling speed were known. In addition to these values detailed data about the vehicle operating cycles is essential to determine how much of the time the engines have been run when at operating temperature, and how many cold starts have occurred (European Environment Agency, 2022). If only mileage and vehicle type is known tier 2 is applicable, and tier 1 uses only the amount of fuel used and emissions factors for the fuels. Figure 2 shows how to select the appropriate method depending on known data.

Figure 2 A flowchart on how to select appropriate vehicle emissions analysation method *(European Environment Agency, 2022)*



3 MATERIAL AND METHODS

The methodology of this work will be presented in the following chapter. The carbon footprint of Neste Oyj Kilpilahti harbour and train discharge terminal was analysed using the existing methodology of carbon footprint analysis as found in literature. The carbon footprint method consists of a clear goal and scope definition, inventory analysis, impact assessment and interpretation of the results. Based on the results, reduction measures were evaluated and recommended to the company.

The general equation for a calculation of a carbon footprint resulting directly from fuel combustion follows the structure of equations 1 and 2, as described by Dong *et al.* (2013):

$$GHG_k = \sum_{i=1}^{n} m_i * EF_{i,GHG_k} \tag{1}$$

$$CF_{energy} = \sum_{k} GHG_k * GWP_k \tag{2}$$

where GHG_k expresses the amount of a specific greenhouse gas, k, released. m_i represents the amount of fuel i consumed, and EF_{i,GHG_k} represents the emission factor for a specific GHG released from the use of fuel i. CF_{energy} stands for the carbon footprint of direct energy consumption, in tCO_2eq. A common unit of measure, tCO_2eq, is achieved by multiplying GHG_k with GWP_k, which represents the global warming potential of the specific GHG.

$$CF = E * EF_E \tag{3}$$

A simplified version of equations 1 and 2 is to calculate the carbon footprint by multiplying the energy used with an emission factor for the particular form of energy, as presented in equation 3. CF is the carbon footprint in tCO_2eq, E is the amount of energy used, and EF_E is the emission factor for the form of energy. For example, electricity used by a household over a year multiplied with the specific emission factor for the electricity supplied to the household.

3.1 Goal and scope

The goal of this analysis was to calculate the carbon footprint of Neste Oyj Kilpilahti harbour and train discharge terminal. This was to be achieved by collecting and analysing data mainly from the company's own monitoring systems. The company constantly monitors several processes and streams, including the use of electricity and steam. The data, which is stored in a utility management system (UMS), was collected and re-compiled in Microsoft Excel for ease of analysis. The collected data was to be analysed considering only the environmental effects, specifically GHG emissions to the atmosphere. In addition to analysing the carbon footprint, this work was to be done in such a way that it could be used as a template for other Neste terminals.

The analysis was to be performed using available theory about carbon footprint analysis, building on the LCA framework. The time frame for a carbon footprint analysis is one year of normal operation for which reliable data can be compiled (GHG Protocol, 2015). A time frame of one year was chosen for this work, but not a calendar year. Data was compiled from July 2021 to June 2022 and some of the data was compared to data from 2019. The reason for this was a major plant turnaround in 2021 and smaller turnaround in 2020. Even though the 2020 turnaround was smaller, there was a notable deviation in energy consumption in the spring of 2020. The 2021 turnaround meant an exception in normal operation during the first half year, as the whole refinery ground to a halt for twelve weeks from April to June (Neste, 2021a). This meant activity at the train discharge terminal and harbour was lower than usual, lowering overall energy consumption.

To perform the necessary data analysis and calculations for this work reliably some boundaries and delimitations in the scope were determined. The main delimitation for this work was that only scope 1 and scope 2 emissions, as defined by the GHG Protocol, were analysed. Additionally, indirect emissions arising from the production and transportation of fuel, defined as scope 3 emissions sources, were included. The defined boundaries were geographical: the enclosed harbour and train discharge terminal areas. The harbour area is divided into three separate enclosures: the main harbour area which includes several buildings of different types, such as offices and workshops, and seven jetties of which five are for loading and unloading vessels, two separate jetties also for loading and unloading. The train discharge area is a single enclosure containing several train tracks with unloading equipment, some buildings, and some pumping equipment. Any emission sources outside these areas were not considered, except the scope 3 emission sources related to the direct use of fuel.

Figure 3 Map of the analysed areas.

3.2 Scope 1 emissions

Scope 1 emissions are defined as direct emission sources, such as production processes which release greenhouse gases, power production, or transportation by company-owned vehicles (GHG Protocol, 2015). Due to the nature of harbour and terminal operation, there are only a few scope 1 emission sources to consider, the only industrial processes being transporting fluids in pipelines from one place to another using electrically driven pumps or compressors. Scope 1 emissions arise also from vehicles being used by the personnel and from a flare system used as a security measure as well as a method of emptying the pipeline before or after a loading or unloading procedure.

3.2.1 Vehicle emissions

The main use of vehicles at the harbour and train discharge terminal is personnel transportation. In total, there are eight cars, two smaller tugboats used as mooring boats, one twelve-meter-long motorboat used for transports as well as an oil spill control and clean up vessel, and two forklifts. Additionally, there are two small outboard-powered motorboats used mainly for maintenance purposes around the harbour. Of the cars, four are diesel-powered and five are petrol-powered. The three larger boats and the forklifts are diesel-powered, and the two smaller boats are petrol-powered. Every car has its own refuelling card from which data could be acquired, and the three larger boats and the forklifts are refuelled from a single tank at the jetty where they are moored. The refilling of the tank could be looked up from bills; thus, the fuel consumption of the boats and forklifts could be compiled and accounted for. Since the only reliable data about the vehicles was fuel consumed, the tier 1 method outlined in *Road Transport 2019* by the European Environment Agency (2022).

Calculations for the vehicle emissions follow the structure of equation 4, building on equations 1 and 2:

$$CF_f = \sum_{i=1}^{n} m_i * LHV_i * EF_i \tag{4}$$

where CF_f stands for the total carbon footprint of the fuels in tCO_2eq, m_i stands for the annual consumption of fuel i in tonnes, LHV_i represents the lower heating value of fuel i in TJ/tonne, and EF_i stands for the emissions factor for fuel i in tCO_2eq/TJ.

A period of six months was chosen for the data analysis of the refuelling of the cars using the refuelling cards. The reasoning behind this decision was that the data acquired began in October 2021, so a full year of data was not achieved. The period chosen was from December 2021 to May 2022, during which time a total of 4.61 tonnes of fuel was bought with the refuelling cards. Of this amount, 58% was petrol and the remaining 42% was diesel. Emission factors and heating values for the fuels were taken from Tilastokeskus (2022c) fuel classification publication and are summarised in table 1. Biofuel shares of 26 % for the diesel and 11.5% for the petrol have been taken into account in the emission factors. Using this information, the carbon footprint of the vehicles at the harbour and train discharge terminal could be calculated. The calculations were done in Microsoft Excel and can be found in appendix 1.

For the diesel-powered boats and forklifts, the gathered refuelling statistics began in 2019. This meant that a three-year average could be calculated, which was found to be 17 tonnes of gas oil annually. Since gas oil is cheaper and permitted to use in company-owned heavy-duty vehicles, gas oil is being used instead of diesel. The heating value and emission factor used for the gas oil were obtained from Tilastokeskus (2022c) and can be found in table 1. A biofuel share of 4% has been taken into account in the emission factor.

Table 1 Heating values and emission factors for the fuels used (Tilastokeskus, 2022c)

	Lower heating value	Emission factor
	GJ/t	tCO_2eq/TJ
Petrol	41.6	65.5
Diesel	42.7	54.6
Gas oil	43.1	70.2

3.2.2 Flare operation

There are two flares within the harbour and train discharge areas, one at the main gas jetty and one at the train discharge terminal. The flares have two main functions: a security measure in case of a failure leading to an immediate need to empty the pipeline or hose and to burn excess product left in the pipes or hoses before or after loading or discharge of a vessel or train car. The flares have pilot burners which burn all the time when the flare is in operation and the active time is transferred to the utility management system. In the UMS, there are calculations for the CO_2eq of both flares using the active time, an estimation of how much product is led from the system to the flare for each vessel or train car, and an emission factor for the product. The calculations for the amount of gas burnt are as follows:

Train discharge terminal flare:

$$GAS_{train} = (X_1 * x_1 * \rho_{LPG}) + (t_1 * y) \tag{5}$$

Gas jetty flare:

$$GAS_{ship} = (X_2 * x_2 * \rho_{LPG}) + (X_2 * t_2 * y) \tag{6}$$

where X_1 and X_2 stand for the number of train cars or ships loaded or unloaded, x_1 and x_2 stand for an assumed amount of gas discharged to the flare per car or ship given in m^3, ρ_{LPG} is the density of LPG in kg/m^3, t_1 and t_2 stand for the active time of the pilot burners in hours, and y represents the hourly gas consumption of the pilot burners. There is no existing active timer for the harbour flare, so an assumed time of 48 hours of flare operation per ship is used in combination with the number of unloaded ships, $(X_2 * t_2)$.

Equations 5 and 6 are coupled to an emissions factor and a lower heating value for liquid petrol gas (LPG) as shown in equation 7:

$$CF_{gas} = (GAS_{train} + GAS_{ship}) * LHV_{LPG} * EF_{LPG} \tag{7}$$

where CF_{gas} represents the carbon footprint of the total use of the flares, LHV_{LPG} is the lower heating value for liquid petrol gas, and EF_{LPG} is the emissions factor for liquid petrol gas.

It was not possible to gather data for the harbour flare for the period used as the time boundary for the carbon footprint analysis for the vehicles, as the number of unloaded ships is entered manually only at the end of each calendar year. This meant deviating from the time boundary, taking the full calendar year of 2021 into account for flare operation instead.

3.3 Scope 2 emissions

Scope 2 emissions are defined as indirect emissions arising from the production of purchased energy, such as electricity or heat in the form of steam (GHG Protocol, 2015). Consumption of purchased energy, mainly electricity, is the most significant emission source for many companies. This means that purchased energy, being the primary emission source for many companies, also provides the best opportunity to reduce GHG emissions by investing in an ever growing green power market (GHG Protocol, 2015). Electricity and steam consumption is recorded in the UMS. The UMS used by Neste shows an annual average combined electricity consumption of 16 GWh at the train discharge terminal and harbour in the period 2018-2021, of which 63.4% was consumed at the harbour. A national 5-year cumulative emission factor for electricity in 2020 was 97 tCO_2/GWh according to Tilastokeskus (2022b). Using these values in equation 3 yields the carbon footprint of the purchased electricity.

At the train discharge terminal and the harbour, process steam is mainly used for maintaining temperature in the pipelines. Most pipes are insulated and within the insulation of select pipes there are smaller steam tubes that are continuously hot to prevent some products from congealing or solidifying, meaning steam is constantly circulating in the heating tubes. In addition to this, steam is often used when preparing pipes for maintenance, circulated through a section to clean out any harmful substances. However, this procedure is only performed whenever it is needed, and the used steam is never measured, which makes it impossible to take intermittent use of steam into account in this analysis.

The process steam is produced on-site by Kilpilahti Power Plant (KPP) and sold to different companies in the area, for example to the harbour and train discharge terminal. The refinery itself also produces steam for use in the refining processes. The steam is fed to different areas through steam substations, and the feed to these stations are monitored by the utility management system. The UMS records consumed steam in tonnes, and converts the value to used energy, given in MWh. However, an uncertainty with the recorded data is that steam monitoring to the harbour and train discharge terminal is based on coefficients, which means that the recorded data is a calculated fraction of a larger stream led to several areas. The system recorded a combined energy consumption of 10 290 MWh at the train discharge terminal and harbour in 2021, of which 89.5% was consumed at the harbour. The emission factor for steam at Neste is used when buying steam from the power plant and was 0.22 tCO_2eq/MWh most recently (Vanhanen, 2022).

$$CF_s = E_s * EF_s \tag{8}$$

Using these values in equation 8 which builds on equation 3, the total emissions from the use of steam at the harbour and train discharge terminal could be calculated.

3.4 Scope 3 emissions

Scope 3 emissions consist of indirect emissions arising from processes upstream from the analysed system or company. For this analysis, fuel production and transport to the end consumer was the only scope 3 item considered. Fuel production and transport emissions are also known as well-to-tank (WTT) emissions (Zemo Partnership, 2022). The WTT emissions are added to the fuel consumption emissions, tank-to-wheel, to get the total of well-to-wheel (WTW) emissions. The Zemo Partnership (2022) provides average well-to-tank emission factors in gCO_2eq/MJ for all commercially available fuels in the United Kingdom, many of which are available globally. As gas oil is not available for use in road-going vehicles and not included in the list, the emission factor for diesel was used instead. Calculations for the scope 3 fuel emissions follow the structure of equation 4 used for the calculation of the scope 1 fuel emissions. The lower heating values of the fuels and emission factors used are summarised in table 2. The unit for the emission factors was converted from gCO_2eq/MJ to tCO_2eq/TJ. The calculations for the WTT emissions were done in Microsoft Ecxel and can be found in appendix 1.

Table 2 WTT emission factors and LHV for the fuels.

Fuel type	Lower heating value	WTT emission factor
	GJ/t	tCO_2eq/TJ
Petrol	41.6	18.8
Diesel	42.7	17.0
Gas oil	43.1	17.0

4 RESULTS

The following chapter presents the findings of the previous chapter. The chapter begins with the results of the carbon footprint calculations and concludes with an interpretation of the results. The results were calculated based on data recorded between July 2021 and June 2022 due to global events and plant turnarounds affecting the accuracy of the data, with some exceptions where data was not available for the chosen period.

4.1 Carbon footprint

The carbon footprint of Neste Kilpilahti harbour and train discharge terminal was calculated using methods presented in chapter 3, based on literature found on carbon footprint and life cycle analysis. Neste Kilpilahti harbour and train discharge terminal carbon footprint was 2 743 tCO_2eq for the analysed period of July 2021 to June 2022, with some exceptions where data was not available for the entirety of the period. This equals the average annual carbon footprint of 1 630 cars according to emission statistics by NimbleFins (2020). Table 3 summarises the emissions and the annual total emissions at the harbour and train discharge terminal. The division between the emission sources is presented in Figure 4.

Neste is committed to achieving a carbon neutral production by 2035, and as a sub-target the company is aiming to swich to the use of 100% green electricity by 2023 (Neste, 2022c). To achieve this green electricity goal Neste has entered into an agreement with several energy suppliers in Finland to use wind power as well as hydro power, and has already begun the use of 100% green electricity in Finland in 2022 (Neste, 2022c). This means that emissions from the use of electricity for the train discharge terminal and harbour are zero.

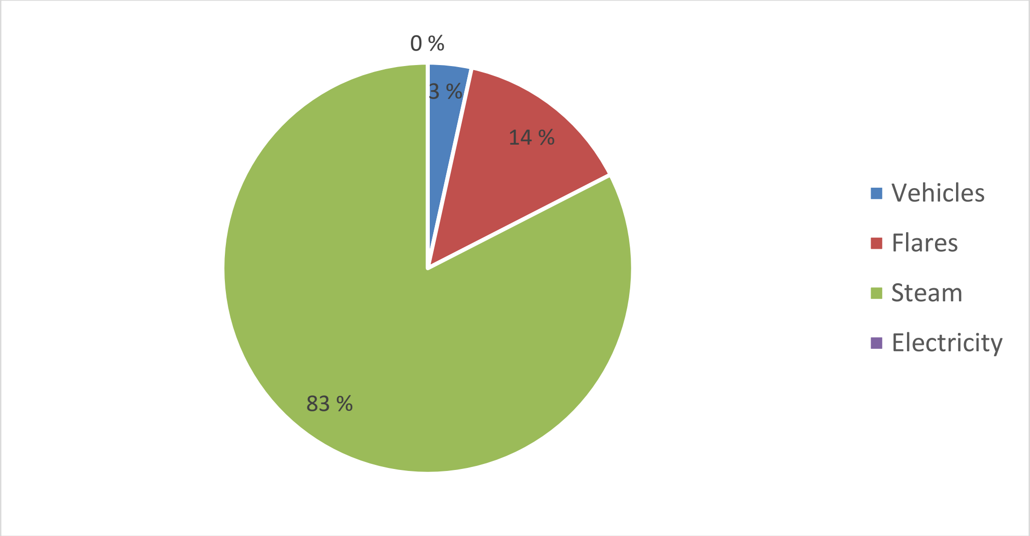
The use of process steam is the biggest contributor to the carbon footprint with a share of 83% of the total footprint. Flares account for 14% of the emissions and vehicles account for the remaining 3%. Since electricity used is 100% carbon neutral it does not contribute to the carbon footprint.

Table 3 Summary of emissions at the Neste harbour and train discharge terminal in Porvoo

	Scope 1	Scope 2	Scope 3	TOTAL 2021	TOTAL 2022
	tCO$_2$eq/year				
Vehicles (estimated for 2021)	74.9	n.a.	19.4	94	94
Petrol	*14.2*		*4.1*		
Diesel	*9.4*		*2.9*		
Gas oil	*51.4*		*12.4*		
Flares (estimated for 2021)	385	n.a.	n.a.	385	385
Harbour	*77*				
Train discharge terminal	*308*				
Electricity (2021 and 2022)				1 552	0
2021	*n.a.*	*1 552*	*n.a.*		
2022	*n.a.*	*0*	*n.a.*		
Steam (estimated for 2021)	n.a.	2 264	n.a.	2 264	2 264
TOTAL				**4 295**	**2 743**

n.a. = not applicable in this case study

Figure 4 Estimation of 2022 Neste Kilpilahti harbour and train discharge terminal carbon footprint



The vehicle emissions were calculated by multiplying the fuel consumed with an emission factor for the specific fuel. This calculation was used for all fuels, and for both direct and indirect emission. The fuel consumption, emission factors, and calculated emissions for the vehicles are summarised in tables 4 and 5.

Table 4 Vehicle fuel consumption and emissions

Type of fuel	Annual fuel consumption	Emission factor	Annual direct emission
	t	tCO_2eq/t	tCO_2eq
Petrol	5.2	2.7	14.2
Diesel	4.0	2.4	9.4
Gas oil	17.0	3.0	51.4

Table 5 Well-to-tank emissions for fuels

Fuel type	Annual fuel consumption	WTT emission factor	WTT emission
	t	tCO_2eq/t	tCO_2eq
Petrol	5.2	0.79	4.1
Diesel	4.0	0.73	2.9
Gas oil	17.0	0.73	12.4

Emissions for the flares were calculated automatically in a utility management system. In this system there are equations taking pilot fuel consumption and product fed through the flares as part of loading operations. Data gathered from the utility management system shows that a total of 385 tonnes of CO_2eq resulted from flare operation in 2021. Of this, 308 tonnes of CO_2eq resulted from flare operation at the train discharge terminal, spread out relatively equally over each month. For the harbour, an annual total of 77 tonnes of CO_2eq was released in 2021 according to the data. Annual emissions from the flares are summarised in table 6.

Table 6 Annual flare emissions

Year	Emission, harbour	Emission, train discharge terminal
	tCO_2eq	
2019	5	325
2020	5	308
2021	77	308

4.2 Interpretation

The last phase of a carbon footprint analysis is the interpretation of the results. The results are evaluated in relation to the predefined goal and scope. This is to be done transparently; meaning assumptions and chosen values should be highlighted, and calculations and methods should be clearly presented.

The goal and scope of the analysis was to calculate the scope 1, 2, and part of scope 3 emissions arising from normal operation at Neste Kilpilahti harbour and train discharge terminal. The carbon footprint of the defined areas was successfully calculated by using methods based on the theory presented in chapter 2. Methods and calculations, assumptions, and chosen values are documented in chapter 3 of this work.

The most significant assumptions and chosen values are the steam consumption and emission factor. Steam usage is presently not accurately recorded, but calculated as a fraction of a larger steam feed using coefficients. Meaning the recorded steam consumption depends more on the upstream total steam feed, than the actual usage at the endpoint. As for chosen values, the steam emission factor chosen was the same as had been used within the company in previous years, instead of choosing a national mean value. The 5-year cumulative average emission factor for district heating in Finland in 2020 was 0.19 tCO_2eq/MWh (Tilastokeskus, 2022b). The company's internal steam emission factor of 0.22 tCO_2eq/MWh was higher than the national factor, therefore, the calculated emissions may be higher than the actual emissions.

Another significant assumption is regarding the flares, specifically the harbour flare. In the calculations in the utility management system a berth time, or operating time, of 48 hours is assumed for each gas vessel. A strict operating time of 48 hours cannot be guaranteed for every ship. For example, since propane deliveries by ship began in the spring of 2022 much larger ships made deliveries. These larger ships often have an operating time of at least 72 hours, meaning the actual emission is larger than the calculated.

5 ASSESSMENT OF RESULTS

The purpose of this thesis was to calculate the carbon footprint of Neste Oyj harbour and train discharge terminal in Kilpilahti. Identifying the carbon footprint is a part of Neste’s actions to reach a carbon neutral production by 2035. By determining the present situation, actions to reduce the footprint can be decided upon. Steps to reduce the carbon footprint at Neste have already been taken. The most significant so far is moving to the use of 100% carbon neutral electricity, as electricity would have been the biggest contributor to the carbon footprint at the harbour and train discharge terminal. The emission reduction resulting from switching to green electricity has reduced the carbon footprint at the harbour and train discharge terminal by 1 552 tCO_2eq, which equals the carbon footprint of approximately 924 cars according to NimbleFins (2020).

The result of the analysis shows the division of emission sources at the harbour and train discharge terminal, which provides a basis for decisions on how to proceed toward carbon neutrality. The emissions must be reduced or compensated for to reach the goal of carbon neutrality. Emission reduction is easier for some sources than for others. For example, a switch to the use of biofuels in the vehicles would not require much more than an economic input, while reducing the use of process steam would require comprehensive area-wide modifications. Large-scale modifications are also subject to feasibility control and extensive scrutiny within the company. One such example would be switching from steam to electricity to maintain pipeline temperature. That would, however, guarantee 100% carbon neutrality given the commitment to use carbon neutral electricity, as long as the electricity supply is able to handle such a load.

Vehicle refuelling data should be very accurate and receipts show the exact amount per refill of the bunker tank. Uncertainties in the data for the vehicles may consist of the alternate time frame for the refuelling data for the cars. Since data was not available for a full year, a half-year total was calculated and doubled to obtain a yearly total. The time frame was chosen to be December 2021 to May 2022 to include as much of varying temperature as possible given the limited data. As well as insufficiencies in the data, the method of analysis is not the most accurate. The European Environment

Agency (2022) has developed a three-tiered method of vehicle emissions analysis, of which the tier 1 method was used in this work. Given more time and resources to collect better data, a higher tier method could have been utilised and a more accurate result could have been obtained.

Indirect emissions arising from the use of process steam is the most significant contributor to the carbon footprint. Therefore, this emission source is the one most in need of reduction or compensation for. This would however require substantial modifications of the pipeline heating solutions, thus, the decision to make the change is not one to take lightly. Pipeline heating is essential for a refinery operating in colder climate. Therefore, taking the magnitude of modifications needed into account as well, substantial actions to reduce the use of steam are currently not considered. A feasible modification of the usage would be to reuse the condensate, which is currently led to a wastewater reservoir. The reason it is not already reused is impurities arising from the heating pipes at the harbour and train discharge terminal. This is something that is being investigated and measures to improve the quality of the condensate are being evaluated.

Flares are essential to the safe operation of a refinery, as well as to loading and unloading operations of combustible gases. As such, there is not much to be done about the use of flares. Additionally, the flare at the train discharge terminal is active all the time, due to gas storage tanks located in the area. The flare acts as a safety measure in case there is a failure leading to the need to relieve pressure quickly and safely from the tanks. A noteworthy deviation from standard operation occurred in 2021 where the harbour flare emissions were over ten times higher than in 2020. This can be explained by the political state of the world in 2021, as propane deliveries from the East were reduced and the propane had to be delivered by ship instead.

6 CONCLUSIONS AND RECOMMENDATIONS

Global warming and greenhouse gas emissions has been a hot topic since the 1990s, with several international treaties and agreements made over the past decades (Gulliksson & Holmgren, 2018). Neste is one of the largest industries in Finland and should therefore be one of the forerunners of combating climate change. There is evidence of great potential to further reduce emissions at Neste, but also great challenges accompanying that potential. Every major action is held back by process safety and budget. Some reduction measures would require a complete rebuild of parts of the refinery. In spite of this, change is on the horizon. The commitment to move away from fossil fuels requires new units and major modifications, of which some are already under way. Here lies great opportunities for emission reduction.

Reduction measures requiring minimal change are already at hand, but not yet in use. One of these would be to switch from fossil fuels to renewable fuels in the company's vehicles. This would not require a technical change, only monetary input to compensate for the more expensive fuel. Another minor change would be to improve the energy usage monitoring. Better monitoring would enable more accurate calculations which in turn allows for smarter usage.

This thesis presented challenges not unlike those explained in literature on the subject of carbon footprint analysis. The main challenge was to gather reliable and accurate data. The utility management system provided great aid in this task, but the reliability of some data was questionable. Clarifying the underlying calculations and measurements for the questionable data was time consuming. In addition to this, finding sources of data not collected by the UMS presented its own challenge.

The defined delimitations for this work made the data gathering more straightforward and manageable. In analysing only scope 1, 2, and a very small part of scope 3 emissions the data could be gathered from systems already in place. For the rest of the scope 3 emissions the data gathering is not necessarily so easy. To expand the analysis to include all scope 3 emissions a dedicated carbon footprint analysis team should handle the data gathering and processing, and a longer period of active data gathering should be defined to allow for better monitoring of material streams.

This thesis is only the beginning of analysing the emissions in detail at Neste terminals, and as such provides a template for other terminals and logistics hubs to improve and build on. The methods used are fairly straightforward, as the equations are relatively simple. The challenge is, as mentioned earlier, to find sources of reliable data. There is also potential to expand this analysis to also include scope 3 emissions, and further include this in analyses carried out elsewhere using this work as a template. Recognising the current situation and how to improve on it is the key to reach the goals of a greener society.

SVENSK SAMMANFATTNING

Kolavtrycket för en oljeterminal

Inledning

Tekniskt avancerat är en term som väl kan användas för att beskriva dagens samhälle. Maskiner och datorer används överallt och för att driva dem behövs energi. Fossila energikällor har varit betydande energikällor för att utveckla samhället, men negativa effekter av förbränning syns redan tydligt. Internationella rapporter bevisar att effekten av en global uppvärmning på 1°C redan orsakar extrema väderförhållanden och en höjning av havsnivån. Åtgärder måste vidtas för att förhindra ytterligare uppvärmning, och flera sådana är redan på gång. Fler och fler företag rör sig mot användning av kolneutrala energikällor, och Neste Oyj är inget undantag. Neste har som mål att nå en kolneutral produktion år 2035, vilket betyder att omfattande förändringar måste göras.

Det första steget mot att reducera sina utsläpp är att kartlägga nuläget genom en kolavtrycksanalys. Genom att identifiera nuläget med jämna mellanrum kan mål för förbättring fastställas. En kolavtrycksanalys tar alla utsläppsströmmar i beaktande och presenterar en helhetsbild över det analyserade systemet för en given tidsperiod. Kolavtrycksanalysen bygger till stor del på metoden för livscykelanalys, där båda analyserna delar samma fyra steg.

Målet för detta arbete var att beräkna kolavtrycket för hamnen och tågterminalen vid Nestes raffinaderi i Borgå. Utöver detta skulle arbetet göras på ett sådant sätt att det i ett senare skede kan användas som modell för kolavtrycksanalyser vid Nestes andra terminaler, främst runtom i Finland. Analysen skulle innehålla de totala utsläppen klassade som omfattning 1 och 2 (scope 1, scope 2), samt de indirekta produktionsutsläppen relaterade till direkt bränsleanvändning som klassas som omfattning 3 (scope 3).

Metod

Den centrala delen av en kolavtrycksanalys är insamling av data. För detta arbete har data i huvudsak samlats från företagets interna övervakningssystem, där statistik för flöden och strömmar såsom elektricitet, ånga, och vatten, samlas. Energiströmmar som ingick i analysen var bränsleåtgång, användning av facklor, processånga, och elektricitet. Efter att all data hade blivit insamlade måste de bearbetas för att få fram ett resultat. Detta innebar att hitta pålitliga utsläppsfaktorer och korrekta ekvationer för varje energiström. Med insamlade data om energiåtgång och -form, samt utsläppsfaktorer, kunde en generell kolavtrycksekvation användas för att beräkna utsläppen. Den generella ekvationen följer strukturen: kolavtryck = mängd bränsle eller mängd energi multiplicerat med en utsläppsfaktor för energitypen.

Vid hamnen och tågterminalen i Sköldvik finns det sammantaget 15 fordon: åtta bilar, två arbetsbåtar, en större och två mindre motorbåtar samt två truckar. Statistik över bränsleåtgång i fordonen på området övervakas inte av det interna systemet, så denna data hämtades från leverantörerna. Bilarna tankas med fordonsspecifika tankningskort som sparar statistiken för varje enskilt fordon. Övriga arbetsfordon tankas från en tankcistern, för vilken påfyllningsstatistik kunde hämtas från bränsleleverantören. Utsläppen för fordonen beräknades utifrån bränsleåtgång genom användningen av en modifierad version av den generella kolavtrycksekvationen. Utöver direkta utsläpp från bränsleanvändning beräknades även utsläppen från bränslets produktion och transport till slutanvändaren. Denna beräkning utfördes på samma sätt som för den direkta användningen av bränslet.

På området där kolavtrycksanalysen utfördes finns två facklor som fungerar som ett säkerhetssystem. Vid oväntade tryckhöjningar i linjer eller tankar som innehåller flytande gas, lättas trycket genom att gas släpps ut via facklan där gasen förbränns på ett kontrollerat sätt. Utöver att facklorna fungerar som en säkerhet, används de också vid lastnings- och lossningsoperationer för att tömma överloppsgas ur slangar som används vid operationen. För facklorna finns färdiga beräkningar i det interna övervakningssystemet som räknar ut utsläppen utifrån facklornas aktiva tid och hur många fartyg eller tågvagnar som tömts. Ekvationerna för facklornas utsläpp följer samma struktur som den generella kolavtrycksekvationen, med några extra steg för att beräkna hur mycket gas som förbränns.

Beräkningar för använd elektricitet finns i det interna övervakningssystemet, det finns emellertid inga beräkningar för utsläpp till följd av elanvändningen. Genom pressmeddelanden om vindkraftsavtal kunde ändå en utsläppsfaktor beräknas och användas. Beräkningarna för elektricitetens utsläpp var något överflödiga eftersom Neste har använt 100 % kolneutral el sedan början av år 2022.

Processånga används överallt på området. Ånga används främst för att hålla produktlinjer vid önskad temperatur, eftersom vissa produkter kan stelna och orsaka förstockningar om de kyls ned. Även användning av ånga övervakas i det interna övervakningssystemet och data sparas. Dessa data samt en utsläppsfaktor som används vid intern kostnadsallokering kunde användas för att beräkna ångans utsläpp enligt den generella kolavtrycksekvationen.

Resultat och diskussion

Det uppskattade kolavtrycket för Sköldvik hamn och tågterminal år 2022 var 2 743 tCO_2eq, samma storlek som för 1 630 personbilar enligt NimbleFins (2020) statistik. Detta är relativt mycket för en terminal där produkter transporteras genom användning av kolneutral elektricitet. Avtrycket är dock över 50 % mindre än det var innan användningen av kolneutral elektricitet, eftersom utsläppen minskat med 1 552 tCO_2eq, en mängd som motsvarar 924 personbilar genom att företaget börjat använda elektricitet som produceras genom vind- och vattenkraft. Orsaken till storleken på kolavtrycket är användningen av processånga för att hålla temperaturen i rörledningarna, vilket står för 83 % av utsläppen.

Beräkningarna innehåller vissa antaganden och valda värden, av vilka de mest vägande är ångans konsumtion och utsläppsfaktor. Ångan mättes inte genom flödesmätare eller dylikt, utan beräknades som en fraktion av ett större flöde till flera områden i närheten. Detta betyder att den uppmätta konsumtionen vid de analyserade områdena inte enbart beror på de analyserade processerna, utan även på grannområdets ångkonsumtion. Utsläppsfaktorn som användes var densamma som företaget använder vid intern energihandel. Denna faktor var högre än den nationella utsläppsfaktorn för ånga, vilket betyder att de beräknade utsläppen kan vara lite högre än de verkliga.

Ett annat vägande antagande berör facklorna, mer specifikt facklan i hamnen. I beräkningarna för hamnfacklan är den aktiva tiden för facklan baserad på en antagen verksam tid på 48 timmar per fartyg. Denna tid kan dock inte garanteras för varje fartyg, eftersom exempelvis propanleveranser började anlända med fartyg i stället för med tåg under våren 2022. Propan levereras med mycket större fartyg än de som normalt använder gasbryggan. Dessa större fartyg har ofta en verksam tid på över 72 timmar, vilket betyder att facklans beräknade utsläpp inte stämmer för dessa fartyg.

Resultatet av analysen visar fördelningen mellan utsläppskällorna inom det analyserade området. Utifrån resultatet kan beslut fattas om hur man ska gå vidare för att uppnå kolneutralitet, eftersom resultatet visar hur mycket utsläppen måste reduceras eller kompenseras för. Vissa förändringar är lättare att genomföra än andra. Till exempel är det lätt att byta till biobränslen i fordonen och det kräver i praktiken ingen annan åtgärd än en större budget för bränsleåtgången. En modifikation av rörledningarnas uppvärmning skulle däremot kräva omständliga mekaniska förändringar, vilket kräver en större budget. Det finns även vissa processer som inte kan modifieras av säkerhetsskäl. En sådan process är facklorna, som måste vara aktiva medan lastning eller lossning av fartyg eller tågvagnar pågår. Dessutom är tågterminalens fackla konstant aktiv, eftersom det på området finns trycksatta tankar som vid nödfall snabbt och säkert måste kunna lätta på eventuellt övertryck.

Detta arbete presenterade utmaningar inte helt olika de som presenterats i litteratur om kolavtrycksanalys. Den största utmaningen var att samla tillförlitliga data. UMS-systemet var till stor hjälp med detta, men vissa datas exakthet kunde ifrågasättas och att utreda bakomliggande beräkningar var tidskrävande. Definierade begränsningar för arbetet gjorde det lättare och mer hanterbart att samla in data, eftersom nästan alla utsläpp av omfattning 3 avgränsades. Detta arbete är dock endast en början på en mer detaljerad analys av Nestes utsläpp, och bör fungera som en mall att bygga vidare på. Metoderna och ekvationerna är relativt simpla, så det svåra är att samla tillförlitliga data för alla system, speciellt om utsläpp av omfattning 3 tas med i sin helhet. Detta är dock någonting som bör göras, eftersom man genom att analysera den nuvarande situationen får kunskap om hur man ska gå till väga för att förbättra framtiden.

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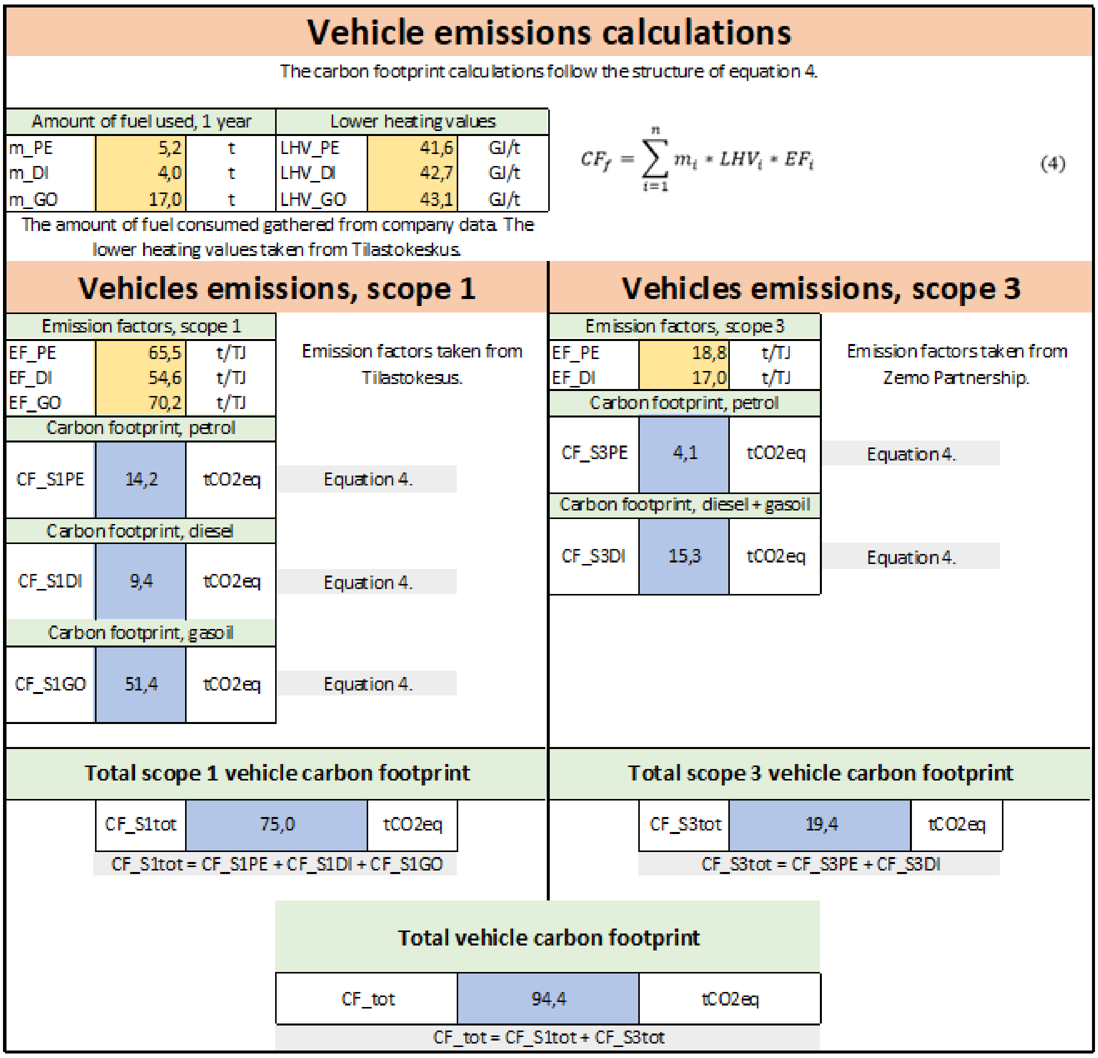
APPENDICES

Appendix 1. Vehicle emissions performed using Microsoft Excel



Vehicle emissions calculations

The carbon footprint calculations follow the structure of equation 4.

Amount of fuel used, 1 year			Lower heating values		
m_PE	5,2	t	LHV_PE	41,6	GJ/t
m_DI	4,0	t	LHV_DI	42,7	GJ/t
m_GO	17,0	t	LHV_GO	43,1	GJ/t

$$CF_f = \sum_{i=1}^{n} m_i * LHV_i * EF_i \quad (4)$$

The amount of fuel consumed gathered from company data. The lower heating values taken from Tilastokeskus.

Vehicles emissions, scope 1

Emission factors, scope 1		
EF_PE	65,5	t/TJ
EF_DI	54,6	t/TJ
EF_GO	70,2	t/TJ

Emission factors taken from Tilastokeskus.

Carbon footprint, petrol		
CF_S1PE	14,2	tCO2eq

Equation 4.

Carbon footprint, diesel		
CF_S1DI	9,4	tCO2eq

Equation 4.

Carbon footprint, gasoil		
CF_S1GO	51,4	tCO2eq

Equation 4.

Vehicles emissions, scope 3

Emission factors, scope 3		
EF_PE	18,8	t/TJ
EF_DI	17,0	t/TJ

Emission factors taken from Zemo Partnership.

Carbon footprint, petrol		
CF_S3PE	4,1	tCO2eq

Equation 4.

Carbon footprint, diesel + gasoil		
CF_S3DI	15,3	tCO2eq

Equation 4.

Total scope 1 vehicle carbon footprint

CF_S1tot	75,0	tCO2eq

CF_S1tot = CF_S1PE + CF_S1DI + CF_S1GO

Total scope 3 vehicle carbon footprint

CF_S3tot	19,4	tCO2eq

CF_S3tot = CF_S3PE + CF_S3DI

Total vehicle carbon footprint

CF_tot	94,4	tCO2eq

CF_tot = CF_S1tot + CF_S3tot