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Transition of non-production facilities towards carbon-neutrality
A Case Study- Volvo CE's Customer Center

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ABSTRACT

Research on historical developments that lead to the establishment of global organizations for climate change has shown that the phenomenon of surface temperature is not a new topic of focus. Increased policy restrictions, brand image, fear of resource scarcity, growing market trends towards sustainability and consumer awareness are among the several external factors that have influenced the growing research in corporate transition towards carbon neutrality. The main aim of this study is to understand through data accounting of major material and energy carrier changes, how a non-production facility could transition to become a carbon-neutral facility. Therefore, an exploratory case study has been performed and conducted at Volvo CE Customer center in Eskilstuna, Sweden, with two objectives: i) to identify and quantify the customer center current footprint by mapping the main contributors to greenhouse gases emissions, and ii) to recommend specific & general measures that can mitigate the carbon footprint of the facility. Three research questions related to the facility's current carbon footprint, measures implemented so far, and the best applied assessment method, have guided us throughout the study. The methodology has been framed to give a theoretical underpinning for understanding the project from a holistic perspective. The split of the methodology has been constructed in line with the theoretical framework that gave the foundation to the needed theories to be taken into account i.e. GHG protocol, which is the tool that has been adopted by the study to attain the desired aim, including the three scopes under the protocol which were also defined accordingly. 'Scope 1' has been taken into account and is a representation of direct emissions, 'Scope 2 represents the indirect emissions, and 'Scope 3' (according to the GHG protocol) takes into account the rest of the indirect emissions arranged into 15 categories, from which applicable to our study were 4 categories (1, 3, 4 and 6). The results showed that during the base year (2019) the highest user within Scope 1 was diesel, followed by HVO, and under Scope 2, The results from Scope 1 and 2, together with the results of Scope 3 category, were analyzed using the attributional LCA approach recommended by the GHG protocol to calculate their contribution to the customer centers' total carbon footprint. It was found that Scope 1 stands for 128.52 t CO_2-eq while Scope 2 stands only for 1.16 t CO_2-eq and finally Scope 3 stands for most of the emissions with 3719 t CO_2-eq. It has been found that in 2019, the customer center has saved 101.05 tonnes of GHG by implementing measures, such as switching from using Diesel to HVO and switching from the mixed electricity to the renewable ones, according to the attributional perspective presented in the GHG protocol. However, different results were found when these values were discussed and analyzed from the consequential perspective, since this perspective analyses the effects of the implemented measures on the global emission level. This concluded that implementation of conservation and efficiency measures must take priority before switching to higher priced renewables. Thus, the resulting carbon neutrality will be consequentially safer. The recommendations stated in this study also follows the same principle "Conserve before investing". Suggestions and recommendations outlined in the study for future implementation approach carbon neutrality as a strategy and not a burden, helping the customer neutral achieve the goal in an Environment, Economic and Socially sustainable manner.

Keywords: Greenhouse Gases (GHG), Attributional life cycle assessment (aLCA), Consequential life cycle assessment (cLCA), Carbon Dioxide (CO_2), Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC

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1 INTRODUCTION

This chapter gives an overview to the study work and the research area, the introduction is going to be presented from different points of view the global standpoint and the Swedish context in order to make it easier for the reader to comprehend and fully understand the study.

Climate change is an age-old phenomenon that in recent times has caused catastrophes that have continued to harm the earth's balanced eco-system , resulting in extreme weather conditions such as drought, heatwaves, floods, rising sea levels, ocean acidification and loss of biodiversity (Jiang et al., 2020).

The research on the phenomenon began in the 1820s, when Joseph Fourier theorized that the surface temperature of earth was the consequential effect of specific components that constitute the earth's atmosphere (Herivel, 1968). Following the suggestion Macedonio Melloni, in 1831, proved that Carbon Dioxide (CO_2) absorbs a much greater amount of heat than other gases (Letcher, 2019). In the 1890s the last link between the CO_2 increase climate change and ice ages was discovered by Svante Arrhenius, who made a scientific calculation illustrating that if CO_2 in the atmosphere was reduced by half, Europe's average temperature would be reduced by 4-5 degrees Celsius bringing back the ice age temperatures (Uppenbrink, 1996).

Scientific theories have repeatedly proven that global warming is largely due to rising CO_2 and the increase in CO_2 from 280ppm before the industrial revolution to 413ppm in April 2017 is largely due to human activities that have triggered the phenomenon of global warming (Trierweiler et al., 2018). But it shall be noted that CO_2 alone cannot be accounted for the rising of the global average temperature, this is largely accredited also to water vapor (Lenderink & Van Meijgaard, 2008). The rising CO_2 level in the atmosphere directly influences the level of water vapor in the atmosphere, which is attributed to cause 60% of the total greenhouse effect, while CO_2 is responsible for 20% of the total (Trenberth, 2011). It is important to note that, a vast majority of the 20% of the greenhouse effect that is caused by CO_2 originates from anthropogenic sources entering the atmosphere due to fossil fuels (Archer & Brovkin, 2008).

Although the science of climate change is not a new field of study, two distinguished events on the timeline of world history that set a concrete platform to development of the science can be noted as the establishment of Intergovernmental Panel on Climate Change (IPCC) in 1988 and the enforcement of the United Nations Framework Convention on Climate Change (UNFCCC) on 21 March 1994 (Edenhofer & Seyboth, 2013; Schipper, 2006). IPCC has long since acted as an assessor of scientific information and literature regarding climate change since its beginning and constantly acts as a supporting body to decisions made by member nations of UNFCCC (Maxwell, 2010). Meanwhile UNFCCC was established to act as a platform with an objective to stabilize the concentration of greenhouse gases (GHG) emissions within a set period of time, to a level that can ensures the prevention of anthropogenic interference with planet's sustainability (Levina & Tirpak, 2006 ; Childs, 2012).

Conference of the parties (COP) is the decision-making body of UNFCCC and all the member nations have representatives who head the enforcement of the convention's decisions from the annual meetings held to revise and acknowledge the agendas to achieve the ultimate goal of the planet's (Childs, 2012). The 21st annual meeting, also known as the Paris Agreement or COP21 under UNFCCC, emphasized on the central fact that to reduce the risk of high impact of global warming, the total increase of the earth's temperature must be limited to 1.5 degrees Celsius above the pre-industrial era (Leung et al., 2019). During this conference, the participating nations set a long term goal in 2016 to curtail the rise in temperature limit to 2 degrees Celsius by the end of the century (McCollum et al., 2018).

Sweden is one of the 195 countries to have signed the Paris agreement, with having a seven out of eight political parties actively supporting climate law frameworks. Sweden aims to become, one among the world's first fossil-free nations with a vision of being a standing example for innovation and fossil free technology (Axelsson, 2019). Ahead of the Paris agreement in 2015, this lead to an initiative called "Fossil Fritt Sverige" or "Fossil Free Sweden" started by the Swedish Government, consisting of companies, municipalities and other actors who have pledged to facilitate Sweden in going fossil-free to achieve climate neutrality by 2045 (Hein et al., 2018). This initiative was mainly established to create a platform for the exchange of knowledge and ambitions in the climate area to help increase the country's adjustment in pace towards the main goal, facilitating a dialogue between actors who show concrete results in accordance to the initiative (Roth et al., 2017). Another notable platform, aligned to the global climate-neutral effort, is the Climate Savers program, run under Worldwide Fund for Nature's (WWF's) flagship. The program aims at transforming businesses into leaders of the low-carbon economy. Global organizations, such as Volvo Group, SKF, Tetra Pak, etc. are being part of the program and it entails that these companies commit to higher reduction of GHG emissions than they would, on their own. Further, the agreement entails that the results must be analyzed by an external agency, signifying that the company is leading in its sector with regards to the effort made in reducing environmental impact (Volvo AB, 2013).

1.1. CASE STUDY BACKGROUND

This section will comprise a clear introduction of the case study which is Volvo CE customer center in this study. This section will also entail the carbon neutrality and link it to the customer center. In more detail, the case study on how the transition towards carbon neutrality can be achieved will be performed at Volvo CE customer center. Which will allow to answer the RQs and achieve the aim of the study.

The European Green deal initiative is set to propose a comprehensive plan for the member nations to increase the climate target from 40% to 55% by 2030 in mid-2020 and has planned a release of revision for the Energy taxation Directives in mid-2021 (European Commission, 2019). The latest development, The European Green Deal of late 2019, further emphasizes the benefits for organizations to initiate steps to achieve climate neutrality. The EU describes the European Green deal initiative as a major step to making Europe climate neutral by 2050. The Green deal initiative discussed above has been declares as its way of protecting people, economy and the planet (Timmermans, 2019).

This would now act as an external influencer and an added influence for Volvo as a group to focus both on its production facilities as well as on the administration and office facilities, which accounts to 35% of the workforces in countries like the USA (Institute, 2002). In EU building sector accounts to 40% of energy use and 35% of GHG emissions, office buildings and travel management is an important proactive approach to GHG mitigation due to the high emission curve from urban transportation (Moschetti et al., 2019). The same thing more or less is applicable in Sweden building sector (Borggren et al., 2013). Volvo CE Customer Center is an example of these facilities, due to the absence of production at the customer center, it is treated as an office facility. The customer center in Eskilstuna/Sweden acts as the center for the marketing and sales officials of Volvo CE for the regions of Europe, Middle East, and Africa. As the center of commerce, the facility includes usage of energy in different forms i.e. electricity, fuels used for the demonstration vehicles, that are used to illustrate the product lines to dealers and their customers. The inventory also includes company-owned cars, office supplies, business travel, intermediary products used for demonstration and their transportation. To achieve carbon neutrality i.e. CO_2 -eq emissions at the customer center equaled to the removal, the customer center needs determination and dedication, along with continual work on improvements implemented. Rather than only taking into account for the emissions that the customer center is responsible for directly, the study will cover a wider Scope including the consequential effects i.e. indirect emissions caused by the customer center in comparison to the attributional reporting that is widely followed around the world.

Volvo Construction Equipment (Volvo CE), is a part of the Volvo group umbrella. Early in 2010 Volvo group has become the first vehicle manufacturing organization in the world to join the initiative, Climate Savers (Volvo AB, 2013). In addition to that, the organization is also a part of "Fossil Free Sweden" initiative which has been introduced earlier in the study (Volvo, 2017). As one of the big contributors to the Swedish economy, Volvo CE a part of Volvo Group, has decided to take a step and be a part of global climate crisis solution. By transforming their customer center into a CO_2 neutral facility, Volvo CE extend the goal globally in the other facilities on the long term. This initiative will help Volvo CE in reducing its carbon footprint and participating in the overall GHG reduction of whole Sweden.

Volvo's customer center with its advanced demonstration facility, has hosted around 24000 individuals in the year 2019 and employing over 150 individuals, with a considerable material consumption level, which poses risk with changing policies. Changing policy risk here refers to changing emission trading programs, carbon and energy taxes accompanied by regulations and standards on emissions will influence the increase in the financial budget i.e., new investments to keep the supply chain green (Robin et al., 2018). It has been stated by WRI (World Research Institute), the organizations setting up GHG inventories and mitigation plans, get the advantages of early recognition of voluntary action on the world platform adding to the better branding. In addition to being termed as the pioneers, the organization will be benefited by rising demand for inter-organizational partnerships between climate-friendly organizations and business opportunities from GHG emission risks (WBCSD and WRI, 2013).

1.2 AIM & OBJECTIVES

For the aim of this study, it is vital to understand the terms "Climate neutrality" and "Carbon neutrality". They hold high importance in the field of climate science and the corporate world and are often used as synonyms. Carbon neutrality is claimed by several researchers as a synonym to the term "Net zero carbon emissions" (Lutzkendorf & Balouktsi, 2019). Net zero emissions and Carbon neutrality are measured in accordance to anthropogenic emission of greenhouse gases and not just Carbon dioxide. Greenhouse gases include Carbon dioxide, Methane, Nitrous oxide, Hydrofluorocarbons, Perflourocarbons, Sulfur hexafluoride, Nitrogen trifluoride (Watson et al., 1992). Also known as the Kyoto gases their global warming potential GWP indicates the amount of warming they cause over a period of time in accordance to Carbon dioxide which is taken as 1, CO_2-e or CO_2-equivalent represents the global warming caused by the GHGs in a single number (Brander, 2012). Hence, the total CO_2-eq emitted from human activities with deduction of total removal of CO_2-eq from the atmosphere by various balancing, reduction measures or offsetting leads to Net-zero emissions (BEIS, 2019). The United Nations Organization defines on different occasions that "Carbon neutrality" status is adopted, when the organization has developed and implemented emission reduction measures as much as possible and further tool is claimed by offsetting the remaining emissions that cannot be mitigated by internal improvements (Goodfield et al., 2014). This is not nearly the same as Climate Neutrality as argued in several literatures because balancing out using greater share of offset measures leaves room for continued usage of fossils which does not completely negate the adverse effects, thus decreasing the quality of the climate (Lutzkendorf & Balouktsi, 2019 ; United Nations, 2010).

The aim of this study work is to explore how a non-production facility, such as a customer center, can be transformed into a sustainable carbon-neutral facility, that will contribute to achieving a low-carbon economy. In order to reach the aim of study, an exploratory case study at the customer center of Volvo CE from Eskilstuna, Sweden has been chosen and the study is performed in that regard, with the following objectives:

- Identify and quantify the customer center's current footprint by mapping the main contributors to greenhouse gases emissions and using the GHG protocol guidance as a systematic method to quantify the current carbon footprint,
- Recommending specific & general measures that can mitigate the carbon footprint of the customer center, thus contributing to the transformation into a sustainable carbon-neutral facility.

However, for this reason the study is not only limited to identifying and quantifying the current carbon footprint of the customer center, but also to contribute to a broader scope, i.e. provide knowledge that will support further work of the customer center to meet their GHG emission targets.

The specific objectives at the end of the study are to make optimal proposal concerning the following aspects as shown in the below figure.

- Fuels conversion & consumption reduction.
- Energy conservation, increasing efficiency & conversion to Renewables.
- Behavioral changes.
- Supplies, Transportation, Travels, Others.

Figure 1: The aspects of the proposed changes

1.3 RESEARCH QUESTIONS

Q1. How can the current carbon footprint of a customer center be assessed?
Q2. How can measures be taken by the center to mitigate their carbon footprint, and how much in quantity can the center save through these measures?
Q3. How can an assessment method be best applied for a more accurate and comprehensive carbon footprint measurement?

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2 THEORETICAL FRAMEWORK

This chapter comprises different concepts and applied theories that will be taken as references in this study. It starts with explaining the carbon neutral term and the GHG protocol which is the tool used in this study. The chapter will also shed the light over other terms like Life cycle assessment and carbon footprint, while highlighting the differences and similarities, while comparing the two different approaches by which LCA can be conducted and relate that to the study. The chapter will also cover other concepts i.e. emission scopes, Global Warming Potential, and emission factors. It also includes theory about GHG emissions and how to calculate them.

2.1 CARBON NEUTRALITY AND CLIMATE NEUTRALITY

Paris agreement emphasizes in its 4th article, the need for attainment of long term greenhouse gas balance (Fuglestvedt et al., 2018). But, before one can start on a pathway to achieve this, it is important to understand the different levels to be achieved in reaching the complete greenhouse gas balance in the context of an organization and ultimately on a global level. In context to this study, the terms deemed important to be addressed are "Carbon Neutrality" & "Climate neutrality". Since these two terms have different level of GHG reductions approaches. As mentioned earlier in the study, The United Nations Organization considers Carbon neutrality and Net Zero Carbon Emissions as synonyms, i.e. for every unit of Carbon dioxide emitted it is compensated with equal amount of carbon dioxide removal. But, in order for this to be economically sustainable on a long term i.e. not to overshoot the carbon budget by only buying offsets, but rather it must be supported by implementation of short & long term emission reduction targets (United Nations, 2010). Although these terms have no uniform definition, a carbon neutrality project's target is declared to be achieved according to Goodfield et al., (2014) when the inventory's total emission accounts to zero across the complete life cycle of all elements involved. Figure 1 depicts that carbon neutrality is the balance between net carbon release and net carbon sequestration i.e., the level of balance of GHG when both these amounts can be deemed equal the said organization or region is declared carbon neutral.

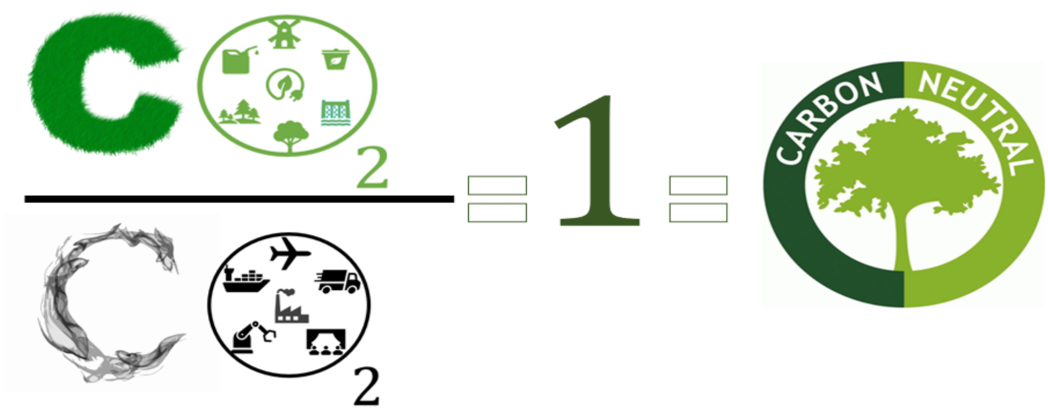


Figure 2: Carbon Neutrality & Net Zero Carbon Emissions definition

On the other hand, Climate Neutrality is considered to be the final level of GHG balance, and it has a wider scope than Carbon Neutrality, where human activities have no net effect on the planet and the climate system (Robin et al., 2018). Briefly stating climate neutrality is not only limited on achieving the balance between the GHG emissions and the removals, but it also considers the regional effects of anthropogenic activities and removal of any excess emissions. This means that climate neutrality questions the new state of the investigated region after implementing the improvements goals. Once the region shows better performance according to climate change impacts and other environmental pressures e.g. perception, weather conditions, air pollution, etc., caused by anthropogenic emissions, it will be declared as climate neutral (Lutzkendorf & Balouktsi, 2019). Table 1 presents popular terms in reference to the climate science; the highlighted terms are those investigated in this study.

Table 1: Climate science terminologies

CARBON NEUTRAL	NET ZERO CARBON EMISSIONS	CLIMATE NEUTRAL
NET ZERO EMISSIONS	ZERO CARBON	NEGATIVE EMISSIONS

2.1.1 STANDARD FOR ACCOUNTING – GHG PROTOCOL

Organizations around the world refer to the GHG protocol published in 1988 by World Resource Institute (WRI) and World Business Council for Sustainability Development (WBCSD) as the primary source of knowledge for Greenhouse accounting and reporting. This standard promotes adoption to facilitate low emission economy worldwide (Institute, 2002). The GHG Protocol Initiative consists of two separate interlinked standards:

1. GHG Protocol Accounting and Reporting Standards, which is a step by step guide for companies to use in quantifying and reporting emissions (WBCSD and WRI, 2013).
2. GHG Protocol Project Quantification Standard, a guide for quantifying reductions achieved from GHG mitigation projects (Levin et al., 2014).

"GHG Protocol Accounting and Reporting" exists as four standards that serve as guidance for emission reporting at various levels i.e., corporate, project and product levels. This protocol, published by WRI, categorizes different emission sources in an organization into direct emissions also known as Scope 1 and Indirect emission which is further divided into Scope 2 (emissions from generation of purchased energy) and Scope 3(emission from the value chain) (WBCSD & WRI, 2011). Section 2.2 of this study discusses further on the different categories of emission that has been introduced by the protocol to facilitate systematic carbon accounting.

The WBCSD and WRI in the protocol further illustrate the aim and benefits of different organizations have in following the guidelines as a tool of study and the following section discusses the same:

- **Governments** across the world study the standard to analyze the subjects of introduction of emission trading programs, carbon or energy taxes, regulations, and standards on emissions before and after implementation
- **Companies** – In addition to managing risks from governmental policies on climate change, companies can also realize other business goals realized from establishing a well-designed and maintained corporate GHG inventory, those include:
  - ✓ Identifying business opportunities that arise from GHG risks
  - ✓ Participating in GHG market
  - ✓ Opportunity to be recognized for early voluntary actions
  - ✓ Participation in public reporting and voluntary GHG programs (Eco-labelling and other certifications)

The general protocol also emphasizes the utmost importance for GHG accounting and reporting organizations to follow the prescribed 5 principles i.e., Relevance, Completeness, Consistency, Transparency and Accuracy (WRI, 2015).

Meanwhile on the other end of the spectrum, according to Brander & Ascui (2016), the GHG protocol follows the attributional approach to reporting and accounting of GHG emissions which has been argued to have neglected the consequential details of carbon mitigation measures. The following two sections introduce the working principle of LCA & carbon footprint and the different approaches of LCA that have been deemed important to this study.

2.1.2 LIFE CYCLE ASSESSMENT AND CARBON FOOTPRINT

Due to the large repercussions and the worsening environmental problems caused by GHGs, as mentioned earlier in the study, it has become very important to imbibe scientific and practical methods to account and analyze the amount of these GHGs that result from humans' activities (Brander & Ascui, 2016). The approach that would meet the need, which is quantifying the amount of GHGs emissions, is Carbon footprint (Skytt et al., 2020). Before diving into this approach, it is important to mention the Life cycle assessment (LCA) and highlight the difference between the two approaches to establish a clear foundation. The one main difference between LCA and Carbon footprint is related to the impact categories that are considered (Fajardo et al., 2016). In a specific context, an environmental assessment that is performed on a product, company, event, etc., is generally done in regard to different impact categories e.g. global warming potential, human health impacts, ecosystem quality, acidification, land use, etc., (Skytt et al., 2020). The carbon footprint approach performs the assessment regarding only one environmental impact category which is global warming potential (greenhouse gas emissions (CO_2-eq)). However, on the other hand, the LCA assessment considers more impact categories such as land use, water use, and acidification, etc. For that reason, the concept of carbon foot printing has been in use since several decades but known differently as life cycle impact category indicator global warming potential (Finkbeiner., 2009). Therefore, a conclusion can be drawn that carbon footprint is basically a subset of LCA (Fajardo et al., 2016). Over the years, a growing number of tools and guidance have been developed to inform, understand, interpret, and conduct carbon footprint studies with the aim of assessing the current situation regarding GHG emissions and helping with structuring sustainable improvements to mitigate these emissions and enhance the carbon footprint of the studied object (Gossling, 2009). The Greenhouse Gas Protocol (GHG Protocol) is one of these tools, and it is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions (Protocol et al., 2015), (Swedish Environmental Protection Agency, 2018). The most important objective identified when a Life Cycle Assessment (LCA) methodology is selected is to showcase the broad width of processes affected by the decisions/procedures followed in a facility (Weidema, 2003). For a better understanding of the two distinctive types of approaches to the assessment i.e. attributional and Consequential approaches see next section 3.5.1.

2.2 EMISSION SCOPES

GHG Protocol initiative has been launched in 1998, as an internationally accepted initiative for GHGs accounting and reporting standards for business, which also promotes their adoption to facilitate low emission economy worldwide (WBCSD and WRI, 2013). "GHG Protocol Accounting and Reporting" has been released in four standards that have specific guidance for emission reporting at levels of corporate, project and product levels (GHG protocol, 2015). The GHG Protocol Corporate Accounting and Reporting Standard generalizes the total emissions into two main categories that are Direct emissions and Indirect emissions which are further categorized into different scopes and these are further filtered due to various limitations to draw a system boundary for this study report. Following Table 2 outlines the general foundation guidelines referred to in setting the scopes according to GHG Protocol Corporate Accounting and Reporting Standard. To project this guideline over this study, the operational boundary must be outlined to be used as a baseline in identifying the customer centers' different scopes. In chapter 3, operational boundary has been clearly presented and used to identify the GHG scopes. Also, it has been used to illustrate the projects' specific boundary conditions that have been adopted in the study.

Table 2: An overview of the scopes including their definition and examples. (GHG Protocol, 2015)

Emission types	Scope	Definition	Example
Direct emissions	Scope 1	Emissions caused by sources owned or controlled by the reporting company	Emissions from combustion and/ or production of fossil fuels in owned or controlled equipment.
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company.	Use of purchased electricity, steam, heating, or cooling
	Scope 3	All the indirect emission categories not falling under the above jurisdiction fall under the label of Scope 3. It mainly includes upstream and downstream activities in the value chain.	Production or purchased products, transportation of purchased products, or use of sold products

Scope 1 considers all direct emissions which as previously described are resulted from operations & activities owned or controlled by the reporting company, e.g. fossil fuels combustions in an equipment owned by the company. According to the Greenhouse Gas

Protocol, it is mandatory to take Scope 1 into account in the GHG inventory (GHG Protocol, 2015). On the other hand, Scope 2 takes into account the indirect emissions from energy consumption e.g. electricity, steam, DH, etc. in the operations of the company and also is mandatory to include in a GHG inventory. It is worth noting that electricity for example is used by the reporting company, but it is produced by another actor which means the reporting company is not responsible for the electricity generation but rather the consumption. This principle makes them indirect emissions. The last scope, Scope 3 includes the indirect emissions, which are not under Scope 1 & 2. They can be generated due to activities owned or/and controlled by the company, but also have other emissions sources i.e. outside actors e.g. suppliers, providers, etc. The other distinctive thing regarding this Scope that according to Greenhouse Gas Protocol it is not mandatory to be included in the GHG inventory. Usually Scope 3 stands for the most of the GHG emissions of the reporting company (WPCI, 2010). Scope 3 emissions sources are classified into 15 categories, such as production or purchased products, transportation of purchased products, or use of sold products. It is not necessarily true to find all the categories applicable on the conducted study. In this study the applicable categories from Scope 3 are highlighted in chapter 3 in the operational boundary 3.3.1 where it will be shown which and why these categories were taken in and which ones were excluded due to their inapplicability and/or lack of data, the will of the company. These emissions are also divided into upstream and downstream emissions. Upstream emissions are related to purchased or acquired goods and services, while the downstream emissions are related to sold goods and services (GHG Protocol, 2015). Table 3 describes the three different scopes included in the inventory of the customer center, see Table 3.

Table 3: An overview of the scopes including examples from the case study. (GHG Protocol, 2015)

Emission types	Scope	Example
Direct emissions	Scope 1	Customer center-Owned Fleet construction equipment (only the demo-field ones) e.g. trucks, excavators, etc. Another contributor is the customer center-owned cars i.e. cars that the employees can use in business related trips.
Indirect emissions	Scope 2	Purchased Electricity for the customer centers' needed operations e.g. lighting, ventilation, etc. and the purchase of District Heating for the customer center heating purposes.
	Scope 3	Business Travels, fleet shipping, Ships & Trucks supplies delivery, etc.

2.3 IMPACT INDICATOR – GLOBAL WARMING POTENTIAL

As discussed earlier in the report, the study has only focused on one impact indicator which is global warming potential which gives an estimation of the impact on climate change of the investigated item e.g. product, event, company etc. This is the key difference between the two terms Life cycle assessment and carbon footprint see section 2.1.2 For more details. To calculate the impact indicators, see the following Equation [1]:

$$\textit{Impact Indicators} = \textit{Inventory Data} \times \textit{Characterization Factor} \ [1]$$

In Equation 1, the inventory data reflects the data collected from the activities the reporting company has considered as GHG contributors. Generally wise, the characterization factor converts inventory data to equivalents in the impact indicator unit, hence the study is only considering one impact indicator which is GWP see equation [2], then the characterization factor converts the inventory data into CO_2-eq (Pandey, D. et al., 2011).

$GWP = \frac{Energy\ absorbed\ by\ 1\ ton\ of\ emitted\ gas}{Period\ of\ time\ (usually\ 100\ years)}$ *[2]* relative to the emissions of 1 ton of carbon dioxide (CO_2) that equals 1, i.e. the rest of the GHG are calculated regarding CO_2, for instance the GWP of methane CH4 = 28–36 over 100 years meaning CH4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH4 also absorbs much more energy than CO_2 (Inventory of U.S. Greenhouse Gas Emissions and Sinks). GHGs that are usually emitted into the atmosphere from different sources, vary from each other in GWP magnitude. A list of all considered GHG by the Intergovernmental Panel on Climate Change (IPCC) is provided, see Appendix I. All GHG emissions are summarized as CO_2-eq emissions to provide the impact GWP, expressed as a carbon footprint (Melanta, S. et al., 2013). However, the study work did not include any GWP calculations but instead the CO_2-eq emissions-factors were gathered from different databases and used to calculate the carbon footprint (GHG emissions) of each activity and this by default will include all the type of greenhouse gases that are emitted, this is explained more in the next section 2.4.

Example: One of the activities emits 100 kg of CO_2 & 80 kg of CH_4 & 2 kg of N_2O. To estimate the impact of this activity on the climate change ($CO_{2\text{-}eq}$), equation 2.1 is used as follows:
Inventory data = 100 kg of CO_2 & 80 kg of CH_4 & 2 kg of N_2O
Characterization factor= 1, 28, 298 respectively

Impact Indicators ($CO_{2\text{-}eq}$) = (100 kg CO_2 × 1) + (80 kg CH_4 × 28) + (2 kg N_2O × 298) = 2936 kg $CO_{2\text{-}eq}$

2.4 EMISSION FACTOR

An emission factor is defined as a factor that converts product or activity data into GHG emissions (GHG Protocol, 2015). In general, the emission factor reflects the amount of GHG emissions that are resulted from using the product or an activity. Taking into consideration that sources of GHG can have different units, for instance, the GHG emissions from fuels' combustion are quantified per volume unit (e.g. Liter, gallon, etc.) and it can be also quantified per mass or length for other products or/and activities (WPCI, 2010). Calculation of the emitted GHG emissions with emission factors is collectively represented by Equation [3]:

$$GHG\ emissions = Activity\ Data \times Emission\ factor \times Characterization\ Factor\ [3]$$

The activity data represents the amount of the used material, energy, or service in both products and/or activity. The emissions factor represents the amount of emissions resulted from the use of the product and/or activity. GHG emissions must be calculated in form of CO_2-eq, therefore, equation [2] includes the GWP characterization factor in the aim of converting the emission factors in the form of CO_2-eq. See section 2.3 for more information regarding GWP conversion. However, in case the emission factor is taken from a database in the form of CO_2-eq then there is no need to include GWP characterization factor in the equation because it is already taken in the emission factor.

Example: One of the activities consumes 80 liters of diesel. Knowing that the emission factor of diesel equals 2.7 kg $CO_{2\text{-}eq}$ / Liter. Note that the emission factor is already given in $CO_{2\text{-}eq}$ form. Therefore, equation 2 is used as follows:
Inventory data = 80 liters of diesel
Emission factor = *2.7 kg $CO_{2\text{-}eq}$ / Liter*

GHG emissions *(kg $CO_{2\text{-}eq}$) = 80 liters × 2.7 kg $CO_{2\text{-}eq}$ / Liter = 2016 kg $CO_{2\text{-}eq}$*

3 METHODOLOGY

The methodology chapter offers the theoretical underpinning for understanding the project from a holistic perspective. This chapter will entail the evolution of the GHG emissions accounting domain, as it will also specify which approach and tool this study is using to achieve the goals. The first section will start with presenting the research process at which this study methodology is based on. Then followed with the procedures overview at the second section. The methodology of accounting can be divided into two main phases i.e., data collection and inventory design, and they are presented in three sections. The third section entails an overall description of data collection regarding materials and energy used and consumed at the customer center in 2019 which will be used in the GHG inventory. The fourth section will describe the procedure at which emission factors were gathered using different sources and databases. Finally, section five will cover the methods used for performing the calculations with the distinguish between the two LCA approaches.

3.1 CASE STUDY DEFINITION

Case study is a methodology of science that contributes to decision making, it is defined by Schramm (1971) as a research method that illuminates the "why" and "how" regarding decisions made to carry out a task or a resulting phenomenon. It is emphasized by Mills et al.,(2013) that framework must be set before the start of analysis as it plays an important role in the success of a case study.

Case study research methodology is an accepted social science method often related to qualitative study of a given field. Yin (2003) in his literature emphasizes the difference between conventional research with that of a case study and the notable points from the literature in relation to this study's framework have been adapted in framing the study. The iterative framework followed is shown below in figure 2.

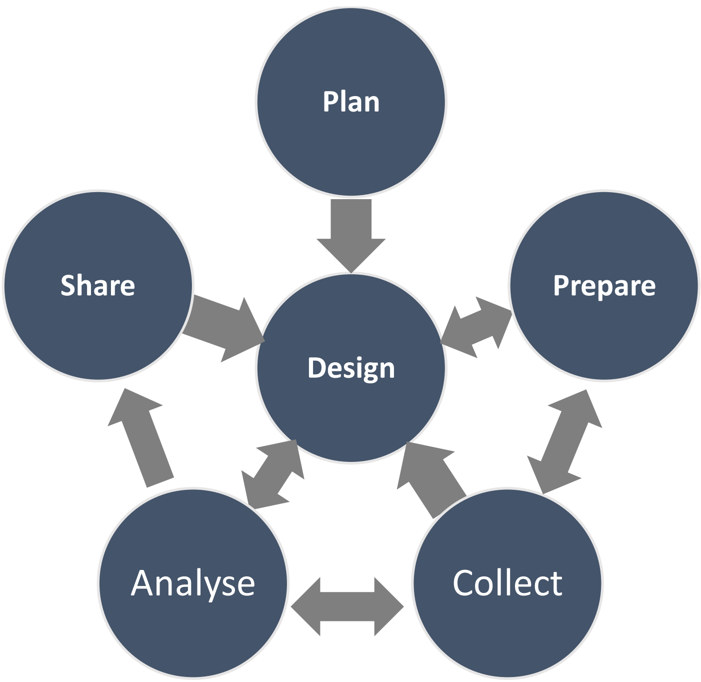


Figure 3: Case study research process adaptation from Yin,2003.

3.2 METHOD OVERVIEW

To facilitate the customer center transition into a CO_2 neutral facility, the main contributors to greenhouse gases emissions from the most impactful items on the inventory shall be mapped, this will facilitate finding the current carbon footprint (Levin et al., 2014). Emitted GHGs from these different sources are mapped based on the GHG Protocol guidance as mentioned in section 2.2. As mentioned before, this study is not only limited to finding the current carbon footprint of the customer center but also aims to support and facilitate the customer centers understanding of the CO_2 neutrality transition by providing practical improvements at different levels, as it will be brought up later in the report.

The work at the study is conducted in a systematic & scientific manner as outlined in the steps below. These stages depend entirely on each other and this interdependence is one of the most distinctive characteristics of the study. As each stage is interlinked to the preceding stage, if something goes wrong in one of the stages it will undoubtedly be reflected in the others. Each stage represents a section in this chapter, respectively.

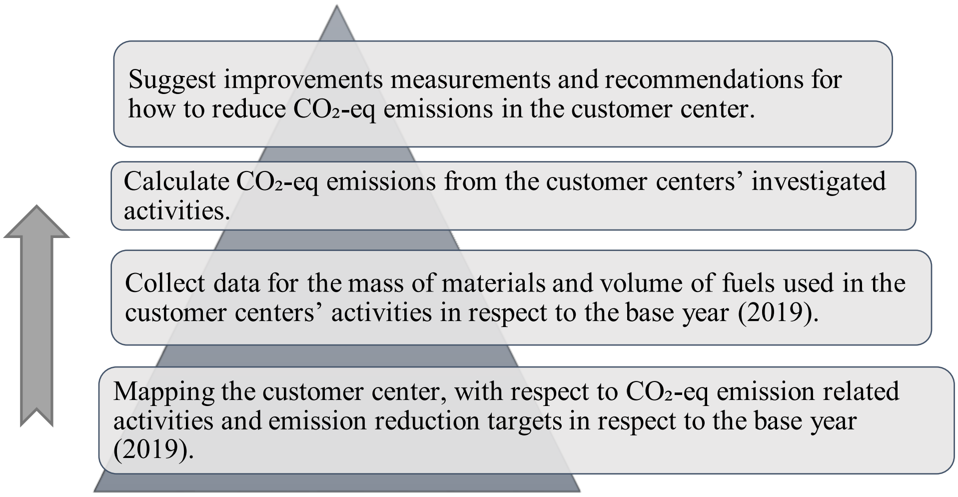


Figure 4: The study method steps.

3.3 DATA COLLECTION OF PURCHASED MATERIALS AND ENERGY USAGE

The Scope 2 accounting in this study is done in accordance to the unit process concept, unit process according to ISO 14040, is the smallest element in LCA for which both input and output can be clearly quantified. While the data for purchased materials and energy consumption is quantized under the generic category of activity data following the protocol. GHG protocol divides the purchased goods or used materials and energy consumption into different scopes and categories as notes in section 2.2. In accordance with some delimitations this section discusses the methodology used for the data collection operations that are included in the system boundary. Hence, the process of data collection is preceded by setting the system boundary and then followed by the data collection phases itself, former will be discussed in the following section.

3.3.1 OPERATIONAL BOUNDARY

As described in section 3.2, the project-specific scope for GHG accounting is discussed under operational boundaries adhering to the several protocols and guidelines that this report is based on.

The mitigation goal is easier to be achieved if the data collection framework capacity is well accomplished (Levin et al., 2014) and this can be done by having a complete picture of the value chain i.e., operational boundary diagram illustrated in Figure 3. The followed procedure included listing of goods and services, under each scope, with no excludion of any operation, illustrated in Figure 5. To have an accurate operational boundries, all categories under Scope 3 are listed in Table 4 and screened for their aplicability with the possibilities of obtaining their data, leading to the structuring of the boundaries.

Table 4: Scope 3 categories.

Scope 3 categories. The ones highlighted with [grey] are excluded due to their inapplicability /lack of data		
1. Purchased goods & services	2. Capital goods	3. Fuel & energy not included in Scope 1 or 2
4. Upstream transportation & distribution	5. Waste generation in operations	6. Business travels
7. Employee commuting	8. Upstream least assets	9. Transportation & distribution of sold goods
10. Processing of sold products	11. Use of sold products	12. End of life treatment of sold products
13. Downstream least assets	14. Franchises	15. Investments

The description regarding the selection flow from Scope 3 is explained more in this section. And the reason why each category has been excluded is also mentioned to provide transparency and consistency as the GHG protocol recommends and requires.

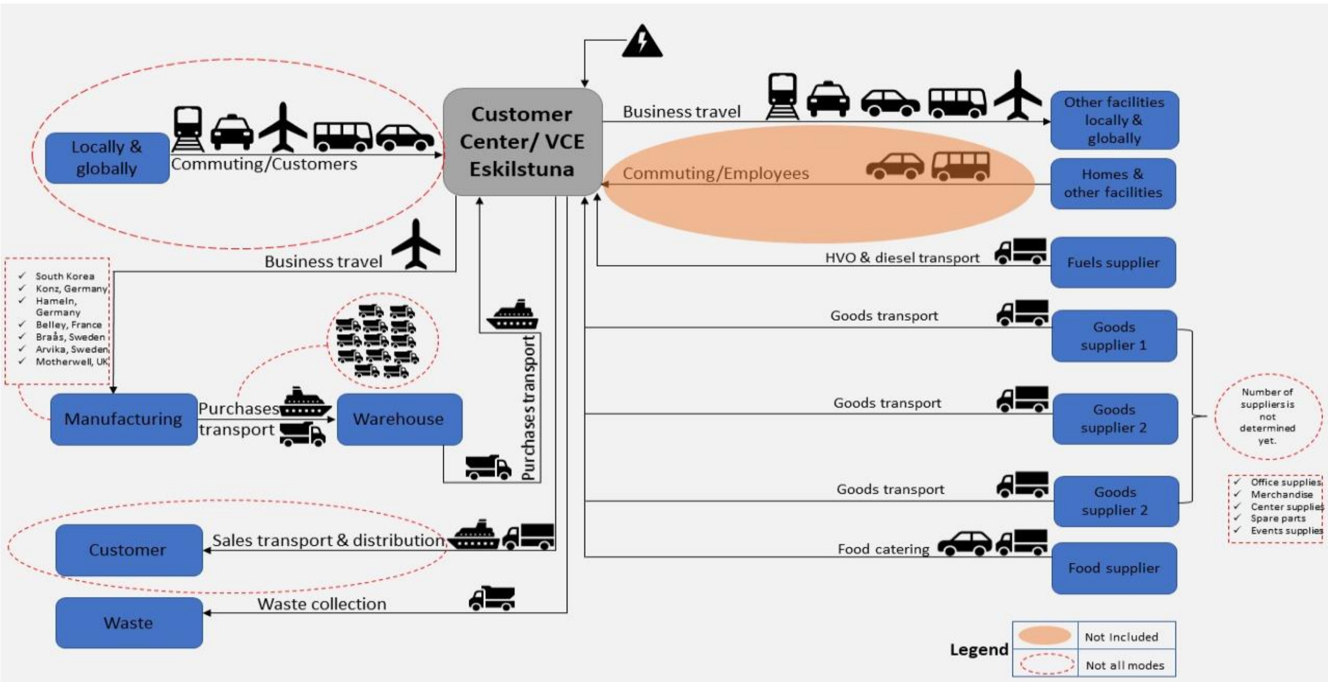


Figure 5: Operational boundary outline: giving an overview of the scopes including in the study.

In this study the source of emissions for Scope 1 comes from the diesel and HVO used in fueling the fleet vehicles and usage in the company cars for the year 2019, latter has been excluded due to the prevailing pandemic situation obstructing data gathering. Diesel use for the fleet of machines in the demonstration area has been phased out and replaced with biogenic fuels from September 2019. The replacement of fossil fuel and its consequences will be included in the discussion section from the LCA consequantial perspective. Scope 2 in the facility is represented mainly by electricity and district heating consumption and this is a part of the indirect emissions. On the other hand, Scope 3 includes all other indirect emissions as illustrated in the diagram the categories considered are purchased goods and services, fuel and energy-related activities. This carefully does not include Scope 1 i.e., diesel used for cleaning along with life cycle emissions from the fuels used in transportation etc., upstream transportation and distribution and Business travels, these categories are explained in more detail as following in this section to outline the reasons behind considering them in this study. All definitions are adopted from the GHG protocol:

- Category 1: Purchased goods and services: This category includes all upstream (i.e. Cradle to gate) emissions from purchased and/or acquired goods and services by the customer center. However, transportation of these goods/services is not included in this category but in category 4. According to the GHG protocol purchased goods and services are categorized as follows:

Purchased goods & services	
Production-related procurement (Direct procurement)	Non-Production-related procurement (Indirect procurement)
Related to the production of a company's products: 1. Intermediate goods: (e.g. Materials and components that the company buy to process) 2. Final goods for re sale 3. Capital goods: (e.g. plant, property, and equipment) that the company uses to manufacture a product, provide a service, or sell, store, and deliver merchandise.	Used to enable operations: 1. Operations resource management: (e.g. Office supplies, frequent supplies, travel service). 2. Maintenance, repair, operations: (e.g. Spare parts, replacement parts).

As mentioned earlier in the study, Volvo CE customer center is not a production facility, therefore, production-related procurement including intermediate goods and final goods are not considered. However, the demonstration fleet has been considered as capital goods since the customer center use it for providing a service and sales. As for the rest of the purchased goods & services some of them under non-production-related procurement were considered e.g. (most frequently purchased materials regarding cleaning supplies). This was determined based on the availability of needed data taking time constraints into consideration. Since there are some other materials that were difficult to obtain, and others were blocked due to the prevailing pandemic situation obstructing data gathering. The list of the materials that were included under this category are listed in section 4.2 with more detail regarding their quantities and their environmental impact.

- Category 3: Fuel & energy-related activities: This category includes Emissions from production, transportation of fuel and energy. E.g. (Diesel & HVO that are used by demonstration fleet). The emissions from the extraction, production, transportation of the diesel & HVO from the source to the customer center are accounted for in this category. But the combustion emissions are accounted for in Scope 1.

Types of Ctegory 3	Description
Upstream emissions of purchased fuels	i.e. Extraction, production, transportation of fuel consumed by the center. Note: (The combustion of fuel is in SCOPE1)
Upstream emissions of purchased Electricity	i.e. Extraction, production, transportation of fuel consumed in the generation of the electricity. Note: (The emissions of electricity usage are in SCOPE2)
Transmissions & distribution loss	Not applicable
Generation of purchased electricity that is sold to end users	Not applicable

- Category 4: Upstream Transportation & distribution: This category includes the transporting and distributing of a product from the supplier to the customer center using carrier (i.e. Vehicle) that is not owned and/or operated by the center. E.g. air transport, rail, road, marine, storage. Excluding fuels since they are already considered in category 3.

Methods for calculating
1. Fuel based method: (i.e. Fuel type * emission factor)
2. Distance based method (i.e. Mass, distance, mode * emission factor)
3. Spend based method (i.e. The amount of money spent for each mode * applying secondary emission factors from databases)

- Category 6: Business travel: This includes emissions from business travel using third party owned transportation mode (e.g. Aircraft, trains, buses, and cars) during the base year.

Procedure for calculating
1. Determining the flight distance in Km.
2. Determining the flight type whether Short-haul flight or Long-haul flight.
3. Finding the emission factor of the flight based on the flight type and class.

The system boundary is restricted in categories due to the nature of the case study scenario i.e., a non-production facility, which implies that categories 8,10,11,12,13,14 and 15 are not applicable. It has been noted from the guidelines that downstream emission categories

9,10,11and 12 can be excluded if the sold products like intermediate parts (spare parts) are not accounted for, which is the case in the customer center.
The WBCSD & WRI in the "Corporate Value Chain (Scope 3) Accounting and Reporting Standard" prescribed boundary requirements and justifications which have been adapted and customized in the process of setting the operational boundaries are, as follows :

1. All scopes and categories must be acknowledged, and omissions are justified based on the specific condition for each Scope if conferred to the standard.
2. If justified the omission of categories in Scope 3 are allowable.
3. Biogenic CO_2-eq cannot be included under the scopes in the result representation but may be included for public records.
4. Any GHG removal must not be accounted for under scopes.
5. For sources where emissions are too small or take too many resources to obtain data or limit in real improvements are justifiably omitted.
6. To Scope 2 if the operation is not under the control of the customer center then it must be excluded.

Time boundary considered during the collection of data for materials and energy has been based on the methodological guide suggested by WBCSD & WRI. Various sections of the GHG protocol carry out analysis to show the future impact from the materials that have/will be used in the reported year of the study.

3.3.2 DATA COLLECTION PHASES

Following the construction of a detailed illustration of the list of operations included in operational boundary, the steps followed have been accounted for in this section.

- Internal departments and branches of Volvo CE that were involved in the supply chain of different operations were contacted.
- With extensive networking and knowledge exchange operations with the greatest potential, most relevant to the business goals and least resource-consuming were further prioritized along with factors like size of the operation and estimated volume of CO_2 emissions from the activity. The approximation of the volume of CO_2 emissions used for this screening process was calculated using Industry-specific average data, proxy data or rough estimates from national average emission factors
- In accordance with the standard, highly prioritized activities were assigned more resources i.e., a larger amount of personnel was enlisted for support and higher time resource was assigned for data retrieval.

For electricity and DH purchase due to well-maintained records primary data source has been used i.e., the data is directly procured from the supplier or other value chain actors which makes it highly accurate. Electricity purchases have been checked for Guarantee of Origin (GO) purchase, GO certificates prove the record percentage of electricity share bought by the renewable company. The electricity however has been recorded in the form of unit processes i.e. interior lighting, etc., as mentioned before to facilitate finding the process that uses the highest share of the energy and give recommendations regarding energy reduction accordingly.

3.4 DATA COLLECTION OF EMISSION FACTORS RELATED TO MATERIALS AND ENERGY RELATED

The second phase under data collection is the collection of emission factors, which has been explained in general in the theoretical framework in section 2.2. For Scope 1 and Scope 3, the emission factors are based on life cycle emissions, while in case of fuels if used for combustion the emission factors are into consideration as a reflection of the use phase which represents the combustion which is the highest contributing factor to fuel emission. For Scope 2 emission, factors are of two types and they are location-based emission factor which is the local grid average and market-based emission factor which is derived from contracts drawn during sales and purchase of energy. Emission factor used for the diesel used for non-combustive purposes in the customer center is based on the life cycle of the diesel fuel used at the present only for cleaning purposes. But, since the fueling of the fleet/equipment in the 1st half of the year was done by diesel, a comparative analysis for diesel being used as a combustive fuel before being replaced with biogenic fuels has also been established. This analysis is done using combustion emission factor from secondary data source i.e., industry or location-based average emission factor. This holds the same for the emission factors for Scope 3 categories due to several constraints.

For Scope 2 due to GO certificate which is covering the whole demand of electricity, Volvo CE is able to claim that they are using renewable power therefore preventing the emission of GHGs i.e. the net emission becomes zero in case of attributional calculation, Figure 4 gives an illustration of the flow at which emission factors are considered in the existence and in the absence of Guarantee of Origin (GO) as they sometime can be found with some share of the electricity demand or covering the whole demand. On the other hand, according to consequential analysis emission factors are not considered as zero but rather the indirect effects and consequences are accounted for and will be presented in the discussion chapter.

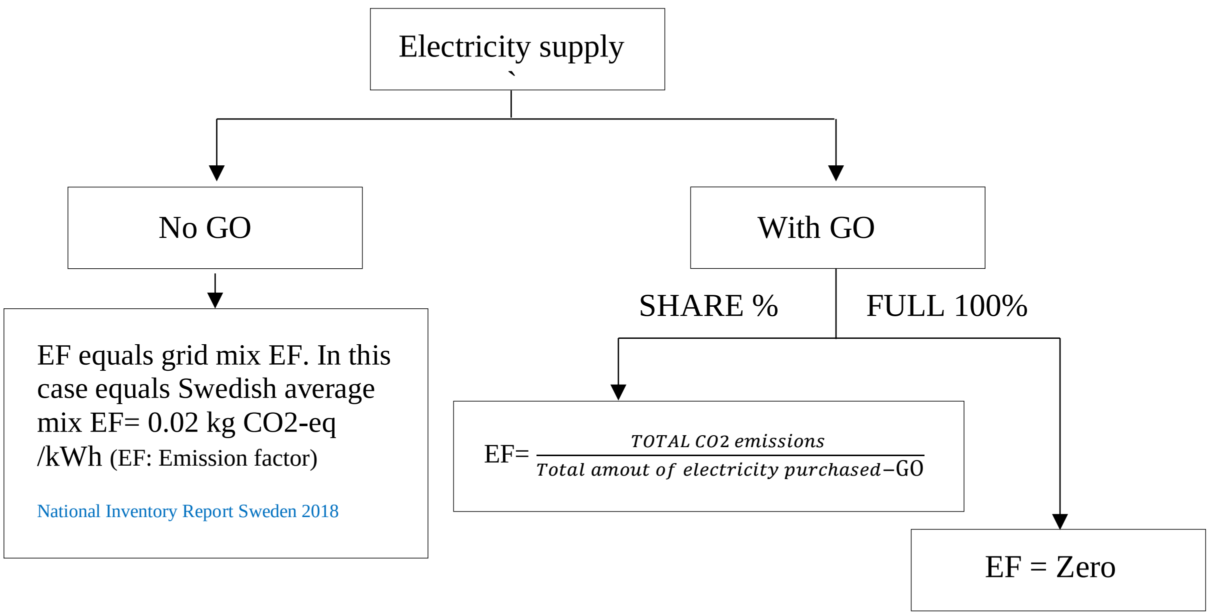


Figure 6: Emission factor consideration flow according to the attributional approach.

3.5 METHODOLOGY FOR CALCULATING CO_2-eq EMISSIONS

In line with the study scope, the expected result is going to be presented as a carbon footprint of the customer center, considering the three scopes which were described in section 2.2. Hence, after being done with data collection i.e. materials usage, energy consumption, Scope 3 data and their emission factors as described in sections 3.3 and 3.4. These data are going to be presented in the result chapter in sections 4.1 and 4.2. The final step in the study structure is to calculate the GHG emissions using equation 2, from section 2.4. The GHG emissions (Carbon footprint) will basically be based on the results from the GHG inventory and their emissions factors. Figure 5 is illustrating a description of the pathway for conducting a carbon footprint.

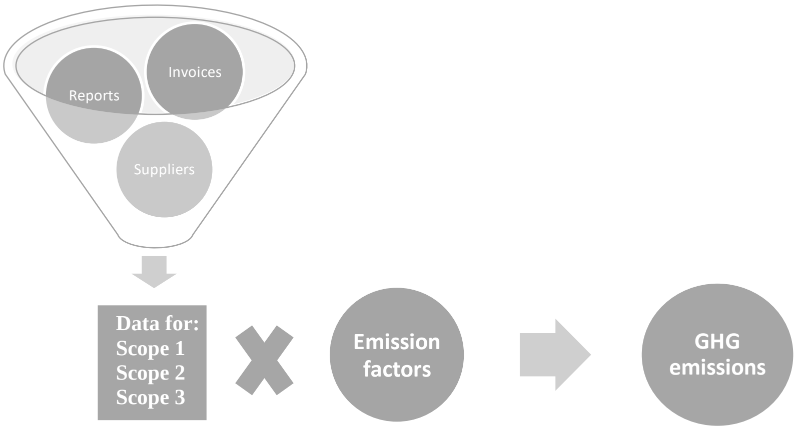


Figure 7 : Description of the pathway for conducting a carbon footprint.

3.5.1 COMPARISION BETWEEN TWO METHODS OF CARBON REPORTING: ATTRIBUTIONAL AND CONSEQUENTIAL METHODS

The most crucial objective identified when conducting an LCA is to showcase the broad width of processes affected by the decisions/procedures followed in a facility and the two distinctive types of approaches the LCA follows are attributional and consequential approaches (Weidema, 2003). The attributional approach is defined as an inventory of emissions accounted for elements at a given system boundary, while the consequential approach is used to capture the consequences of the decisions made by the organization based on the elements in the inventory (Brander & Ascui, 2016) and hence broadening the scope of focus to entail consequential implications occur on the global scale. GHG protocol follows the attributional approach when conducting an LCA and findings show that attributional corporate reporting may not be able to showcase the entirety of the consequences of the elements accounted for, therefore it is not sufficient to plan the remediation measures (Brander, 2017). It is important to consider the perspectives of various scientific publications regarding the need for the consequential methodology application. Taking into consideration various perspectives, in order to establish the complete scenario of the effects caused by the material and energy flows in the customer center, the study decided to scientifically analyze and include the consequential implications associated with these flows and discuss the results from the two different point of views. The goal in doing this is to assure that the study will comprehensively drive the customer center to attain the aim of being climate neutral.

4 RESULTS

In this chapter, the results regarding the predefined objectives of this study are presented. The chapter is divided into three sections. First section covers Scope 1 & Scope 2, which are summed up in the base year energy consumption, such as diesel & HVO as a representation of Scope 1, and electricity & district heating as a representation of Scope 2. Second section covers Scope 3, which are summed up under the base year mass of used materials and other categories e.g. category 1,3,4 & 6. Later, in the third section, the CO_2-eq inventory and the carbon footprint are presented as the result for the CO_2-eq emission calculations for all Scope at the Volvo CE Customer Center during the base year 2019.

4.1 BASE YEAR FOR ENERGY USAGE

Scope 1: As it has been demonstrated earlier, diesel and HVO are representing Scope 1 since they are used and combusted in sources owned and/or controlled by the reporting company. Hence, the study commenced with accumulating data regarding diesel and the HVO usage throughout the base year, this section and the following one both are an introductory step for the CO2 inventory completion, and then afterward the carbon footprint calculations will be performed in the analysis chapter.

Table 5 gives an illustration of the diesel and HVO usage throughout 2019, it is showing that Volvo CE customer center has used 54 m3 of diesel throughout the base year where they have been completely used by the demonstration fleet. The study has found that the used diesel at the center was of specification *Diesel MK1 93% + RME/FAME 7%*. The customer center, as introduced before, acts as the center for the marketing and sales officials of Volvo CE for the regions of Europe, the Middle East, and Africa. Therefore, due to the marketing reasons the center owns a large fleet of different types of construction equipment, where diesel is used for the test run of finished equipment (wheel loaders, dump trucks, etc.) to demonstrate in front of the customers and this justifies the diesel and HVO usage.

Table 5: Diesel and HVO usage during 2019.

Months (2019)	Diesel (Liters)	HVO (Liters)
January	6000	0
February	8000	0
March	8000	0
April	0	0
May	16000	0
June	8000	0
July	0	0
August	8000	0
September	0	9000
October	0	0
November	0	8000
December	0	0
Total (Liters/year) 2019	54000	17000
Total (m3/year) 2019	**54**	**17**

Volvo CE customer center has worked over the past years on improving and enhancing its carbon footprint and its overall sustainability within different aspects. For example, in the context of Scope 1 the center has switched from using diesel in September 2019 to a different green & sustainable substitute, which is HVO, as was shown in the previous table. Accordingly, the centers' need for fuel during September, October, November, and December 2019, have been fully supplied by HVO with nearly 17 m3. Consequently, the centers' direct emissions have been improved and reduced, since HVO is considered as a sustainable fuel and the emissions due to its combustion are deemed to be biogenic. Figure 6 gives an easier representation of the fuel usage at the center throughout the base year, and it also shows when the fuel-switching occurred. However, according to the attributional-consequential debate, switching from diesel to HVO does not necessarily mean that the center's carbon footprint has been reduced. This controversial critique comes due to the neglect of the consequential impact approach which reflects the indirect emissions, this will be debated in more detail in chapter 6.

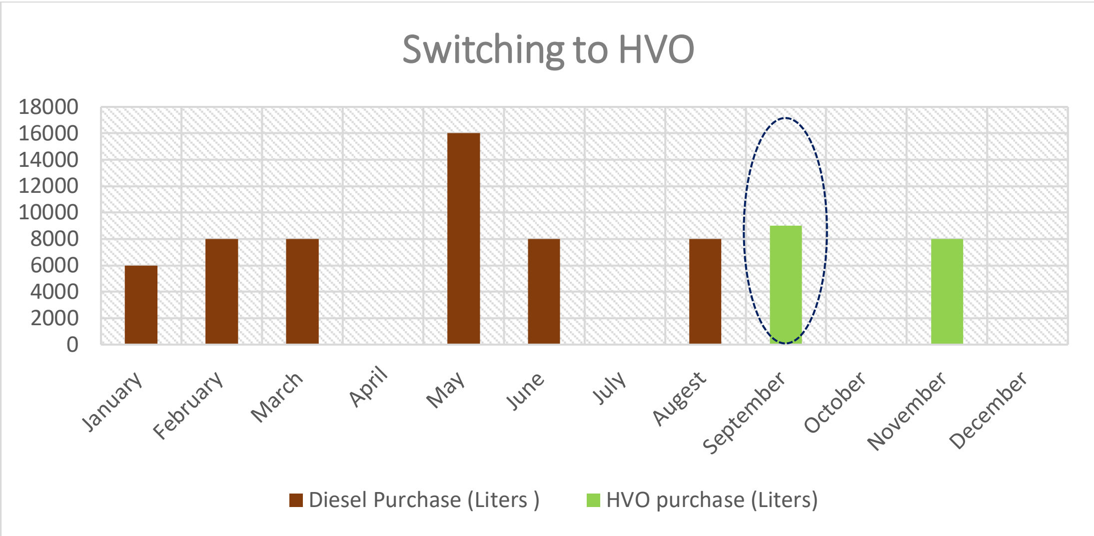


Figure 8: Fuels usage at the CC during base year focusing on the switching to HVO

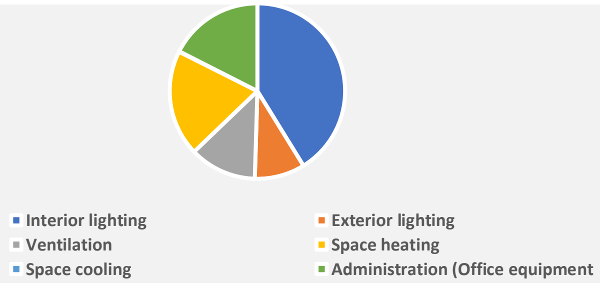
Scope 2: As a continuation of the preceding step, the study has proceeded to collect data concerning Scope 2. As it has been stated earlier, electricity and district heating are representing Scope 2 as an indirect emission since they are produced by another actor and the center is only responsible for the emissions from usage. Regarding the data of the electricity usage at the center it has been obtained from the monthly electricity bills as shown in Table 6. The table tells that the customer center usage of electricity during the base year 2019 was 1010 MWh.

Table 6: Electricity usage during base year 2019

Months (2019)	**Electricity usage (KWh)**
January	123018
February	98443
March	95140
April	71682
May	65294
June	57893
July	53972
August	58274
September	64960
October	95720
November	112100
December	113400
Total consumption (KWh)	1009896
Total usage (MWh)	**1010**

Electricity is used in different support processes at the customer center as listed below:

- Interior lighting
- Exterior lighting
- Ventilation
- Space heating
- Space cooling
- Administration (Office equipment)



Interior lighting accounts for about 40 percent of the customer center's electricity use which approximately equals 400 MWh/year as the largest electricity user at the center. On the other hand, the exterior lighting uses around 9 percent. Office equipment including computers, printers, screens, and others stands for 17 percent of the center's electricity use with about 180 MWh/year. Ventilation stands for 12 percent of the total electricity use with about 120 MWh/year. Electricity is also used for space heating at some parts of the demonstration field and this share of the electricity stands for about 19 percent with about 195 MWh/year. The electricity usage at the customer center is following the same general pattern as other facilities in Sweden, the electricity usage increases in winter and declines in summer. Figure 7 gives a representation of the electricity usage pattern along the base year.

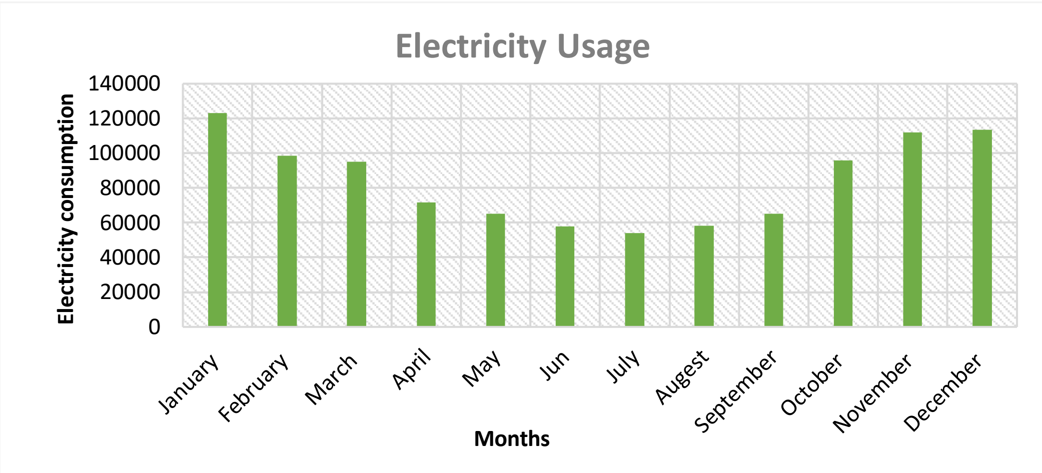


Figure 9: Electricity usage pattern along the base year.

From on-site observation and invoice analysis it can be deduced that, the Volvo CE customer center has also worked on improving and reducing their carbon footprint in the context of Scope 2. Volvo CE customer center has switched from using electricity mix to buying green electricity from renewable sources. Therefore, the customer centers' needs of electricity during the base year 2019, have been fully supplied by green electricity. By doing that the customer center has improved and reduced its indirect emissions from electricity to zero according to the GHG protocol which follows the attributional approach. However, according to the attributional consequential debate, the customer center might have not reduced its overall carbon footprint by switching to green electricity. This analysis debates the neglect of the consequential impact approach which reflects the indirect emissions, this will be discussed in more details in chapter 6.

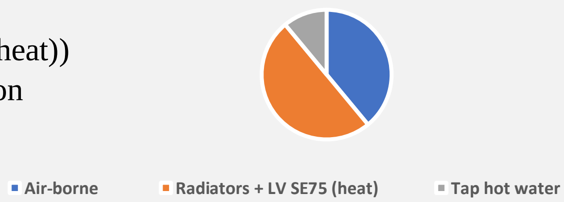
District heating comes also under Scope 2 i.e., considered as an indirect source of emissions since it is produced by another actor and the customer center is only responsible for the usage of the steam/heat. To account for the district heating emissions into the GHG inventory, data regarding the usage throughout the base year were needed. The needed data regarding the customer center's district heating usage was derived from the monthly bills as presented in the below table.

Table 7: District Heating (DH) usage during base year 2019.

Months (2019)	**DH usage (KWh)**
January	106459
February	87082
March	76195
April	42542
May	20517
Jun	5540
July	6610
August	4940
September	10185
October	46973
November	71480
December	78800
Total DH usage (KWh)	557323
Total DH usage (MWh)	**557**

The table shows that the purchased heat during the base year was 557 MWh and this heat was used in different support processes as listed below:

- Space heating via (Radiators + LV SE75 (heat))
- Air-borne space heating, through ventilation
- Tap hot water



Space heating accounts for about 50 percent of the center's heat use and that is approximately 278 MWh/year, the largest heat user. Building ventilation/heating stands for about 39 percent of the center's heat use and the rest is for domestic hot water. Figure 8 gives an illustration of the pattern regarding the district heating usage; it is showing that the usage increases during winter and declines during summer due to the warm weather and vacations.

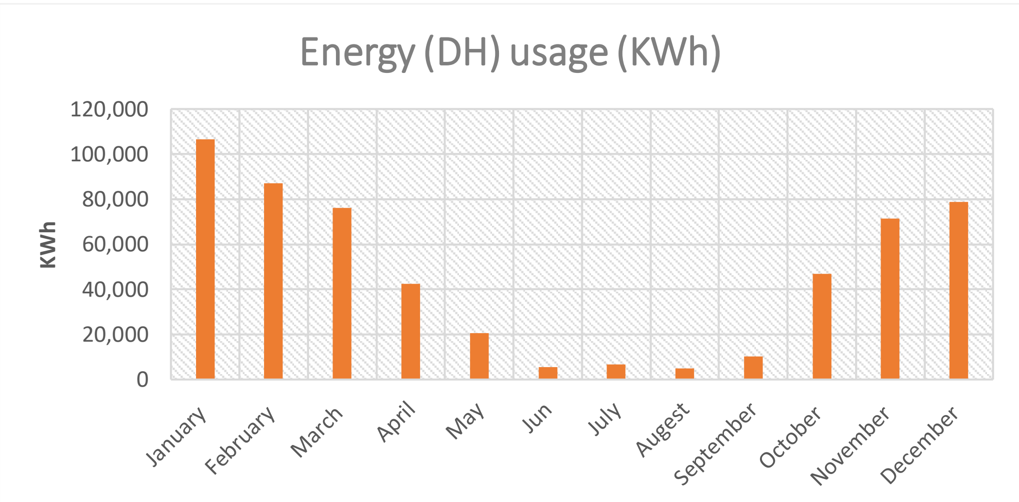


Figure 10: DH usage pattern along the base year.

4.2 BASE YEAR FOR MASS OF USED MATERIALS & OTHER CATEGORIES

Scope 3 emissions, also identified as the value chain emissions, is an optional reporting category that takes into account all other indirect emissions that are not captured by Scope 1 and 2. These emissions are a consequence of activities related to the customer center, but occur from sources not owned or controlled by the center. In most cases, it is estimated to be the most challenging to capture and cover, but at the same time, it is deemed to be responsible for most emissions, and this is why the study has recorded it in a separate section.

In section 3.3.1, Scope 3 categories have been listed and then screened according to their applicability in reference to the study context. After filtering the 15 categories, the study has proceeded with 4 categories. This section is going to present the results regarding each one of the considered categories:

- Category 1: Purchased goods and services: This category has been limited to take into account only the most frequently purchased cleaning supplies, due to the nonexistence of any sort of production and any other frequent purchases.

Table 8 presents the list of the most frequently purchased cleaning supplies taking into consideration that the quantity is per full package e.g. Paper towels have been purchased 184 times (Full package) during 2019 this is also applicable on the rest. The data regarding the purchase's quantities have been derived from the monthly purchase bills given by the customer center. Later in the analysis chapter the carbon footprint from each product is performed.

Table 8: The Most frequently Purchased cleaning supplies during 2019

Item	Order Qty	Product/Service Description
1	7	(Toilet paper Type 1 64rl/fp)
2	184	(Paper towel)
3	12	(Towel roll Type 1 11rl/fp)
4	14	(Towel roll Type 2 6rl/fp)
5	41	(Toilet paper Type 2 12rl/fp)
6	252	(Hand cleaning Sterisol)
7	200	(Waste and trash bag roll)
8	138	(Garbage Bag)
9	40	(Green bag roll)

The demonstration fleet has also been considered under this category as capital goods since the customer center uses the fleet for providing a service and for commercial sales. Table 9 presents data concerning the equipment fleet that the customer center has purchased and transported throughout 2019. This table gives the advantage of tracking each equipment to the producer i.e. the table tracks the first equipment SD75B which is the soil compactor to the manufactured in Hameln, Germany. Hence, this will facilitate accounting each country's emissions to the total. The study has only considered the GHG from the production phase as will be shown in the analysis chapter, however, the transportation phase has been neglected due to the lack of data. It must be noted that the highlighted equipment i.e., sourced from South Korea have been included in the table to increase the completeness and transparency of the report but due to high uncertainty of the quantity of their impact, attributed to insufficient data and time constraints, the final analysis (section 5.3) shall not include them.

Table 9: Customer center demonstration fleet

Equipment type	Arrival date at CC	Sales date from CC	Origin
SD75B (554139)	2019-01-10	2019-09	Germany, Hameln
L260H (1502)	2019-01-21	2019-09	Sweden, Arvika
ECR355EL (310211)	2019-01-21	2019-10	Changwon, Korea
L350H (1301)	2019-01-24	2019-11	Sweden, Arvika
ECR145EL (311834)	2019-01-30	2019-10	Changwon, Korea
EWR150E (322611)	2019-01-30	2019-10	Germany, Konz
EC380DL (271811)	2019-02-03	2019-12	Changwon, Korea
A30G (342795)	2019-02-05	2019-07	Sweden, Braås
EC250EL (323013)	2019-02-05	2019-11	Changwon, Korea
EC750EL (310141)	2019-02-05	2019-12	Changwon, Korea
SD160B (570031)	2019-02-05	2020-01	Germany, Hameln
A45GFS (352066)	2019-02-11	2019-10	Sweden, Braås
EW220E (320055)	2019-02-11	2019-10	Germany, Konz
SD135B (556144)	2019-02-15	2019-08	Germany, Hameln
L90H (16090)	2019-02-27	2019-08	Sweden, Arvika
L70H (14048)	2019-03-05	2019-12	Sweden, Arvika
L60H (13578)	2019-03-06	2020-01	Sweden, Arvika
EC27D (27499)	2019-03-13	2019-12	France, Belley
ECR58D (281909)	2019-03-13	2019-12	France, Belley
EW240EMH (320062)	2019-03-19	2019-07	Germany, Konz
EW220E (320261)	2019-03-19	2019-07	Germany, Konz
EC380EL (311846)	2019-03-29	2019-12	Changwon, Korea
ECR25D FL (26598)	2019-04-02	2019-12	France, Belley
L70H (14108)	2019-04-05	2019-12	Sweden, Arvika
A45G (352155)	2019-04-10	2019-12	Sweden, Braås
L180HHL (1419)	2019-04-17	2019-11	Sweden, Arvika
A40G (352143)	2019-04-26	2019-12	Sweden, Braås
L180H (15173)	2019-05-07	2019-12	Sweden, Arvika
A25G (342497)	2019-05-09	2019-11	Sweden, Braås
L120GZ (671812)	2019-05-16	2019-11	Sweden, Arvika
EC300EL (313055)	2019-05-22	2020-01	Changwon, Korea

L25HS (1420207)	2019-05-28	2019-11	Germany, Konz
L35GT (3626019)	2019-05-29	2019-10	Germany, Konz
EC380DL	2019-10-23	2019-11	Changwon, Korea

- Category 3: Fuel & energy-related activities: This category has been decided to take into account the upstream emissions of purchased fuels including diesel & HVO. This study considered that upstream emissions include emissions only from the production phase.

Purchased diesel & HVO 2019		
Fuel type	Quantity	Application
Diesel	54 m3	Demo fleet
Diesel	0.8 m3	Fleet cleaning
HVO	17 m3	Demo fleet

The quantity for the diesel that was used at the demonstration fleet has been presented earlier in Scope 1 as a direct emission source due to the GHG emissions at the combustion. However, from the monthly bills it was found that there are another 800 liters (0.8 m3) that the customer center has used for cleaning purposes e.g. cleaning the fleet machines, this quantity hasn't been taken into account in Scope 1 because the used diesel has not been combusted it has only been used for cleaning, therefore, no emissions coming out of the use phase. Yet, this quantity of diesel has an indirect emission from the production phase and that is why it has been accounted for in this category.

- Category 4: Upstream Transportation & distribution: This category has been decided to take into account the upstream emissions from transporting the purchased materials from the supplier to the customer center, excluding fuels (diesel & HVO) since they are already taken into account in category 3.

Every order that arrives to the customer center comes in a truck from Logistics service provider's warehouses in Falköping passing Jönköping directly to customer center in Eskilstuna. The following table shows the number of travels and the travelled distance during 2019.

Transportation			
Destination one	Destination 2	Distance	Travels number
Falköping	Customer center	348 km	21

The supplier uses Volvo trucks for their deliveries as shown in the below picture. The distance travelled in every delivery is about 348 km. The carbon footprint associated with the supply's transportation is presented in the analysis chapter where the truck fuel efficiency has been considered.

Figure 11: An example of the trucks used for transporting purchased supplies to the CC.

- Category 6: Business travel: This category has been decided to take into account the emissions of the business travel using third party owned transportation mode (e.g. Aircraft, trains, buses, and cars) during the base year 2019.

Business travels data have been provided by the internal office specializing in reservations at Volvo group CE. The obtained data comprised the number of flights booked by the customer center in 2019, accounting to 1500 trips. These trips have been processed to find their contribution to the carbon footprint. Table 10 is given to demonstrate how the sorting and screening processes which will be also explained in the next paragraph have been performed. The table presents only 17 trips taking into consideration their repetitions, to see the whole flights check Appendix. 2. The calculations regarding their carbon footprint have been conducted in the analysis chapter as the rest of the categories.

The study started processing these data by sorting the bookings so that the trips with the same routes were combined to reduce the total number of trips and duplications. Then the study proceeded with calculating the distance traveled in each flight using the International Civil Aviation Organization (ICAO) calculator (*ICAO Carbon Emissions Calculator*, n.d.). The study completed the screening process so that trips were classified into short-haul flight and long-haul flight based on the traveled distance, i.e. the trip which traveled more than 1500 km is classified as long-haul and the trip that is less than 1500 km is classified as short-haul as this sort is one of the factors used to determine the emission factor from the trips, and the other factor is the flight class and since the vast majority of the trips were economy class so it was applied to all trips. This mode of sorting has been adopted from my-climate flight emission calculator which their calculations and assumptions are in line with the European standard DIN EN 16258 (Myclimate, 2015).

Table 10: The screening process used at processing the business travels.

Flight Number	**Routing**	**Flight distance** (Km)	**Flight type**	**Flight class**	**Repeat**	**Travelled distance** (megameter) = 1000 km
1	ABJ/MJC/ABJ	394	Short-haul flight	Economy	1	0.394
2	ACC/KMS/ACC	396	Short-haul flight	Economy	4	1.584
3	ADA/ADB	729	Short-haul flight	Economy	1	0.729
4	ALG/CDG	1370	Short-haul flight	Economy	1	1.37
5	ALG/FRA	1542	Long-haul flight	Economy	8	12.336
6	ALG/TUN	624	Short-haul flight	Economy	3	1.872
7	AMS/FRA	367	Short-haul flight	Economy	1	0.367
8	FRA/HOG	7889	Long-haul flight	Economy	4	31.556
9	AMS/MAN	484	Short-haul flight	Economy	4	1.936
10	ARN/ADD/ARN	11794	Long-haul flight	Economy	3	35.382
11	ARN/ADD/FBM/ADD/ARN	16996	Long-haul flight	Economy	9	152.964
12	ARN/ADD/FCO	10376	Long-haul flight	Economy	1	10.376
13	FCO/TUN	576	Short-haul flight	Economy	1	0.576
14	ARN/ADD/JNB/ADD/ARN	19922	Long-haul flight	Economy	1	19.922
15	ARN/ADD/LAD/ADD/ARN	18702	Long-haul flight	Economy	1	18.702
16	ADD/NBO	1160	Short-haul flight	Economy	5	5.8
17	ARN/AGH	4708	Long-haul flight	Economy	1	4.708

5 ANALYSIS (CO_2-eq INVENTORY CALCULATIONS)

In this chapter, the carbon footprints regarding the predefined scopes of this study are presented. In the previous chapter the results regarding Scope 1,2,3 was managed and presented, and now the CO_2-eq emission calculations are going to be performed to find the carbon footprint for each scope. This chapter is divided into three sections, each section presents the carbon footprint calculations of each scope. This chapter is connected to the previous one, all the data that will be used in the calculations are obtained from the previous chapters' tables.

5.1 SCOPE 1 CO_2-eq EMISSION CALCULATIONS (CARBON FOOTPRINT)

As it has been stated earlier in section 4.1, the customer center has used 54 m3 diesel and 17 m3 HVO throughout the base year 2019. To proceed with calculating the CO_2-eq emissions i.e. (The carbon footprint) from using this amount of fuels, equation 3, from section 2.4 is going to be used.

$$GHG\ emissions = Activity\ Data \times Emission\ factor.$$

This equation is going to be applied in the following sections as well. To apply the equation in this section, data regarding each component of the equation are needed. Table 11 provides the amount of diesel used which represents the activity data and the amount of GHG emitted due to the combustion of one unit of the diesel represents the emission factor. To get the emission factor accurately it's important to take into consideration the fuel specification, in this study it is Diesel MK1 (*Diesel MK1 93% + RME/FAME 7%*).

Table 11: Scope 1(Diesel) GHG emissions calculation

Scope 1		
Diesel (m3)	**Emission factor (Kg CO_2-eq / liter)**	**CO_2-eq emissions (t CO_2-eq)**
54000	2.38	129

The emission factor is obtained from Eco invent database giving that 2.38 kg of CO_2-eq is emitted due to the combustion of one liter of diesel. Therefore, the carbon footprint from using 54000 liters equals 129-tonne CO_2-eq. Figure 9 gives a more helpful representation of the customer centers' diesel usage and the corresponding carbon footprint.

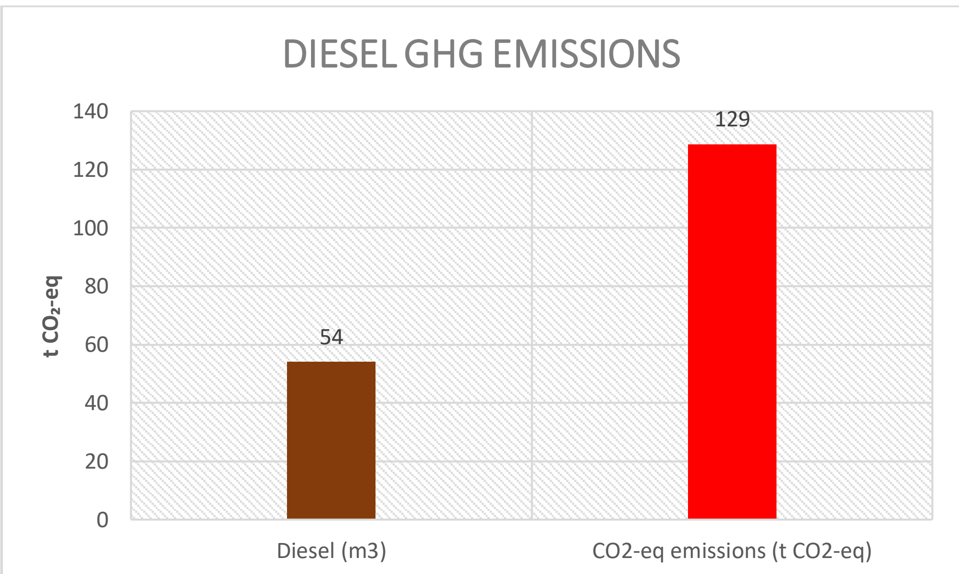


Figure 12: Diesel carbon footprint

The same calculation procedure is applied over HVO. As stated in the result chapter, the customer center has switched to using HVO in September 2019. Since HVO is considered a green substitute, therefore, emissions at the combustion are deemed to be biogenic. Most of the literature and other companies' projects always assumed that the emission factor for HVO is Zero. In contrast, this study followed a different approach in trying to find an approximate value for the HVO emissions. The approach was done by creating a hypothetical scenario claiming that the emissions from the used HVO are equal to the average emissions of the used raw materials at the production stage. The producer of HVO uses three different types of raw materials, which are wastes and residues (e.g. animal and fish fats from food industry waste, vegetable oil processing waste and residues), Tall oil, and Other vegetable oils (e.g. rapeseed). Neste states in its sustainability report that the HVO produced from the first type of substrates reduces emissions by 90 % compared to fossil diesel, the second type reduces emissions by 56 %, and the third type by 50–60% (Neste Corporation, 2015). The study took the mean of these three values as follows: (Note: It has been also assumed that 70% of HVO is produced from type 1 and 15% from type 2 and 15% from type 3, this is in line with Neste general assumption).

((2.38 kg CO_2-eq/ liter of diesel * 0.1* 0.7) + (2.38 * 0.31* 0.15) + (2.38 * 0.45* 0.15)) / 3 = 0.44 kg CO_2-eq/ liter of HVO.

This means 0.44 kg of CO_2-eq is emitted due to the combustion of one liter of HVO. Table 12 contains the components of the carbon footprint equation. The table shows that the carbon footprint from using 17000 liters equals 7 tonne CO_2-eq.

Table 12: Scope 1 (HVO) GHG emissions calculation

Scope 1		
HVO (m3)	**Emission factor (Kg CO_2/lite)**	**Biogenic CO_2-eq emissions (t CO_2-eq)**
17	0.44	7

Figure 10 gives a clear illustration of the customer centers HVO usage carbon footprint. Taken into consideration that these emissions are considered as biogenic because HVO is bio-based materials other than fossil fuels. According to the GHG the biogenic emissions whether in Scope 1 or Scope 2 or Scope 3 shall be reported and presented in the final carbon footprint report, but separately.

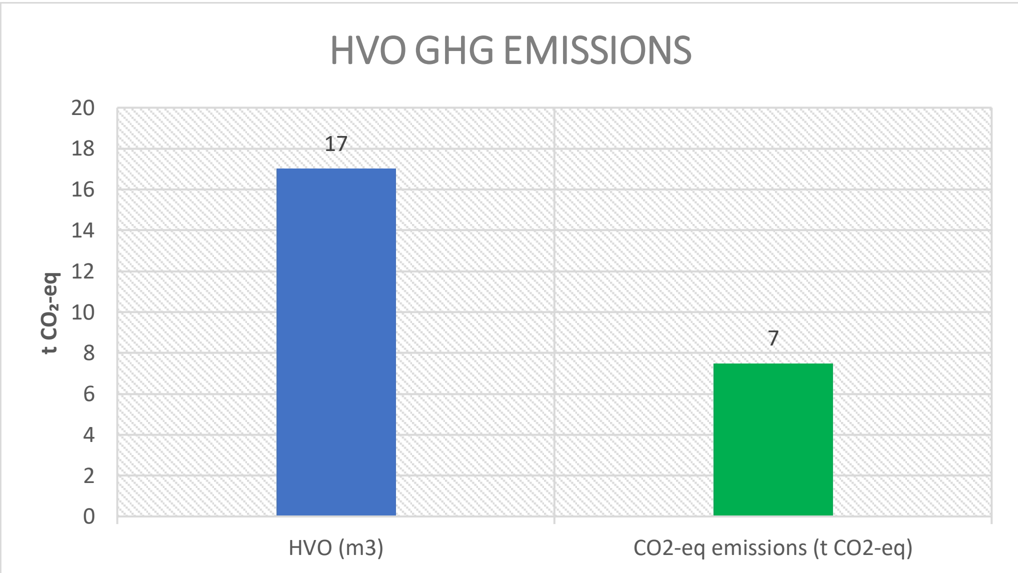


Figure 13: HVO Carbon footprint

5.2 SCOPE 2 CO_2-eq EMISSION CALCULATIONS (CARBON FOOTPRINT)

The carbon footprint of Scope 2 including both electricity and DH follows the same procedure as Scope 1 calculation which is based on the *GHG protocol* setting. To find the *CO_2-eq* emissions due to the usage of electricity, the amount of the used electricity is multiplied with the emissions factor (*Unit CO_2-eq / Unit Wh*) as presented in Table 13. The emission factor of electricity varies all the time from one region to another and from one country to another. The reason for this variation is the electrical power system structure i.e. the type of power generation plants used to generate electricity in the investigated region. The electrical power system comprises a different type of generation plants some of them are fossil fuel-based e.g. Oil, Coal power plants, and others are non-fossil fuel-based i.e. renewable sources e.g. Hydro power plant. Consequently, the more fossil fuel-based power plants are involved in the composition of the electrical system the higher the emissions factor gets. Otherwise, the more the renewable power plants are involved in the composition of the electrical system the less the emissions factor gets.

Table 13: Scope 2 (Electricity) GHG emissions calculation

Scope 2		
Electricity (MWh)	LCA emission factor (t CO_2-eq/MWh)	CO_2-eq emissions (t CO_2-eq)
1010	0	0

In the context of this scope, it was found earlier that the customer center electricity usage throughout the base year 2019 equaled 1010 MWh. It was also found that Volvo CE purchases electricity *Guarantee of Origin certificates (GO)* i.e. Volvo CE purchases certificates that guarantee that one MWh of electricity/GO has been purchased from the supplier has been produced from renewable energy sources. Accordingly, purchasing certificates that cover the whole electricity usage mean that the emission factor and the *CO_2-eq* emissions out of the electricity usage equal to zero as was shown in the previous table. Table 14 presents the number of certificates that Volvo CE purchased every month through the base year. The second column of the table represents the total electricity usage including the customer center and extra 2 Volvo facilities in Eskilstuna. The third column represents the number of the purchased certificates and it is clearly shown that they are equal to the electricity usage for the whole year. E.g. The electricity demand in January 2019 was 1 165 MWh, and the number of certificates was 1166, given that each certificate guarantees one MWh, then this covers the total electricity demand.

Table 14: The number of certificates Volvo CE Purchased in 2019

Months (2019)	**Total electricity usage KWh**	**Number of certificates**
January	1165773	1166
February	106271	1063
March	1151174	1151
April	1130714	1131
May	1156957	1157
Jun	1079415	1079
July	732881	733
August	877513	878
September	1045564	1046
October	10033815	1004
November	944530	945
December	821019	821
Total Certificates	12172072	12 172

Finally, Figure 11 gives a clear illustration of the customer center electricity CO_2-eq emissions (carbon footprint). However, according to the attributional-consequential debate, switching green electricity does not necessarily mean that the center's carbon footprint has been reduced. This controversial critique comes due to the neglect of the consequential impact approach which reflects the indirect emissions, which will be discussed in more detail in chapter 6.

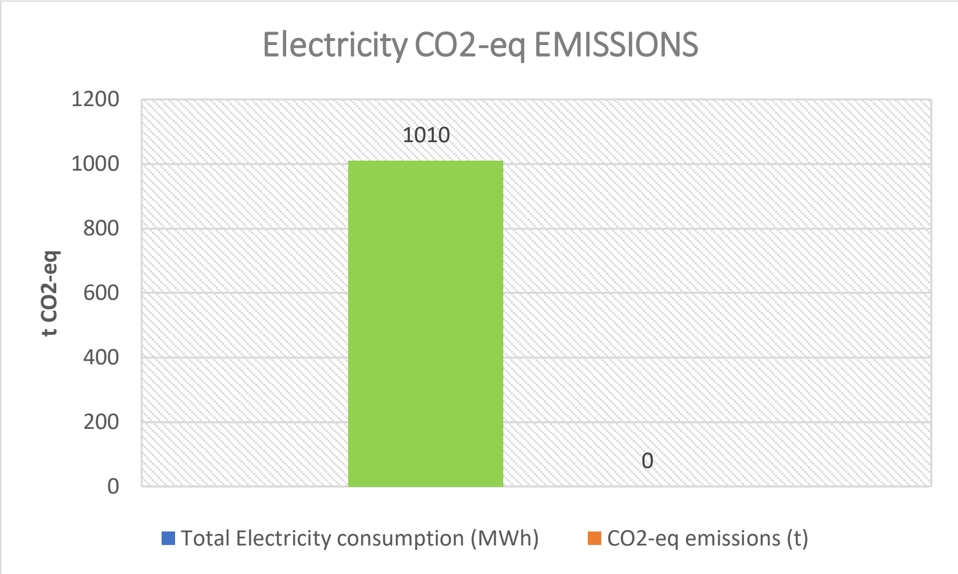


Figure 14: Electricity Carbon footprint

As a continuation of Scope 2 carbon footprint, the same previous calculations are applied to the district heating usage at the customer center. In the result chapter it was found that the customer center used 557 MWh heat during 2019. The emission factor of DH equals to 2.08 kg CO_2-eq/MWh obtained from source officially provided by the producer and supplier of the used heat at the customer center (*Eskilstuna Energi & Miljö*, 2019). Table 15 presents the CO_2-eq emissions (carbon footprint) calculations regarding the heat used at the customer center during the base year. The calculations show that the usage of 1 MW of heat at the customer center results in emitting 2.08 kg of CO_2-eq, this means that the total heat used in the base year caused 1.16 ton of CO_2-eq emissions.

Table 15: Scope 2 (DH) GHG emissions calculation

Scope 2		
DH (MWh)	LCA emission factor (kg CO_2-eq/MWh)	CO_2-eq emissions (t CO_2-eq)
557	2.08	1.16

The GHG emissions due to the DH usage is relatively small compared to the other form of energy used at the customer center, the reason for that is the dominance of the renewable generation plants used at the production phase. Renewable energy sources do not contribute to the greenhouse effect but their emissions if found then according to the GHG protocol are reported as biogenic. Table16 presents the Biogenic CO_2-eq emissions, the data regarding the biogenic emission factor obtained from the data provided by the supplier responsible for the heat production and supply.

Table 16: Scope 2 (DH) Biogenic GHG emissions calculation

Scope 2		
DH (MWh)	LCA emission factor (kg CO_2-eq/MWh)	CO_2-eq emissions (t CO_2-eq)
557	464	258

Figure 12 gives a better illustration of the two both types of emissions caused by DH. As mentioned before, according to the GHG protocol biogenic emissions are to be considered when performing carbon footprint mapping but they are reported separately from the fossil-based emissions.

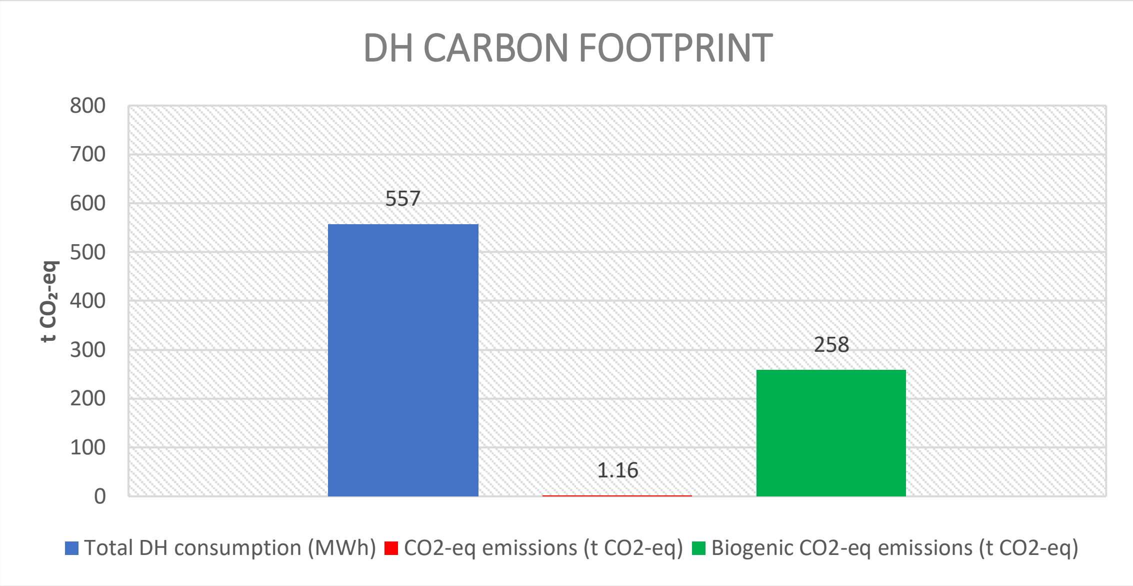


Figure 15: DH carbon footprint including both types of emissions

5.3 SCOPE 3 CO_2-eq EMISSION CALCULATIONS (CARBON FOOTPRINT)

The carbon footprint of Scope 3 including the 4 chosen predefined categories also follows the same calculations procedure used in Scope 1 & 2 as counseled by the GHG protocol. Scope 3 carbon footprint calculations are going to be performed in 4 stages while each stage representing one category, and at the end of the section the total carbon footprint will be compiled in one figure.

Starting with Category 1: Purchased goods and services carbon footprint, in the results chapter the data regarding the materials flow quantities were presented. Accordingly, to proceed with finding the carbon footprint, the cradle to gate emissions out of the production of each item are required. Table 17 shows the calculations which were carried to get the carbon footprint of each item. The procedure is the same as equation 3 explained in the previous sections, where the cradle to gate emissions are multiplied with the activity data i.e. material quantity. Note that item 4 has been excluded due to the lack of the emission factor from the provider.

Table 17: Purchased goods carbon footprint

Item	Order Qty	Cradle to gate emissions	CO_2-eq emissions
1+2	7 + 184	7.7 Kg CO_2 -eq/package	1473 Kg CO_2 -eq
3+4	12 + 14	10.9 Kg CO_2 -eq/ package	283 Kg CO_2 -eq
5	41	13.3 Kg CO_2 -eq/package	544 Kg CO_2 -eq
7	200	3.7 Kg CO_2 -eq/roll	740 Kg CO_2 -eq
8+9	138	4.5 Kg CO_2 -eq/package	621 Kg CO_2 -eq

The hand towels and toilet paper packages (Items 1-5 in Table 17) are manufactured by a company which has completed an LCA from cradle to gate and these values were obtained from the reports presented by them through the web link presented by IVL Swedish Environment Institute, which is a Swedish independent research institute. The calculations were carried out in the manner presented below:

One roll of item 3 weighs: 1.35Kg
The presented results in the report is in accordance to 1010 kg package which is deduced to approximately 748 rolls
The GWP for 1010kg or 748 rolls is 1360 Kg CO_2 -eq
1 roll is 1.18 Kg CO_2 -eq
In case of Volvo, each pack contains 6 rolls included in the packaging i.e., 10.9 Kg CO_2 -eq/order quantity

The garbage bags used in the facility are of three types and since the green bags are made of bio based raw materials they are neglected in this study. The items 5 and 7 in Table 17 represent the remaining two fossil-based bags whose emission factors have been presented by Hallberg et al., 2018, as a part of a study completed by IVL. The presented results were for a functional unit representing 1000 bags and hence necessary calculations have been done to equate it to units used in the inventory reporting of the customer center. This can be explained by the difference that for item 6 (correct it in the table)– 200-unit order quantity is translatable to 200 rolls which 100 bags each. While item 7 is sold in packages which consists of 6 rolls each with 25 bags per roll, translatable to 150 bags per unit order quantity. The calculation of this section was done in the manner below:

If 1000 bags produce say 37 Kg CO_2 - eq then 200 bags would produce 37/5 units of CO_2- eq.

As a complementing of category 1, the fleet that the customer center purchased during the base year as discussed in the results chapter, has been considered as capital goods since they use it for selling services and final sales afterward. Taking the fleet emissions into account in this study was a challenge, due to several limitations. Firstly, each equipment in the fleet is manufactured in a different production facility & a different country, making the process of data collection a tough task especially with the time constraints. Secondly, the production facilities under Volvo CE have not yet conducted an LCA on their products i.e. they do not have knowledge regarding the emissions associated with the production of each equipment. It was found that only Braås facility in Sweden, has conducted an LCA on their produced equipment. However, the study has also found that Volvo CE has recently initiated a project aiming to conduct an LCA on the rest of their equipment. But, due to the time limit of this study, which is not in line with Volvo CE project, the study proceeded with a different approach to get an approximate value of the emissions associated with the production of each equipment. The adopted approach states that the emissions out of producing one single equipment in any facility equal the total emissions of the facility divided over the total number of productions. For example, if a facility's total emissions equal 135,000 t CO_2 -eq and its total production capacity is 1500 equipment, then the emissions per equipment equal 135,000 / 1500 = 90 t CO_2 -eq. This approach does not give an accurate value to the emissions, but it meant to be roughly close. The total emissions from each production facility have been obtained from Volvo Group sustainability report, and the total production per facility in 2019 has been obtained from the sustainability department in Volvo CE. Table 18 presents the LCA emissions for each equipment using the predefined approach.

Table 18: LCA emissions for the customer center demonstration fleet.

Equipment type	**Origin**	**LCA emission Factor (t CO_2-eq/Equipment)**
SD75B (554139)	Germany, Hameln	170
L260H (1502)	Sweden, Arvika	150
ECR355EL (310211)	Changwon, Korea	-
L350H (1301)	Sweden, Arvika	160
ECR145EL (311834)	Changwon, Korea	-
EWR150E (322611)	Germany, Konz	170
EC380DL (271811)	Changwon, Korea	-
A30G (342795)	Sweden, Braås	105
EC250EL (323013)	Changwon, Korea	-
EC750EL (310141)	Changwon, Korea	-
SD160B (570031)	Germany, Hameln	170
A45GFS (352066)	Sweden, Braås	105
EW220E (320055)	Germany, Konz	170
SD135B (556144)	Germany, Hameln	170
L90H (16090)	Sweden, Arvika	150
L70H (14048)	Sweden, Arvika	150
L60H (13578)	Sweden, Arvika	150
EC27D (27499)	France, Belley	200
ECR58D (281909)	France, Belley	200
EW240EMH (320062)	Germany, Konz	170
EW220E (320261)	Germany, Konz	170
EC380EL (311846)	Changwon, Korea	-
ECR25D FL (26598)	France, Belley	200
L70H (14108)	Sweden, Arvika	105
A45G (352155)	Sweden, Braås	105
L180HHL (1419)	Sweden, Arvika	105
A40G (352143)	Sweden, Braås	105
L180H (15173)	Sweden, Arvika	105
A25G (342497)	Sweden, Braås	105
L120GZ (671812)	Sweden, Arvika	105
EC300EL (313055)	Changwon, Korea	-
L25HS (1420207)	Germany, Konz	170
L35GT (3626019)	Germany, Konz	170
EC380DL	Changwon, Korea	-

Notwithstanding, these values are not asserted to be conclusively accurate, given that important factors such as the quality and the types of electricity used in factories, the quality and the efficiency of production, the source of raw materials, the quality and types of fuel used and other important factors have been neglected. Yet, it can be said that the total output of emissions summed collectively may be close to actuality taking into consideration a margin of error.

Figure 16 gives a better illustration of the demo fleet production locations. The figure further gives the total emissions in a small chart under each country. The emissions are summed and collected from the previous table. As explained in section 4.2 for the highlighted equipment i.e., equipment from South Korea due to lack of data and high margin for error in approximations has been excluded from the study's analysis inventory. It must be noted that this has influenced the systrem boundary for the category and the present system boundary includes equipment manufactured in Europe only.

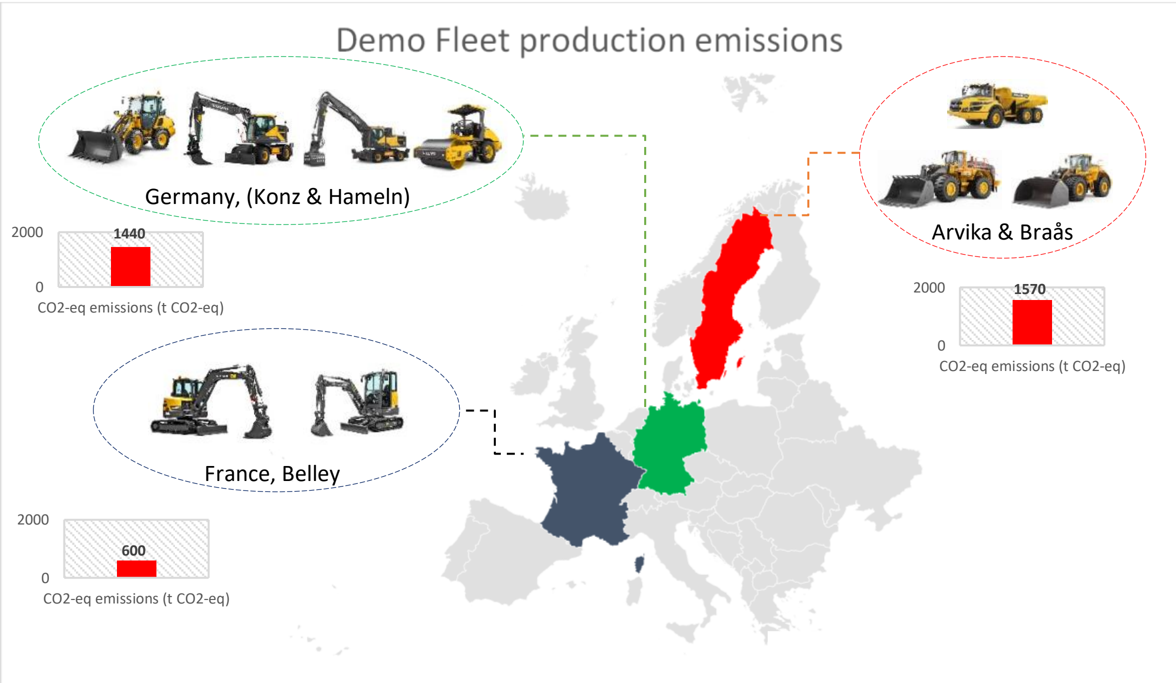


Figure 16: Demo fleet production emissions. The map is designed by the study using Microsoft excel, equipment pictures are taken from the public published reports of Volvo CE. The emissions tables were designed by the study using Microsoft excel and then together with the picture were planted and projected on the map.

Category 3: Fuel & energy-related activities: To calculate the carbon footprint associated with the production and transportation of the fuel at the customer center. The study has followed the same formula used in the other scopes and categories. In the result chapter, it was found that the customer center has used 54.8 m3 of diesel (50 m3 at the demo fleet and 0.8 m3 for cleaning purposes) and 17 m3 of HVO, these values regarding the quantities represent the activity data which will be used in the carbon footprint formula. The study has continued with gathering data regarding the upstream emissions (Well to tank) of the purchased fuels including diesel & HVO excluding the combustion emissions since they have been already considered in Scope 1.

The study began with diesel, taking into account that the amount of the consumed diesel, found previously in the results chapter with a quantity of 54 m3. Correspondingly, to complete with the upstream emissions the study has used Eriksson & Ahlgren, 2013, who have conducted a Life cycle analysis over different types of fuels in the Swedish context, in cooperation with the Swedish Knowledge Centre for Renewable Transportation Fuels (f3). It was found based on the diesel specifications that the diesel type that has been used at the customer center is Diesel MK1, and according to Eriksson & Ahlgren, 2013 the well to tank emissions in Sweden are between 9.25 to 9.34 g/MJ. Taking into consideration that the thermal energy of diesel equals 35.9 MJ / liter this concludes that the well to tank emission equals 334 *g CO_2 -eq/ liter*.

The study proceeded with examining HVO upstream emissions, taking into consideration that the consumed HVO was found to be 17 m3. The study has used Andersson & Rydberg, 2019 who have conducted an analysis in cooperation with (f3), the project comprised results regarding the well to tank emissions associated with the production of HVO from every single raw material. For instance, HVO that is produced completely from Rapeseed has 58 g CO_2-eq/

MJ well to tank emissions. On the other hand cooking has 12 g CO_2 -eq/ MJ. The completed list of the raw materials' well to tank emissions is presented bellow:

- Slaughtered animals: 35 g CO_2 -eq/ MJ
- Cooking oil: 12 g CO_2 -eq/ MJ
- PEAD: 15 g CO_2 -eq/ MJ
- Tall oil: 5 g CO_2 -eq/ MJ < cut off >

To obtain viable and approximate upstream emission factor the study has implemented the same hypothesis regarding HVO raw material composition used in section 5.1. The hypothesis stated that 70% of the raw material came from Cooking oil, Slaughtered animals, PEAD and the other 30% came from the other types of oils. Consequently, the well to tank emissions factor has been calculated as below:

Average of the first set of raw materials: 58 + 5 = 31.5 g CO_2 -eq/ MJ and this stands for 30% of the HVO giving that the contribution of these raw materials to the total well to tank emissions equals 31.5 * 0.3 = 9.45 g CO_2 -eq/ MJ.
Average of the second set: 35 + 12 + 15 = 20 g CO_2 -eq/ MJ and this stands for 70% of the HVO giving that the contribution of these raw materials to the total well to tank emissions equals 20 * 0.7 = 14 g CO_2 -eq/ MJ. Therefore, the total well to tank emissions of the used HVO equals 23.45 g CO_2 -eq/ MJ. Taking into consederation that the thermal energy of HVO equals 34.4 MJ / liter this concludes that the well to tank emission equals 807 g CO_2 -eq/ liter.

Table 19 presented the carbon footprint calculation. The value of the emission factors and the quantity have been converted to be per m3 instead of liter.

Table 19: Category 3 carbon footprint calculation.

Scope 3 (Category 3)			
Fuel	Quantity (m3)	Emission factor (Kg CO_2/m3)	CO_2-eq emissions (t CO_2-eq)
Diesel	54.8	338	19
HVO	17	807	14

The following figure gives a better illustration of the emissions with regards to the used diesel and HVO, the emissions from both fuels have been gathered in one graph as shown below.

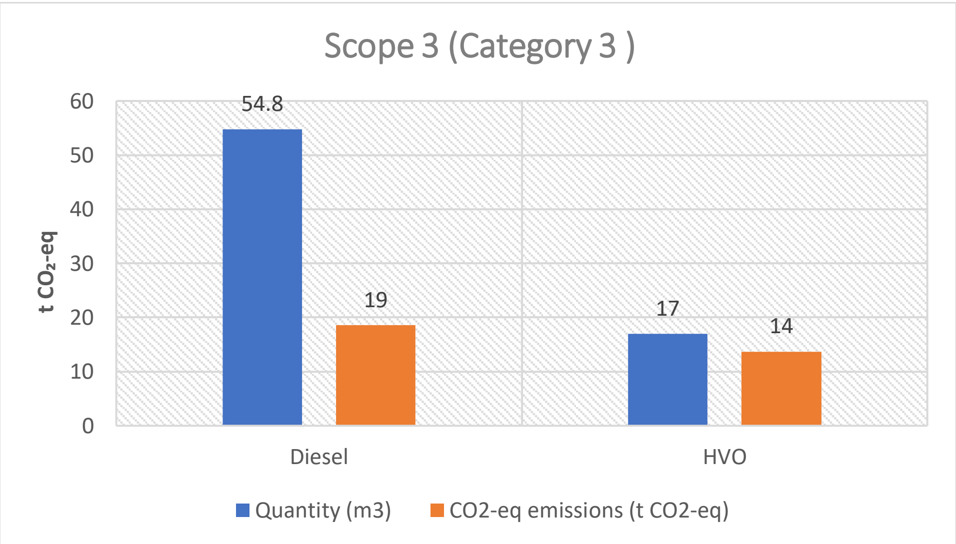


Figure 17: Diesel and HVO upstream emissions

Category 4: Upstream Transportation & distribution: To calculate the carbon footprint associated with this category, the study had to gather data regarding the fuel used at the trucks and fuel efficiency. The data regarding the used fuel in the trucks has been obtained from the transportation department of the logistics agency, given that the used fuel is diesel. As for the fuel efficiency of the used trucks i.e. the number of diesel liters consumed per 1 kilometer, it has been found that the fuel efficiency can be affected a lot by the driving behavior. For instance, according to Volvo trucks' specifications, it is stated that the fuel efficiency ranges between 23 to 37 (L/ 100 Km), accordingly, the average of the two values has been chosen as the value of this study, giving that the truck consumes 30 L of diesel per 100 Km. These data have been projected over the customer centers' case as presented in the below table.

Table 20: Upstream Transportation carbon footprint calculation

Transportation					
Distance	Delivery	Fuel efficiency (L/1 Km)	Fuel Used (L)	Emission factor (Kg CO_2-eq / liter)	CO_2-eq emissions (t CO_2-eq)
348 km	21	0.3	2190	2.38	5.2

The delivery distance from logistics agency warehouse to the customer center is nearly 348 Km that has been repeated 21 times throughout the base year, giving that the total traveled distance was 7308 Km. Considering the fuel efficiency is 0.3 L/ Km, this indicates that the total fuel used during all the deliveries in 2019 was 2190 liters, roughly 2.2 m3. Finally, to comprehend the carbon footprint associated with the combustion of this fuel, the same emission factor of the diesel combustion used in Scope 1 has also been used here, therefore, the carbon footprint equals the 2.2 m3 multiplied by 2.38 Kg CO_2-eq / liter equals to 5 tonnes CO_2-eq. Figure 17 gives a better illustration of the total used diesel and its carbon footprint.

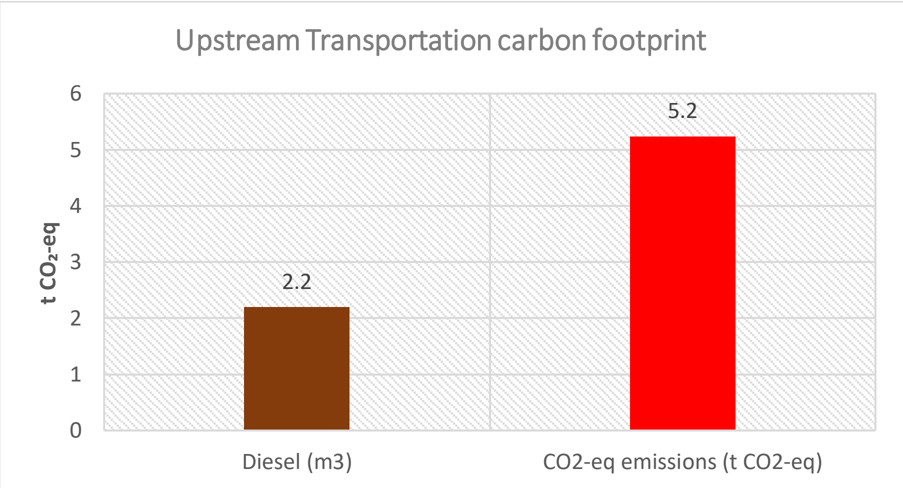


Figure 18: Upstream Transportation carbon footprint

Category 6: Business travel: In the results chapter, the date regarding the flight distance, type, and class have been presented. To proceed with the carbon footprint calculations, equation 3 as the rest of the scopes has been applied, where the activity data has been already given in the result chapter, and what left is the emission factor regarding each trip. The study has noticed that the emission factor is determined by the flight type i.e. if it is a short-haul flight or long-haul flight. It was found that the short-haul flight emission factor equals 0.09 (Kg/Pa-Km) while on the other hand long-haul flight emission factor equals 0.08 (Kg/Pa-Km).

This analysis gives an idea that short-haul flights have more environmental impact than long-haul ones. Due to many factors e.g. the fact that the majority of the GHG emissions from flights occur at the takeoff and landing alongside other factors like the number of passengers and seats etc. The carbon footprint of each trip has been calculated by first giving the emission factor to each trip based on its type, and then multiplying the total flight distance with the emission factor. The demonstration of the calculation has been displayed in the below table. Note that only 15 trips have been included in the table and the rest of the trips are presented in Appendix 2.

Table 21: Business travel carbon footprint calculation

Nu	**Routing**	**Flight distance** (Km)	**Flight type**	**Flight class**	**Emission factor** (Kg/Pa-Km)	**Repeat**	**Travelled distance** (megameter)	**Flight carbon footprint** (t CO_2-eq)
1	ABJ/MJC/ABJ	394	Short-haul flight	Economy	0.09245	1	0.4	0.04
2	ACC/KMS/ACC	396	Short-haul flight	Economy	0.09245	4	1.6	0.15
3	ADA/ADB	729	Short-haul flight	Economy	0.09245	1	0.7	0.07
4	ALG/CDG	1370	Short-haul flight	Economy	0.09245	1	1.4	0.13
5	ALG/FRA	1542	Long-haul flight	Economy	0.08263	8	12.3	1
6	ALG/TUN	624	Short-haul flight	Economy	0.09245	3	1.9	0.2
7	AMS/FRA	367	Short-haul flight	Economy	0.09245	1	0.4	0.03
8	FRA/HOG	7889	Long-haul flight	Economy	0.08263	4	32	2.6
9	AMS/MAN	484	Short-haul flight	Economy	0.09245	4	2	0.2
10	ARN/ADD/ARN	11794	Long-haul flight	Economy	0.08263	3	35.4	3
11	ARN/ADD/FBM/ADD/ARN	16996	Long-haul flight	Economy	0.08263	9	153	13
12	ARN/ADD/FCO	10376	Long-haul flight	Economy	0.08263	1	10.4	0.9
13	FCO/TUN	576	Short-haul flight	Economy	0.09245	1	0.58	0.1
14	ARN/ADD/JNB/ADD/ARN	19922	Long-haul flight	Economy	0.08263	1	20	1.6
15	ARN/ADD/LAD/ADD/ARN	18702	Long-haul flight	Economy	0.08263	1	19	1.5

The total carbon footprint associated with the customer centers busines travels is presented in the below figure to give a full picture and a better illustration of the carbon footprint. The figure data has been derived and obtained fully from Appendix 2. It has been noted that the business travels stands for a very large share of the total carbon footprint of the customer center.

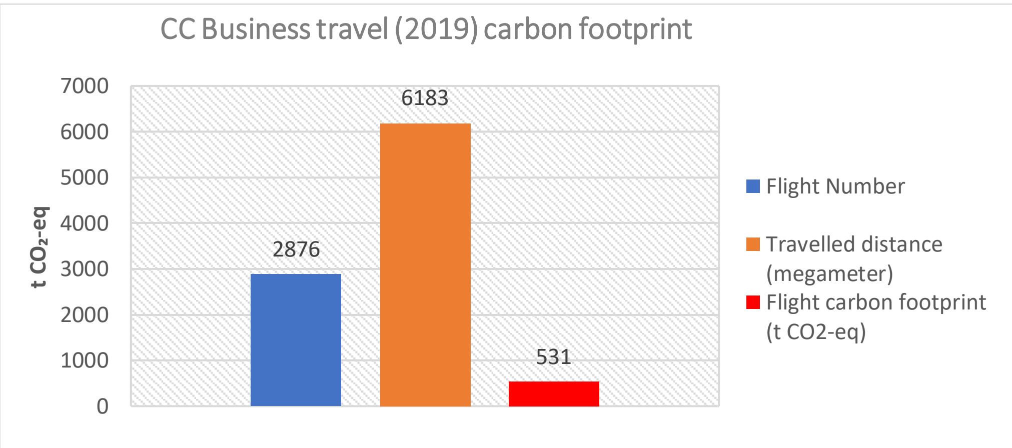


Figure 19: CC Business travel (2019) carbon footprint

6 DISCUSSION

The discussion focuses on the research questions in this study. The chapter starts with a section regarding the current carbon footprint which represents an answer to the first research questions. The second section regarding GHG savings represents an answer to the second RQ. The study findings derived from the results and analysis are discussed with the focus on the attributional and consequential variation which will be linked to answering the third question. Finally, the discussion continues with an introduction of how to reduce emissions in the customer center which will be presented more in detail later in the next chapter to achieve the aim of the study.

6.1 CURRENT CARBON FOOTPRINT

The carbon footprint of the customer center equals the sum of the GHG emissions associated with the investigated scopes (1,2,3) and categories (1,3,4,6). In the analysis chapter, the GHG emissions, i.e. the carbon footprint, given individually for each scope. This section gives an answer to the first research question.

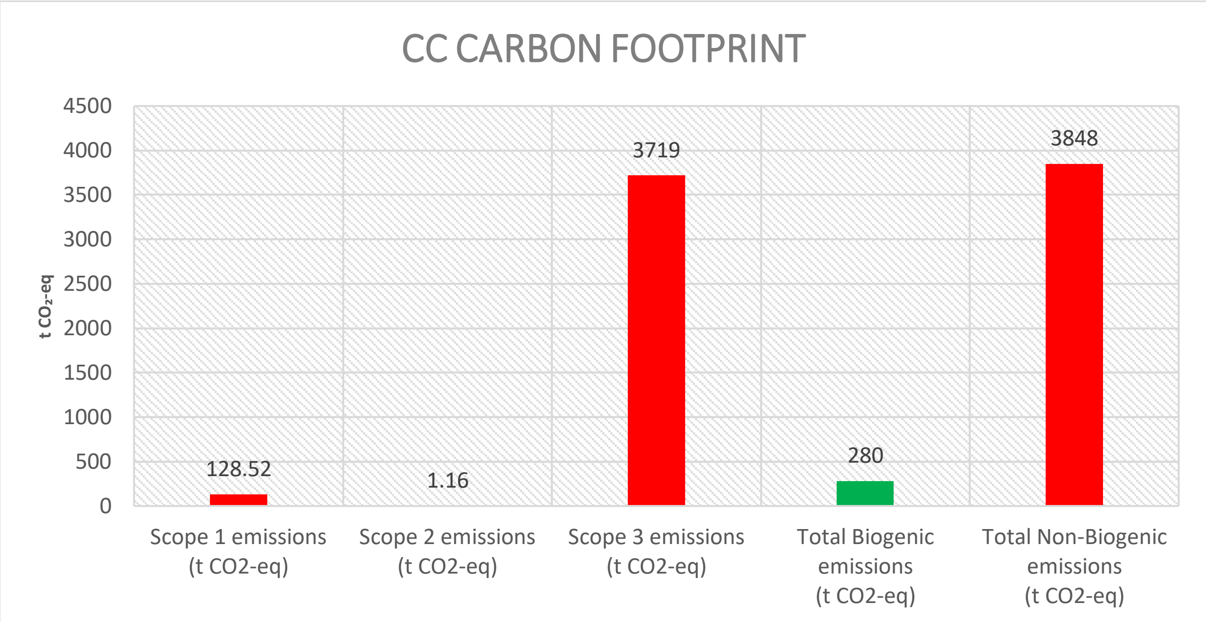


Figure 20: The customer centers' total carbon footprint including the biogenic carbon footprint.

As directed by the GHG protocol the figure 20 illustrates the total biogenic and non-biogenic carbon footprint separately. The figure is the pictorial representative of the emissions under the three different scopes in accordance to the ALCA emission factors. In this graph, the emissions under Scope 1 is this study is from the MK1 diesel mix used in the customer center and under Scope 2, although the magnitude is negligible, the emissions are attributed to the yearlong usage of district heating service in the facility. The remaining emissions i.e.., 3719 ton out of total 3848 ton of CO_2 -eq emitted by the customer center as illustrated above is from different categories under scope 3, with the largest contributor being the demo fleet equipment (Category 1) which is responsible for more than 80% of the emissions, based on assumptions and approximations made by the authors. But, due to the high fluctuation of number of equipment in each financial year, high impact of marginal errors from assumption on the study results and the fact that Volvo CE has started a project on calculating with accuracy the life cycle assessment data for all its machinery, for the time being this study has deemed to not highlight the results from the assumed impact of the fleet equipment in the final results. But, saying that cannot negate the importance of the fleet on the impact scale and hence it is advisable in future for the customer center to update the present assumed results with accurate ones. Understanding of the carbon inventory excluding the fleet equipment can be drawn from the figure 21. With the removal of the fleet equipment emissions the highest contributor to the inventory is the business travel Category 6 of Scope 3, which contributes to more than 75% of the total emissions but unlike the emissions from the equipment it has more accuracy and a larger scope for reduction and reformation.

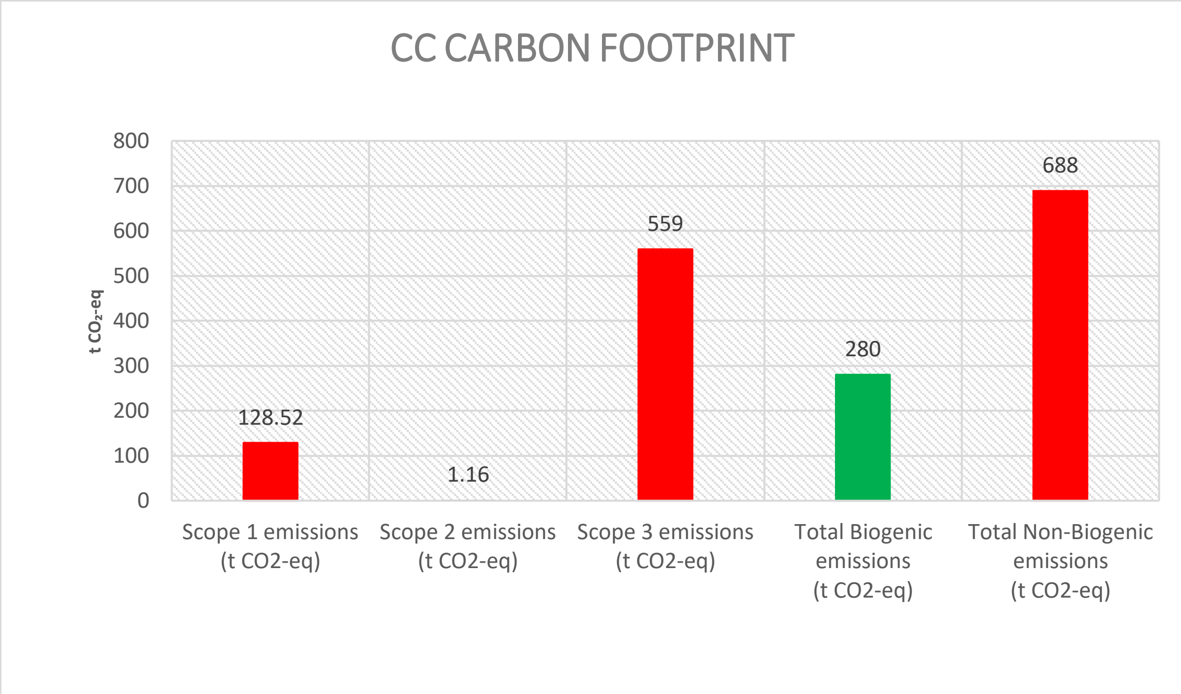


Figure 21: The customer centers' total carbon footprint excluding the fleet

6.2 GHG EMISSIONS SAVINGS

As stated earlier in some sections, the customer center has done over the past years several initiatives with the intention of mitigating its carbon footprint and becoming more sustainable. One example of these initiatives was purchasing green electricity which had an impact on Scope 2 by reducing the emission associated with electricity to zero. Followed by a recent initiative intending to switch from diesel to HVO, in September 2019, which also had an impact on Scope 1, as will be shown later in this section. To easily understand the impact of these initiatives and outline the reduction that occurred on the customer centers' carbon footprint, so far, the study has done a two scenarios comparison. The first scenario is the carbon footprint without including the electricity and fuel improvements i.e. if the customer center still uses mixed electricity and diesel as fuels. On the other hand, the second scenario includes these improvements. By doing this, the current GHG savings can be shown which will lead to answering the first two research questions.

According to scenario 1, the customer center still consumes the same amount of electricity which is 1010 MWh during the base year 2019. The parameter that has changed is the emission factor since the scenario states that the electricity is supplied from the mixed grid. The table below presents the Swedish electricity production sources which were obtained from Sverige officiella statistik and the last updated on the 29th of November of 2019.

Table 22: Swedish electricity production sources

Source 2018	**Production GWh**	**Share %**
Hydro power	61820	35%
Wind power	16623	9.5%
Solar power	391	0.2%
Nuclear power	65801	37.7%
CHP in public steam	8806	5.0%
CHP in industry	5914	3.4%
Condensing steam power	289	0.2%
Conventional thermal power	15027	8.6%
Gas turbines and others	17	0.01%
Total	**174688**	**100%**

The emission factor regarding the electricity mix has been obtained from Eco invent database taking into account the electricity mix presented in the previous table. It was found that using 1 MW from the grid accounts for 0.06 t CO_2-eq emissions. After applying the GHG emission equation i.e. (activity data * EF) over the new scenario the carbon footprint associated with the electricity usage has become 60.59 t CO_2-eq as presented in the below table.

Scope 2		
Electricity (MWh)	LCA emission factor (t CO_2-eq/MWh)	CO_2-eq emissions (t CO_2-eq)
1010	0.06	61

In the actual scenario of the center the emissions out of the electricity usage were found to equal zero. But when the electricity mix has been considered without any green certificates the carbon footprint has increased. This concludes that the customer center has saved 61 tonnes of GHG by switching from the mixed electricity to the renewable ones, as presented in the below figure.

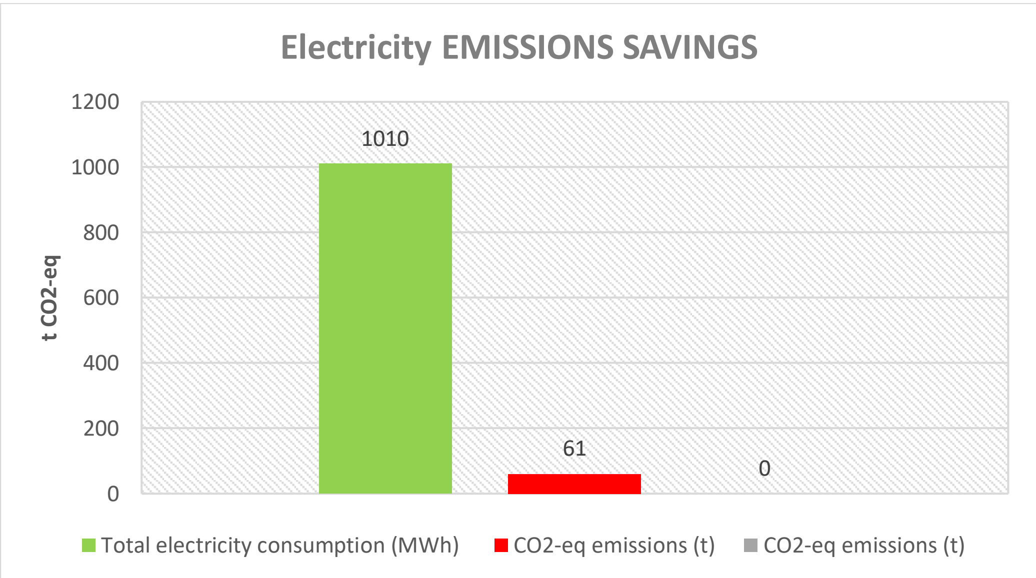


Figure 22: Electricity EMISSIONS SAVINGS

Yet, the current savings might seem positive since the GHG protocol follows the ALCA, however, according to the CLCA, this conclusion is not all positive, this is explained and discussed in more details in 6.2.2. According to the second scenario, it states that the customer center has used diesel during the whole base year. The idea from this scenario is to calculate the expected carbon footprint of Scope 1 from using diesel all the year and then compare it with the actual situation i.e. switching to HVO in September 2019. The same calculation used with electricity has also been used on diesel. The emission factor has been used before in Scope 1 and the quantities of the used diesel in September, October, November, December have been taken the same as HVO quantities. The below table shows the new carbon footprint of Scope 1 after applying the scenario.

Scope 1		
Diesel (m3)	**Emission factor (Kg CO_2-eq / liter)**	**CO_2-eq emissions (t CO_2-eq)**
71	2.38	169

It has been found that the GHG emissions from Scope 1 would have been 169 tonne if the customer center has not switched to HVO. The customer center has saved 40.46 tonne of GHG by switching to HVO during the end of the base year. The below figure presents the savings in a better illustration.

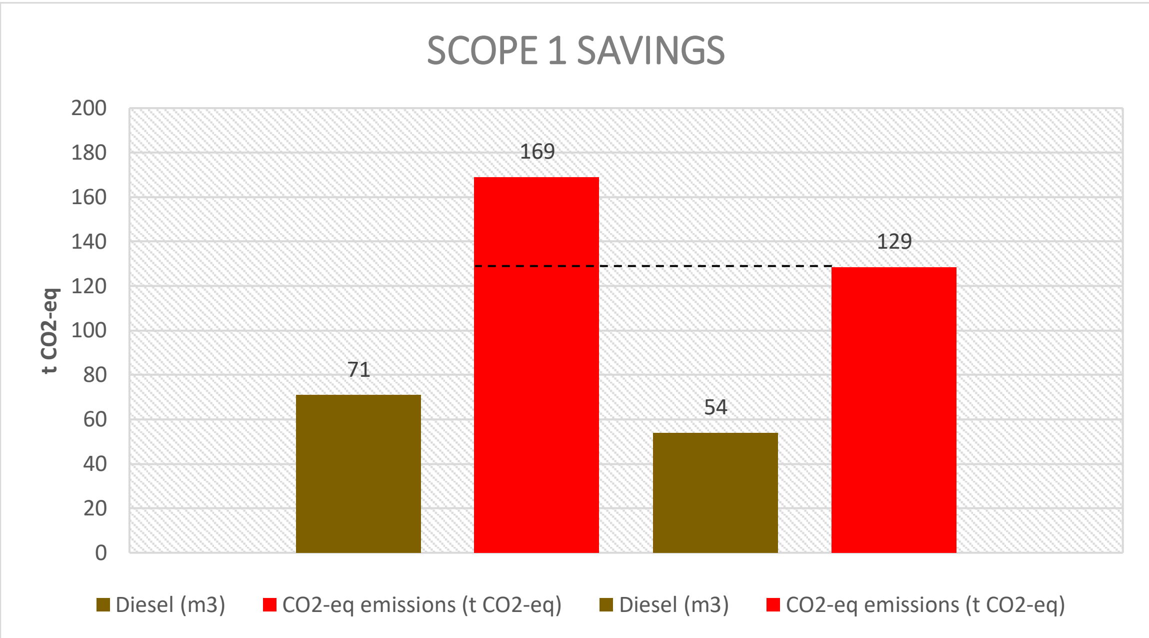


Figure 23: Scope 1 emissions savings

The savings in Scope 1 will also be discussed and debated according to the ALCA and CLCA in the following section. The previous scenarios comparison was an effective method to answer the second question of this study, which was related to the amount of savings made by the customer center, due to the changes made in previous years. It was clear and obvious that the purchase of green electricity was one of the factors that contributed to a considerable amount of reduction in the GHG emissions by about 60.59 tonnes. In addition to that, the switch from diesel to HVO in September 2019 has also played an important role in the overall reduction with about 40.46 tonnes. It can be analyzed from this comparison that the center still can reduce 129 tonne of GHG by completely dispensing diesel and replacing it with HVO. In fact, the center since the first month of the switch in September 2019, HVO was adopted as a complete alternative to diesel, and accordingly, the carbon footprint for the upcoming years for example year 2020, will be less than the base year with about 128.52 tonne more coming from Scope 1.

6.3 CARBON FOOTPRINT VARIATION BETWEEN ATTRIBUTIONAL & CONSEQUENTIAL

This section of the discussion is used to answer the third question of this study. The comparison between the two-life cycle approaches the attributional one which the GHG protocol follows and the other one the consequential which considers the indirect emissions that are not considered or accounted for in the attributional one.

6.3.1 TRANSITION FROM DIESEL TO HVO

The rising transition from Diesel to Hydrotreated Vegetable oil (HVO) in Sweden is driven by various supporting policies established by the government to achieve the goal of carbon neutral energy system by 2045 as discussed in section 1. Replacement of HVO is indeed a controversial option due to several reasons including indirect land use, water usage and the significant food vs. fuel priority effects in the developing nations, as a result of growing demand for biofuels and HVO (Edwards et al., 2010).

The GHG protocol uses ALCA methodology, where the system under question is influenced by decisions made by a single large stakeholder. While CLCA is the modelling of this result, when several external actors who do not belong in the system boundary influence assumptions regarding the output or the working decisions of the stakeholder considered in ALCA (Martin et al., 2015). LCA for biofuels is a two-steps approach, as deduced from Yang, 2016:

1. The first step includes carbon footprint for the elements in the static system boundary, which is under ALCA, and this is done by using supplier specific emission factors
2. The second step estimates the scenarios that could influence a change in flow by using market-based relationship, which is CLCA, and this corresponds to use of marginal suppliers/emission factors and with increasing market trends even the most sustainable supply sources are influenced (Prapaspongsa & Gheewala, 2017).

It must be noted that ALCA relies on several assumptions, such as unlimited supply of input of feedstock, which would lead to changes that are not considered in the static model of ALCA, hence must be addressed by CLCA (Yang, 2016).The possible effects on the CLCA scenarios result from increase in competition of food oils, food products and palm oil to compensate the growing need substitution of consumption of raw materials, and it is to be noted, that raw materials play a very important role in determining the CLCA results of the analysis (Aatola et al., 2009).

The ideology of HVO supporting climate neutrality according to ALCA, assumes by 1litre of HVO would reduce X grams of GHG emissions from being emitted when used in place of diesel. But it is neglected to note that 1 liter of HVO produced does not completely ensure that 1 liter of diesel was not produce. It must be regarded as 1 liter of additional fuel produced, not as avoided emission, but a rebound effect as emission considered was not verified as avoided use of the diesel on a global scale but increase in fuel availability on the whole (Yang, 2016).

In case of the customer center, Volvo group has switched over to HVO and according to producer's reports the raw materials used in producing this fuel is about 68% from residual material with claimed focus on reducing raw materials that can be used for other purposes (Neste Corporation, 2015).

But it is to be noted that as explained earlier the sudden shift to HVO could increase the pressure on the system to produce more bio based raw materials elsewhere in the world. This also implies that although a large portion of the material used are residual by products from other industries, as the volume of the demand increases the supply and input of raw materials will also increase.

Must be noted that this would lead to increased substitution of non-residual raw materials to compensate with the need, as waste or residual products cannot be assumed to be produced or supplied in surplus quantity (Soam & Hillman, 2019).

The scenario can be illustrated in the following manner, if increasing demand in market fluctuation and policy changes lead Volvo to switch 100% to HVO in a single month, then in a hypothetical scenario on the supplier/producer side can be explained as follows:

If 50,000,000 liter of food crop oil (assuming rapeseed oil) was previously used as a part of the 30% non-residual raw material input per month to supply to all the subscribed customers then after the switch assuming that Volvo's demand influences an increase of input of all raw materials by additional 500,000 liter then the new implications are as follows:

- The 30% of non-residual raw materials constituting of rapeseed oil (assumed): 150,000 liters.
- The final raw material in volume: 50,150,000 liters

This translates to 150000-liter higher production of the oil elsewhere in the world mostly in developing and underdeveloped regions. This increase leads to inevitable change in the land use pattern due to economic gains and lack of sustainability priority (Fargione et al., 2008). It must be noted that damage caused by crops grown to alleviate the increased demand is higher due to increased fertilizer use, deforestation, techniques used to grow crops in non-monsoon seasons (Brander, 2016). It can be thus stated that CLCA discusses the crucial question of how emission trend was influenced by increase in unit production of HVO on a global scale (Yang, 2016).

6.3.2 TRANSITION FROM ELECTRICITY-MIX TO RENEWABLE

As discussed earlier in the report, the project's goal is to measure the customer centers' carbon footprint and compile it in what is called carbon dioxide inventory. To accomplish the mission effectively and correctly, the GHG protocol has been taken as a tool to conduct the study and to track the contributors of carbon dioxide and dividing into three different scopes (Scope 1, Scope 2, Scope 3) as listed before in section 2.2.

One of the most influential contributors to take into account is electricity consumption, which plays a significant role since mostly every product or service demands a certain quantity of electricity to be produced and achieved (Chuang et al., 2018). According to the GHG protocol, the carbon footprint that is associated with energy consumption (e.g. electricity, DH) is basically, quantified using the following Equation [3]:

*CO_2-eq emissions (Unit CO_2-eq) = Total consumption (UnitWh) * LCA emission factor (Unit CO_2-eq/UnitWh).* *(WRI, 2015)*

However, it is very crucial to notify the distinction between the two different types of measurements that are used to perform the upper formula, since, the carbon footprint of electricity varies according to the type of method used to calculate (Sarbring, 2014).

In fact, there are two methods for calculating the amount of emissions associated with electricity and they are whether the electricity mix or the marginal power plant method (Weidema et al., 1999). Both methods can end up with considerable different results, and that is basically due to the variation in the LCA emission factor (Unit CO_2-eq/UnitWh) since the first parameter ((Total consumption (UnitWh)) is fixed (Weidema et al., 1999 ;Ekvall & Weidema, 2004).

This variation linking the two methods is also correlated to the different LCA approaches, ALCA & CLCA approaches that have been introduced earlier in the study. While the electricity mix method represents an ALCA approach, the marginal power plant method represents a CLCA viewpoint focusing on system changes and how a change at the customer center will be influencing somewhere else on the wider scale (Curran et al., 2005).

According to the Swedish merit order curve, the electricity production plants are arranged so that renewable ones are the first that operates to meet the demand, and this is due to their lower marginal cost compared to the conventional plants (Swedish Energy Agency, 2019). Hence, the demand is being fulfilled from the renewable sources, once the demand for electricity exceeds their capacity the conventional plants must start operating resulting in GHG emissions. Luckily, the Swedish electricity is dominated by renewable sources and that gives distinction for lower GHG emissions. However, there are still some fossil-based power plants that are needed to cope with the demand peak, which means GHG emissions are still in the system (Regett et al., 2018).

According to the two methods used to calculate the GHG emissions of the electricity consumption, the mix method suggests that the emission factor is determined by weighting the specific CO_2 emissions of each power plant with its share in total electricity production, so the emissions factor is basically the average of all the plants connected to the grid and contribute in fulfilling the demand (Andersen, 2014). On the other hand, marginal method suggests that the emission factor of electricity is equal to the specific emission factor of the marginal power plant that is operating to fulfill the needs for the studied case and that is not an easy task to find. This is why the marginal method is a complex method and it required a tracking system to know which plant is operating at every hour to meet the demand (Vélez-Henao & Garcia-Mazo, 2019).

For the customer center the case is different, since Volvo group purchases green electricity and by doing that the emissions factor according to the ALCA approach equals zero, as was presented in Figure 13 in section 5.2. However, according to the CLCA approach, that is not the case. This is because by buying only green electricity that is going to affect the merit curve resulting in reducing the share of the renewable sources that operates the first to meet the demand, and therefore the conventional plants must operate to meet the demand and that means the global GHG has increased. So, it is true that Volvo has declined its own carbon footprint by switching to green electricity, but on the global scale that results in increasing the total GHG of the country and the global, as well. By looking at the graph it is shown how the share of the renewable will be reduced.

7 IMPROVEMENTS & RECOMMENDATIONS

This chapter is used to answer the third question of this study. To come up with a set of recommendations that can enhance and improve the current carbon footprint of the customer center. These recommendations and improvements are meant to be implemented in both short and long term as will be explained below.

Due to increasing alarm caused by climate related catastrophe and growing stringent pollution policies worldwide, governments and organizations around the world are turning towards making their countries and organizations climate safe (Ruhl, 2010). This has been supported by the large number of publications related to climate study as reflected in various previous sections of this study. IEA (2019), emphasizes in its Sustainable Development Scenario, that stabilization of global warming could be achieved to a large extent by fuel and material efficiency, electrification (renewable sources) and fuel switching. It must be noted that although 100% fuel switch and renewable electrification ensures carbon neutrality under Scope 1 and Scope 2 categories of ALCA approach, it does not ensure sustainability in either economic or social settings for the company on the long run.
This is justified by fluctuating prices of GO certificates to prove the usage of renewable energy and the highly debatable origin of biofuels/HVO with rising demand on the marginal producers as discussed in section 6.1.1&6.1.2. In order to move towards sustainable neutrality which would not only help making the customer center climate safe in accordance to CLCA but also ensure reduced monetary investments i.e., additional investment made in purchasing GO at a large amount and higher budget needed of switching from diesel to HVO due to the cost difference. This approach is not new to Volvo CE and the recommendations chapter are based on the Volvo's strategy for energy management that applies to the customer center, as illustrated below:

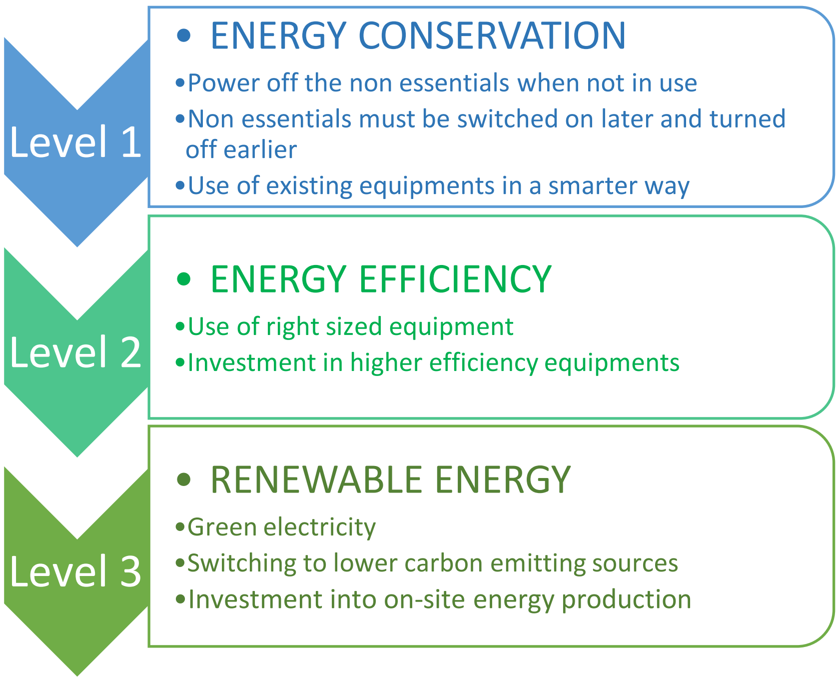


Figure 24: Volvo's strategy for energy management

7.1 SCOPE 1: DIRECT EMISSIONS

One of the major reforms recommended by VCE's internal policies to step towards carbon neutrality is its early investment in switching to HVO which constitutes as one of the major non fossil fuel alternatives. The fuel usage system boundary for this study includes fuel used to run the fleet for the demonstration facility and 71.8 metric cube was used in the year 2019 i.e., as highlighted in section 4.1. This step on an average will save about 150-200 tons of fossil-based CO_2 -eq emissions annually in the future, fluctuating in accordance to the usage. But this step which is on the level 3 of Volvo energy strategy can be accompanied by careful evaluation of other supporting strategy keeping in mind that sudden switch to HVO has repercussions of this actions extends on both societal and environmental levels (see section 6.1.1). With the 100% switch to HVO from diesel, the carbon neutrality has already been attained in accordance to the ALCA approach and this is done by imbibing the 3rd level of Volvo's energy strategy. But, it can be seen that since the adaptation of the 3rd level strategy, there has been no strong move towards planning of efficiency of fuel consumption and this can be observed from figure 6 of section 4.1, where the level of consumption of HVO stays constant as level of consumption of diesel in the previous years before the switch was initiated. This observation indicates that the focus of customer center to maintain the neutrality status is reducing the overall consumption and GHG emissions on the short and long term. A crucial example in this context is the reduction of idle time which will contribute widely to the goal. Volvo CE's being the Original Equipment Manufacturer (OEM) with the machines being well pre-equipped with various fuel saving and emission control measures and having the necessary knowledge makes it easier for the center to adopt the measures.

Idle time reduction : Volvo CE's equipment generally are equipped with auto shut off mode and auto idle mode, this makes them well efficient, but during the cold winter it is mandatory for the equipment to run on idle to avoid the phenomenon of cold start i.e., pre-heating of the parts of the equipment to avoid damage. According to Proc, 2004, idle time for the purpose of heating up the equipment can be completely avoided by the use of equipment such as coolant heaters compatible with biodiesel or block heaters. This study's focus on the GHG emission reduction and not technicalities efficiency of the equipment, one of the OEM's study, highlights the two important environmental benefits:

- Fuel usage reduction: The amount of fuel or power consumed by this equipment is negligible (few ounces per hour) compared to that of running a construction equipment (10-30 liters per hour) with added exhaust tail emissions. Thus, contributes to the fuel saving in a large collection of heavy machineries. However, the main advantage of this recommendation falls on reduction of tail emissions.
- Emissions : It can be deduced from Bielaczyc et al., 2001's study that there is high tail emissions of NO (40%) and particulate matters (50%) and Hydrocarbon emissions during the first 60 seconds of the 3-4 minutes idling time used for heat up. Researchers claim that pre-heating reduced the particulate matters production by 27%. Thus, making these heating devices key elements to lowering emissions and keeping the ambient air healthy. Although use of HVO makes emissions biogenic, particulate matter and NO are highly dangers elements which makes it the responsibility of the demo facility to put efforts to reduce it.

During the duration of the study it was brought to notice that although the pre-heating technology has been used on some equipment in the collection (demo fleet) it is not strictly mandatory to be used on all the machines. This recommendation hence concludes by emphasizing the importance of installation of devices for all the fleet equipment and the training that shall be imparted to the drivers on the importance of the same.

Recommended future changes: The following section outlines the possible future changes that can be explored to further reduce the consumption of resources under Scope 1:

- HVO fuel consumption: Although the recommendation measure would lead to start of adoption of the 1st and the 2nd level of Volvo energy strategy. There is a need for in-depth study approach concentrating on reduction of fuel usage in demo fields scenario due to unstable future scenario with revolving policies and world energy outlook with regards to the fuel and energy sector. It must be noted that energy conservation & efficiency measures if implemented in the customer center would make a considerable difference due to the high fuel consumption nature of the fleet and the large number of equipment in action on the demo field. Reduction of consumption will help reduce the risk of overstressing the production demand curve which results in various unavoidable changes on land and water use, increased pollution rates in developing countries, which has been discussed under the cLCA approach. This will also help reduce the chances of overshooting the budget on fuel as the cost of HVO is higher than that of conventional fuel. The saved funds can be directed to invest on ventures and reductions measures necessary for Scope 3 categories.
- Company cars owned use for business travel: Due to the COVID-19 crisis this part of the study had to be not been covered in this study but, it is of high importance that the customer center takes interest in making further automobile investments in electrified vehicles or vehicles that support renewable fuels if the customer center wants to take a step ahead towards climate neutrality. This can also be done by encouraging the employees to switch to renewable fuel or electrification instead of fossil fuel and further to remain true to sustainability the present vehicles can be used to the full capacity or traded before they are replaced by carbon neutral driving options.

7.2 SCOPE 2: INDIRECT EMISSIONS FOR ELECTRICITY & ENERGY

The mitigation plan for Scope 2 of the study includes the accounting for emissions from electricity and district heating, this has been explained in the previous sections of this study. Since, there is no production of energy in the customer center the emissions from the energy usage is indirect to the center. As discussed in section 6.2. it is not enough to switch to renewable electricity without making efforts to adopt the energy conservation and energy efficiency measures. GO certificates are extra investment from the energy budget that can be clearly reduced, and the money saved can be used for other improvements recommended in the study. But, in order to realize the changes to be made in the individual elements of the center it is important to address the importance of coordinating with the energy management team to monitor the emissions from energy consumption in this scope.

From a recent study on sustainable energy management in Volvo CE (Sannö et al., 2019) the importance of dedicated energy management team can be realized. A dedicated team could help map the progress of the energy savings and the need for continual improvements at every stage, helping the center keep in pace with the rest of the organization in terms of improvements. This can be easily realized by setting up time sensitive goals with the existing support team in the main facility and dedicating a minimum time schedule to conduct meetings each month to track progress of both old initiatives and new continual improvements. This step opens channels for communication playing a big role in introducing new innovative solutions, understanding the predictable changes and barriers to implementation of the set goals from other facilities' experiences.

After the study of reports of successfully implemented projects the following section presents the recommended measures under Scope 2 the measures that can be taken to reduce emissions in accordance to different support process that exist in the customer center that have been previously discussed in detail in section 4.1.

Interior lighting: Lighting on the inside of the customer center accounts to 40% of the usage of electricity. It was observed during the study period in the center that there were several avoidable consumptions that take place during the working hours and some of them are listed below:

- Lights left running in the restrooms and toilets when not in use.
- The kitchen and lunchroom's lighting are left running even after the lunch break and until late evening which is about 4-5 hours unnecessary consumption.
- Meeting room lights are sometimes left running with no one inside.
- Printing room.

The following remediation measures for this segment are to negate human errors by easy energy saver equipment which is addressed as one of the improvements by Volvo globally yet has not been included in the customer center lighting systems.

- Motion sensors for the above-mentioned areas, can save up to an average of 50% of the consumption. According to the various statistics, this can be arguably true in the case of restrooms, kitchen, and lunchroom areas of the customer center.
- Passive Infrared (PIR) sensor: According to results of a study conducted by IEEE, PIR sensor is useful in saving considerable amount of electricity. The Customer center with no fixed working hours, the lighting is assuredly switched off manually or automatically hours after the last employee leaves. PIR works based on the heat radiation emitted by people in the room. It can be set to maintain the level of illumination based on the level of sunlight or lighting in the room making it useful in reducing energy wastage due to human negligence.
- Changing the bulbs in washroom to low consumption light fixtures

Results from these measures' savings are statistically diverse and can vary between 15 – 50% or more depending on the room they are placed in. Even if 15% is taken as expected saving customer center would save up to 60MWh electricity per year.

Building ventilation: Ventilation is a large user of electricity and this can be avoided by simply switching completely off or adopting methods like that of lighting – motion sensors. Experience accounting from fine tuning of ventilation system saved up to 25% of the consumption. If not already present, it is beneficial to install heat recovery from HVAC system which can give remarkable results in cold climatic conditions (Jokisalo et al., 2003). It is also worth checking if all HVAC systems are upgraded to VAV (Variable Air Volume) system instead of CAV (Constant Air Volume) system, although the initial investment for VAV is higher but analysis shows that on a long run it has higher cost savings due to notable energy savings and lower fan operating cost (Aktacir et al., 2006). Although, it cannot be stated with certainty the level of energy cost savings some studies state that there can be up to 30% savings with the use of VAV system(Karunakaran et al., 2010).

Exterior lighting: As a study has already been conducted for this section, therefore, this study will not delve into it.

Space heating: A part of the heating in the Customer center is done by electric heater, which is carbon neutral but not sustainable as it consumes 19% of total electricity used for a considerably low area heating. It must also be noted that the heating used in certain area are always left running which can be optimized by temperature modulation for days when the demonstrations are not running.

Office equipment: Office equipment account to 180 MWh of electricity usage in the customer center and the revision for the section are as follows:

- Some measures to optimize the consumption is by automatic timer is a good strategy like cutting off power of printers, coffee machines, ovens, meeting room equipment on standby is a good way to save energy.
- Office equipment during upgrades shall upgrade to energy efficient models i.e., with Energy star labelling which can save up to 30-70% consumption in general. Computers can be set to go on energy saving mode 30 minutes of inactivity which can be changed to 10 minutes of inactivity.
- Reduce the number of devices that are not necessary in large numbers like printers, scanners, copiers, and fax machines, as the customer center has almost become paper print free this should not be a difficult step to enforce

It is important to emphasize the importance of replacing lighting in corridor and coffee, fika areas, franchise shop and the reception with low energy lighting like LED or CFLs can save up to 80% consumption if it has not been already done it is highly recommended.

Recommended future changes: **District heating**: The customer center relies completely on district heating for heating and cooling purposes which is an economical solution. But to become more independent from the grid, it is a good idea to examine the idea of possibility of internally purchasing the recovered heat from the production facility of Volvo CE for heat recovery and reuse. It is a known fact that large amount energy for cooling is required during the production of equipment and as the heat recovery has already been instigated in the Eskilstuna center, this idea holds merit. The customer center can also explore the idea of possibility of heat recovery from its own center, thus giving rise to the possibility in becoming energy independent at least to an extent.

7.3 SCOPE 3: INDIRECT EMISSIONS APART FROM SCOPE 2

Scope 3 consists of elements that are required in running a successful business but the key to reducing the emissions is by making the smarter choices and taking responsibilities for the emissions produced. Categories included in this study are Categories for Purchased goods and Services (1), Fuel and Energy related activities (3), Upstream transportation (4), Business travel (6) and general recommendations for waste management.

7.3.1 CATEGORY 1: PURCHASED GOODS AND SERVICES

Category 1 of Scope 3 in this study includes accounting for most consistently purchased material or products that have been listed in Table 8 and Table 9 from section 4.2. Customer center with office like work force has no production output and hence category 2 is negated. As it can be noticed from the inventory, most of the frequently used products are hand towels, toilet rolls, liquid soap, dish washing soap liquid, garbage bags etc., which are necessities in a work place inventory and the best way to reduce their emission is to switch to brands that are guaranteed to cause lower environmental impact and sourced from sustainable resources.

Eco – labeling: Practical approach to this method is purchasing goods possess eco-label certifications and those that are locally sourced. Eco-labels are manifestation of products approved under ISO 14020 which is only given to products with transparency of their environmental activities, they help consumers choose toxic free, recycled material produced with constraints of energy efficiency and minimal wastage conditions. The most frequently used products in the center have been eco-labelled by either Nordic swan or EU-ecolabel. This does not negate the fact that they still are made from material that cause effects.

- Trash bags in particular are all eco-labeled but only some of them are made out of recycled material or sustainable material and Volvo being a large procurer has a strong voice in influencing a change and procuring sustainable materials will increase the demand and on the long run thus, help shift the production chain.
- Eco-labelled Toner and ink for printers are made from up to 75% recycled material saving oil and plastic consumption

Fossil use emissions: The 1st step to encouraging climate neutral behavior in the customer center is for the management to start making small noticeable effort in the inventory of the supplies. This could include phasing out all plastic. Although not included in the analysis, there is small but definite amount of plastic and fossil-based products or waste packaging material that is produced from this category, along with harmful chemicals released from the cleaning supplies that have large consequences. Sweden boosts a handful of producers of natural fiber-based cleaning products producers. Behavioral change instigation in the office environment can be made by changing the following:

- This is including plastic cleaning equipment, which have a small share of carbon footprint but are more harmful due to the release of micro plastic, while in use, this can be replaced by much durable sustainable wooden brushes & equipment with natural fiber parts and replaceable brush heads. These brushes are made to last for much longer time with completing negating all effects.
- Plastic bins at each table: This can also be replaced by containers made of natural fibers

- Cleaning liquids in sustainable packaged material produced by small scale industries: Not only does this drive down the carbon emission and help change behavior and increase awareness in the customer center but also helps localization of Sustainable Development goals setting example for other organizations to follow.

Recommended future changes: The prospective study could include accounting for the outsourced food supply along with event and demo days material supply. During peak seasons cutlery and utensils and the lunch boxes provided on a daily basis by the vendor supplying to Volvo can be completely phased out by adopting the use of materials like bagasse utensils and renewable material made containers which are completely pollution free.

7.3.2 CATEGORY 3: FUEL & ENERGY-RELATED ACTIVITIES

Although the emissions from fuel & energy related activities is not as high as that of Scope 1, it hold equal importance due to the fact that it gives a wider opportunity for the customer center to become climate safe with the help of the 1st and 2nd strategies of Volvo Energy strategy instead of high cost offsets. The system boundary of this study includes upstream emissions of HVO used in running the demo field equipment and the diesel used for cleaning purposes.

In-land logistics is a high consumer of transport fuel, according to IVL, heavy trucks constitutes to 20% of the road transport CO_2 emissions in Sweden and this is mainly due to the use of fossil fuels. HVO dealership for supply to the customer center is handled by an external dealer, responsible for supply from the producer to Volvo. Although, biofuels are used for this transportation it must be noted from the discussion section of the study that using biofuels alone does not negate the ill effects. It has to emphasized that from various studies by IVL that it will not be easy for the biofuel producers to supply the complete road freight sector with biofuels taking into consideration that the other non-fossil based energy source, electrification in freight system is neither convenient nor cheap with respect to the infrastructure. It is thus important to take measures to reduce the risk of overloading the system is using the existing resources to their highest potential. It must be realized that the policies are usually highly influenced by the activities of large companies and hence it is important for Volvo which is the largest company of the country to take steps in being the leader in proactive approach. Following sections address various approaches that can be taken to phase out emissions in this category.

Fuel sourcing: Market growth and alignment of future technology development are highly dependent on the demand curve for the sector or a product type, example for this is the growing investment in research and development of sustainable fossil free energy technology. Similarly, logistics of transportation of HVO to Volvo inventory and this is said to use biofuels for running the cistern. In order to increase the lower the emissions from this category, Volvo can look into the aspect of establishing a contract with logistics company for free information exchange on the type of biofuel used and express its preference for biofuels generated from waste which will negate the production emission and is much sustainable in an environmental perspective.

Product service system in bulk management: The dealer who supplies the HVO is situated in Linköping which is about 120 Km from Volvo in Eskilstuna supplies the HVO used in the facility in large cisterns of capacity of 20,000-50,0000 liters per delivery. But the customer center procures about 8000-9000 liters at a time at a frequency of about once a month, but this cannot to be stated with certainty due to changing demand of the center. It can be deduced that only 20-25% of the capacity of the tanker is utilized each time but the amount of fuel used remains the same each time, this can be translated easily to the fact that in order to deliver say 40,000 liters of fuel the truck would travel about 4-5 times and thus consume that much more fuel energy in transportation and creating a higher burden on the supply chain. Although, it is to be noted that HVO supplied by producer through dealer is tested to be stored for an amount of time without complications, the biggest issue that customer center would face with trying to expand its fuel storage capacity is the issue of extra investment, space, human resource. To be able to reduce human resource and cost of investment in non-core products like owning a fuel storage tank, Volvo could investigate Product Service Solution (PSS). This is provided by different organizations that deal with fuel management. As this report is strictly academical and does not hold bias or preference towards any organization, the study does not recommend any product or solution. But to understand the product-service offering in fuel management better the following example can be considered, the present dealer offers a product-service system for operations with low storage tank space or low area of storage. This solution the fuel is supplied in bulk and stored in the container provided on rent to the interested company accompanied by maintenance and monitoring services. It is important to notice that there exist other options like purchasing a storage tank system, but due to high materiality and human resource investment, it is to be carefully evaluated between different existing solutions before selecting the suitable option. It must be noted that there are a good number of PSS producers for storage tank solutions in Scandinavian region. The most important advantages of using PSS is gaining expert human resource without hiring non-core business workers, low resource consumption i.e., in the case of the customer center avoiding indirect carbon emissions from purchase of a tanker and also lowering of the number of trips involved per year to supply HVO from Linköping.

It must be noted that this measure is recommended to be considered in the last level of changes due to possible higher investment.

Recommended future changes: Diesel used for cleaning purposes: To completely phase out fossil use from the carbon inventory of category 3, customer center can initiate a study on replacing diesel used for cleaning purposes. Although it does not emit carbon dioxide due to combustion, it is a well-known fact that extraction of fossil fuels causes high levels of ecological problems effecting species around the world. The emission analysis non combusted diesel is illustrated in section 5.3 to further support the argument. This section has been mostly neglected due to the below minimum emissions produced compared to the other sources of emissions of the customer center's carbon inventory.

7.3.3 CATEGORY 4: UPSTREAM TRANSPORTATION

This category includes logistics involved for all non-fuel related supply of materials although due to the time constraints, the logistics of the machines involved in the working of the demo field. The supplies are supplied in a Volvo manufactured truck by a Logistics agency to the customer center. Phasing out the emissions in this category can be done with respect to the Volvo Energy Strategy by first reducing the use of non-essential resources i.e., reduce the number of times the delivery is done to the customer center either by making a contract agency that is presently responsible for the facility management agency to store inventory at a larger volume.

The next level of strategy which will make the category carbon neutral is by requesting for a switch in the fuel used in transportation and adopting the method used by the HVO dealer i.e., renewable fuel for transportation. It is not advisable to switch to biofuels in 100% capacity instead steps must be taken to reduce the consumption of the fuel as much as possible before requesting for switching to renewable fuel. This would not only help the customer center lower the emissions but also ensures that the consequential footprint of the center is reduced without creating a burden on the supply chain.

7.3.4 CATEGORY 6: BUSINESS TRAVEL

Business travel and commuting can be described as an unavoidable element of corporate carbon inventory. A study based on Australian companies' Scope 3 emission assessments says that the aviation emission which in most of the carbon inventory takes the largest share of emissions compared to rest of the sources accounted for on in Scope 3 inventory, this is especially true for corporate sector with international trading services like Volvo. This category according to the GHG accounting standard includes emissions from business travel by any non-company owned mode of transport. This study has chosen to neglect the footprint by taxi and trains due to lack of data accounting for non-company owned cars or taxis and low carbon footprint of trains in Sweden in comparison to the very high emission rate of the air travels made.

In the UN organizations 50-60% of the total emissions is accounted for under climate footprint from office travel by staff. Most of the successful implementations of cut down in category 6 emissions have been the effect of introduction of changes to travel policies with continual efforts made by the management to instigate behavioral changes in the employees. The 1st step to reduction of emission is for the top managerial personnel to imbibing the policies thus setting a more influential effect of the rest of the organization. It is important to also acknowledge the lessons that must be learnt from unpredictable predicaments like COVID-19 that e-communication can be adopted not only because it cuts down the emissions, but also because it is economical, both in avoiding reimbursement, and in buying carbon offsets. The following section gives an overview about the changes that has be inculcated in various organizations in the world to take a step closer to reducing the high quantity emissions from aviation, keeping in line with the Volvo Energy Strategy.

Avoid emission - e-communication: The 1st priority in reduction of energy use or carbon saving must be given to avoiding the use or utilization of the source of emission, in this case avoid flying as much as possible. In the world of digitalization, the COVID 19 has pushed organizations to increase their on-line work capacity to the highest efficiency which can be taken advantage of by continuing to conduct avoidable travels for meeting using digital platforms. It is understood in the study that being the center of commerce it is impossible for the employees to stop flying at once but instead these measures which have been used by various organizations of UN are highly relatable as solutions to this category.

- United Nations Population Funds (UNFPA) approves trips for purposes that cannot be fulfilled by e-communication or conferencing
- Universal Postal Union, reduced the number of staff that can travel for the same mission and deploys local staff to complete the tasks thus, delegating responsibilities both task wise and in environmental implications
- E-communication technology measures helped WRI save 4.4 metric tons of CO_2 and about nine staff days

Reduce emission - minimum miles & time scale: Sweden is a country with highly developed railway system and the mode of transport with all Swedish trains running on hydro and wind sourced electricity. Observation of the inventory that in 2019,130 trips were in the Nordic region. Although not all these flights trips can be switched, it is highly recommended that all travels under 6 -7 hours travel time by train can be done so. The train ride is indirectly more convenient due to the lack of waiting time and the travel time to the Arlanda airport to Eskilstuna which approximately is 2.5 – 4 hours in addition to the flying hours, along with the travel time taken to transfer from the destination airport to the venue. This process can be avoided conveniently by taking a train when feasible, thus also cutting down the emissions.

- The emission from transfer by taxi or diesel-powered car which is mostly used to travel to Arlanda airport by the customer center employees which is 1.5 hours of travel
- Emission from flying which is mostly fossil fueled
- Emissions from taxi used to travel from destination airport to the city center as airports are usually situated outside the city

Travel optimization can be made, instead of flying a multiple time the objectives of various travels distributed across the months can be fulfilled in one single trip irrespective of the distance of travel i.e., includes short Nordic flights. Another UPU guideline is the discouragement of business class travels due to its higher emission impact i.e., business class allows higher luggage allowance.

Renewable fuels - pay for renewable travel: Under a new scheme one of the well-known Airlines companies has introduced, pay to travel using renewable Jet fuel which is produced by Neste is claimed to reduce CO_2 emission share by 80% from sustainable sources. The sustainability assessment of this scenario says that using waste and non-primary biofuels can support up to 50% of the requirement with maintaining the food balance. This strategy shall be the last resort to be taken after the steps of avoiding and reducing emissions as it falls under the 3rd layer of Volvo Strategy. Reduction outcome for these recommendations cannot be predicted, the effect of the recommendations can only be realized if there is a change in the behavior of the employees, it is important to notice even small behavioral changes will show notable results and lower carbon offsetting budget.

7.4 GENERAL RECOMMENDATIONS

The following section includes suggestions for waste management planning in the center based on general analysis and observations from the duration of study of the customer center along with the criteria for selecting offsetting projects.

7.4.1 WASTE MANAGEMENT

One the most important steps towards making a workplace proactively sustainable is waste management, it is also an influencer of behavioral changes and emission reduction. Waste reduction can be directly linked to the Volvo Energy Strategy, lesser the waste means lesser the material demand which is translated to lesser production and investment of energy to produce it along with reduced upstream and downstream transportation of material involved. Waste management around the world is mostly based on what is called the waste hierarchy ladder which relies on the hierarchy shown in the figure below, which goes from most preferred to least preferred methodology for waste management.

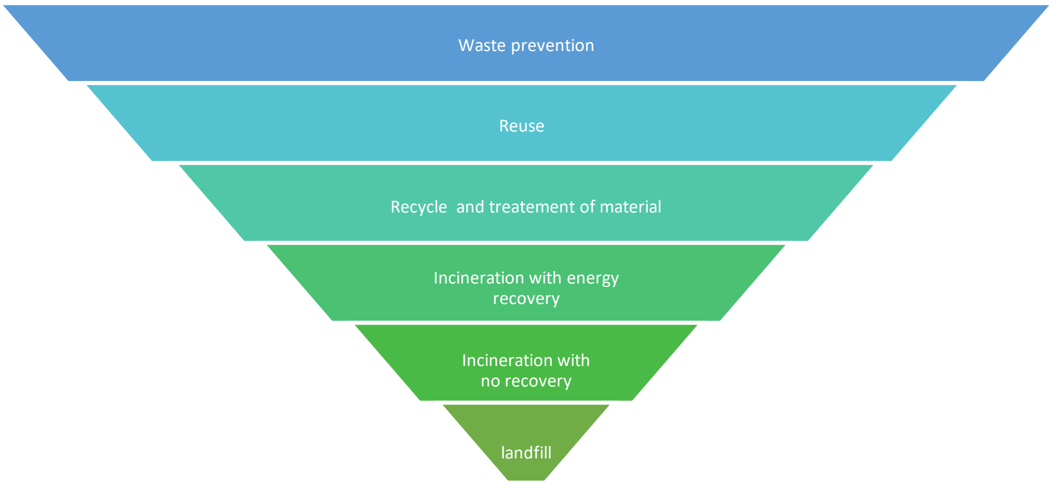


Figure 25:FIG num: Hierarchy for waste management

Sweden has one of the best waste management systems in the world in accordance to energy recovery and recycling, but it must be noted that even with the exemplary system that exists in the country, it will only be useful if followed rigorously. The importance of following the waste hierarchy cannot be stressed enough if the Swedish vision for fossil free Sweden must be realized. Incineration of waste due to lack of sorting its vision towards circular economy and creates a high burden on material and resource chain of the country and also increases the CO_2 release into the atmosphere, of which $1/3^{rd}$ is fossil based. The main reason for this, despite of high advancement of recycling technology in Sweden, is mixed waste or the unsorted waste from households and offices, hinders the vision of closing the material loop and decreases recyclability the higher the mix waste. Increased unsorted waste results in increased material going into the landfill with or without incineration.

It is said that in some parts of Sweden 40% of the waste is mixed waste is forced inevitably goes to incineration plants instead of recycling. It has been stated in Liljenström & Finnveden, n.d.'s study that on an average 0.39 GJ/ton of energy is required to sort plastic alone. It is said that 1 ton of recycled plastic can replace up to 14.1 GJ in the supply chain and 0.9 ton of virgin plastic and this can be done with 1.9 ton of waste plastic, this alone shows the necessity for a proper sorting system in offices like customer center. Another important material that is produced in abundance in offices in wastepaper, not only white paper, but posters, packaging, advertising material should be separately disposed instead of disposing in the mixed waste or the waste bin. It is said that instead of technological improvements the solution to the problem lies in the behavioral changes. Some easy changes to be inculcated in the customer center are listed below.

Contribute to the biofuel supply chain by separating organic waste : IEA, 2018 states that out of 63% of Swedish renewable energy source that makes up the total primary sources of Energy in Sweden, 81.2% is from solid biomass which is forest based and only 7.2% is from renewable solid waste. In order to support the climate neutrality vision in a sustainable manner and decrease the use of the highly debated use of natural forests (not under discussion in this study), every citizen of Sweden must contribute and this can be done by simply decreasing the consequential effect of biofuel or bioenergy use by strictly sorting the organic waste. Organic waste bins can be introduced at all coffee and meeting areas in the customer center with green bio-based bags instead of only in the kitchen and the dining area. It is recommended by various successful waste reduction strategies around the world that behavioral changes go in parallel with creating awareness about what shall be disposed in what container. Organic waste includes Food scraps, Coffee grinds, tea bags etc.

Upcycle station for old equipment and furniture: Upcycling room can be introduced to decrease the purchase of material in the facility. The room can include shelf system to store old office and maintenance supply in one designated area, this can be used to store extra supplies and supplies, folders, furniture and electronic materials left behind by employees who move away from the customer center, thus circularity is introduced when a new employee needs to use the same material without ordering it again.

Centralized recycling and removal of individual trash cans: Although there is recycling cabinet in the facility it is only used by employees mostly during lunch time and this creates higher production of mixed waste. This behavior is most probably due to the individual trash can which are much more convenient and accessible than the walking to the kitchen every time there is something to dispose. This can be easily solved by removal of all the individual mix waste bins, which would also reduce the plastic consumption due to purchase of the plastic bins and the cleaning equipment used for cleaning them. The figure 25 shows an example for a cabinet that could be optimized based on the office area and space and if made of material from the old furniture or upcycled from other used products, can be almost completely climate neutral with no consequential effects.

Supplier contract revision to reduce packaging: A part of the emissions accounted for in category 1 of Scope 3 is the result of packaging waste and this can be to an extent avoided by communicating with the vendor responsible for the necessities. A person in charge of the supply chain and commodity procurement would be able to handle the same. The customer center can check if it is a possibility to convince the vendor to provide packaging that can be recycled or reused or can be returned to the supplier itself for reuse.

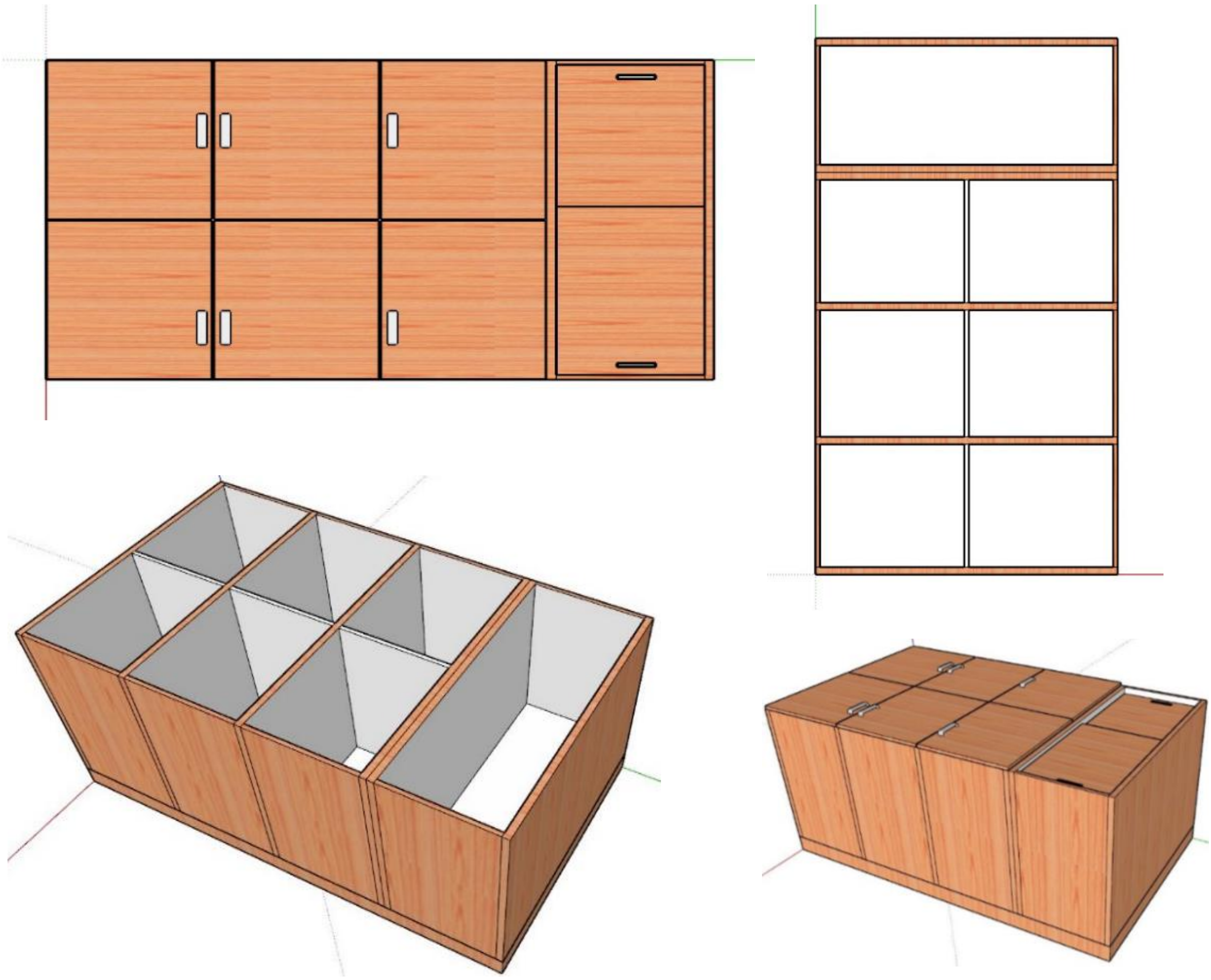


Figure 21: Centralized recycling and removal of individual trash cans

7.4.1 OFFSET CRITERIA

Even the most meticulous plans for carbon reduction cannot always help reach net zero emissions, especially when business travels are involved. Carbon neutrality as explained in the Introduction is in this era co-dependent on offsets. But offsetting and buying carbon credits has now been proved to be 70% null, mostly because most of the investments are temporary and ill management. For example, planting trees in the name of carbon credits can only act as a carbon sink when it is nurtured as a forest for years and the true emission credits has been realized by equal units of carbon absorption over the years, which is in most cases not achieved. WWF for this purpose established Gold Standard, a certification mark to validate the credibility of carbon offsetting investments (Blum & Lövbrand, 2019). Customer center must keep the offsetting strategy as the very last stage of planning carbon neutrality if they want to truly advocate climate neutrality instead of just carbon neutrality. If the criterion used by UN organizations are studied, it can be learnt that it is less risky and more effective to invest the carbon budgets into supporting Gold standard certified in geographical locations (preferably Sweden) that hold meaning to the works of the customer center.

- Funding projects related to renewable energy as customer center has a big share of energy from these sources.
- One of the projects funded by WRI is methane to energy, a big part of global emission is due to methane which has multiple times higher GWP compared to CO_2 and hence investing in energy recovery from waste methane from abandoned mines and landfills. This as expected will have a greater reduction effect at a lower cost.
- Carbon Capture and Utilization schemes from metal and chemical industries
- Another inspiration for carbon offsetting can be drawn from one of VCE's European dealers, who offers green dealership by offsetting the emissions by paying in recycling of heavy machineries. Although there is a lack of specific information, Volvo in the similar way can adopt or create projects like these in countries where the heavy machineries are dumped into landfills, resulting in methane production along with toxic chemicals like leachate. This also has the added advantage of material recovery and circular economy benefits. Furthermore, it is beneficial to increase employee's involvement by casting a poll across the office to know the preference or type of project that is favored thus driving an indirect behavioral change effects by educating them towards carbon neutrality

8 CONCLUSION

Contradictory to the general belief that one cannot generalize based on an individual case study, as Flyvbjerg, 2006 justifies "force of example" is often underestimated. Acknowledged from the findings of various case studies around the world that represent results from reduction strategy GHG emission in non-production facilities, it can be deduced that although results of analysis can be to an extent predicted, the result from future reduction cannot be estimated accurately due to high dependency on human behavior.

Carbon neutrality and sustainability require continual planning and efforts that are to be renewed on a timely basis. Growing innovative technology has made emission neutral renewable energy cheaper and more accessible over the past years. There has been a reduction of 101.05 t CO_2- eq in the year 2019 in comparison to the state of emission at the center before green electricity and HVO strategies were adopted. It is estimated that with the switch to complete HVO and with continued usage of green electricity the customer center can avoid around 229.5 t CO_2- eq per year.

The large part of the remaining emissions are attributed to activities in Scope 3 due to the nature of the departments housed in the customer center i.e., most of the employees belong to service sector which means business travels, product testing and hosting exhibitions for marketing that are inevitable making these categories the largest emitters presently also. Although, these categories have always been present, they will pose to be a carbon budget risk along with the additional cost that is now necessary to be invested into buying the Carbon offsets as well as renewable energy certificates.

As discussed in the study, the consequential effects are not only the financial stress that is created on the company internally, but external stress on renewables' demand and supply system. The most notable take away from this study is that organizations at all levels should rephrase the question from "How to become carbon neutral?" to "How to be consequentially carbon neutral?". This hold immense importance on a long term because in the quest to reach net zero status, the organizations cannot forget that the Earth has only enough resources to have a balanced system and renewable fuels have their own consequences, that in future, if used in high demand, will have imbalanced demand – supply curve leaving us with a new set of problems to address.

After the aim of the study was rephrased, the solution path of the study transitioned from high level monetary investments to "Conserve before investing" and hence in the last section of report (Chapter 7 : Improvements & Recommendations) of this study has looked into small and big changes that can be made in the facility, to not just making a leap the journey of carbon neutrality, but also to drive behavioral changes in the facility use after analyzing the consequences of changes in the internal working and to the external stakeholders chain.

It can be thus concluded, by repeating, that carbon neutrality can be only attained by continual efforts and optimization of planning, and this report represents the analysis of how reduction of emissions following the consequential approach mindset will help achieve environmental, social and economic sustainability in the center.

9 APPENDIX

Appendix 1: GHG types & their GWP100

GHG type	Chemical Formula	Characterization factors for GWP100
dioxide	CO_2	1
Methane	CH4	25
Nitrous oxide	N2O	298
Substances controlled by the Montreal Protocol		
CFC-11	CCl3F	4 750
CFC-12	CCl2F2	10 900
CFC-13	CClF3	14 400
CFC-113	CCl2FCClF2	6 130
CFC-114	$CClF_2CClF_2$	10 000
CFC-115	CClF2CF3	7 370
Halon-1301	CBrF3	7 140
Halon-1211	CBrClF2	1 890
Halon-2402	$CBrF_2CBrF_2$	1 640
Carbon tetrachloride	CCl4	1 400
Methyl bromide	CH3Br	5
Methyl chloroform	CH3CCl3	146
HCFC-22	CHClF2	1 810
HCFC-123	CHCl2CF3	77
HCFC-124	CHClFCF3	609
HCFC-141b	CH3CCl2F	725
HCFC-142b	CH3CClF2	2 310
HCFC-225ca	CHCl2CF2CF3	122
HCFC-225cb	$CHClFCF_2CClF_2$	595
Hydrofluorocarbons		
HFC-23	CHF3	14 800
HFC-32	CH2F2	675
HFC-125	CHF2CF3	3 500
HFC-134a	CH2FCF3	1 430
HFC-143a	CH3CF3	4 470
HFC-152a	CH3CHF2	124
HFC-227ea	CF3CHFCF3	3 220
HFC-236fa	CF3CH2CF3	9 810
HFC-245fa	CHF2CH2CF3	1 030
HFC-365mfc	CH3CF2CH2CF3	794
HFC-43-10mee	CF3CHFCHFCF2CF3	1 640
Per fluorinated compounds		
Sulphur hexafluoride	SF6	22 800
Nitrogen trifluoride	NF3	17 200
PFC-14	CF4	7 390
PFC-116	C2F6	12 200
PFC-218	C3F8	8 830
PFC-318	c-C4F8	10 300
PFC-3-1-10	C4F10	8 860
PFC-4-1-12	C5F12	9 160

PFC-5-1-14	C_6F_{14}	9 300
PFC-9-1-18	$C_{10}F_{18}$	>7 500
Trifluoromethyl sulfur pentafluoride	SF_5CF_3	17 700
Fluorinated ethers		
HFE-125	CHF_2OCF_3	14 900
HFE-134	CHF_2OCHF_2	6 320
HFE-143a	CH_3OCF_3	756
HCFE-235da2	$CHF_2OCHClCF_3$	350
HFE-245cb2	$CH_3OCF_2CHF_2$	708
HFE-245fa2	$CHF_2OCH_2CF_3$	659
HFE-254cb2	$CH_3OCF_2CHF_2$	359
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	575
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	580
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	110
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	297
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	59
HFE-43-10pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$	1 870
HFE-236ca12 (HG-10)	$CHF_2OCF_2OCHF_2$	2 800
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	1 500
Perfluoropolyether's		
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	10 300
Hydrocarbons and other compounds – Direct Effects		
Dimethyl ether	CH_3OCH_3	1
Methylene chloride	CH_2Cl_2	8.7
Methyl chloride	CH_3Cl	13

Appendix 2: Business travels screening process

Nu	Routing	Flight distance (Km)	Flight type	Flight class	Repeat
1	ABJ/MJC/ABJ	394	Short-haul flight	Economy	1
2	ACC/KMS/ACC	396	Short-haul flight	Economy	4
3	ADA/ADB	729	Short-haul flight	Economy	1
4	ALG/CDG	1370	Short-haul flight	Economy	1
5	ALG/FRA	1542	Long-haul flight	Economy	8
6	ALG/TUN	624	Short-haul flight	Economy	3
7	AMS/FRA	367	Short-haul flight	Economy	1
8	FRA/HOG	7889	Long-haul flight	Economy	4
9	AMS/MAN	484	Short-haul flight	Economy	4
10	ARN/ADD/ARN	11794	Long-haul flight	Economy	3
11	ARN/ADD/FBM/ADD/ARN	16996	Long-haul flight	Economy	9
12	ARN/ADD/FCO	10376	Long-haul flight	Economy	1
13	FCO/TUN	576	Short-haul flight	Economy	1
14	ARN/ADD/JNB/ADD/ARN	19922	Long-haul flight	Economy	1
15	ARN/ADD/LAD/ADD/ARN	18702	Long-haul flight	Economy	1
16	ADD/NBO	1160	Short-haul flight	Economy	5
17	ARN/AGH	4708	Long-haul flight	Economy	1
18	AMS/ARN	1152	Short-haul flight	Economy	92
19	AMS/ACC/AMS	10418	Long-haul flight	Economy	9
20	AMS/AMM/CDG	6781	Long-haul flight	Economy	1
21	ARN/AMS/ARN	55872	Long-haul flight	Economy	1
22	AMS/CPH	632	Short-haul flight	Economy	9
23	AMS/GLA	716	Short-haul flight	Economy	3
24	AMS/HAJ	335	Short-haul flight	Economy	10
25	AMS/HAV	7813	Long-haul flight	Economy	5
26	HAV/CDG	7738	Long-haul flight	Economy	1
27	AMS/IAD	6204	Long-haul flight	Economy	1
28	IAD/CDG	6193	Long-haul flight	Economy	1
29	AMS/ICN	8549	Long-haul flight	Economy	4
30	ICN/PUS	338	Short-haul flight	Economy	4
31	PUS/GMP	327	Short-haul flight	Economy	4
32	AMS/LBA	460	Short-haul flight	Economy	6
33	AMS/LIS	1844	Long-haul flight	Economy	9
34	AMS/LUX	314	Short-haul flight	Economy	3
35	AMS/LUX/AMS	628	Short-haul flight	Economy	6
36	BHX/AMS	439	Short-haul flight	Economy	4
37	AMS/MRS	985	Short-haul flight	Economy	2
38	AMS/MUC	663	Short-haul flight	Economy	2
39	AMS/NBO/AMS	13344	Long-haul flight	Economy	1
40	AMS/OPO/AMS	3186	Long-haul flight	Economy	2
41	AMS/TLS	995	Short-haul flight	Economy	1

42	ARN/BCN/ARN	4628	Long-haul flight	Economy	1
43	BGO/OSL	323	Short-haul flight	Economy	1
44	OSL/ARN	383	Short-haul flight	Economy	43
45	ARN/BLL	678	Short-haul flight	Economy	28
46	BLL/OSL	509	Short-haul flight	Economy	1
47	BRU/ACC/BRU	10104	Long-haul flight	Economy	1
48	BRU/FRA	304	Short-haul flight	Economy	1
49	ARN/BRU	1286	Short-haul flight	Economy	69
50	BRU/CPH	753	Short-haul flight	Economy	16
51	BRU/FNA	4973	Long-haul flight	Economy	7
52	BRU/FNA/BRU	9946	Long-haul flight	Economy	3
53	BRU/MUC	595	Short-haul flight	Economy	14
54	MUC/ARN	1316	Short-haul flight	Economy	238
55	ARN/BUD	1306	Short-haul flight	Economy	4
56	ARN/CDG	1539	Long-haul flight	Economy	64
57	CDG/ABJ/CDG	9798	Long-haul flight	Economy	4
58	ARN/CDG/ARN	3078	Long-haul flight	Economy	41
59	ARN/CDG/CMN/AMS	5791	Long-haul flight	Economy	1
60	ARN/CDG/CMN/CDG/ARN	6934	Long-haul flight	Economy	2
61	CDG/GOT	1156	Short-haul flight	Economy	2
62	ARN/CDG/HAV/CDG/ARN	18554	Long-haul flight	Economy	2
63	ARN/CDG/JNB/CDG/ARN	20540	Long-haul flight	Economy	15
64	JNB/CPT	1268	Short-haul flight	Economy	5
65	ARN/CDG/JNB	10270	Long-haul flight	Economy	14
66	JNB/DUR/JNB	952	Short-haul flight	Economy	2
67	JNB/DUR	476	Short-haul flight	Economy	7
68	JNB/MPM/JNB	433	Short-haul flight	Economy	4
69	CPT/CDG/ARN	10894	Long-haul flight	Economy	2
70	CDG/LYS	410	Short-haul flight	Economy	1
71	CDG/MAD	1061	Short-haul flight	Economy	1
72	CDG/MXP	597	Short-haul flight	Economy	2
73	ARN/CMN/ARN	6930	Long-haul flight	Economy	3
74	ARN/CPH/AMS/CPH/ARN	1178	Short-haul flight	Economy	2
75	ARN/CPH/ARN	1092	Short-haul flight	Economy	10
76	CPH/ATH	2137	Long-haul flight	Economy	3
77	CPH/BLQ	1236	Short-haul flight	Economy	3
78	DUB/CPH	1239	Short-haul flight	Economy	3
79	CPH/EDI	999	Short-haul flight	Economy	2
80	CPH/GVA/CPH	1138	Short-haul flight	Economy	2
81	CPH/HAJ	401	Short-haul flight	Economy	14
82	CPH/IAD/CPH	13072	Long-haul flight	Economy	3
83	CPH/KEF	2142	Long-haul flight	Economy	3
84	KEF/OSL	1780	Long-haul flight	Economy	2
85	CPH/KRK	778	Short-haul flight	Economy	2
86	KRK/ARN	1070	Short-haul flight	Economy	2

87	ARN/CPH	546	Short-haul flight	Economy	147
88	CPH/LIS	2470	Long-haul flight	Economy	6
89	LIS/ARN	2997	Long-haul flight	Economy	1
90	CPH/LUX	795	Short-haul flight	Economy	45
91	LUX/ARN	1341	Short-haul flight	Economy	3
92	CPH/MAN	993	Short-haul flight	Economy	1
93	CPH/MUC	809	Short-haul flight	Economy	18
94	CPH/NRT	8708	Long-haul flight	Economy	2
95	NRT/PUS	1036	Short-haul flight	Economy	2
96	PUS/PEK	1213	Short-haul flight	Economy	3
97	PEK/CPH	7192	Long-haul flight	Economy	11
98	PEK/ICN	901	Short-haul flight	Economy	2
99	ICN/PVG	822	Short-haul flight	Economy	2
100	PVG/CPH	8274	Long-haul flight	Economy	17
101	PVG/PUS	800	Short-haul flight	Economy	3
102	HKG/CPH	8647	Long-haul flight	Economy	1
103	STN/CPH	912	Short-haul flight	Economy	2
104	CPH/SXF/ARN	365	Short-haul flight	Economy	1
105	SXF/ARN	853	Short-haul flight	Economy	1
106	CPH/WAW/CPH	666	Short-haul flight	Economy	8
107	CPH/WRO/CPH	575	Short-haul flight	Economy	6
108	CPH/ZRH	950	Short-haul flight	Economy	1
109	ARN/DME	1276	Short-haul flight	Economy	2
110	DME/KZN	715	Short-haul flight	Economy	1
111	ARN/DOH	4616	Long-haul flight	Economy	5
112	ARN/DOH/ARN	9232	Long-haul flight	Economy	6
113	DOH/JNB	6238	Long-haul flight	Economy	4
114	ARN/DOH/SAW	7307	Long-haul flight	Economy	1
115	ARN/DUB	1624	Long-haul flight	Economy	8
116	ARN/DUB/ARN	3248	Long-haul flight	Economy	16
117	LHR/ARN	1461	Short-haul flight	Economy	11
118	ARN/DUS/ARN	1162	Short-haul flight	Economy	27
119	DUS/CPH	618	Short-haul flight	Economy	1
120	DUS/OSL	1024	Short-haul flight	Economy	4
121	ARN/DXB/ACC/DXB/ARN	22130	Long-haul flight	Economy	2
122	ARN/DXB/ARN	9562	Long-haul flight	Economy	33
123	ARN/DXB/JED/DXB/ARN	12954	Long-haul flight	Economy	1
124	ARN/DXB/JNB/DXB/ARN	22378	Long-haul flight	Economy	1
125	ARN/EDI	1318	Short-haul flight	Economy	19
126	EDI/OSL	969	Short-haul flight	Economy	2
127	ARN/EWR/ARN	12608	Long-haul flight	Economy	1
128	ARN/FCO	2021	Long-haul flight	Economy	1
129	FRA/ARN	1223	Short-haul flight	Economy	241
130	FRA/ABV/FRA	9118	Long-haul flight	Economy	4
131	FRA/ADD/FRA	10690	Long-haul flight	Economy	1

132	FRA/ALG/FRA	3084	Long-haul flight	Economy	7
133	TUN/FRA	1468	Short-haul flight	Economy	3
134	FRA/BEY	2836	Long-haul flight	Economy	3
135	FRA/BUD/FRA	832	Short-haul flight	Economy	2
136	FRA/CMN/FRA	4548	Long-haul flight	Economy	1
137	FRA/CPT/MUC	18556	Long-haul flight	Economy	1
138	FRA/DME/FRA	4090	Long-haul flight	Economy	1
139	FRA/HAM/FRA	410	Short-haul flight	Economy	2
140	FRA/HOG/FRA	15778	Long-haul flight	Economy	3
141	FRA/IAD/BRU	12792	Long-haul flight	Economy	3
142	FRA/IAD/FRA	13096	Long-haul flight	Economy	1
143	FRA/JED/FRA	8260	Long-haul flight	Economy	4
144	FRA/JNB/FBM/JNB/FRA	20598	Long-haul flight	Economy	4
145	FRA/JNB/FRA	17364	Long-haul flight	Economy	3
146	FRA/JNB	8682	Long-haul flight	Economy	13
147	MPM/JNB	433	Short-haul flight	Economy	5
148	JNB/POL	1944	Long-haul flight	Economy	2
149	JNB/TET	1247	Short-haul flight	Economy	2
150	JNB/LHR	9069	Long-haul flight	Economy	1
151	FRA/KWI/FRA	8182	Long-haul flight	Economy	1
152	FRA/LAD/FRA	13112	Long-haul flight	Economy	2
153	FRA/LEJ/MUC/FRA	940	Short-haul flight	Economy	1
154	FRA/LIN/FRA	1024	Short-haul flight	Economy	1
155	FRA/LUX	175	Short-haul flight	Economy	11
156	FRA/LUX/FRA	350	Short-haul flight	Economy	12
157	FRA/LUX/MUC	605	Short-haul flight	Economy	4
158	LUX/VIE	776	Short-haul flight	Economy	1
159	VIE/ARN	1286	Short-haul flight	Economy	18
160	LUX/ZRH	295	Short-haul flight	Economy	3
161	ZRH/ARN	1487	Short-haul flight	Economy	4
162	FRA/LYS/FRA	1088	Short-haul flight	Economy	3
163	FRA/MAD/FRA	1418	Short-haul flight	Economy	2
164	FRA/MCT/FRA	10352	Long-haul flight	Economy	1
165	FRA/MRU/FRA	18386	Long-haul flight	Economy	3
166	FRA/RUH/FRA	8578	Long-haul flight	Economy	2
167	FRA/RUH	4289	Long-haul flight	Economy	2
168	DXB/FRA	4839	Long-haul flight	Economy	2
169	FRA/SIN/FRA	20544	Long-haul flight	Economy	2
170	FRA/KRK	800	Short-haul flight	Economy	2
171	FRA/SOF/FRA	1395	Short-haul flight	Economy	2
172	FRA/SZG/FRA	814	Short-haul flight	Economy	1
173	FRA/TUN/FRA	2936	Long-haul flight	Economy	6
174	FRA/TUN	1468	Short-haul flight	Economy	2
175	FRA/VIE	620	Short-haul flight	Economy	1
176	FRA/WRO/FRA	1198	Short-haul flight	Economy	1

177	GOT/ARN	394	Short-haul flight	Economy	7
178	ARN/GOT/ARN	788	Short-haul flight	Economy	2
179	ARN/GVA	1682	Long-haul flight	Economy	12
180	ARN/GVA/ARN	3364	Long-haul flight	Economy	13
181	ARN/HAM/ARN	826	Short-haul flight	Economy	2
182	ARN/HEL	398	Short-haul flight	Economy	42
183	ARN/HEL/ARN	796	Short-haul flight	Economy	25
184	HEL/BUD	1477	Short-haul flight	Economy	1
185	HEL/CPH	890	Short-haul flight	Economy	12
186	HEL/OUL	510	Short-haul flight	Economy	2
187	HEL/OUL/HEL/BMA	1426	Short-haul flight	Economy	1
188	HEL/PVG/HEL	14784	Long-haul flight	Economy	4
189	HEL/SVO	872	Short-haul flight	Economy	1
190	HEL/VAA/HEL	794	Short-haul flight	Economy	1
191	ARN/IST	2174	Long-haul flight	Economy	82
192	IST/ACC/IST	9782	Long-haul flight	Economy	1
193	IST/ADB/IST	714	Short-haul flight	Economy	2
194	IST/ADB	357	Short-haul flight	Economy	1
195	IST/ALG/IST	4510	Long-haul flight	Economy	4
196	IST/AMM/IST	1241	Short-haul flight	Economy	4
197	IST/DOH/IST	5512	Long-haul flight	Economy	1
198	IST/DXB/IST	6052	Long-haul flight	Economy	1
199	IST/ESB/SAW	702	Short-haul flight	Economy	1
200	IST/JED/IST	4774	Long-haul flight	Economy	2
201	IST/JED	2387	Long-haul flight	Economy	1
202	DMM/IST	2531	Long-haul flight	Economy	1
203	IST/KWI/IST	4380	Long-haul flight	Economy	1
204	IST/MCT	3368	Long-haul flight	Economy	2
205	DXB/IST	3026	Long-haul flight	Economy	2
206	IST/RUH/IST	4908	Long-haul flight	Economy	2
207	IST/TLV/IST	1165	Short-haul flight	Economy	4
208	IST/TUN/IST	3334	Long-haul flight	Economy	1
209	ARN/KEF/ARN	4280	Long-haul flight	Economy	5
210	ARN/LGW/ARN	2948	Long-haul flight	Economy	1
211	ARN/LHR	1461	Short-haul flight	Economy	25
212	ARN/LIN	1680	Long-haul flight	Economy	2
213	ARN/LIN/ARN	3360	Long-haul flight	Economy	17
214	ARN/LIS	2997	Long-haul flight	Economy	13
215	ARN/LLA/ARN	1374	Short-haul flight	Economy	1
216	ARN/LUX/ARN	1375	Short-haul flight	Economy	4
217	LUX/CPH	795	Short-haul flight	Economy	7
218	ARN/MAD	2597	Long-haul flight	Economy	8
219	LIS/MAD	512	Short-haul flight	Economy	4
220	MUC/CDG/FRA	1130	Short-haul flight	Economy	1
221	MUC/CPH/ARN	1396	Short-haul flight	Economy	5

222	MUC/FRA	298	Short-haul flight	Economy	1
223	MUC/GRZ/VIE	462	Short-haul flight	Economy	1
224	MUC/HAJ/FRA	758	Short-haul flight	Economy	1
225	MUC/KRK/MUC	1220	Short-haul flight	Economy	1
226	MUC/LEJ	341	Short-haul flight	Economy	1
227	MUC/LIS/MUC	3966	Long-haul flight	Economy	1
228	MUC/LUX	430	Short-haul flight	Economy	15
229	MUC/LUX/FRA	605	Short-haul flight	Economy	12
230	FRA/HEL	1537	Long-haul flight	Economy	1
231	MUC/LYS/FRA	1130	Short-haul flight	Economy	2
232	MUC/MAD/FRA	2913	Long-haul flight	Economy	1
233	MUC/OTP/MUC	1172	Short-haul flight	Economy	2
234	MUC/TBS/MUC	5372	Long-haul flight	Economy	1
235	ARN/MXP	1674	Long-haul flight	Economy	2
236	MXP/CPH	1144	Short-haul flight	Economy	1
237	ARN/ORY	1539	Long-haul flight	Economy	3
238	OSL/MAN	1109	Short-haul flight	Economy	1
239	OSL/SVG	340	Short-haul flight	Economy	4
240	SVG/BGO	860	Short-haul flight	Economy	2
241	BGO/ARN	708	Short-haul flight	Economy	3
242	ARN/PEK/ARN	13576	Long-haul flight	Economy	3
243	ARN/PRG	1086	Short-haul flight	Economy	9
244	PRG/OSL	1138	Short-haul flight	Economy	1
245	PVG/LYI/PVG	1072	Short-haul flight	Economy	1
246	PVG/ARN	7776	Long-haul flight	Economy	4
247	PVG/PUS/PVG	800	Short-haul flight	Economy	2
248	ARN/RAK/ARN	7322	Long-haul flight	Economy	2
249	ARN/RIX/ARN	930	Short-haul flight	Economy	8
250	ARN/SAW/ARN	4458	Long-haul flight	Economy	9
251	ARN/SFT/ARN	1150	Short-haul flight	Economy	2
252	SIN/KRK	800	Short-haul flight	Economy	1
253	FRA/SIN	10272	Long-haul flight	Economy	1
254	ARN/SVO/ARN	1218	Short-haul flight	Economy	38
255	SVO/DXB	3710	Long-haul flight	Economy	1
256	ARN/TKU/ARN	514	Short-haul flight	Economy	1
257	ARN/TLL	389	Short-haul flight	Economy	18
258	ARN/TMP/ARN	730	Short-haul flight	Economy	3
259	ARN/TXL/ARN	838	Short-haul flight	Economy	1
260	ARN/UME/ARN	950	Short-haul flight	Economy	2
261	ARN/VAA/ARN	856	Short-haul flight	Economy	1
262	VIE/CDG	1035	Short-haul flight	Economy	2
263	VIE/FLR/MUC	1138	Short-haul flight	Economy	1
264	VIE/KRK/MUC	390	Short-haul flight	Economy	1
265	VIE/SKG	983	Short-haul flight	Economy	1
266	ATH/MUC	450	Short-haul flight	Economy	1

267	VIE/SKP/VIE	789	Short-haul flight	Economy	4
268	VIE/TLV/VIE	4718	Long-haul flight	Economy	1
269	ARN/VNO	711	Short-haul flight	Economy	1
270	ARN/WAW	855	Short-haul flight	Economy	33
271	WAW/KRK/WAW	490	Short-haul flight	Economy	3
272	WAW/TLL/ARN	1229	Short-haul flight	Economy	1
273	WAW/WRO	304	Short-haul flight	Economy	12
274	ARN/ZRH	1487	Short-haul flight	Economy	44
275	ZRH/GVA	229	Short-haul flight	Economy	1
276	ZRH/LUX/FRA	470	Short-haul flight	Economy	1
277	ZRH/LUX/ZRH	590	Short-haul flight	Economy	1
278	LUX/MUC	430	Short-haul flight	Economy	4
279	ATH/SOF	529	Short-haul flight	Economy	2
280	BRU/BMA	1265	Short-haul flight	Economy	73
281	BMA/OSD	463	Short-haul flight	Economy	4
282	BMA/VXO	328	Short-haul flight	Economy	5
283	BRU/ARN	1286	Short-haul flight	Economy	2
284	BRU/CMN	2181	Long-haul flight	Economy	11
285	BRU/DSS	4466	Long-haul flight	Economy	10
286	BRU/ASS	5052	Long-haul flight	Economy	6
287	BRU/RBA	2081	Long-haul flight	Economy	1
288	CMN/ALG	1046	Short-haul flight	Economy	2
289	BEY/IST	1019	Short-haul flight	Economy	1
290	IST/ARN	2174	Long-haul flight	Economy	2
291	BMA/UME	507	Short-haul flight	Economy	1
292	BMA/AAR	549	Short-haul flight	Economy	2
293	BUD/ARN	1360	Short-haul flight	Economy	1
294	BHX/CPH	999	Short-haul flight	Economy	1
295	BLL/CDG	871	Short-haul flight	Economy	2
296	BRU/LYS	576	Short-haul flight	Economy	1
297	BMA/HEL	406	Short-haul flight	Economy	1
298	BLL/RIX	921	Short-haul flight	Economy	1
299	CAI/BEY	562	Short-haul flight	Economy	5
300	CAI/IST	1262	Short-haul flight	Economy	4
301	IST/CPH	1976	Long-haul flight	Economy	4
302	CAI/LXR	510	Short-haul flight	Economy	2
303	CPH/CDG	1004	Short-haul flight	Economy	7
304	CDG/DUS	393	Short-haul flight	Economy	1
305	CDG/MUC	681	Short-haul flight	Economy	2
306	MUC/WRO	476	Short-haul flight	Economy	2
307	OSL/CDG	1357	Short-haul flight	Economy	1
308	CFE/CDG	360	Short-haul flight	Economy	1
309	CIA/NYO	1762	Long-haul flight	Economy	1
310	CPH/CMN	2923	Long-haul flight	Economy	1
311	AMS/BRU	156	Short-haul flight	Economy	1

312	AMS/EDI	665	Short-haul flight	Economy	1
313	AMS/LHR	367	Short-haul flight	Economy	1
314	CPH/BHX	999	Short-haul flight	Economy	9
315	BRU/EDI	763	Short-haul flight	Economy	2
316	CDG/CAI	3209	Long-haul flight	Economy	2
317	BEY/CDG	3185	Long-haul flight	Economy	2
318	CPH/DOH	4608	Long-haul flight	Economy	4
319	DOH/SLL	950	Short-haul flight	Economy	4
320	CPH/FRA	679	Short-haul flight	Economy	11
321	FRA/CMN	2274	Long-haul flight	Economy	4
322	FRA/KBP	1582	Long-haul flight	Economy	1
323	MUC/KBP	1395	Short-haul flight	Economy	3
324	MAD/FRA	832	Short-haul flight	Economy	1
325	MUC/CPH	809	Short-haul flight	Economy	6
326	FRA/TLV	2950	Long-haul flight	Economy	4
327	TLV/MUC	2652	Long-haul flight	Economy	4
328	CPH/GVA	1138	Short-haul flight	Economy	2
329	IAD/CPH	6536	Long-haul flight	Economy	2
330	CPH/IST	1976	Long-haul flight	Economy	1
331	IST/TLV	1165	Short-haul flight	Economy	1
332	CPH/LHR	977	Short-haul flight	Economy	4
333	DUB/LHR	449	Short-haul flight	Economy	2
334	TLV/FRA	2950	Long-haul flight	Economy	1
335	OSL/CPH	515	Short-haul flight	Economy	9
336	OSL/HEL	761	Short-haul flight	Economy	6
337	CPH/RIX	711	Short-haul flight	Economy	2
338	RIX/TLL	280	Short-haul flight	Economy	2
339	CPH/STN	912	Short-haul flight	Economy	6
340	CPH/TLL	837	Short-haul flight	Economy	3
341	CPH/VIE	877	Short-haul flight	Economy	1
342	TLV/BRU	3248	Long-haul flight	Economy	1
343	VIE/TLV	2359	Long-haul flight	Economy	1
344	CPH/YYZ	6265	Long-haul flight	Economy	2
345	YWG/YYZ	1503	Long-haul flight	Economy	1
346	CPT/AMS	9679	Long-haul flight	Economy	2
347	CPT/JNB	1268	Short-haul flight	Economy	1
348	CRL/NYO	1220	Short-haul flight	Economy	1
349	DNZ/SAW	346	Short-haul flight	Economy	1
350	DOH/MCT	798	Short-haul flight	Economy	1
351	MCT/DXB	348	Short-haul flight	Economy	5
352	DSS/IST	5293	Long-haul flight	Economy	2
353	DUB/STN	470	Short-haul flight	Economy	6
354	DUR/JNB	476	Short-haul flight	Economy	5
355	DUS/ARN	1162	Short-haul flight	Economy	5
356	DXB/ADD	2517	Long-haul flight	Economy	1

357	ADD/ARN	5897	Long-haul flight	Economy	3
358	DXB/MCT	348	Short-haul flight	Economy	3
359	EDI/AMS	665	Short-haul flight	Economy	1
360	EDI/ARN	1318	Short-haul flight	Economy	3
361	FBM/ADD	2601	Long-haul flight	Economy	2
362	FNA/BRU	4973	Long-haul flight	Economy	2
363	GOT/AMS	763	Short-haul flight	Economy	4
364	AMS/JNB	9011	Long-haul flight	Economy	1
365	AMS/MAD	1456	Short-haul flight	Economy	6
366	LIN/AMS	830	Short-haul flight	Economy	1
367	ARN/TKU	257	Short-haul flight	Economy	4
368	GOT/BRU	903	Short-haul flight	Economy	4
369	MUC/GOT	1033	Short-haul flight	Economy	5
370	CDG/AMS	398	Short-haul flight	Economy	1
371	GOT/CDG	1156	Short-haul flight	Economy	1
372	CDG/LAD	6513	Long-haul flight	Economy	2
373	CPH/GOT	227	Short-haul flight	Economy	8
374	GOT/FRA	882	Short-haul flight	Economy	10
375	FRA/ALG	1542	Long-haul flight	Economy	2
376	MUC/BHX	1057	Short-haul flight	Economy	1
377	BHX/FRA	764	Short-haul flight	Economy	1
378	CDG/FRA	449	Short-haul flight	Economy	1
379	BRU/GOT	903	Short-haul flight	Economy	1
380	LAD/FRA	6556	Long-haul flight	Economy	2
381	BRU/LAD	6556	Long-haul flight	Economy	2
382	GOT/HEL	782	Short-haul flight	Economy	2
383	GOT/LHR	1065	Short-haul flight	Economy	1
384	MUC/LYS	586	Short-haul flight	Economy	3
385	GVA/BRU	531	Short-haul flight	Economy	1
386	GVA/CDG	409	Short-haul flight	Economy	2
387	GVA/HEL	1989	Long-haul flight	Economy	1
388	GVA/MSQ	1769	Long-haul flight	Economy	1
389	GVA/VIE	816	Short-haul flight	Economy	1
390	AMS/HEL	401	Short-haul flight	Economy	1
391	BLL/HEL	851	Short-haul flight	Economy	1
392	HEL/LGW	1857	Long-haul flight	Economy	1
393	MUC/HEL	1572	Long-haul flight	Economy	3
394	OSL/BLL	507	Short-haul flight	Economy	1
395	HEL/SIN	9270	Long-haul flight	Economy	2
396	HGH/LYI	568	Short-haul flight	Economy	1
397	LYI/PEK	582	Short-haul flight	Economy	8
398	JNB/HRE	958	Short-haul flight	Economy	1
399	IST/ESB	381	Short-haul flight	Economy	2
400	IST/WAW	1344	Short-haul flight	Economy	1
401	JED/RUH	850	Short-haul flight	Economy	1

402	RUH/DMM	352	Short-haul flight	Economy	1
403	JNB/BFN	378	Short-haul flight	Economy	1
404	KIM/JNB	452	Short-haul flight	Economy	1
405	DXB/JNB	6408	Long-haul flight	Economy	1
406	DXB/ARN	4781	Long-haul flight	Economy	1
407	ARN/KEF	2104	Long-haul flight	Economy	1
408	ARN/KRN	914	Short-haul flight	Economy	3
409	ARN/KLR	343	Short-haul flight	Economy	2
410	KZN/SVO	740	Short-haul flight	Economy	1
411	ARN/SVO	1218	Short-haul flight	Economy	5
412	AMS/LAD	2036	Long-haul flight	Economy	1
413	LEJ/DUS	378	Short-haul flight	Economy	1
414	ARN/LGW	1474	Short-haul flight	Economy	1
415	VXO/AMS	819	Short-haul flight	Economy	16
416	ARN/LLA	687	Short-haul flight	Economy	9
417	LUX/CDG	274	Short-haul flight	Economy	2
418	LYS/FRA	681	Short-haul flight	Economy	1
419	MAD/BRU	1313	Short-haul flight	Economy	1
420	MAD/LIN	1176	Short-haul flight	Economy	1
421	MAD/LIS	512	Short-haul flight	Economy	3
422	ARN/MAN	2597	Long-haul flight	Economy	2
423	MCT/SLL	848	Short-haul flight	Economy	5
424	CDG/MRS	650	Short-haul flight	Economy	1
425	MUC/MRS	745	Short-haul flight	Economy	1
426	JNB/MRU	3 066	Long-haul flight	Economy	1
427	MSQ/WAW	507	Short-haul flight	Economy	1
428	OSL/MUC	1315	Short-haul flight	Economy	2
429	HAJ/MUC	478	Short-haul flight	Economy	1
430	ZRH/MUC	261	Short-haul flight	Economy	1
431	NYO/KRK	985	Short-haul flight	Economy	1
432	NYO/STN	1297	Short-haul flight	Economy	7
433	NYO/WAW	779	Short-haul flight	Economy	3
434	OPO/LIS	277	Short-haul flight	Economy	1
435	ORY/GVA	393	Short-haul flight	Economy	1
436	OSL/TOS	1115	Short-haul flight	Economy	2
437	OSL/TRD	362	Short-haul flight	Economy	1
438	OUL/HEL	510	Short-haul flight	Economy	1
439	ARN/OUL	703	Short-haul flight	Economy	1
440	HEL/GOT	782	Short-haul flight	Economy	1
441	POL/TET	817	Short-haul flight	Economy	2
442	PUS/HKG	2042	Long-haul flight	Economy	1
443	CMN/RAK	200	Short-haul flight	Economy	1
444	RIX/ARN	465	Short-haul flight	Economy	2
445	ARN/RNB	407	Short-haul flight	Economy	6
446	RUH/DXB	872	Short-haul flight	Economy	2

447	ARN/SAW	2229	Long-haul flight	Economy	7
448	SHA/LYI	507	Short-haul flight	Economy	6
449	PVG/LYI	536	Short-haul flight	Economy	6
450	MUC/SKG	1241	Short-haul flight	Economy	1
451	CAI/MCT	2754	Long-haul flight	Economy	3
452	SOF/WAW	1067	Short-haul flight	Economy	2
453	STN/AMS	311	Short-haul flight	Economy	2
454	STN/NYO	1297	Short-haul flight	Economy	7
455	STN/VST	1329	Short-haul flight	Economy	9
456	SVG/ARN	702	Short-haul flight	Economy	1
457	SVO/AAQ	1218	Short-haul flight	Economy	2
458	SVO/ARH	975	Short-haul flight	Economy	2
459	TLV/ATH	1193	Short-haul flight	Economy	1
460	ARN/TMP	365	Short-haul flight	Economy	1
461	CDG/TUN	1485	Short-haul flight	Economy	1
462	ARN/TRD	560	Short-haul flight	Economy	1
463	ARN/UME	475	Short-haul flight	Economy	1
464	VNO/RIX	266	Short-haul flight	Economy	1
465	GOT/BMA	378	Short-haul flight	Economy	2
466	CPH/WAW	666	Short-haul flight	Economy	1
467	WRO/CPH	575	Short-haul flight	Economy	2

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