ROADMAP TOWARDS CARBON NEUTRALITY IN HEAVY MACHINERY MANUFACTURING AND GLOBAL SERVICE OPERATIONS – CASE: PONSSE PLC

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ABSTRACT

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Roadmap towards carbon neutrality in heavy machinery manufacturing and global service operations – Case: Ponsse Plc

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The purpose of this master's thesis is to compare possible Scope 1 and 2 carbon footprint reduction measures for Ponsse's global operations, based on which roadmap proposals towards carbon-neutral operations at Ponsse are prepared. The theoretical part of the thesis examines the terms related to the climate work of companies, the climate goals and actions set by countries around the world, and the climate impacts of heavy machinery manufacturing and service operations. The empirical part presents Ponsse's operations, examines the carbon footprint of the initial situation and introduces emission reduction opportunities. The emission reduction measures under consideration are those that emerged in held workshops and interviews. Based on these, in the work roadmaps towards carbon-neutral operations are created for the parent company (plant and RD) and subsidiaries.

In 2019 Ponsse's Scope 1 and 2 carbon footprint was 7,972 tons of CO_2 equivalent, more than half of which came from the use of road vehicles. When selecting emission reduction measures for the roadmaps, the size, cost and suitability of the emission reductions to be achieved by the measures are taken into account. The roadmaps, completed as a result of the work, present alternatives for reducing emissions and current opportunities that could be used to reaching the target of carbon neutrality. The potential for reducing emissions currently varies greatly from country to country. The greatest emission reductions can be achieved by changing fuels from heavy vehicles and test machines to renewable alternatives, shortening test drives and switching to use renewable district heat. With the measures presented in the roadmaps, it would be possible to reduce the Ponsse concern's fossil carbon footprint by approximately 73% from the 2019 level.

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Tämän diplomityön tarkoituksena on vertailla mahdollisia Scope 1 ja 2 hiilijalanjäljen vähennystoimia Ponssen globaaleille toiminnoille, minkä pohjalta luodaan Ponsselle tiekarttaehdotelmat kohti hiilineutraalia toimintaa. Työn teoriaosassa tarkastellaan yritysten ilmastotyöhön liittyviä termejä, eri puolilla maailmaa valtioiden asettamia ilmastotavoitteita ja -toimia sekä raskas kone tuotannon ja huoltotoiminnan ilmastovaikutuksia. Empiirisessä osassa esitellään Ponssen toiminta, tarkastellaan lähtötilanteen hiilijalanjälki ja tutustutaan päästövähennysmahdollisuuksiin. Tarkasteltavat päästövähennystoimet ovat niitä, jotka nousivat esille pidetyissä workshopeissa ja haastatteluissa. Näiden pohjalta työssä luodaan tiekartat kohti hiilineutraalia toimintaa emoyhtiössä (tehdas ja RD) ja tytäryhtiöissä.

Ponssen vuoden 2019 Scope 1 ja 2 hiilijalanjälki oli 7 972 CO_2-ekvivalenttitonnia, josta yli puolet oli peräisin tieliikenneajoneuvojen käytöstä. Tiekarttoihin päästövähennystoimia valittaessa huomioitiin toimilla saavutettavien päästövähennysten suuruus, kustannukset ja soveltuvuus Ponssen käyttöön. Työn tuloksena valmistuneet tiekartat esittävät vaihtoehtoja päästöjen vähentämiselle ja tämänhetkisiä mahdollisuuksia hiilineutraaliustavoitetta kohti pyrkiessä. Mahdollisuudet päästöjen vähentämiseen vaihtelevat tällä hetkellä maittain suurestikin. Suurimmat päästövähennykset on mahdollista saavuttaa raskaiden ajoneuvojen ja testikoneiden polttoaineiden vaihtamisella uusiutuviin vaihtoehtoihin, testiajojen lyhentämisellä sekä uusiutuvan kaukolämmön ostoon siirtymisellä. Tiekartoissa esitetyillä toimilla Ponsse konsernin fossiilista hiilijalanjälkeä olisi mahdollista pienentää noin 73 % vuoden 2019 tasosta.

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Vaan näin se tämä diplomityö päättää opiskeluni LUT-yliopistossa. Vastahan minä astuin ensimmäisen kerran Lappeenrannan kampukselle. Melkein puolet opinnoistani kului etäopiskellessa kotoa käsin vallitsevan pandemian takia. Siksi haluankin kiittää perhettäni ja ystäviäni, jotka ovat tukeneet ja kannustaneet minua eteenpäin opintojeni aikana. Olen näinä vuosina oppinut paljon ympäristötekniikasta ja siitä huolimatta tiedon nälkäni aihetta kohden kasvaa vain koko ajan. Voin viimeistään tässä vaiheessa myöntää, että kyllä minä lähdin ihan oikeaa alaa opiskelemaan neljä vuotta sitten. Voinkin tästä jatkaa hyvillä mielillä eteenpäin kohti uusia haasteita.

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Emilia Tuononen

ABBREVIATIONS

CCS	Carbon Capture and Storage
CDP	Carbon Disclosure Project
CH_4	Methane
CO_2	Carbon Dioxide
CO_2-eq.	Carbon Dioxide Equivalent
COP26	26th Conference of the Parties
CTL	Cut-To-Length
ETS	Emission Trading Scheme
EU	European Union
FAME	Fatty-Acid Methyl Ester
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
HSE	Health, Safety and Environment
HVO	Hydrogenated Vegetable Oil
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standardization Organization
LED	Light-Emitting Diode
N_2O	Nitrous Oxide
NDC	Nationally Determined Contribution
PFC	Perfluorocarbon
RD	Research and Development
SBT	Science Based Target
SF_6	Sulphur Hexafluoride
VOC	Volatile Organic Compound

Table of contents

APPENDICES

Appendix I	Held interviews and workshops
Appendix II	Used sources for emission reduction calculations

1 Introduction

The last four decades in a row have been warmer than any decade before that since 1850. In the 2010s, the global surface temperature was 1.09 °C warmer than in 1850-1900. It is very likely that the increase in greenhouse gases (GHG) in the atmosphere were the main driver for this warming since 1979. This human caused climate change is already affecting several weather and climate extreme conditions around the world. Such extreme conditions are heatwaves, droughts, floods, and tropical storms. Other effects include ocean warming leading to melting glaciers and rising sea levels. Every additional rise in global warming makes the changes in extreme events even larger. For this reason, it would be very important to reduce the quantity of greenhouse gases released into the atmosphere quickly. In all possible emissions scenarios examined, global surface temperature is expected to continue to rise until at least the middle of the century. In the best scenarios, the average global temperature would rise by 1.5 °C or 2 °C compared to pre-industrial times. However, this will require significant reductions in GHG emission in the coming decades. (IPCC 2021, 5-6, 10-11, 17, 19.)

Mitigating and adapting to climate change is one of the greatest international challenges of the moment. Every part of the world is feeling the effects of climate change in some way. The climate warming will continue, but its magnitude will be affected by current measures. If emissions are not reduced, the climate will warm by 3 to 4 °C this century, leading to a situation in which global warming feeds itself because of the collapse of glaciers and the melting of permafrost. In that case, humans would no longer be able to curb global warming by their own actions. (Dufva 2020, 9, 13-15.) Many governments have already taken steps towards reducing greenhouse gas emissions with national policies that includes regulations, standards, emission trading programs and carbon taxes. Also, many countries, organizations and industry fields have set carbon neutrality goals for their operations. Hence, companies must be capable of understanding and controlling their GHG emission risks if they want to secure future prosperity in competitive business environment, and to get ready for future coming climate policies. (GHG Protocol 2004, 3.) Companies with global operations should consider the different carbon neutrality targets, emission reduction requirements, changing regulations and legislations in different countries. These and general attitudes towards climate change can vary greatly around the world. In fact, Nordic customers may have very different requirements for emissions of product or service than, for example, in the North America.

1.1 Background

To curb global warming, 195 parties have ratified the Paris Agreement that entered into force in 2016. It is an international arrangement about climate change, which aims to restrain global warming to well below 2 °C, rather 1.5 °C in comparison to pre-industrial times. The Paris Agreement is a legally obligatory agreement, and it has been signed by all the European Union's (EU) member nations. Under the commitment, the countries have agreed that the EU will become the first climate-neutral economy and society by 2050. (European Parliament 2019.) In the end of 2021, 26th United Nations' Climate Change Conference, COP26 (Conference of the Parties), was held in Glasgow. The Glasgow Climate Pact aims to limit global temperature rise to 1.5 °C and accelerate climate actions. Countries will review their emission reductions as early as 2022, and not five years later, as was originally intended. The single biggest issue in the final document of the meeting is the mention of the continuous reduction of coal power for the first time. (COP26 2021, 3, 5.)

The Finnish government has declared Finland's target of being carbon neutral already in 2035 and quickly thereafter carbon negative. However, the government program does not specify the definition of carbon neutrality or how it should be achieved. However, it is deciding on further steps to achieve this goal. (Koljonen et al. 2020, 8.) Finland's total greenhouse gas emissions were 48.3 million tonnes of carbon dioxide equivalents (CO_2-eq.) in 2020. Of these, only 11% came from industrial processes and product use, which equals to 5.2 million CO_2-eq. tons. (SVT 2020.) However, the energy consumption of the industrial sector is high, and industry used up to 45% of Finland's total energy consumption, which was about 378 TWh in 2019. From that 86.1 TWh was electricity consumption. (SVT 2019.)

In 2020, the Finnish technology industry published its own low-carbon roadmap, which will help it promote the goals of a carbon-neutral Finland by 2035 and the EU by 2050. Technology industry's direct emissions and emissions from using purchased energy are about 6 million CO_2-eq. tons annually. Technology industry aims to reduce its own emissions by 38% by 2035 and by 80% by 2050. Technology industry consists of many different sectors of which emissions varies a lot. From industry's emission reduction operations many will based on electrification of processes and machines, improving energy and material efficiency, circular economy and using digital solutions. On the other hand, the pursuit of low carbon will lead to an increase in the need for electricity in industry. The amount of electricity used by industry is estimated to increase from the current 30 TWh to 50 TWh by 2035 and to almost 70 TWh by 2050. (Soimakallio 2020, 3, 5, 11.) So, it is also essential to pay attention to reducing energy consumption in addition to the emission reductions.

Ponsse Plc is Finnish technology company that manufactures forest machinery. At the moment, Ponsse is one of the world's leading forest machine producers. All their machines are manufactured in Finland where it headquarters is located. Additionally, company has twelve subsidiaries around the world, which are 100% owned by Ponsse. (Ponsse, 2, 8, 16, 34-35.) In addition to these, in November 2021, Ponsse announced the establishment of a subsidiary in Chile and in February 2022 about forming of a subsidiary in the Czech Republic. These new subsidiaries will take care of all Ponsse machine service in above mentioned countries during the year 2022. (Arvopaperi 2022.) The company has also dealers around the world that sells and offers maintenance services for Ponsse machines. Ponsse's goal is to achieve carbon neutrality in its global operative operations and its solutions one day. This is a long-term target that they strive for in its day-to-day operations. The target includes only Ponsse's owned operations, so dealer network is left out of it because they are own companies that Ponsse does not have control. (Ponsse, 2, 8, 16, 34-35.) Ponsse will commission this study and roadmaps, that they can choose and make the necessary operations to achieve this carbon neutrality goal in the future.

1.2 Objective and limitations

The purpose of this study is to provide Ponsse Plc's global operations two roadmap proposals towards carbon neutrality. One for the supply chain, covering the factory, and research and development (RD), and another one as common to all subsidiaries. This is because the structure of the subsidiaries' operations and emissions are mainly in line with each other. The roadmap addresses how Ponsse can reduce emissions from their own operations in a cost-effective manner and to enable it to achieve their goal of being carbon neutral one day.

The roadmap contains possible actions and measures that they can use in the future to reduce emissions. In addition, the purpose of the work is to identify development-related measurement challenges in Ponsse's current operations and to try to find ways to monitor the progress of the goal. This study seeks to answer questions, which activities generate the most emissions, i.e., where the greatest emission reduction potentials are, and which would be the most cost-effective and efficient emission reduction methods.

The carbon neutrality roadmap made in this work only deals with the emissions of Ponsse's own operations and emissions from used energy, i.e., Scope 1 and 2 emissions. Emissions in the value chain, Scope 3 emissions, are excluded from the review as those have not yet been determined. The most significant Scope 3 categories of Ponsse's operations are currently being defined so that the resulting emissions can be calculated in the future. The emission reduction operations under consideration are those that have emerged in workshops and interviews during the roadmap work.

1.3 Methodology and structure

In the theoretical part of the work, a literature review is used as a method. The work begins with a theory section that deals with commonly used climate work terms and what they mean. After the terminology, the climate targets and mitigations actions around the world are examined, so that differences in counties' legislations and emission targets can be taken into account in the roadmaps. The last part of the theory deals with the climate aspects of heavy machinery manufacturing and service operations in terms of emissions and energy consumption. After the theory part, an empirical section begins, which introduces Ponsse as a company, its operations, the strategic approach to sustainability and the background to why Ponsse aims to be carbon neutral in the future. Then the study will take a closer look to the roadmap's baseline situation and the current carbon footprint. Once the largest emission sources have been identified, possible emission reduction measures and their costs are compared. Finally, it is part of the creating a carbon-neutral roadmaps for Ponsse and consider how the progress of the goals can be monitored.

The empirical part is based on interviews and workshops. Regarding the background to the carbon neutrality goal set by Ponsse, two 45-minute interviews were held. The results of the carbon footprint calculation were presented, and the emission reduction brainstorming was performed in twelve 1.5-hour workshops. These were held for the environmental and safety, and management teams of the subsidiaries and Ponsse Finland’s operations. The emission reduction measures that emerged in the workshops were used as the basis for the roadmap. In addition, seven 1-hour interviews were held with the various manufacturing departments, during which the department's operations, emissions and energy consumption were examined in more detail, as well as possible measures to reduce them. These interviews were attended by a supervisor, specialist, or manager in each department. All Ponsse's production departments were interviewed during the work. These interviews were used as a basis in the roadmap for planning production emission reduction measures. The dates and participants of the interviews and workshops can be found in Appendix I.

Additionally, the work also included making the data collection form for the carbon footprint data and supporting subsidiaries in the data collection phase. After collection, the data tables had to be checked and reviewed. After the calculation, as part of the work, the results were presented in twelve different workshops, for which presentation materials was be prepared based on the theory of this study and calculation report. In addition, information material was created on the subject, which was translated into the language of each subsidiary. It aimed to share information and increase the knowledge of the network about the carbon footprint, its calculation, carbon neutrality and the roadmap work.

2 Terms related to companies' climate work

Many companies are determining their carbon footprint to set targets to be carbon neutral or have net zero emissions in the future. Some have even more ambitious goals by aiming for carbon negativity through carbon sinks and sequestration. Rarely do emission reduction measures alone achieve desired goal and many companies use carbon offsetting and insetting to meet their targets. The climate benefits of the product, on the other hand, are reported using a carbon handprint. Several factors are driving companies toward lower-emission operations. These include legislation, taxonomy, various initiatives, and organizations such as the Carbon Disclosure Project and Science Based Targets.

2.1 Carbon footprint

The carbon footprint is the total amount of the GHG emission produced by organization, individual or product. The company's carbon footprint describes the climate impact of its operations over a certain period of time, usually a year. The unit for carbon footprint is carbon dioxide equivalent. It is used worldwide to express the global warming potential (GWP) of greenhouse gases, presented in terms of the GWP of one carbon dioxide unit (GHG Protocol 2004, 97).

2.1.1 Greenhouse gas emissions

A greenhouse gas is a gaseous element of the atmosphere that absorbs and emits radiation inside the earth's surface and atmosphere (ISO 14064-1, 9). The carbon footprint calculation takes into account the six greenhouse gases covered by the Kyoto Protocol. These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). These emissions can be generated directly or indirectly from company's operations. Direct emissions are from company owned or controlled sources. Indirect emissions, on the other hand, are the result of the company's activities, but they are owned or managed by another company. (GHG Protocol 2004, 3, 25.) These different greenhouse gases have different lifetimes and specific radiative forcing in the atmosphere. The warming effect of GHGs is proportional to carbon dioxide using a cumulative radiative forcing of one hundred years, the so-called GWP coefficients. In carbon footprint calculation these greenhouse gas emissions are converted into unit of tonnes of CO_2-eq. by using appropriate GWP factors. According to ISO 14064-1 (International Standardization Organization) standard, in calculation the latest Intergovernmental Panel on Climate Change (IPCC) GWP factors for time of 100 years should be used. (ISO 14064-1, 10, 18.) The table below summarizes the GWP factors for 100 years for all six GHGs considered in the carbon footprint calculation according to the IPCC's fifth assessment report. Presented factors' for HFCs and PFCs are averages for all those substances.

Table 1. Global warming potential factors for 100-year period for different GHGs (IPCC 2013, 731-734).

Greenhouse gas	Chemical formula	GWP-factor
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265
Hydrofluorocarbons	HFCs	2,213
Perfluorocarbons	PFCs	8,628
Sulphur Hexafluoride	SF_6	23,500

Emissions from different sources can belong into one of the following three classes: Scope 1, 2 and 3. Scope 1 consist of all direct emissions from company owned or managed operations. Which means emissions from combustion of used fuels in company owned vehicles, energy production, processing, and fugitive emissions. The Scope 2 includes GHG emissions from manufacturing of purchased energy that is used by the company. This means electricity, steam, heat, and cooling, if it is produced externally. Lastly, Scope 3 includes all remaining indirect emissions that are a consequence of the company's operations but are originate from sources that are not owned or commanded by the firm. (GHG Protocol 2004, 25, 27, 29.) These Scope 3 emissions are further divided into upstream and downstream emissions through monetary operations. Upstream emissions are associated with bought or acquired commodities and services. Downstream emissions have to do with emissions from sold products or services. GHG Protocol Scope 3 standard classifies Scope 3 emissions into 15 different categories. These categories are meant to offer systemic framework to arrange, understand and report the different operations that are part of a value chain. According to GHG Protocol Corporate Standard greenhouse gas inventory for Scope 3 is optional and company can choose to report any Scope 3 emissions that it chooses. In many cases Scope

3 emissions generates the biggest part of company's carbon footprint, offering the greatest emission reduction potentials. Thus, along to the GHG Protocol Scope 3 Standard companies must report their Scope 3 emissions by following the Scope 3 Standard's requirements. (GHG Protocol 2011, 5-6, 29.) Carbon dioxide emissions from biogenic sources shall be reported separated from normal Scope reporting in carbon footprint calculation. These are called biogenic carbon emissions and can formed in biomass combustion or biofuel use. (ISO 14064-1, 12.) Figure below describes the different Scopes and what kind of operations they include.

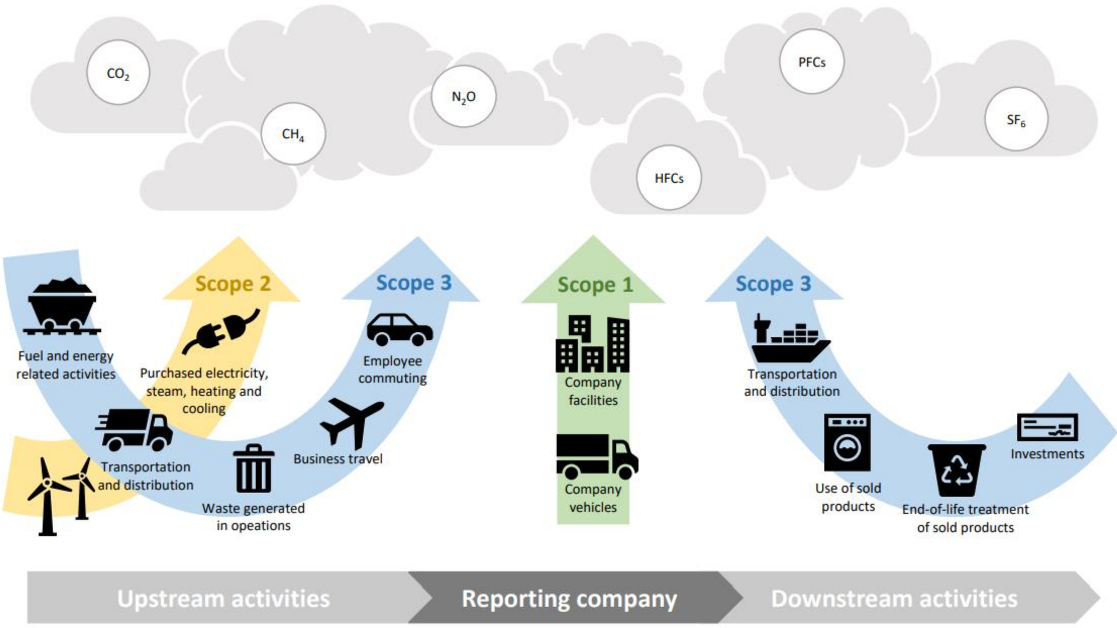

Figure 1. Different Scopes and emissions within the value chain (GHG Protocol 2011, 5).

If a company has high Scope 3 emissions in upstream operations, it means that the company is dependent on high-emission products and services provided by others. In some situations, it is possible to look for, for example, raw material or service with smaller emissions to replace the current one. But in some situations, a company has to wait for a change in another industry field, such as steel production, before it can reduce its emissions there. The large downstream Scope 3 emissions again mean that the use and final disposal of the company's own products results in large emissions. These can be reduced by making your own product less emitting, extending its lifetime, and improving its end use.

2.1.2 Standards and approaches

There are many different standards for calculating the carbon footprint. For companies and organizations' carbon footprint calculation there are GHG Protocol Corporate Standard, GHG Protocol Corporate Scope 3 Standard and ISO 14064-1 standard. The GHG Protocol Corporate Standard is instructions for companies to prepare a greenhouse gas emissions inventory. It helps companies to represent actual and truthful emissions accounting, using standardized manner of approaches and principles. GHG Protocol also enhances coherence and transparency in greenhouse gas accounting and reporting among different companies, which make it easier to follow and compare the progress over time. (GHG Protocol 2004, 3, 7.) GHG Protocol Corporate Scope 3 Standard gives requirements and guidance to companies for reporting indirect emissions from the operation of its value chain, i.e., Scope 3 emissions. It also gives several of allowable methods for recording Scope 3 emissions, which cannot usually be determined exactly. (GHG Protocol 2011, 4.) Based on the GHG Corporate Standard, ISO 14064-1 standard is made, and it gives specific principles and requisites for planning, improving, controlling, and reporting company-level greenhouse gas inventories. It consists of requirements for the defining boundaries of GHG emissions and removals, their quantification, and the identification of emission control functions. It also describes the requirements and guidelines for qualitative inventory management, reporting, and internal verification and the organization's responsibilities in it. ISO 14064-1 does not give strict guidelines for the categorization of indirect emissions and places different requirements on the structure and content of the report. (ISO 14064-1, 6.)

According to all three previously presented accounting standards, a good greenhouse gas accounting and reporting should follow five different principles – relevance, completeness, consistency, transparency, and accuracy (GHG Protocol 2004, 7; GHG Protocol 2011, 21; ISO 14064-1, 14-15). In carbon footprint calculation companies should account all their emissions for all Scopes and include all six greenhouse gases in calculation. If any exclusions are made, these must be justified and explained in report. Scope 3 should mainly include emissions from company's actions that happened in the reporting year, for example emissions from sold products during one year. Total emissions shall be reported in unit of metric tons of carbon dioxide equivalent and biogenic emissions should be excluded from this. Biogenic emissions are reported separately. Scope 1 and 2 emissions shall be reported in accordance with the GHG Protocol Corporate Standard, and Scope 3 emissions separately by Scope 3 categories. Descriptions of the used types and origin of data, emission factors and GWP values shall be shown in the report. Also, the description of calculation methods, allocation approaches and assumptions made, should be reported. Lastly in general, the calculation is verified by a first or third party to prove the completeness, accuracy, consistency, transparency, relevancy and that it is free from misstatements. Assurance is not a requirement in standards. (GHG Protocol 2011, 21, 32, 113.)

There are two different approaches that can be utilized in GHG emissions' consolidation – the equity share and the control approaches. The selection of used approach can transform categorization of emissions when operational boundaries are set in cases of entirely possessed and join operations. In equity share approach company calculates emissions for its actions accordingly to portion of equity in the operation. In control approach, a firm calculates all emissions from its operations which it has control. (GHG Protocol 2004, 16-17.) Control approach is further divided into financial control and operational control approaches. In financial control, a company is responsible for 100% of the greenhouse gas emissions that it has financial command. It disregards emissions from activities that in which it owns a share but has no financial command. Similarly, according to operational control approach, the firm calculates 100% of the emissions that it has operational command. It does not consider emissions from the activities it possesses but has no operational authority. The selected consolidation method should be used consistently through all Scopes inventories. The approach chosen affects which activities in a company's value chain are classified as direct and indirect emissions. Operations excluded from firm's Scope 1 and 2 inventories due to organizational boundary definition may become relevant when Scope 3 emissions are calculated. For example, when using the operational control method, emissions from assets managed by the company are included in direct emissions. But if a company does not have command over the assets it owns, such as investments, it is excluded from direct emissions and included in the Scope 3 inventory. (GHG Protocol 2011, 6, 28-29.)

2.1.3 Setting emission reduction targets

The company may set a variety of targets, such as a single target for total emissions from all Scopes or different target for Scope 1 and 2, and other one for Scope 3 emissions. There can be also more specific goals for single Scope 3 categories or combo targets that combines the above options. (GHG Protocol 2011, 100.) There are two kinds of greenhouse gas reduction goals – absolute and intensity-based. An absolute goal is often presented in terms of a reduction over time in a specific amount of GHG emissions, typically in tons of CO_2-eq. An intensity target is given as decrement in the ratio of GHG emissions proportional to other business meter. It can be, for example, output of the company (like per kWh or product), sales or revenues. To be able to set emission targets and track emission reductions, base year should be chosen. For the base year firms should choose the earliest relevant time that they can provide trustworthy data. Reductions in firm's emissions are calculated comparing changes over time relative to a base year. Company has also set the target completion year by when it will strive to achieve the set goal. Companies often go through different kind of structural changes over time, which makes company's emission tracking and comparison difficult. Other reasons can be edits in calculation methodology, upgrades in it, or discovery of significant errors in data. To keep consistency and comparability over time, previous emission data will have to be calculated again. (GHG Protocol 2004, 34-36, 59, 77.)

2.2 Carbon neutrality, net zero and negative emissions

Carbon neutrality usually refers to greenhouse gas neutrality, which means that the amount of greenhouse gas emissions generated does not increase the greenhouse gas content in the atmosphere. Carbon neutrality or GHG neutrality can be determined as the annual net zero emission and sink balance measured in carbon dioxide equivalents. (Koljonen et al. 2020, 11.) Negative emissions refer to the situation after carbon neutrality has been achieved, in which carbon dioxide binds more to natural and anthrophonic storages than is emitted into the atmosphere. In this way, more carbon is sequestered from the atmosphere than is released there. (Wennersten et al. 2015.)

At this moment there is not any standard or commonly used approach to determine carbon neutrality. Use of standards ensure that decisions about measures to be taken will based on real, scientific information. Then calculations are comparable with each other. A company can state that it is carbon neutral or that it strives for carbon neutrality, but it can mean almost anything. Many organizations claim to be carbon neutral, but they might not have a full understanding what carbon neutrality means and how it can be achieved. However, this is about to change, because International Organization for Standardization has standard about carbon neutrality, ISO 14068, under work and it will be ready in few years. According to the standard to be made, the carbon neutrality will first require minimizing own emissions and only after those remaining emissions can be compensated as a last possible measure. In carbon offsets, there must invest in projects that remove carbon from atmosphere genuinely and permanently. In this way, the standard will cut down on companies that use green washing, which only offsets all their emissions to say they are a carbon-neutral company with no intention of reducing their own emissions. (Hänninen 2021.)

2.3 Carbon sink and sequestration

In order to curb climate change, carbon dioxide emissions should be reduced to zero and, in addition, CO_2 already released into the atmosphere should be removed and stored in a carbon sink. On the other hand, according to many scenarios, the change to renewable energy sources from fossil ones will not happen fast enough to keep global warming within the desired limits. Indeed, hopes have been raised that carbon capture technologies could provide additional time for sustainable energy change. Carbon sequestration refers to the removal of carbon dioxide from the atmosphere to reduce the effects of CO_2 emissions on climate change. Carbon dioxide from atmosphere is sequestrated into natural or anthropogenic carbon sinks. The capturing can happen via biological, chemical, or physical processes. Carbon dioxide is sequestrated via photosynthesis into biomass and through dissolution in oceans. Then again, the term carbon capture and storage (CCS) is used to refer to industrial processes that separate carbon dioxide before emissions are emitted into atmosphere. CCS technologies are often used in power plants, steel mills and cement plants. Captured carbon is then reserved in geological formations on land or in the bottom of oceans for long times. Many technologies already exist for CCS, but there are economical barriers in their use. (Wennersten et al. 2015.)

2.4 Emission trading, carbon offsetting and insetting

Emission trading is a market-based, cost-effective solution for reducing greenhouse gas emissions. In emission trading system (ETS) carbon permits are sold, which gives a permission to release one ton of CO_2. The traded installations or companies need a number of permits equal to their emissions that they can trade. Operators can purchase or sell permits through the market and the price is set by the market. The total number of allowances on the market determines the total emissions of all installations covered by the emissions trading scheme. In emission trading GHG emissions are decreased where it is the most affordable to reach. If it is cheaper to purchase emission permits on the market than to carry out emission reduction operations, it is more cost-effective to purchase permits than decrease the emissions. Similarly, if emission reduction actions are cheaper then reduction operations are worth to implement. There are many different market areas and trading systems for different kind of emissions, such as EU-wide trading system for greenhouse gases. The activities covered by emissions trading vary between different markets. In EU emission trading covers power and heat generation, large industrial installments with a high thermal input and flights inside the European Economic Area. The European Commission has proposed adding new sectors to emissions trading, which require stronger actions. For example, emissions from maritime transport (large ships with gross tonnage over 5,000) would be included in the current ETS. This would apply to all emissions from intra-EU voyages and half of emissions from voyages starting or ending outside of the EU. In addition, the application of emissions trading in other sectors, such as private road transport and residential building heating, has been proposed through a separate new system. (European Commission 2021a.) The price of carbon permits has risen significantly over the last couple of years and its price has doubled during this time. On 20th January 2022, the price of one carbon allowance was risen to 81.7 €, which allows to emit one ton of carbon dioxide. (Trading Economics.) The figure below shows the evolution of the price of EU ETS allowances over the last ten years.

Figure 2. EU ETS carbon emissions allowance prices in last ten years (Trading Economics).

As shown in the figure, in the beginning the price has remained so low that it has not driven a shift effectively towards low-emission technologies. However, the recent rapid rise in prices has made it a viable mechanism for moving to low-emission solutions. Reducing emissions has become cheaper than purchasing for allowances.

A carbon offset is a greenhouse gas emission reduction made to compensate emission made in elsewhere. Buying carbon offsets is common operation for companies to reach carbon neutrality when all reduction operations are already done and there is little amount of GHG emission left that cannot be reduced in other ways. Offset projects can be related to increasing renewable energy or carbon sinks, improving energy efficiency or sequestration of GHG emissions. This kind of carbon offsets can be purchased from voluntary offset markets where emission reduction credits are sold. One emission reduction credit is equivalent to emissions of one tonne of CO_2-eq. The starting point for compensation activities is an implemented project that has reduced GHG emissions or increased sinks. Problem of voluntary offset markets is that there is no harmonized international legislation or control. However, various standards have been developed for emission compensation projects, such as Golden Standard and Climate Action Reserve. These standards ensure the quality and implementation of reductions and set required criteria for activities. Compensation projects must be measurable, permanent, incremental (would not have happened naturally), verified by third party, and avoid double counting and carbon leakage. With increased emissions compensation for businesses and consumers in the voluntary market is expected to continue to grow. To mitigate climate warming to 1.5 °C sequestration and removal of emissions has been evaluated to cover 2 gigatonne which meaning that the voluntary offset market will need to grow about 15 time larger by 2030. (Finish Ministry of Environment 2021, 9, 13, 17, 20-22, 24-25.) At the moment, the price of carbon offset varies from few euros to tens of euros. It is assumed that the price of one carbon offset will increase to around 45 € by 2030 and potentially more expensive than that, up towards 100 € per metric ton of carbon dioxide. (Holder 2021.)

When carbon offset projects could be done anywhere around the world, in carbon insetting the project must be done inside a firm’s own supply chain and supply chain organizations. So, the reduction project has be lie directly in the upstream supply chain of the firm and the project must be in a geographical area directly affected by the operation of the supply chain.

Examples of the supply-chain activities could be raw material acquisition, product transformation or transportation. The activities covered can be any project that produced GHG emission reduction units that comply with the principles of international standards: additionality, uniqueness, measurability, and verifiability. The projects must always be inspected by a carbon offset standard done by third party. In addition to the emission reductions made, the firm generates revenue through, among other things, growing efficiency in the supply chain and customer loyalty. The popularity of insetting is growing, and more and more organizations are involved in its development, promotion and use as a management strategy in the private sector. Some companies have started to use carbon insetting due to carbon offsets do not concentrate enough on decreasing emissions at the origin and increasing pressure to invest in supply chain emission reductions from stakeholders and customers. (Davies et al. 2016, 2-4, 8-11.) However, there is no mention about this in the GHG protocol or ISO standard, so it can be assumed that the method is not widely used, at least not yet.

2.5 Carbon handprint

Indicator for climate change mitigation potential is called carbon handprint. It presents reduction in GHG emissions made by the consumer when the consumer switches from a baseline solution to a new solution offered. So, companies can communicate their products, services, or technologies' positive climate benefits via carbon handprint. These kind of products helps users to reduce their own carbon footprints. Companies can enlarge carbon handprint, for example, by increasing energy efficiency, extending service lifetime, or storing carbon into their products. Carbon handprint can be used among the other things for identifying the improvement potentials, product development and comparison of alternative raw material or solutions. In climate work it is crucial to set up target to strive for increasing the carbon handprint, and in same time to minimize the carbon footprint (Pajula et al. 2021, 10-13, 15.) Product with a significant carbon handprint could be renewable fuel, for example, that would replace fossil fuels.

2.6 Carbon Disclosure Project (CDP)

Among the others, investors and customers are increasingly requiring companies to report their emissions data, environmental impacts, and actions. One body developed for this purpose is the Carbon Disclosure Project (CDP) established in 2000. It is a non-profit organization that publishes environmental information for companies and cities. CDP annually collects questionnaires from the world's largest listed companies through questionnaires. (Depoers et al. 2016.) Currently, the organization has three questionnaires related to different topics: climate change, forests, and water security. Companies that have joined in the organization can request and challenge their major suppliers to report their environmental data through a certain CDP questionnaire. (CDP.) In a climate change survey, companies answer questions about their greenhouse gas emissions and climate action, among other things. CDP aims to inform companies about investors 'concerns about climate change and to provide investors with information about companies' risks related to climate change. The results of the survey are mainly intended for financial agents and investors who want to assess the economic impact of GHG emissions and climate change. Through CDP, investors can use their financial power to put pressure on companies to pay more attention to their own environmental impacts and actions. It is voluntary for companies to respond to the survey, and it is up to them to decide whether the response will be public or only visible to those who have purchased a CDP license. (Depoers et al. 2016.) Understanding and applying climate change in companies is scored and assessed on a scale of A to D based on their responses. A-rating means that the topic is understood and applied in the company all the way up to the management level, while D meaning that the data related to climate change is only at the reporting level. In addition, a rating of F means that the company did not provide sufficient information to be assessed in this category or did not reply to the questionnaire at all. In 2020, 9,526 companies responded to the climate change related survey. (CDP.)

2.7 Science Based Targets (SBT)

While CDP is platform for reporting and publishing corporate climate data, Science Based Target (SBT) initiative is an organization founded in 2014 that seeks to harmonize corporate emission reduction targets. According to the name of the initiative, companies set their emission reduction targets based on scientific data, meaning that the targets are in line with pathways with a high probability of limiting global warming to well below 2 °C, preferably 1.5 °C. Companies should set a target for at least Scope 1 and 2 emissions reductions, these can be either absolute or intensive targets. In addition, companies must also set a target for Scope 3 emissions if those are for at least 40% of the company's total emissions (Scope 1, 2 and 3 emissions). The Scope 3 target contain cover at least two - thirds of the total emissions in question. The target can be an absolute, intensive, or supplier engagement goal. A commitment target means that a certain proportion of suppliers have set their own targets based on scientific knowledge by the set year. Scope 3 objectives do not need to be science based, as their control and influence are more limited. The company's SBTs are developed using common resources and goal setting methods, after which they are evaluated and approved by the technical advisory group. The weakness of SBT is that it does not monitor the progress of these goals, but relies on companies' own reporting, for example through annual CDP reporting. (Giesekam et al. 2021.)

By the end of 2021, more than 2,194 companies have already taken part and set themselves science-based targets. Of these, 1,044 have already set their targets, which have been approved. (SBT.) The goals of all the companies participating in the initiative are visible to everyone on SBT initiative’s website. The table below summarizes the science-based goals set by three different companies and shows an example that which kind of targets can be set.

Table 2. Different companies’ Science Based Targets (SBT).

Company	Target for Scope 1 & 2	Target for Scope 3
Stora Enso	50% absolute emission by 2030 from base year 2019*	50% absolute emissions by 2030 from base year 2019
Komatsu Ltd.	49% per unit of production by 2030 from base year 2010	46% absolute emissions by 2030 from base year 2012
Mercedes-Benz AG	50% absolute emissions by 2030 from base year 2018	42% emissions from use of sold product per vehicle kilometer by 2030 from base year 2018
**Includes biogenic emissions and removals from bioenergy feedstocks.*		

These companies were selected for the review because Stora Enso manufactures forest industry products, thus extending their Scope 3 objectives to Ponsse's operations. Komatsu Ltd. is again a multidisciplinary company that manufactures building, mining, military and forestry machinery, making it one of Ponsse 's competitors. Mercedes-Benz AG is a global car brand that also manufactures heavy-duty diesel engines used also by Ponsse to power their machines. Thus, also their Scope 3 targets reaches all the way to Ponsse. Of these, Komatsu has aligned its goals with a 2 °C warm-up and the others with a 1.5 °C warming (SBT).

2.8 EU taxonomy

As part of the European Green Development Program, the European Union's sustainable finance classification system, EU Taxonomy, has been published. It will help focus funding on measures that promote low-carbon, resilient and resource-efficient transitions. The aim is therefore to create an EU-wide rating system that allows investments to be targeted. (European Commission 2021b.) It concerns financial market participants and investors, EU member states, and companies and groups, which are already required to report on their activities and key performance indicators. The measures will be assessed based on sustainability criteria, so that funding and investment can be directed towards measures that are truly constructive for the future and promote ecological transition. In general, a measure is taxonomically valid if it significantly benefits at least one of the six environmental objectives, does not significantly harm the other five objectives, and complies with the ethical principles of labor and human rights of the United Nations, the Organization for Economic Co-operation and Development and the International Labor Organization. The six environmental objectives are: climate change mitigation, adaptation to climate change, sustainable use and protection of water and marine resources, the transition to a circular economy meaning waste prevention and recycling, pollution prevention and control, and the protection of healthy ecosystems. Objective can be achieved through measures that facilitate the transition, such as switching to low-emission forms of energy, or through measures that facilitate the transition elsewhere, such as the production of low-emission energy production equipment. In the future all investments marketed to support the transition should be in line with the taxonomic criteria. (Lankinen 2020.) It will extend EU’s sustainability reporting requirements to all large companies and all listed firms. Therefore, it will cover almost 50,000 companies within the EU. (European Commission 2021b.)

3 Global differences in countries' climate strategies and actions

Changes happening in societies and surrounding environments speed up shift towards climate friendly operations in companies. Countries' carbon neutrality and low emission targets will tighten legislation, and these create new smaller goals to help reaching the main target. Smaller targets and limitations can be related to energy consumption or energy efficiency. Countries' climate policies should be based the best procurable science (Norway 2020b, 32). On the other hand, customers in different countries have different levels of requirements due to variable legislation and limitations for subcontractors' emissions.

In this section the focus will be on examining the climate targets set by different countries and the operations to achieve them, mainly based on the nationally determined contributions (NDC) returned by the countries. Information has been sought from other sources unless the necessary information has been obtained from the NDC. The review focuses only on countries where Ponsse has subsidiaries. According to Siriwardana and Nong (2021) each country that signed the Paris Agreement must represent their obligation to decrease GHG emissions and adjust to climate change, to manage the increment of global average temperature clearly below 2 °C and make plans to achieve possibly below 1.5 °C. These commitments are called nationally determined contributions. Countries are expected to review and enhance their NDCs and submit more ambitious measures to reducing GHG emissions by every five years. However, there is no uniform methods to reach the contributions, so parties are free to contemplate their own action plans. If each country adheres to its planned NDCs, it is projected to reduce global warming compared to all specific climate policy scenario. (Siriwardana & Nong 2021.)

At the same time, it is seen that countries and organizations can have very ambitious emission reduction targets on the paper, but the goals set by the countries are not producing the desired result fast enough. Partly because many have set targets where the fence is the lowest. According Rowlatt and Gerken's article (2021) there have been a massive leak of documents which are showing how different countries are trying to get some changes done in a crucial scientific report about mitigating the climate change meaning IPCC's assessment report. The United Nations has received over 32,000 propositions from governments, firms, and other parties. Many big fossil fuel producer and consumer countries have been trying to claim that the use of fossil fuels does not have to be reduced as quickly as report's draft recommends. A large beef and animal feed crop producers are strongly disagreeing with the statement of reducing meat consumption would be necessary. Rich countries again argue that developing countries will require especially financial assistance from rich countries to be capable of achieving emission reduction targets. Countries have been asking for downplaying, changing the wording, and even deleting some parts or conclusions. These kinds of changes have demand, among the others, China, Norway, Brazil, and the Organization of the Petroleum Exporting Countries. (Rowlatt & Gerken 2021.)

3.1 Nordic countries

Norway has legally binding goal to be a low-emission society by 2050 at the latest. This objective is contained in the Norwegian Climate Change Act, which states that a low-emission society is one in which GHG emissions have been reduced according to the best available scientific information to avoid the harmful effects of climate change. In practice, the target means reducing emissions by 90-95 %. In addition to this long-term target, Norway has a reduction target for 2030, which is 50-55% of 1990 emission levels. According to Norway's NDC, country also aims to reduce emissions from non-ETS sectors by 40% by 2030 compared to 2005. About half of Norway's GHG emissions have been covered by the EU Emissions Trading Scheme, although the country is not in the European Union. Non-ETS sectors have their own regulatory tools, and the target is achieved through domestic emission reductions and flexible mechanisms within the EU. (Norway 2020a, 1, 7.) The Norwegian government intends to gradually tighten its climate policy and related principles to achieve the long-term goal. The current carbon tax, which applies to almost all non-emissions trading fossil fuels, will help to achieve this goal. The tax will be gradually increased, which is expected to provide stable and predictable economic development and at the same time promote the development of a market for new low-emission and zero-emission solutions. Provisions that help Norway towards its goal include bio-quota obligations for road transport fuels and prohibition on the use of mineral oil to heat buildings. (Norway 2020b, 24-25, 29.)

Finland’s target is to be carbon neutral society in 2035, which is fifteen years earlier than EU has set its goal. Finnish government has also set goal to be quickly after 2035 carbon negative. In addition, there are set target to reduce 39% non-ETS greenhouse gases by 2030 compared to 2005, and energy and climate policy targets to help to reach earlier mentioned targets. These include phasing out use of coal for energy by 2029, at least halving consumption of peat by 2030, linear increasing the proportion of biocomponent in road transport fuels to 30% by 2030, 10% an obligation to mix bioliquids with light fuel oil for heating buildings and diesel for work machines in 2030. For renewable electricity the target is to be at least 50% of end demand in 2030. The long-term strategy is based on Regulation (EU 2018/1999) of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action, also known as the ‘Governance Regulation’. To achieve these goals, actions will be made to increase use of renewable and bioenergy in energy usage and transportation, improving energy efficiency and decreasing amount of the end demand of energy. From renewable energy, amounts of wind and solar power will increase significantly, in addition to these heat pumps will bring a significant share of the increase. From bioenergy, the use of wooden-based fuels will increase most and expansion of biogas production from energy crops and agriculture side streams. The importance of biogas is seen to be much smaller than that of other biofuels, although its use is expected to expand significantly. (Finnish Ministry of Employment and the Economy 2020, 2, 6, 8, 12, 14, 20-21.)

Sweden aims to have zero net greenhouse gas emissions by 2045 at the latest. This means that GHG emissions should be at least 85% below 1990 levels. Shortly after this goal, the country is working to achieve negative emissions. In addition to its long-term targets, Sweden aims to reduce emissions from effort sharing regulation sector by 63% by 2030 and by 75% by 2040 compared to 1990 emissions. In addition, Sweden has milestone goals: a 70% reduction in domestic transport emissions from 2010 to 2030, a 100% increase in renewable electricity production by 2040 and a 50% increase in energy efficiency by 2030 compared to 2005 in relation to gross domestic product. To achieve its climate goals, the country uses many national and EU-wide policy instruments. The basis for governance is emissions pricing forms, complemented by targeted initiatives. To further reduce GHG emissions, a government co-financing program for local climate investments was introduced. These investments cover all industries, and all types of organizations can seek for grants. The choice of the investment granted is based on the estimated GHG emission reduction in relation to the costs. The Fossil Free Sweden initiative, launched in 2016, aims to increase the government's dialogue with industry, municipalities, civil society, and other public sector actors. The initiative also aims to create roadmaps for facilitate faster emission reductions. (Swedish Ministry of the Environment 2020, 3, 5, 10-11, 18, 26, 37-39.)

3.2 Rest of Europe

The European Union member countries have a common NDC, which is binding all of members, so they do not have separate country-specific ones. For this reason, more detailed targets for EU countries were examined based on other sources. According to the EU’s updated NDC (2020) its target is to achieve climate neutrality by not later than 2050. Reduction goal for GHG emissions is 55% from 1990 levels by 2030. According to EU’s adopted legislation, European Union and its member countries shall achieve at least 40% GHG emission decrease across the different sectors of the economy. EU will cut emissions in sectors included by its emissions trading system by 43% by 2030 compared to 2005 levels. Reduction goal for sectors external from its ETS are determined for each country separately. For Finland it is 39%, Sweden 40%, France 37%, Ireland 30%, and Czech Republic 14% from 2005 by 2030. (European Union 2020, 1, 6, 8, 13.)

France aims to achieve carbon neutrality by 2050. According to the French National Low Carbon Strategy, the goal means a balance between anthropogenic emissions and anthropogenic GHG absorption, which means absorption into the natural environment by man and certain industrial procedures. France’s commitments including the 40% GHG emission reduction from 1990 levels by 2030. To reach carbon neutrality, country is planning to fully decarbonise energy production by 2050, significantly reduce energy consumption in all sectors, reduce non-energy-related emissions as much as possible and increase carbon sinks by factor of two compared to today. Other actions are replacing combustion vehicles with electric ones or changing into use of biofuels depending on the mode of transport, significant in energy efficiency improving for heave vehicles, increasing use of heat pumps and the growing amount of used biomass will come from agricultural sector. (Ministry for the Ecological and Solidary Transition of France 2020, 5, 11, 15, 19-22.)

The United Kingdom of Great Britain and Northern Ireland has set a goal of achieving net-zero emissions by 2050. The country is also committed to reducing GHG emissions in the economy by 68% by 2030 – CO_2, CH_4 and N_2O emissions compared to 1990, while HFCs, PFCs and SF_6 emissions compared to 1995 levels. Covered sectors and greenhouse gases are according to IPCC 2006 guidelines. In Scotland, there are more ambitious targets by trying to reach net-zero GHG emissions already in 2045. Additionally, there are intern emission reduction goals of 56%, 75% and 90% by 2020, 2030 and 2040 respectively, compared to years 1990/1995 baseline situation. Meanwhile, Wales aims for reducing all emissions at least by 80% by 2050 against year 1990/1995 baseline. Wales's target for 2020, 2030 and 2040 are 27%, 45% and 67%. (UK Government 2020, 1-2, 4, 7-8.) UK's government has made Clean Growth Strategy which lists key policies and proposals to help achieving these emission reduction targets. It includes operations, such as giving financial support to businesses to improve their energy productivity by at least 20% by 2030, decommissioning of high-carbon fossil fuel heating systems, finishing sales of new petrol and diesel cars and vans by 2040, development of an electric vehicle charging network, decommissioning of unabated coal for electricity generation by 2025, and seeking opportunities to install more offshore wind capacity. (HM Government 2017, 12-15.)

Ireland has set a long-term target of net-zero emissions by 2050. The country has also set a goal to reduce its GHG emissions by an average of 7% annually between 2021 and 2030. The target for emissions outside the EU ETS is a 30% reduction from 2005 levels by 2030. Ireland also wants to uppgrade the use of renewable energy sources from 30% to 70% and reach a 34% share of renewable energy in energy consumption by 2030. In addition, the country has a goal to improve energy efficiency by at least 32.5% by 2030. To achieve these objectives, Ireland has planned measures such as development of offshore renewable energy production, phasing out of coal and peat for electricity generation and the acceleration of the deployment of electric vehicles through policy instruments. Other measures include raising bio-shares in motor fuels, banning the sale of new fossil fuel vehicles from 2030 onwards, developing a compressed natural gas network to meet the fuel needs of gas cars and prohibition on installing oil boilers in new homes from 2022 and on gas boilers from 2025. (Irish Department of Communications, Climate Action and Environment 2019, 11, 14-15.)

The Czech Republic aims to reach carbon neutrality by 2050. According to the Pathways to Decarbonize the Czech Republic (2020), this means a 95% reduction in greenhouse gas emissions relative to 1990 levels. The rest of the emissions, about 9 million tons, are planned to be offset by land use, land use change and forestry. In addition, Czechia aims to reduce its GHG emissions by 40% by 2030 from 1990 amounts. Actions to achieve these goals include reducing the use of coal, adding the capacity of renewable energy sources, increasing the use of natural gas and nuclear power, improving energy efficiency, and promoting electrification in transport, heating, and cooling. (Hanzlík et al. 2020, 9-11.)

3.3 Russia

In 2021, president of the Russian Federation said that Russia could stop emitting greenhouse gases into the atmosphere by 2060 (Troianovski 2021). As a part of the execution of the Paris Agreement, the Russian Federation announced that their target for limiting GHG emissions, which provides for a reduction by 2030 to 70% relative to the 1990 level. This target is covering all sectors and greenhouse gases from IPCC report. (Russian Federation 2020, 1, 9.) A more ambitious than the country’s goal is in the Sakhalin region, which is aiming for carbon neutrality as early as 2025 by a decision of the regional government, as the first region in Russia. Country is investing in renewable energy, while the new wind farms under construction are producing energy that will be used to extract coal. Emissions trading, hydrogen power, renewable energy plants and the development of carbon sinks will be important steps in Russia's pursuit of carbon neutrality. In addition, the switch from coal to natural gas will also be a major part of sustainable change. The government is working to provide financial incentives for car owners to convert their engines to natural gas. Additionally, natural gas is more than twice cheaper than gasoline. Russia is aiming to double the amount of carbon absorbed by its forests and other ecosystems nationwide by 2050. The plan is to maintain existing fossil fuel industries for as long as possible. (Troianovski 2021.)

3.4 China

China's nationally determined contribution is only available in Chinese, so country's climate targets and emission actions are considered based on other sources. Brown's article (2021) tells that in 2020 China's president said that country aims to carbon neutrality before 2060. Another target is to have the highest emission point by 2030 at the latest. However, country has not explained how exactly they will achieve these goals. According to the president's speech, China will phase down the coal consumption from 2026 and not building new coal-fired projects abroad. But at the moment, China is building new coal power plants across the country. Nevertheless, China is one of the leading countries in manufacturing green technology, like solar panels and large-scale batteries. The number of wind power installations was three times bigger than any other country in 2020. It is also predicted that almost all new vehicles sold in country will be electric or hybrids by 2035. The electricity production should be generated from low emission sources to be able to reduce emissions from transportation. The country also states that the share of non-fossil sources generated energy should be 25% by 2030. (Brown 2021.)

3.5 The United States of America

The United States of America has set a goal of striving for net-zero emissions by 2050 at the latest. The country has also set a target to reduce its net GHG emissions by 50-52% by 2030 compared to 2005 emissions. These targets consist of all sectors and greenhouse gases defined in the IPCC 2006 guidelines. One of county's goals is also to achieve 100% carbon pollution-free (renewables and nuclear) electricity in 2035. The USA is supporting the development of a new generation of low-emission renewable fuels, improving energy efficiency, and switching to electric heating for buildings. Research, development, demonstration, commercialization and deployment of low-carbon and zero-carbon industrial processes and products will also be supported. The country encourages to use of carbon capture and new sources of hydrogen in power industrial facilities. (The United States of America 2021, 3.) The United States Mid-Century Strategy for the industrial sector includes actions like improving the efficiency of heating and motors, switching to low-carbon fuels and feedstocks. Additionally, vision is to switch to electricity and other possible low-carbon fuels in transport, buildings, and industry. (The United States of America 2016, 42, 64.)

3.6 South America

Brazil has set itself the goal of reaching climate neutrality by 2060. The country has also committed to reducing its absolute GHG emissions by 37% by 2025 and 43% by 2030 compared to 2005 amounts. These targets cover all six greenhouse gases. (Federative Republic of Brazil 2020, 1-3.) To reach these goals Brazil intends to adopt future actions like growing the proportion of biofuels in the energy mix to around 18% by 2030 which can be achieved by adding the supply of ethanol and increasing the proportion of the biocomponent in the diesel mixture. Increasing the share of renewables in the energy mix to 45% (mainly by increasing non-hydropower production) and improving energy efficiency by 10% in the electricity sector by 2030. Brazil also plans to promote new clean technology standards and further increase energy efficiency. (Federative Republic of Brazil 2016, 2-4.)

Uruguay's target is to have net carbon dioxide removal by 2030 with domestic resources. Country's global unconditional objectives for GHG emissions intensity regarding the evolution of the economy for 2025: reductions of 24% for CO_2 emissions, 57% for CH_4 and 48% for N_2O (in emissions intensity per gross domestic product) compared to base year 1990. Targets cover only three greenhouse gases and include sectors of energy, transport, agriculture, waste, and industry, which covers about 95% of considered greenhouse gases. There are more specific targets for food production because around 74% of Uruguay's total emissions comes from agriculture and from it two thirds are from beef production. Addition to these, there are specific objectives for the land-use change and forestry sector. (Oriental Republic of Uruguay 2017, 3-5.)

Chile's long-term target on global warming mitigation is to achieve greenhouse gas neutrality by 2050. According to Chile's national GHG inventory and predictions based on it, it's have been estimated that operations would achieve about 30% reductions and potentially up to 45% by 2030 compared to 2016 levels if emission mitigation and capture are taking into account. To be able to reach neutrality goal, Chile is committed to have greenhouse gas emission peak before 2025. Between 2020-2030 accumulated GHG emissions in country shall not exceed total amount of 1,100 Mt CO_2-eq. These targets cover all six greenhouse gases and all sectors. Also, the total emissions from black carbon will decrease by at least 25% from 2016 levels by 2030. The country has also committed to shut down all coal-fired power plants by 2040. Examples of planned actions are replacing thermal power plants by renewable energy, increasing distributed energy generation, 60% of private and commercial vehicles would be electric in 2050, 71% of cargo transportation would work via hydrogen by 2050, motor-electrification in industry would increase in 67% and to have a 100% urban residential residues deposit in landfills with incineration or biogas use. (Government of Chile 2020, 32-34, 83-84, 89-90.)

4 Climate aspects of heavy machinery manufacturing and service operations

The business of heavy work machines can be divided into the supply chain, and sales and service activities. The supply chain includes the manufacturing of the machinery, the procurement of components and logistics. The production process usually consists of component fabrication (welding and machining), surface treatment, and assembly. In-house logistics and delivery operations also play a big role in production. When considering the climate impact of operations, the manufacturing buildings – factories themselves must also be considered. Service activities are divided into preventive maintenance according to the service program or based on component wear, as well as repair activities due to breakage. Both are done at the service points where the machinery is brought in for service and at the customer's sites where the mechanic goes. (Appendix I.)

The lean production or manufacture is a systematic method of eliminating waste. Central to this is the identification and elimination of all non-value-added activities, i.e., waste. Lean production seeks to eliminate unproductive activities from transportation, warehousing, movement, waiting time, overproduction, overprocessing, and defective products. The aim is to improve the quality of production, reduce costs and shorten delivery times. The idea is that the right number of the right things with the right quality is got in the right place at the right time. In many industrial processes, non-value-added activities can account for up to more than 90% of a total output. (Dhiravidamani et al. 2018.) Although lean practices may not have the direct purpose of reducing environmental impacts, their introduction often improve energy efficiency, decrease emissions, and reduce waste. According to Bai et al. (2019), lean production practices have a direct link to a company’s environmental sustainability. (Bai et al. 2019.) Overall, this waste consumes energy and fuel causing more emissions. By cutting of these kinds of wastes will reduce the climate impacts of production process.

All starts from the design of the product. The workability of the part in the manufacturing processes should be considered already in the product design, so that the part becomes as easy to handle in different processes as possible. For example, according to Raisio (2020), when it comes to assembly, product design should consider the ease of assembly. This would simplify and reduce the number of steps in the process. This would also shorten the time the product stays in the process. (Raisio 2020, 11-12.) Regarding machining, the part should be designed so that the material should be removed as little as possible in the process. The less material to remove, the faster the machining times and thus the lower the energy consumption. On the other hand, product design can also affect the serviceability and maintenance needs of the finished product. (Appendix I.)

4.1 Manufacturing

In industrial sector, manufacturing is an important part and usually in it, raw materials are converted into products by using electricity. At the same time process generates emissions and wastes. Manufacturing's carbon footprint is highly depended on energy sources that are used to produce the used electricity in processes. Manufacturing processes need a lot of energy. For example, in the USA the industrial sector consumes around 31% of the total energy consumption and from that amount manufacturing takes about 60%. In addition to emissions, it is very important to decrease the energy consumption in manufacturing. (Zhao et al. 2017.) The most significant environmental impacts of Ponsse's supply chain come from inbound and outbound logistics, raw material acquisition and production (Ponsse 42). This section examines the major emission sources and energy consumers of the various processes in the manufacturing industry, as well as the potential for reducing them in general.

The aim of manufacturing execution is to control production so that it can meet the requirements for the manufacturing of the ordered products in terms of quality, quantity, and delivery time. The production system, on the other hand, is a combination of thought patterns, themes and techniques that make production work well. It raises important points about what action is being taken and what is being done to make production work well. The manufacturing execution systems is an information system that monitors production and documents the transformation of raw materials into finished products. (Appendix I.) Traditional manufacturing execution systems do not support ecological sustainability goals, but the most appropriate background for extending sustainability is monitoring, control and evaluation. An intelligent production control system collects resource consumption data directly from the machines. It combines data collection on production operations and resource consumption, such as energy consumption and energy efficiency. In the study of Larreina et al., the refrigeration compressor shutdown message was successfully generated to reduce standby power consumption by approximately 50% without adverse effects on productivity or quality efficiency. (Larreina et al. 2013, 467-468, 471.)

A lot of energy is needed through the production processes. Energy is consumed by process-specific functions, but in addition to these, there are also common activities that are used in many stages of production. One such is the use of compressed air and its production, which consumes a lot of electrical energy. (Appendix I.) In compressed air systems, part of the generated compressed air is lost in leaks, this share can be up to 25-50% of the total amount produced. To reduce energy consumption, it would be important to identify and repair any air leaks in the system and switch off the compressors when compressed air is not needed. The control technologies of the latest systems have evolved to produce power only when needed. The energy needed to produce compressed air can also be reduced by not using it inappropriately and utilizing appropriate controls. To minimize pressure losses, should make sure that the piping and storage are the right size, and remember to change the filters regularly. These are because the pressure drop reduces the efficiency of the compressor. Today, there are adjustable speed compressors that are suitable for many different applications; in use, the operating pressure should be adjusted to suit the intended use. When the compressor produces compressed air, heat is also generated which can be recovered. This can be recycled and utilized elsewhere. For example, a 50-horsepower compressor rejects approximately 37 kW heat in hour. (Korn 2011.)

4.1.1 Welding

Welding is a joining process for a metal in which the joining is performed by heating it to a proper temperature with or without filler metal. Welding is a very common operation in many industries and therefore there are several, more than 50, different kind of welding processes that can be utilized in very different working conditions. Indeed, the different processes differ considerably in terms of heat, pressure and the type of equipment used. These different processes also produce different particle compositions and morphology. The main components of welding emissions are various metal oxides that result from the contact between oxygen in the air and vaporized metals. During welding, the materials in the arc evaporate, which in turn condenses to form vapors upon oxidation upon contact with air. The most common gases released during the process are ozone, nitrous oxide and carbon monoxide. Gases are generated due to high temperature and ultraviolet radiation from the arc. Inert gases such as carbon dioxide or argon can be used to prevent oxidation. They are used as shielding gases, but they also have unwanted environmental effects. These emissions occur in all welding processes, although their amounts may vary. Another significant air pollutant released from welding processes is nanoparticles. (Golbabaei & Khadem 2015.)

Welding fume particles range in size from fine to ultrafine. The rate and composition of welding fumes depend on many different factors, such as amperage, voltage, gas used, arc temperature and heat supply process, consumable, welded material, and process duration. While the formation of fumes and gases is directly connected to the welding process. Flue gas emissions from tungsten inert gas welding are lower compared to manual metal arc and metal inert gas welding. Less ozone and nitrogen oxides are also released during tungsten inert gas welding compared to metal inert gas/metal active gas welding. The composition of the vapors is mainly due to the composition of the wire used. However, the tungsten inert gas method produces smaller particles, less than 100 nm (nanoparticles), than other welding processes. Methods using higher energy intensities release higher amounts of nanoparticles. While short-circuit welding reduces the amount of these particles due to the low current intensity and arc temperature. The material to be welded also contributes to the formation of nanoparticles, such as stainless steel. (Golbabaei & Khadem 2015.)

Lean welding requires as little material and labor as possible, and it reduces waste and production time. The reduction in production time has a direct effect on reducing the climate impact of welding. When planning welding, it is essential to look at which parts need manual welding, and which can be implemented with automation. As technologies evolve, reliance on manual labor has been reduced. The use of robotic welding is a function that is utilized to speed up production and increase productivity. (Gupta 2018.) However, in general, production cannot be done by robotic welding alone, as the parts have to be assembled by hand welding before robotic process (Appendix I). In lean welding, it is essential to select the most suitable welding methods for each application, after which the appropriate equipment should be selected for the method and application. Welding equipment should be remembered to be calibrated regularly as their production decreases with use and age.

Without calibration, gauges and adjustments no longer show the correct parameter setting, which degrades productivity quality and extends delivery time. In addition to calibration, equipment should be serviced and inspected at regular intervals to maintain it in optimal condition. Energy consumption in welding can be reduced, for example, by eliminating the variation in primary power, improving driving speed and reducing heat production with a pulse function. (Gupta 2018.)

4.1.2 Machining

The idea of machining is to file the pieces so that they go together and can later be combined into larger components. There are manual and automatic machining. In the manual, the person commands and controls the machine and changes the tools used. In automatic, the machine reads the code and operates on it. Of these, automatic machining is faster, more uniform, and more energy efficient. (Appendix I.)

In manufacturing, machining is an important process cluster. Machine tools have many energy-intensive components, such as motors and hydraulic pumps. Consumption of energy in machining can be concerned in three different levels: machine, spindle, and process level. The machine level includes energy consumption from, among other things, control systems, cooling and lubrication units, operating systems, and spindle motors. The machining processes' energy efficiency is often very low – only around 15% of the total energy is used by the actual machining process. Machining of hard and brittle materials results in lower material removal rates and longer machining times. Thus, due to the poor machinability of the material more energy is used. Other machining processes, such as turning and grinding, show similar energy consumption behavior. For this reason, improving the energy efficiency of machining processes can decrease energy usage and the environmental impact. (Zhao et al. 2017.)

Energy consumption in machining can be reduced by replacing old machines with new, more energy-efficient equipment. They are more energy efficient overall, but also at the element level, such as guide rails, hydraulics, and drive systems. The monitoring of energy consumption is facilitated by the proliferation of real-time monitoring in machines, so that large energy consumers can be identified. In lean machining, it is important to use machines of the right size, with the equipment dimensioned for the intended application. In this way, the devices make the most efficient use of floor space and consume less energy than devices that are too large for the application. (Korn 2011.) The efficiency of the next step, welding and welding joints depends largely on the preparation of the joint and fastening before welding itself. This preparation is done by either manual or automated machining. However, due to the accuracy of the welded joint and the dependence on the finished fire process, automation is a more desirable means. (Gupta 2018.)

4.1.3 Surface treatment

Surface coating workshops apply decorative or protective coatings to substrates, such as paints, varnishes, and lacquers. Coatings, in liquid or powder form, can be applied by many kinds of methods, such as brushing, rolling, spraying, dipping, and flow coating. (Athappan et al. 2014.) The loss of painting can also be reduced by choosing a painting method. The highest efficiencies are in powder, roller, and brush painting. While with spraying techniques, the efficiencies are clearly superior. (Veiste 2008, 16.) After application of the coating, the surface is air and/or heat dried to remove volatile solvents from the coated surface. Surface coating plants are major sources of volatile organic compounds (VOCs) in urban areas. Paint shops release VOCs as the organic solvents in the coatings evaporate. These VOCs can contribute to the formation of ground-level ozone, and many are hazardous air pollutants. (Athappan et al. 2014.)

The current trend in surface treatment is to move towards lean processes. These new paint shops are energy-optimized, resource-saving and have a shorter lead time. The VOC content is highest in solvent-based and water-based paints, so-called wet paints. Emissions can be reduced by switching to water-based paints with a higher dry matter content, or powder paints. Water-based paints contain about 5-10% solvents, but otherwise the solvents are replaced with water. The drying of these paints begins with the evaporation of this water. For water-based paints, the VOC content is less than 100 g/l compared to solvent-based paints with a concentration of 400-500 g/l. Water-based paints are more environmentally friendly than solvent-based paints, but their use imposes special requirements on painting work. For example, pre-treatments must be done more carefully, and the conditions must be optimal, not too humid or too dry, during painting and drying. The energy costs of water-based paints are also about half that of solvent-based paints. (Veiste 2008, 3, 6, 14-15, 17.)

Powder coating of heavy components has become more common recently. Powder coatings have a solids content of 100%, which means that they do not contain any solvents. Another advantages of powder coating are that the powder that has passed can be recovered and recycled, which reduces waste and its costs as a coating method. In powder coating, an attempt is made to obtain a cloud of powder around the painted body, from which the powder is transferred to the surface of the body due to the electrical charge. The paint is therefore electrically charged and the part to be painted is grounded. The disadvantages of powder coating are that the crosslinking of the binder and hardener requires higher temperatures (160-200 °C), and the painted part is forced to be used in the oven. Nevertheless, the energy costs of a powder coating are half of solvent-based paints. (Veiste 2008, 7, 20-21.)

To speed up the painting process, the painted piece is usually placed in an oven to quicken the drying of the paint. In this case, the heat production process is essential for the emissions of the painting process. The use of renewable energy sources, such as the burning of biogas, reduces the fossil carbon footprint of the process. On the other hand, heat recycling increases the benefits of used fuel. Heat can be recovered and recycled for space heating in the winter. Reducing the drying time and lowering the required temperature, can also decrease energy consumption and thus lower emissions. (Appendix I.)

4.1.4 Assembly

The purpose of the assembly process is to produce a whole, either a finished end-product or one of its parts. In it, the components are joined together to form larger entities. The process involves many steps and functions, and it is not just a single event. Assembly can be manual, robotic, or automated. In the manual one, the person executes and controls the process, while in the robotized, the robots handle the individual workstations or steps, and in the automated process, the assembly is handled by automation. The assembly involves moving the parts from their storage location to the manufacturing site in the correct order. It is essential to place the parts on the workstations so that the installation is done with only minor modifications. (Raisio 2020, 10, 12-15.)

Assembly processes can be divided according to the mode of transport – synchronous and asynchronous. In a synchronous system, the same function is performed for each part, regardless of its path through the system. The parts move from one stage of work to another at a certain rate along the conveyor. It is well suited for mass production. On the asynchronous or non-real-time system different functions can be performed to part to be assembled, depending on its route through the assembly system. Products move freely from one workstation to another without a predetermined pace. This is used more in systems with subassemblies and sub-modules. (Raisio 2020, 15.)

The assembly system should adapt quickly to product changes, their variations, and variances in quantity. By modulating the product, the throughput time required for assembly can be reduced and the quality of the product can be improved. It can also achieve space and capacity optimization in manufacturing as well as production flexibility. In modulation, the component desired by the customer is assembled from the subcomponents. It also simplifies and speeds up the assembly process thanks to consistent installation methods and tools. The benefits of modularity come to the fore especially in automated assembly processes. (Raisio 2020, 5.) On the other hand, modularity can complicate assembly and cause variation in assembly times between different machines. The assembly does not use large amount electricity powered tools, which makes it difficult to reduce emissions from the assembly process. (Appendix I.)

4.1.5 Test drive and delivery operations

The test drive can be used as a quality assurance method after the machine is completed and before its delivering to the customer. During the test drive, the operation of the machine is tested and possible leaks, for example, are monitored. The most significant emitters during the test run arise from the transport of the machines for testing and the fuel consumption of the tested machines. Emissions from test drives can be decreased by reducing the amount of fuel consumed. For example, by performing testing closer to the factory, which shortens transport distances, or by shortening the duration of the test drive, which decreases the amount of fuel consumed. On the other hand, the better the quality of the machines leaving from the factory and detection of possible defects already during the production process, the less test drive is required from the point of view of quality assurance. Product development also plays a major role in machine emissions, such as fuel consumption, hydraulic system efficiencies and other operating solutions. Changes in these also affect the magnitude of emissions from the test drive. (Appendix I.)

Delivery operations is the last step before the machine is delivered to the customer. Any faults that may have occurred during the test drive will be rectified, the machine will be washed and equipped with equipment selected by the customer. The machine is prepared for transport and delivered to the customer. Emissions from delivery operations arise mainly from transporting machines to customers if this is done with company’s own trucks. Options to reduce emissions from heavy road transport are currently limited to route design, optimization and switching to use renewable fuels, as other solutions are not yet commercially available. (Appendix I.)

4.1.6 In-house logistics

In-house logistics refers to the management of material flows within a factory, terminal, and warehousing area. It includes the receiving, shelving, storing, transporting, and transferring of goods in production. In addition, it also contains collecting, packaging, shipping, and recycling. Now days, it is essential to manage the flow of information to make operations timely in relation to needs. Inefficient in-house logistics slows down work, causes unnecessary warehousing, slows inventory turnover, and increases the amount of capital tied up in the inventory. (Transval 2022.) The reason for storing can be, among other things, the arrival of raw materials at the factory in large batches or waiting for the finished products to be transported to the customer (Logistiikan maailma). It is therefore essential to define what are reasonably batch sizes, as larger stocks require more space and thus the need for heating and handling increases. According to Transval (2022) inefficient logistics inside factory also increases material and semi-finished products between work steps and slows down turnaround time. The production work phases also included logistics, in which case the efficiency of both suffers and the capacity of the production phase is wasted. Delivery times are extended, delivery security suffers, and products may not be delivered as promised. Improving internal logistics will increase the efficiency of the entire production chain. Well-functioning internal logistics enable efficient flow, allowing the product to flow through production smoothly and efficiently. (Transval 2022.) The aim is to guide manufacturing through controlled production. The means of production control include capacity management, which means that work steps are timed correctly and in the correct order. Inventory management, on the other hand, manages material flows during the production process in the factory area. (Logistiikan maailma.)

Lean production involves eliminating waste, which in logistics means minimizing unnecessary handling, transportation, waiting, and overstocking. Logistic solutions that affect efficiency include fast turnaround times, a steady production pace, customer-tailored production, minimizing work in progress, and reducing inventory. Accuracy is more important than speed and efficiency. Bottlenecks can be dismantled by increasing the capacity of the phase. (Logistiikan maailma.) Ways to reduce emissions from logistics include reducing the need for logistics, improving energy efficiency, shifting to environmentally friendly modes of transport, optimizing logistics, and developing and adopting new technologies. The need for logistics can be reduced, for example, by sharing freight, avoiding empty loads and capacity utilization rates. Also, by improving driving routes and reducing extra distance through better route planning and daily updating as needed. (Rahman 2020, 14-16.) Regarding internal logistics, it is essential to consider the batch sizes to be delivered – whether it makes sense to run one or more pieces at a time, inventory's automation, the way the pieces are collected (manually or automatically) and the production layout. The design of the factory and production lines should be done so that the delivery route for the components is as short and fast as possible. Driving with an empty load should also be avoided as much as possible. The goal of logistics is to get the right amount of the right quality right goods in the right place at the right time. (Appendix I.) Low carbon fuel options are discussed later in section 4.2.3.

4.1.7 Factory buildings

According to Bipat (2021), buildings can account for up to 39% of the country's total CO_2 emissions (Bipat 2021). This includes not only emissions during operation but also emissions during the construction phase. The proportion can vary noticeably depending on where in the world it is. The figure above is based on US statistics and may be higher or lower in other countries. As reported by Merggers et al. (2012) emissions from the construction phase and their disposal, as well as from the construction process itself, are considered for emissions during the construction phase. However, two-thirds of emissions from buildings are generated during use. (Meggers et al. 2012.) Buildings cause direct emissions when they use equipment that utilizes combustion. Examples are boilers for space heating and the use of fuel for water heaters. On-site electricity generation also causes emissions, such as electricity generated by diesel generators. Indirect emissions from buildings are related to energy purchased and produced elsewhere but used in the building, like emissions from district heat production. (Bipat 2021.)

Emissions from the used energy can be significantly reduced by switching to renewable energy sources instead of fossil fuels. For example, by generating electricity using solar panels or by replacing space heating with heat pumps. (Bipat 2021.) Large roof areas in large production buildings are potential places to install solar panels and reduce electricity emissions. Fossil fuels, on the other hand, can be replaced by biomass-based fuels, both in energy production and in processes. However, the location of the building and the fuel supply in the area must be considered when using these, as it varies considerably from region to region and from country to country. (Meggers et al. 2012.)

Another way to reduce emissions from a building's energy consumption is to decrease energy use and improving the energy efficiency. Also, simple actions such as changing the temperature of thermostat or cooling, outside working hours affect the amount of energy consumed. In terms of lighting, the use of electricity can be reduced by switching to LED lights. In addition, turning off the lights when the area is not in use or by using motion detectors decrease the use of electricity. Switching to more efficient and better controlled systems reduces energy consumption. (Korn 2011.) Better manageability can be achieved with intelligent systems as they help to minimize operational inefficiencies. Such systems may include, for example, active monitoring and optimization of heating, cooling, lighting, and ventilation. The energy efficiency and energy use of these systems are directly related to the energy consumption of the entire building. On the other hand, for heat and cooling, it is possible to recover the wasted part and recycle it. Heat escape from the property can be reduced by improving insulation. (Meggers et al. 2012.) According to Soininen's article (2021), a company is typically able to reduce heat consumption by 5-20% and electricity consumption by 3-5% by implementing the measures recommended by energy audits. Often, savings can be made without investment, just by adjusting equipment and changing practices. More common measures to improve energy efficiency include improving ventilation, recovering and recycling waste heat, optimizing lighting and automatic control, and improving the use of the compressed air system. (Soininen 2021.)

The actions of the building's users also have an impact on the emissions of the property. Users' behaviour is strongly influenced by the culture and lifestyle present. By guiding building users to better practices, such as turning off the lights when leaving the room, closing the exterior door behind them, and lowering the interior temperature by one degree, for example, have already affect in the energy consumption. (Meggers et al. 2012.) The length and uniformity of the working week also influences the amount of energy consumed. According to Korn's article (2011), one machine shop saved more than 5% in energy costs by moving from a normal five-day work week to a four-day work week and 10-hour workdays. (Korn 2011.) This does not mean that the length of the working week should be shortened, but it can be concluded that the uniformity of shifts affects the amount of energy consumed. If only one department is at night shift, the factory lights and heating are on just for them. On the other hand, if all the departments were at work at the same time, the heating could be reduced on weekends, for example, when no one is present.

Emissions during the use of buildings also include leakage of refrigerants used in heat pumps, air conditioning and refrigeration equipment. Those emissions can be reduced by minimizing leaks by improving equipment maintenance. However, leaks cannot always be avoided. (Appendix I.) In this case, the alternative is to change the refrigerants to those with lower climate impact (Devecioğlu & Oruç 2015). Refrigerants commonly used in heat pumps, air conditioning and cooling, and lower-GWP coefficient alternatives for those are shown below. The global warming potential factors of refrigerants are according to the IPCC's Fourth Assessment Report.

Table 3. Common refrigerants and lower GWP option for those (Darment; Devecioğlu & Oruç 2015).

Refrigerant	GWP-factor	Alternative	GWP-factor
R134a	1,430	R1234yf	4
		R1234ze	7
R22	1,810	R444b	296
R407c	1,774		
R410a	2,088	R454b	466
R507a	3,985	R449a	1,397

As can be seen from the table, alternative refrigerants have a lot lower global warming potential. Thus, even with small leakage rates, the GWP factor of the refrigerant matters. In general, the refrigerant cannot be used directly to replace other, usually modifications must be made to the machines for the new refrigerant to be used successfully (Appendix I).

4.2 Service operations

The purpose of maintenance is to extend the life of the machines. Maintenance can be either reactive, preventive, predictive or proactive. Reactive maintenance means that the machine is serviced only when it is not working efficiently, or something is breaking down, which are results from lack of preventive and predictive maintenance. This is the most expensive of the maintenance strategies and can cause much more downtime compared to others. In preventive maintenance, the equipment is serviced regularly and may include, for example, oil changes, replacement of worn parts, and cleaning. There information from past experiences is used to plan when certain maintenance operations should be performed. For example, if it is known that the expected life of a particular component is three years under its operating and environmental conditions, it should be replaced before that. Predictive maintenance involves evaluating the current condition of the machine. Various technology tools have been developed for this purpose, which are intended to measure the symptoms of the faults and to indicate the existence of a problem. The issue with this model is that when measuring fault symptoms, the problem already exists. Lastly proactive maintenance, which does not focus on repairing machines, but seeks to eliminate the root causes of problems. For instance, checking the oil level in a splash-lubricated components. The model should know the reasons that lead to most machine failures and know what they look like. (Wright 2016.)

If a heavy machine breaks down on a working site, getting it to a service center is usually challenging, making it easiest for a mechanic to perform minor maintenance on site. On the other hand, larger and harder maintenance work requires more tools, and it is safer for the mechanic to bring the machine from the site to the service point. In each case, the driving distance is accumulated, either when the mechanic drives to the site or when the machine is transported to the service point. With preventive regular maintenance faults and the need for repairs can be avoided, machine productivity increased, and thus minimize the number of trips. (Appendix I.)

4.2.1 Energy and fuel consumption

At service points, energy is needed, like a factory, to maintain the building's heating, lighting, and air conditioning. The difference with the factory's energy consumption is the production of energy on the customers’ work sites with generators, where it is otherwise challenging to obtain energy. Generators usually run-on gasoline or diesel. (Appendix I.) The reduction of the energy consumption of the service buildings themselves is achieved in the same way as described for the factory building in section 4.1.7.

In addition to reducing energy consumption, it is possible to change the heating mode or switch the energy source used. Low carbon heat can be generated for example by heat pumps. Heat pumps use electricity to generate heat, usually with high efficiencies. They take heat from the air, ground, or water to warm the interior of a building. Some heat pumps can also be used for cooling in the summer. In the case of electric and district heating, emissions depend a lot on the energy sources that is used for energy production. Producing heat from renewable energy sources lead to fossil CO_2 emissions to be zero. In the future, the growing use of renewable energy will reduce emissions from purchased energy. (Lindgren 2019.) For boilers, renewable fuel options can be switched to replace fossil fuels. For example, there are a bio-based alternative to propane and options for fuel oils made from renewables. (Appendix II.)

Energy can be also produced by utilizing solar radiation. It can be used to generate electricity with solar panels and heat with a solar collector. Usually, heating uses solar energy together with some other form of heating, as seasonal variations and weather affect energy supply. Another form of heating may be, for example based on a pellets, wood, or heat pumps. Solar energy can be used for heating the space and hot water. Its use reduces emissions and lowers the overall cost of heating. In Central Europe, there is five times more solar radiation than in Finland. However, even in Finnish conditions, the sun provides enough energy to be a worth taking advantage of utilizing it. The panels are usually connected to the grid, in which electricity is purchased from when the panels do not produce enough energy in relation to consumption. (Motiva 2016, 1-2, 4-5, 8.)

In the maintenance of heavy machinery, fuel is used to drive service vehicles to the customer and the broken machine. Emissions from service vehicles and generators can be reduced by changing the fuel used. (Appendix I.) More on this in the next section 4.2.2. According to Rahman (2020) emissions from driving can be reduced by improving the energy efficiency of engines, optimizing the routes driven, and avoiding empty loads and unnecessary driving. Other ways include improving driving routes and reducing extra driving distances with route planning. (Rahman 2020, 14-16.) Ways to decrease driven mileage also include utilization of remote control of machines and technical support in repairing faults. For the remote support to be as efficient as possible, the machine should be able to communicate externally, allowing the support person to see the machine's sensor data and parameters. (Appendix I.) For example, it is pointless to drive 100 kilometres if the same fault can be fixed remotely.

4.2.2 Fuel options for vehicles

There are a wide variety of alternatives to fossil fuels for road vehicles. In addition to diesel and petrol, light vehicles can use, for example, electricity, natural gas, biogas, ethanol fuels, biodiesels, or hydrogen. However, the distribution of fuel alternatives varies from country to country, and there is still no commercial distribution of hydrogen, for example. (Ahola 2021.)

In electric vehicles, the electric motor is powered by the battery, and it moves the vehicle. Usually, this is a lithium battery, but a solid electrolyte and lithium sulfur batteries are currently under development. Disadvantages of electric cars are their shorter range, and in addition, cold weather conditions can quickly reduce the lifetime of batteries. Charging times for electric vehicles can be long. Lithium batteries also have a lower energy density than gasoline, which is why large batteries increase the car's mass. These make it difficult to electrify heavy road traffic. On the other hand, the efficiency of electric cars is better than internal combustion engines. The emissions during the use of an electric car depend on the electricity used to charge it. Emissions from an electric car powered by coal produced electricity can be as high as 300 g CO_2/km, while emissions from renewable electricity driven vehicle is around 73 g CO_2/km. The corresponding carbon dioxide emissions are about 246 g/km for petrol and 213 g/km for diesel. (Ahola 2021, 12, 14.) It should be noted that the above figures are only CO_2 emissions and not the carbon footprint. Meaning nitrogen oxides, among others, have been excluded from the analysis.

Electricity is also used by hybrid vehicles, which have a battery and an electric motor in addition to an internal combustion engine (petrol or diesel). These can be connected in series or in parallel. When connected in series, the internal combustion engine is used only to generate electricity and only the electric motor drives the wheels of the vehicle. When connected in parallel, both the electric and internal combustion engines can rotate the transmission line, i.e., they act as mutually supportive power generators. Hybrids are divided into plug-in hybrid and hybrid electric vehicles, the difference being that plug-in hybrid cars can be charged using a plug. The emissions of hybrid electric vehicles (100 g CO_2/km) are not much lower than in a similar petrol car (100-120 CO_2/km). While a plug-in hybrid vehicle can significantly reduce carbon dioxide emissions compared to a gasoline car. (Ahola 2021, 24-26.)

Most of the natural gas and biogas, about 90%, is methane. Natural gas is a fossil fuel and biogas are produced from biomass, for example by digestion. These are more commonly used as transport fuel in pressurized or liquefied form. In liquefied form, they can also be used as fuel for trucks. There are bi-fuel and dual-fuel gas cars. The bi-fuel vehicle has two of separate fuel systems – one for gas and another for diesel or petrol. It can run without gas or alternatively with gas alone. In a dual-fuel car, gas and diesel/petrol are mixed, which means that it is not possible to drive with only one fuel. Almost all petrol and diesel cars can be converted to use gas with the help of a retrofit kit. The downside to these gaseous fuels is the lower energy density than gasoline, which makes fuel tanks take up more space in the car. The carbon footprint of natural gas is about 20% and biogas up to 90% smaller than for fossil diesel. Exhaust emissions of both gases are about 20% lower than diesel. (Ahola 2021, 16-18.)

Ethanol, or ethyl alcohol, is also a substance that can be used as a transport fuel. It can be used as fuel alone or blended in petrol in various proportions. In Finland, it typically is mixed with petrol in 5% and 10% proportions. In order for a vehicle to use higher proportions of ethanol, such as 85%, the car must have either a FlexFuel or bi-fuel model. The FlexFuel model has a single fuel system that detects gasoline and ethanol to keep the engine running properly. The bi-fuel vehicle has two separate fuel systems, as described in the previous paragraph. (Ahola 2021, 20-21.) Ethanol is more widely sold in higher blend percentages in Brazil. The GHG emission reduction potential of conventional ethanol is 65-80% depending on calculation methodology. For lignocellulosic based ethanol the emission mitigation potential is up to 95%. (LCTPi 2015, 24-26.)

Biodiesel is a renewable alternative to conventional diesel, and it is made from organic material. Traditional biodiesel, FAME (Fatty-acid Methyl Ester), is prepared by esterification with methanol. (LCTPi 2015, 35.) Usual raw materials for FAME are soybeans, palm oil and sunflower seeds. Biodiesel should be produced from raw materials that do not compete with food production. The disadvantages of biodiesel are its high viscosity and low calorific value, which can be overcome by mixing it with fossil diesel. (Ahola 2021, 21-22.) Also, the storage stability is very challenging in the case of biodiesel. (Garraín et al. 2010). Overall diesel engines are more energy efficient than petrol engines and thus consume less fuel during the same journey. Diesel is widely used as a heavy-duty fuel, for which biodiesel is also a low-carbon alternative. (Ahola 2021, 21-22.)

In addition to biodiesel, there is existing renewable diesel, HVO (hydrogenated vegetable oil). HVO is produced by refining vegetable oils by hydrotreating, where oxygen is removed from the oil. (LCTPi 2015, 35.) HVO has properties closer to fossil diesel than FAME – including very high cetane number, higher low calorific value, and lower oxygen content. It can therefore be used without modification in vehicles normally running on diesel, meaning also heavier road transportation. Its storage capacity is also better than in traditional biodiesel. (Garraín et al. 2010.) The difference compared to FAME is that HVO uses waste and residues as raw materials. However, this means that the growth potential of HVO's production depends on the volume of the source industry. Example of HVO is NesteMY, which is 100% renewable diesel sold in Finland and its use is said to reduce the car driver’s carbon footprint by 90%. (Ahola 2021, 21-23.)

In a hydrogen vehicle, an electric motor moves the vehicle. The electric motor draws its energy from a fuel cell that produces electricity using hydrogen. Its advantages are fast refueling times and the fact that they do not require a heavy battery. However, hydrogen is not yet in commercial distribution for road transport. (Ahola 2021, 26.)

4.2.3 Alternatives for work machinery fuels

In work machines, the fuel options are very much the same as those used in road transport. Fuel containing 7% conventional biodiesel, FAME, can be used in all types of diesel vehicles, including non-road machinery. The maximum permissible concentration varies depending on the machine manufacturer. Whereas HVO can generally be used in concentrations of 100% and up to 30% on all machines without any problems. The biggest problem with the use of renewable diesel is its availability. In addition to diesel fuels, natural gas and biogas in pressurized or liquefied form, are used as the energy source in work machinery. Gas engines also have dual-fuel systems as alternatives, in which about 80-90% of the energy required is produced with gas and the rest with diesel. For example, this kind of tractors are a testing phase, but the problem is limited range due to the limited size of the machine's gas tank. In addition to bio-based fuels, electricity machines are an alternative. They are not very common in heavier mobile machines, but the trend of electrification is also visible on the side of work machines. An example is an electric hybrid wheel loader. The advantages of fully electric machines are their zero emissions, especially in indoor use. The reduction in emissions from the use of electricity and hybrid machines is highly influenced by the electricity utilized. By using renewable electricity, it is possible to reduce the climate impact of the machine significantly. (Helms et al. 2017, 21, 27-28, 30.)

5 Case study: Ponsse Plc

Ponsse Plc is a Finnish listed company manufacturing forest machines, founded in 1970 by Einari Vidgrén. Ponsse is at the moment one of the world's leading forest machine manufacturers, and by 2020 the family company has already sold more than 16,000 forest machines. They have active operations in 40 different countries. More than 60% of the company is owned by the Vidgrén family. (Ponsse, 2, 32.) Ponsse focuses on the manufacture, sale and service of forest machines that uses the cut-to-length (CTL) method. In the cut-to-length method, trees are already processed in the forest according to the intended use. The harvester dumps, prunes, measures, optimizes, and breaks the hull into customer-ordered commodity types at once. Commodity type refers to logs obtained from a single tree for different uses, such as various sawn wood, plywood and small logs, pulpwood, and wood for energy use. Today, CTL machines perform more than two-thirds of global mechanized industrial timber harvesting. Advanced CTL harvester automation maximizes value yield and minimizes the amount of loss. (Ponsse 2020, 3, 5.) In CTL method the fuel consumption is significantly lower towards harvested cubic meter than in whole tree harvesting because of fewer number of machines and CTL machinery is usually lighter. (Ponsse, 42).

5.1 Operations of Ponsse

Ponsse's operations are divided into production, and sales and services. Production takes place in Finland – forest machines are manufactured in Vieremä and information systems are manufactured in Ponsse’s subsidiary Epec in Seinäjoki. Ponsse manufactures different kind of harvesters, forwarders, combination machines and harvester heads. In Vieremä all forest machines and harvester heads are manufactured, from the manufacture of main components to assembly. Epec manufactures intelligent machine control systems for manufacturers of mobile work machines. (Ponsse, 2, 35.)

Ponsse Plc has twelve different subsidiaries all over the world – in Finland, Sweden, Norway, France, the United Kingdom, Ireland, Russia, China, Brazil, Uruguay, and the United States, which offer sale and service operations, and earlier mentioned Epec. Ponsse has over 200 service centers around the world including dealers. Usually with a spare parts warehouse is in connection with the service workshop. Ponsse also offers field maintenance, which allows service to be performed on site, in the forest. (Ponsse, 16, 33-35.) In addition to these twelve subsidiaries, Ponsse established new subsidiaries in Chile in the end of 2021 and in Czech Republic in the beginning of 2022. In the future, the subsidiaries will handle sales, spare parts and service operations in Chile and the Czech Republic. (Arvopaperi 2022.) The following figure shows all the company's subsidiaries, except the newest in Chile and Czechia, and dealers from around the world.

Figure 3. All locations of Ponsse’s offices, subsidiaries, and dealers in 2021 (Ponsse).

Around 80% from Ponsse’s turnover comes from exporting. The main operating areas, which are the Nordic countries, Russia, Germany, France, and North and South America, can easily be deduced from the distribution of subsidiaries and dealers from figure 3. (Ponsse, 33, 120-121.) The main market areas are located coniferous forest zones, for which the CTL method is best suited (Ponsse 2020, 14-15).

5.2 Strategic approach to sustainability

Ponsse's purpose is to offer sustainable solutions to customers in accordance with the goals of sustainable development. Sustainability is a way and an opportunity for new innovation and operating models, and Ponsse considers it important that their technology is part of a solution that can provide a good future for upcoming generations. They develop new sustainable solutions for the needs of the responsible forest industry and the company's vision is to be the most desirable partner in the responsible forest industry. Ponsse uses the ISO 14001 standard for their environmental management. Company’s environmental responsibility focuses on supporting sustainable forestry, product life cycle management and the sustainable use of natural resources. Their goal is to improve sustainable forestry and save the natural environment with innovative products and services such as the CTL method. They have also carried out life cycle assessments for their products to determine the environmental impact of their products. The most significant risks in environmental responsibility are recognized to be surprising environment accidents related to manufacturing operations, product’s usage, or maintenance services. (Ponsse 2020, 6-7, 30-31, 36, 41.)

5.3 Aim to be carbon neutral

During 2020, the Ponsse updated its mission and vision. Part of this vision is the pursuit of carbon neutrality in a long-term. This is what all solutions and functions are intended to strive for. In its annual report, company states that “We systematically strive for carbon neutrality in our operations and solutions.” During 2020, the company also calculated for the first time the carbon footprint of its parent company, Epec, Finland’s sales and service, and subsidiary in Sweden. Calculation was expanded in 2021 to cover all subsidiaries. (Ponsse, 8, 11, 30.) This carbon neutrality is a long-term goal, and no exact year when Ponsse strives to be carbon neutral has been set. It will be considered based on the roadmaps after this study is completed. The goal of carbon neutrality is seen as a guarantee for business in the future. Customers are already starting to pay attention to environmental aspects, and some of them are demanding to report some environmental measures, for example in connection with orders. At present, legislation on emissions is changing rapidly and restrictions will only be tightened in the future. The interviews raised the view that it is good to be at the forefront of combating climate change, both in terms of changes in legislation and the company's competitiveness. It can be assumed that companies will have to pay later if they miss this ongoing climate trend now. (Appendix I.)

5.4 Carbon footprint calculation

Ponsse's first global carbon footprint for Scope 1 and 2 emissions was calculated for years 2019 and 2020. The plan is to use year 2019 as a base year for further calculations. The calculation was done by a consult company, but the data collection was conducted at Ponsse during this thesis work. The carbon footprint is calculated according to the GHG Corporate Standard. Greenhouse gas emissions inventory includes all six GHGs – CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. Only Scope 1 and Scope 2 emissions are included in the calculation, and Scope 3 emissions are excluded. Also, all Ponsse's sites are included in the calculation from all different subsidiaries. In the greenhouse gas inventory market-based approach was used. In the calculation applies five principles of standard as far as possible. Biogenic carbon dioxide emissions are calculated but reported separately. At five sites, energy consumptions were determined by area of the building and the specific energy consumption of the building's type. Electricity consumption in one place was estimated on average electricity consumption of other sales and service locations. For refrigerant fugitive emissions, the loss of 2% was assumed to be from the total amounts of refrigerants that circulates in systems. (LCA Consulting 2021, 6, 9-11, 64.)

5.4.1 Results of the calculation

Total carbon footprint for Ponsse Plc for 2019 was 7,972 t CO_2-eq. and for 2020 it was 4,657 t CO_2-eq. These values do not include carbon dioxide emissions from biogenic sources. The biogenic emissions were separately reported for both years and the amount for 2019 was 2,863 t CO_2-eq. and for 2020 it was 2,445 t CO_2-eq. The absolute climate impact of Ponsse's global operations is therefore the carbon footprint added to biogenic emissions. (LCA Consulting 2021, 23-26.) These climate impacts for both years from Ponsse's global operations is presented in the figure below.

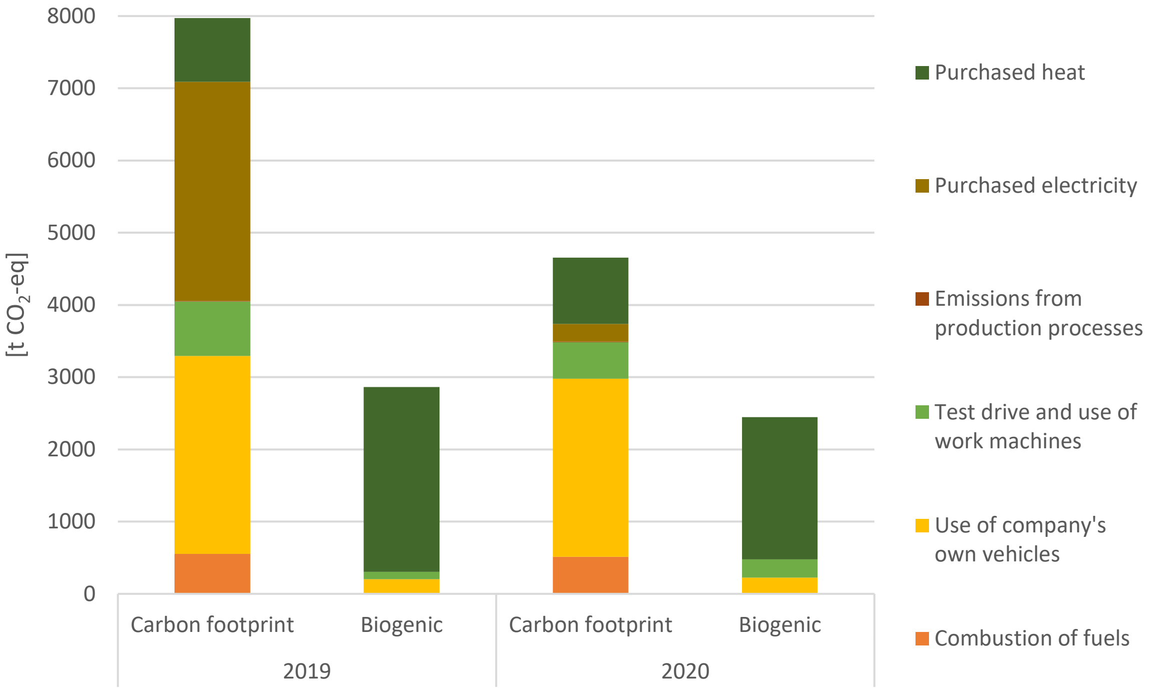

Figure 4. Ponsse's carbon footprints and biogenic emissions in 2019 and 2020 (LCA Consulting 2021, 23-26).

In the figure 4 and the coming figure 5, combustion of fuels means fuels used in generators, pressure washers and for other applications, and use of company's own vehicles includes usage of passenger cars, pick-ups, vans, and trucks. Test drive and use of work machines consists of emissions from forest machinery test drive, and usage of forklifts and wheel loaders. Emissions from productions processes means climate impact from fugitive refrigerant emissions from factory. Ponsse's production operations do not involve stages in which large amounts of greenhouse gases escaped and therefore fugitive emissions are very small or almost non-existent. Lastly impact from purchased electricity and heat is coming from production of purchased and used energy. The share of Scope 1 and 2 emissions in the carbon footprint for 2019 was approximately the same, but in 2020 the impact of Scope 1 emissions was significantly higher, around 75% of total carbon footprint. (LCA Consulting 2021, 13-21.) The following figure shows in more detail about the effects of different functions on the carbon footprint of each year.

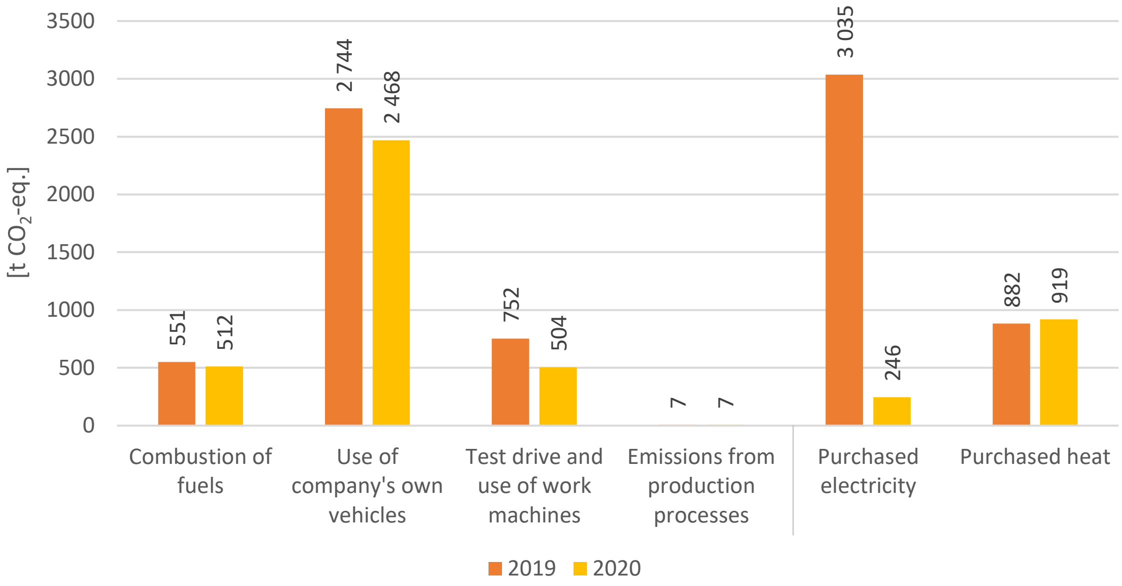

Figure 5. The impact of different operations on Ponsse's carbon footprint (LCA Consulting 2021, 27).

The last figure shows the shares of parent company and twelve different subsidiaries in Ponsse's carbon footprint. In the figure the parent company operations are production factory, and research and development (RD) in Finland.

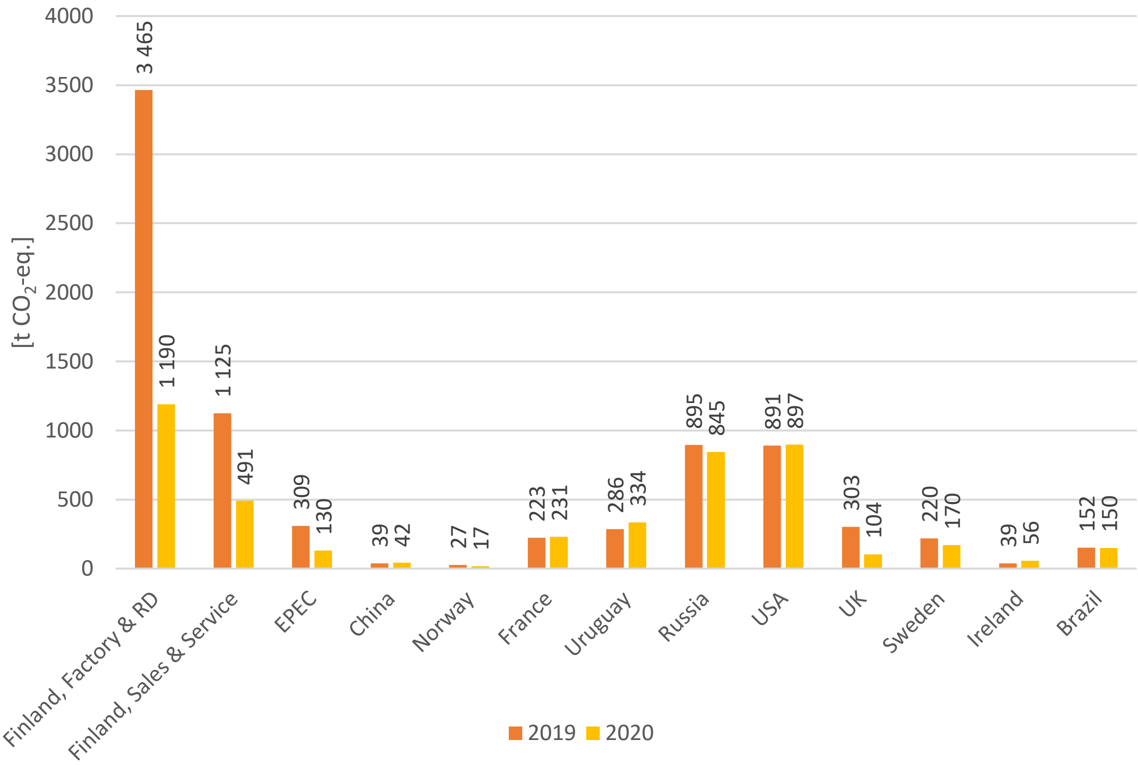

Figure 6. Emissions from each subsidiary in tonnes of carbon dioxide equivalent in 2019 and 2020 (LCA Consulting 2021, 44-45).

In the calculation, the distributions for the effects of the different activities on the carbon footprint were obtained for each subsidiary. They largely followed the same formula – the largest impact on all other subsidiaries, except Finland's sales and service and Epec, came from the use of vehicles. In Finland's sales and service, and Epec had the largest impact on the carbon footprint from purchased heat. For the factory and RD, the biggest impact was on the use of vehicles. (LCA Consulting 2021, 44-45.)

5.4.2 Analyzation of results

As can be seen from the figure 4, the carbon footprint decreased by almost a third from 2019 to 2020. The reason for this can be found from the figure 6, which shows that the emissions of the Finnish operations (factory & RD, sales & service and Epec) decreased significantly, by more than half. This is a result of the fact that the Finnish facilities, which are owned by Ponsse, switched to purchasing and using certified 100% hydropower. According to the figure 4, most of the carbon footprint in 2019 came from electricity, but because of the above-mentioned change in 2020, around half of the carbon footprint came from the use of company's own vehicles. Which included the use of passenger cars, vans, pick-ups, and trucks.

According to the figure 5, the second largest impact on the carbon footprint of Ponsse's operations in 2020 was purchased heat, followed by the test drive and use of work machines, and the combustion of fuels. The impact of purchased electricity is second smallest, and the smallest impact is from production processes' emissions, which included fugitive refrigerant emissions. Only the impact of heat on the carbon footprint increased from 2019 to 2020 and the impact of emissions from production processes remained the same. The carbon footprint of every other operation decreased.

Perhaps a little surprisingly, the factory and RD accounted for only about a third of the total carbon footprint in 2020, as shown in figure 6. Finland's service and sales, and subsidiaries together accounted for about two-thirds of the carbon footprint. Of the subsidiaries, Russia and the US had the largest impact on the overall result. Subsidiaries in China, Norway and Ireland had very small carbon footprints. On the other hand, it should be noted that these subsidiaries vary greatly in size, turnover, and number of employees. In Finland's sales and service, and Epec largest impact on carbon footprint was from purchased heat and other subsidiaries it was use of vehicles. The reason for this is that the distances traveled in Finland are shorter than in Russia, for example, and the need for heating is greater than in countries further in south. For example, subsidiaries in China, Uruguay and Brazil have no need for heating at all.

The total climate impact from Ponsse's operations, i.e., the carbon footprint summarized with biogenic emissions, also decreased by approximately 3,730 tons of CO_2-eq. According to the figure 4, most of the biogenic emissions came from purchased heat. Biogenic emissions also consisted of the bio-proportions of fuels used in vehicles, test drive and use of work machines.

5.5 Activities done earlier to reduce emissions from operations

Solar panels have been installed on the roof of the plant in 2017 to reduce the amount of electricity purchased. In connection with the expansion of the factory, a bitumen coating was placed on the roof, which makes the air on the roof cooler, which reduces the energy consumption of the air conditioner. In 2019, renewable HVO diesel was switched to production to reduce fossil emissions, and in 2020, all Finnish offices switched to use certified 100% renewable electricity. In production, the lighting has been replaced by light-emitting diode (LED) luminaires with motion sensors. (Ponsse 2020, 43.) Other changes made in 2020 – replacement and increase of insulation in the upper floor of Ponsse's factory in Vieremä, as well as increase in wall insulation, renewal of the lighting of the front frame welding house stalls, renewal of building automation, and review of all air conditioning machines in addition to Vieremä and in Kouvola. In addition, LEDs for rental properties were changed to a form of lighting in Pirkkala. (Appendix I.) By decreasing energy consumption, emissions from purchased energy have been reduced.

An energy review for the Kouvola service point was made in 2019, based on which various energy saving projects have been carried out in 2020. Actions that have taken place include a change in the way the door curtain lifting is used during the summer, a reduction in the partial airflow of the air handling units and changes in the control of the exhaust fans and an earlier time control with these changes. Energy review makers estimated that emission reductions of these measures were a total of 32.8 t CO_2. Behind the energy reviews are energy efficiency agreements in which Ponsse is involved as part of the technology industry. The agreements oblige certain companies to monitor their energy consumption and carry out energy audits. (Appendix I.)

6 Roadmap toward carbon neutral Ponsse

Main target of this work is to create a carbon neutrality roadmap for Ponsse's parent company (factory and RD) and subsidiaries. At the end of this section, two proposals for roadmaps are presented – one to the parent company and another to subsidiaries. Done emission reduction calculations are also shared between the factory and subsidiaries. More detailed subsidiary-specific emission reduction calculations and carbon neutrality roadmap proposals will be submitted only to Ponsse. The roadmap proposals are based primarily on reducing the fossil carbon footprint and, secondarily, on reducing absolute emissions.

Emission reduction opportunities are addressed by activity in the order that they were presented in section 5. In addition, the individual measures that could achieve significant emission reductions are treated as separate entities. Changes in emissions and annual costs due to activities are reported compared to 2020 levels. A negative change (-) in the tables means a decrease to the 2020 values and a positive (+) means an increase. Changes in emissions are reported in tons of carbon dioxide equivalents for the fossil carbon footprint, and biogenic and absolute emissions. The emission reductions are once occurring and would affect in the year in which they are implemented. In addition, the tables show the effect of the measure as a percentage of the Ponsse concern's carbon footprint in base year (2019), which was 7,972 t CO_2-eq. This is only intended to illustrate the magnitude of the change. Changes in annual costs include only direct costs, such as fuel and energy costs. Indirect costs are disregarded, such as possible reductions in working hours.

For the factory, biogas is being considered as an alternative in many cases, although it is not yet available. However, a biogas plant is planned to come in Vieremä and resulting biogas would be used as a reserve for district heating and later in electricity generation. A biogas refueling point is also planned, allowing vehicles and forklifts to be refueled. (Kangas 2021.)

6.1 Method description

The emission reduction measures to be considered are those that emerged from the workshops and the interviews. A total of twelve 1.5-hour workshops were held, attended by the management of the subsidiaries and business areas, and the HSE (Health, Safety and Environment) team. Seven 1-hour-long interviews were conducted, and they were held for the supervisors and managers of the various departments of the factory. Emission reduction measures are examined by Scope 1 and 2 category and, more specifically, by function.

The workshops and interviews highlighted the need to add general guidance and change existing practices. This includes, among the others, switching off lights and electrical equipment when leaving the room, reducing unnecessary driving, and harmonizing working hours. On the other hand, the automation of lift doors, for example, have no benefit if they are misused. The table below shows the emission reduction measures mentioned in the workshops and interviews. It also shows figures for how many times it was presented as a way to reduce emissions. Activities not related to Scope 1 and 2 emission reductions are excluded from the table. The measures that have emerged focus on those that can be used to calculate the achievable emission reductions. For this reason, the use of energy-saving and properly sized equipment, the transition to better lighting technology and the minimization of compressed air system losses have been omitted from the table.

Table 4. Emission reduction measures mentioned in workshops and interviews.

	Emission reduction operation	**Times it raised in workshops**
Scope 1	Low-emission transport fuels/modes	10
	Route optimization and utilization of remote control	6
	Low-emission energy sources for work machines	4
	Low-emission options for other fuel applications	4
	Reducing test drives at logging sites	2
	Water-based paints in paint shop	2
Scope 2	Own electricity production	8
	Heat recovery and recycling, and improving insulation	6
	Automated, energy-saving and properly sized systems/equipment	5
	Low-emission electricity	2

For Scope 1 emissions, the means of reduction became the replacement of road transport fuels, either renewable, natural gas, electricity, or in the future hydrogen. New solutions would be introduced as their distribution infrastructure develops in each area. In addition, the development of the vehicle fleet should take place in line with the current vehicle renewal cycle. Reducing mileage could be achieved by rationalizing driving, always arranging maintenance at the customer's nearest location, and utilizing remote management for where possible. Options for work machines would be renewable fuels and electrical or hybrid machinery. These same renewable energy sources emerged as alternatives to other fuel usages. Regarding the test drives at forest sites close by the Vieremä production plant, the question arose as to whether it was needed, as reducing it would decrease the fuel used for transport. Switching to water-based paints, on the other hand, would reduce the amount of energy required for drying and thus reduce emissions from burned fuels.

With regard to Scope 2 emissions, increasing solar energy production with solar panels and heaters emerged as reduction measures. Reducing the need for heating would be achieved through heat recovery and recycling, as well as improving the insulation of buildings. Alternative heating methods to decrease emissions include geothermal heat, heat pumps, natural gas, and district heating from biogenic sources. Purchased low-carbon electricity could be from renewable and nuclear sources.

In the emission reduction calculation, the emissions of the measure under study have been calculated and deducted from the 2020 values. Thus, the possible magnitude of the reduction has been determined. Fuel and energy costs have been determined by country, as prices vary widely around the world. The fuel and energy costs of 2020 and reduction actions have been calculated based on the most recent or 2021 average fuel and energy prices collected from suppliers, internet sources and employees of subsidiaries. Based on these, potential annual savings or costs have been estimated. Instead of actual 2020 prices, the latest prices have been used to be able to compare costs, as fuel and energy prices have risen since 2020. The sources of the data used in the emission reduction calculations are presented at the end of the work in appendix II.

6.2 Possible Scope 1 emission reduction operations

In 2020, 75% of Ponsse's global carbon footprint came from Scope 1 emissions, the largest impact of which came from the use of vehicle fuels as could be seen earlier from figure 5. The effects of other fuel combustion, as well as the use of work machines and the test drive of forest machines, have a smaller impact. Emissions from fuels can be decreased by reducing fuel use and consumption, switching to lower-emission alternatives, or changing energy source that the machine or vehicle work with.

6.2.1 Reducing use liquefied petroleum gas and changing fuel for paint shop

In 2020, the components painted in the factory's paint shop were dried with heat, which was produced by burning liquefied petroleum gas. Its impact on the carbon footprint was 177.6 t CO_2-eq. which was about 15% of the carbon footprint of the factory and RD. This can be reduced either by decreasing the amount of fuel burned or by changing the fuel used. The need for heating can be decreased by reducing the required temperatures or by shortening the time the oven produces heat or is on. The table below shows the change in emissions from solvent-based paints to water-based paints. According to the Veiste’s (2009, 17) study the energy costs of using water-based paints are about half that of solvent-based paints. This information has been used in the calculation. It should be noted that the values are therefore indicative only and not based on accurate data.

Table 5. Reduction of emissions by replacing solvent-based paints with water-based in paint shop.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Change to water-based paints	-63.3	-0.8%	0.0	-63.3	-22,500 €

Changing the amount of paint used in 2020 to water-based would reduce the carbon footprint by 63.3 t CO_2-eq., which equals to 0.8% of the base year's fossil carbon footprint. There would be no change in biogenic emissions, so reduction in absolute emissions would be 63.3 tons of CO_2-eq. The emission reduction is once occurring and would affect the year in which it is implemented. The savings in fuel costs due to the change would be 22,500 € per year. The annual savings do not include possible changes in the price of paints, or costs of changes required in the systems.

Another option is to change the fuel used for heat production. The nearest fully renewable alternative is liquefied biogas and conventional biogas. If the same amount of heat were produced with biogas, the absolute climate impact would not change significantly, but the resulting emissions would be mainly biogenic. By using these fuels, it would be possible to reduce the impact of paint shops fuel to the carbon footprint almost to zero.

Table 6. Change in emissions when switching to use biogas and liquefied biogas in paintshop.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Liquefied biogas	-154.6	-1.9%	+177.0	+22.4	-
Biogas	-153.1	-1.9%	+148.7	-4.5	49,400 €

These fuels have different energy contents; liquefied biogas have almost same energy content and density than liquefied petroleum gas. But biogas has almost half smaller calorific value, which means more biogas is needed to produce the same amount of energy. According to Juutila, because of change into biogas, the burner nozzles would have to be modified, which would cost a few thousand euros. The piping and equipment do not need to be modified, but the change in calorific value is compensated by increasing the pressure coming on the burner. If the old, liquefied petroleum gas system is to be left as a backup system, a small change must be made to the burner regulators to allow the fuel to be changed in demanding situations. (Appendix II.) The increase in fuel costs would be around 49,400 € annually, calculated on the required energy that was consumed in paint shop in 2020. For liquefied biogas there was not price available.

6.2.2 Low-emission options for combusted fuels used in other applications

Fuels are also used for other purposes, such as generators, washers, various tools, and burned to heat. It is not possible to replace most of these with electric ones, so renewable fuels are a viable option. The table below shows emission changes of the replacement of fossil fuels in those other applications with renewables by replacing diesel with HVO, light fuel oil with renewable fuel oil and propane with bio propane. Changes include the exchange of fuels used in the France to bio propane, UK to renewable diesel, and Finnish facilities to renewable fuel oil.

Table 7. Change in emissions when switching into renewable fuels in other applications.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD	-12.4	-0.2%	+12.7	+0.3	+1,800 €
Subsidiaries: Finland, UK & France	-125.2	-1.6%	+127.6	+2.4	+11,300 €

In the case of subsidiaries, the carbon footprint would be seemingly reduced, but the change would not decrease absolute emissions. Like it was assumed the annual costs of renewable fuels will increase compared to fossil alternatives.

6.2.3 Reducing driven mileage and switching fuels for vehicles

In 2020 most of the carbon footprint, 2,464 t CO_2, was coming from use of road vehicles. Options to decrease vehicle emissions include reducing mileage and changing vehicle fuel. Reducing the distance traveled can be achieved, among other things, by optimization and route planning, as described earlier in section 4.2.1. The table below shows the reductions if the optimization would reduce vehicle mileage by 10% (Skydel 2014). The values include deductions for all vehicle categories.

Table 8. Reductions by optimizing 10% of driven milage off.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD	-38.2	-0.5%	-13.7	-51.9	-41,900 €
Subsidiaries: All	-195.5	-2.5%	-14.3	-209.8	-102,500 €

Another option to reduce vehicle emissions is to change fuel. There are more options for smaller vehicles than for heavier ones and therefore these are considered separately. The table below shows alternatives to the parent company's and different subsidiaries' passenger car fuels, as well as the emission reductions and costs of the changes. Emissions from hybrids have been calculated assuming 70% electric or gas driving and the remaining 30% on secondary fuel. The effects of the fuel change have been calculated from the reduced mileage according to Table 8.

Table 9. Emission reduction possibilities in passenger car in alternative fuels.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD					
Renewable diesel	-7.7	-0.1%	+12.2	+4.5	+800 €
Biogas	-5.2	-0.1%	+3.0	-2.2	-700 €
Electricity	-5.4	-0.1%	-0.6	-6.0	-3,000 €
Subsidiaries: Finland & Epec					
Renewable diesel	-5.6	-0.1%	+5.8	0.2	+700 €
Natural gas	-1.9	-0.0%	-0.4	-2.3	-800 €
Biogas	-4.1	-0.1%	+1.1	-2.9	-1,000 €
Electricity	-4.2	-0.1%	-0.4	-4.6	-2,300 €
Subsidiaries: Sweden & Norway					
Renewable diesel	-67.0	-0.8%	+68.0	+1.0	+15,400 €
Electricity	-47.0	-0.6%	-19.0	-66.0	-40,500 €
Subsidiaries: France & Russia					
Natural gas	-89.5	-1.1%	-8.8	-98.3	-47,700 €
Electricity	-124.1	-1.6%	-8.8	-132.8	-38,900 €
Subsidiaries: Brazil					
Ethanol	-59.9	-0.8%	-1.5	-61.3	-4,300 €
Subsidiaries: UK & China					
Electricity	-6.1	-0.1%	-0.5	-6.5	-2,100 €

Of these, the largest reductions in absolute emissions are in electric hybrid vehicles. The introduction of electric cars requires a review of the adequacy of charging infrastructure in the area. Emissions from electric hybrid vehicles varies depending on the electricity used to charge the car if it is produced from renewables, emissions are lower than electricity produced from fossil sources. The annual mileage of the subsidiaries in Sweden, France and Russia is so large that it is necessary to consider whether renewable diesel or natural gas is a more sensible option than electric. Switching to use electric vehicles has also the biggest annual savings in fuel costs. Presented annual costs and savings include only changes in fuel costs. Of the vehicle acquisition costs, electric cars are a bit higher than diesel and petrol vehicles in all subsidiary countries. In Brazil, ethanol cars are at the same prices as petrol vehicles, the same in Russia and France as the prices of gas cars, if not even a little cheaper. In addition to these, Ponsse should invest in electric car charging points for its facilities. The prices of these vary from country to country, for example in Finland the energy company

Väre installs charging stations in detached houses at a price 1,600 €, but at a lower price for companies (Väre).

There are currently very few alternative fuels worldwide for larger vehicles, such as pick-ups, vans, and trucks. In the Nordic countries, renewable HVO diesel is an alternative to diesel, and in the US, there is B20 diesel on the market, of which 20% is bio-based. The changes in emissions when switching to these are shown below. The switch for renewable diesel in factory does not include trucks that drives forest machines to test logging sites, which is only around 10% of trucks' total mileage. Those will be presented later with test drive reductions. Switching to use B20 biodiesel in the US includes only pick up vehicles because there are options for biodiesel utilizing motors for those.

Table 10. Changes by switching fuels for larger vehicles.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD					
Renewable diesel	-368.0	-4.6%	+383.1	+15.1	+47,200 €
Subsidiaries: Finland, Sweden & Norway					
Renewable diesel	-173.3	-2.2%	+177.4	+4.2	+28,000 €
Subsidiary: USA (only pick-ups)					
B20 biodiesel	-52.9	-0.7%	+59.6	+6.8	-6,600 €

These options therefore reduce the fossil carbon footprint, but not absolute emissions. Annual fuel costs would decrease in the USA as biodiesel is cheaper than fossil, but then again B20 biodiesel utilizing pickup vehicles are slightly more expensive than conventional ones. In the future, however, vehicle technology will certainly evolve towards lower-emission forms of heavy road transport. There are already electric hybrid pick-up trucks and natural gas vans on the market, but at present their carrying capacity is not sufficient for Ponsse's current operation mode and need.

Although there are not yet very low-emission alternatives for heavy vehicles, the need to consider large cars can be considered as a solution. In the USA, for example, larger pick-up vehicles are used instead of cars. The table below shows the reductions in emissions if the pick-ups used in subsidiary in the USA were to be replaced by normal passenger cars or electric hybrid vehicles. In electric hybrid vehicles, it is assumed that 70% of driving is electric powered and the rest is petrol.

Table 11. Changes by switching used pick-ups to smaller vehicles in USA's subsidiary.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Passenger cars	-146.5	-1.8%	0.0	-146.5	-55,100 €
Electric hybrid vehicles	-192.0	-2.4%	0.0	-192.0	-67,300 €

It is seen that changing one's own habits can also significantly reduce emissions and annual fuel costs. Do you need to drive a bigger, more consuming vehicle if you can also travel the same distance in a smaller vehicle? This is something that should be considered also in other subsidiaries in the future.

6.2.4 Switching to renewable fuel oil and shortening test drives

Ponsse tests its most of machines in forest sites in the vicinity of the factory where trucks transport the machines and some in the test track next to the factory. At the moment, Ponsse does not accurately measure the amount of fuel consumed during test runs, so the carbon footprint calculation is based on the assumption that approximately 75% of the fuel refuelled on the production line is consumed during the test run. By refining the measuring of this fuel consumption, it would be possible to detail the calculation result and possibly reduce the amount of carbon footprint.

In the initial situation of this calculation, it has been assumed that every forest machine completed in 2020 has been tested at a forest site, as only a little proportion of machines goes to the test track. It is possible to reduce the amount of fuel used for the test run and for transporting the machines there, and thus also the emissions. By reducing the time taken for the test run, it is possible to decrease fuel consumption in test machines. One possibility would be to reduce the number of machines to be tested at logging sites and test those closer to the factory on the test track. The table below shows the emission reductions if only 20% of the machines completed in 2020 went to logging sites for testing, of which the duration and transport distance would remain the same as now. The remaining 80% of the machines would go to the test track, where the test run time would be half as short as it is now, which would also reduce the amount of fuel needed to refuel the machine (Appendix II). If the test track is in the vicinity of the factory, the transport phase of the machines would be eliminated. The trucks drive also other trips than just machines to the test sites, and it is not possible to get exact mileage for transporting machines to testing. It is estimated that the transport of the machines to test runs is about 10% of the total truck times.

Table 12. Changes if 80% of machines goes on the test track where the test run time would be half from current.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Forest machinery, renewable diesel	-0.4	-0.0%	-55.0	-55.4	-41,300 €
Forest machinery, light fuel oil	-147.0	-1.8%	0.0	-147.0	-62,000 €
Trucks, diesel	-35.9	-0.5%	-5.7	-41.6	-32,600 €
Total	**-183.3**	**-2.3%**	**-60.7**	**-244.0**	**-134,900 €**

Of course, the cost would be incurred in designing and constructing the test track. The cost of this is currently impossible to estimate. If the test track were still paved in some way, it would reduce the need to wash the machines, which in turn would reduce water consumption and shorten the manufacturing time by eliminating one step at a time.

The reduction in the carbon footprint of the previous table could be enhanced by switching the remaining fuels to renewables. Renewable diesel is already being refueled in machines, but it could also be used in trucks to transport machines. In addition, Neste has introduced 100% renewable fuel oil to the market as an option for fossil light fuel oil that could be used in test machines (Neste). Table 13 below shows the previously mentioned situation and in addition the fuels have been switched to renewable alternatives.

Table 13. Reductions when 80% of the machines on the test track, where the test run time would be half from current and the fuels would be changed to renewables ones.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Forest machinery, renewable diesel	-0.4	-0.0%	-55.0	-55.4	-41,300 €
Forest machinery, renewable fuel oil	-366.2	-4.6%	+225.1	-141.1	-23,000 €
Trucks, renewable diesel	-44.8	-0.6%	+3.8	-41.0	-31,500 €
Total	**-411.4**	**-5.2%**	**+173.9**	**-237.5**	**-95,800 €**

A comparison of the tables shows that the fossil carbon footprint would be significantly reduced by switching to renewable fuels. However, for absolute emissions, the change would not be huge meaning. With renewable fuel options being more expensive than at present, the annual savings would be lower than in table 12.

If it were possible to reduce the time of the test run on the test track or to test even fewer machines in the forest, the emissions from the original forest test drive would be significantly reduced. The table below shows the changes in emissions if only 10% of the completed machines go to forest in test sites and the remaining 90% to the test track, but the test run on the track would be shortened to a quarter of the original (Appendix II). In addition, in the situation in the table, the remaining fuel quantities have been replaced by renewable alternatives.

Table 14. Changes if 90% of the machines on the test track, where the test run time would be only a quarter of the original and fuel change to renewables.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Forest machinery, renewable diesel	-0.6	-0.0%	-92.9	-93.5	-70,000 €
Forest machinery, renewable fuel oil	-248.0	-3.1%	0	-248.0	-92,000 €
Trucks, renewable diesel	-44.8	-0.6%	-1.7	-46.5	-36,100 €
Total	**-293.4**	**-3.7%**	**-94.6**	**-388.0**	**-198,100 €**

When considering emission reductions for a test drive, it should be noted that they are based on the scenarios made, and the calculations should be refined when more detailed information is available on, for example, the number of machines going to test felling and the duration of testing on the test track. Also, only the annual savings in fuel costs have been considered in the calculation, and indirect costs, such as reduced working hours due to the change, have not been considered. The number of working hours would be decreased as the test run time and the need for transport for test drive would be reduced. If the test track were paved, the washing step would be eliminated, which would also reduce the workload at this point. Shortening the test run and omitting the washing phase would also shorten the production lead time.

6.2.5 Alternative fuels for work machines

For work and forest machines, the fuel options are for different light and heavy machinery. In the case of light work machines, i.e., forklifts, it is possible to switch to electronic versions in all subsidiaries. There are many more biobased alternative fuels in the Nordic countries and the UK than in other countries. In France, liquefied biogas or bio propane is also an option. The following table shows the emission reduction fuel options for the forklifts. For electric forklifts, the driving time on a single charge, 10 hours, is calculated as the average of the intervals reported by Oksanen and Siitonen (2015). The electricity required to charge one forklift is determined by using information on the maximum capacity and volts of a battery of forklift with a lifting capacity of 1.5 tons. The lifting capacity has been selected according to the most common forklifts used. The need for electricity may in reality be lower or higher depending on the forklift used.

Table 15. Changes in forklifts' emissions in alternative fuels.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD					
Liquefied biogas	0.0	-0.0%	-1.0	-1.0	-
Electricity	0.0	-0.0%	-11.7	-11.7	-4,200 €
Subsidiaries: Finland, Sweden, Norway & UK					
Renewable diesel	-12.7	-0.2%	+8.0	-4.8	+4,400 €
Liquefied biogas	-11.4	-0.1%	+6.8	-4.6	-600 €
Electricity	-12.2	-0.2%	-2.3	-14.4	-3,500 €
Subsidiaries: France					
Liquefied biogas	-0.1	-0.0%	+0.1	0.0	< 100 €
Electricity	-0.1	-0.0%	0.0	-0.1	< 100 €
Subsidiaries: Russia, China, USA & Brazil					
Electricity	-18.6	-0.2%	0.0	-18.6	+2,700 €

Of these, switching to electric forklifts has the greatest potential for reducing emissions in terms of carbon footprint and absolute emissions. The annual savings in fuel costs are also the biggest when switching to electricity. The use of electricity in forklifts brings higher annual costs in Russia, the USA and Brazil, as the annual charging volumes would be high. In addition, fossil fuel costs in these countries are cheap. For heavier machines, electricity or hybrid alternatives do not yet exist, but are mainly limited to bio-based fuels such as renewable fuel oil and HVO diesel. The potential for reducing emissions by switching to heavy-duty fuels is shown below.

Table 16. Emission reduction possibilities for wheel loaders and forest machines.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD					
Renewable fuel oil	-25.5	-0.3%	+26.2	+0.7	+4,500 €
Subsidiaries: Finland & Sweden					
Renewable diesel	-12.6	-0.2%	+4.0	-8.6	+2,300 €

Switching to renewable fuels would not reduce absolute emissions much but would shift emissions from the fossil carbon footprint to biogenic emissions. The possibility of reducing absolute emissions in the future could be gas or electric hybrid wheel loaders, which are currently under development and testing.

6.2.6 Switching to more climate friendly refrigerants

In 2020, refrigerants were reported only from the factory and accounted for 7.1 tons of carbon dioxide equivalent. In the carbon footprint calculation, the effect of refrigerants can be taken into account either based on the actual reported leakage rates or, alternatively, the average refrigerant leakage of different cooling systems. (Appendix I.) Ponsse's calculation used a leakage factor based on tabular data, so the opportunity to reduce the carbon footprint of refrigerants is to start monitoring and reporting actual leaks. It is possible to reduce the climate impact of refrigerants either by minimizing leaks and losses, but this is not always possible. Thus, the main way to reduce the resulting carbon footprint is to replace the refrigerants used with those with lower-GWP factors. In this calculation refrigerants were replaced with lower climate impact options according to table 3 presented earlier.

Table 17. Emission reductions by switching to lower-GWP refrigerants.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Lower-GWP refrigerants	-5.7	-0.1%	0.0	-5.7	-

With these changes, the impact of fugitive emissions of refrigerants would be only 1.4 t CO_2-eq. in terms of carbon footprint. This could be reduced in the future when the development of new, even lower-climate impact refrigerants will happen. Refrigerant prices were not received for this calculation.

6.2.7 Changes independent of own actions

However, making emission reductions do not always depend alone on individual companies or persons. For example, bio-based fuel alternatives are not yet available in Russia and China. On the other hand, although there are alternatives to vehicle fuels in the Nordic countries, their distribution network is still concentrated in the metropolitan areas and there may be as many as thousands of kilometers between filling stations. In these cases, switching to a new, lower-emission fuel are not possible. Governments have a major role to play in expanding and deploying new, lower-emission fuels. Increasing the share of biofuels was also mentioned in the climate strategies of many countries. An example of this is in 2019 introduced a proposal by the Swedish Ministry of Infrastructure (Infrastrukturdepartementet 2021) that included increasing the bio-shares of road transport fuels, petrol, and diesel, annually until 2030. According to the proposal, bio-shares will be increased so that in 2030, 28% of petrol and 66% of diesel will come from renewable sources. (Infrastrukturdepartementet 2021, 6.) With these increases in bio-shares, the fossil carbon footprint of the Swedish subsidiary would decrease by 58.8 t CO_2-eq., biogenic emissions would increase by 72.0 t CO_2-eq. and absolute emissions would grow 13.3 t CO_2-eq. This would mean that the subsidiary's carbon footprint would be reduced by more than 65% compared to 2020 levels without any action being taken to reduce emissions by themselves.

Currently, there is no alternative power source to diesel for heavy vehicles and work machines. Therefore, reducing emissions from heavy road transport and wheel loaders is still difficult. Electric hybrid pick-up vehicles have appeared on the market, while wheel loaders with gas and electric hybrid machines are under development in the testing phase. In the case of heavy-duty road vehicles, it must be waited for the development of vehicle technology and the solutions they bring to reduce emissions.

6.3 Possible Scope 2 emission reduction operations

According to the earlier presented figure 5, only 25% of Ponsse's global carbon footprint came from Scope 2 emissions in 2020. Purchased heat accounted for the largest share, while purchased electricity accounted for only one-fifth of the Scope 2 category and 5% of the total carbon footprint of 2020. Emissions of purchased energy can be reduced by decreasing energy consumption or switching to use renewable energy.

6.3.1 Reducing electricity consumption and switch to renewable electricity

In 2020, the impact of purchased electricity on the carbon footprint was 246.0 t CO_2-eq. The possibilities for reducing this are to decrease electricity consumption and switch to low-emission electricity. The table below shows the emission reduction potential if improving energy efficiency could reduce electricity consumption by 3% (Soininen 2021). Emission factors for electricity purchased in 2020 have been used in the calculation. In the case of the factory and RD, the reduction will be small because it uses only electricity produced from renewable sources, the emissions of which are already low.

Table 18. Reductions if increasement in energy efficiency would reduce electricity consumption by 3%.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD	-0.3	-0.0%	0.0	-0.3	-24,900 €
Subsidiaries: All	-7.1	-0.1%	0.0	-7.1	-13,700 €

Due to the electrification of machinery and vehicles, it is unlikely that electricity consumption will decrease, at least significantly. Likely electricity consumption is on the rise as efforts are made to get rid of combustion of fuels. In addition to decreasing electricity consumption, another option is to switch to carbon-free electricity. Renewable electricity is already being purchased for Finland’s factory and RD, and sales and service offices. It is currently available for purchase in Sweden, Norway, Brazil, France and the UK (currently for households only) (Appendix II). The effects of switching to renewable electricity on emissions have only been calculated for these countries mentioned above.

Table 19. Emission reductions by switching to use 100% renewable electricity.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Subsidiaries	-14.5	-0.2%	0.0	-14.5	+11,000 €

For these subsidiaries, switching to renewable electricity would not reduce emissions much, because most of the electricity already purchased is produced in zero-emission energy sources, as renewables and nuclear power. The biggest change in the purchase of green electricity would be in those subsidiaries where electricity's grid mix is mostly generated from fossil sources. But in Russia, the USA and China, for example, there is no possibility to choose the source of the electricity purchased. In countries where the purchase of renewable electricity alone is not possible, one could consider increasing own electricity generation. However, this requires a more site-specific examination of the potential, cost, and rationality of electricity generated at the site.

6.3.2 Decreasing heating demand and changing to use renewable heat

Emissions from purchased heat formed 918.9 CO_2-eq. tons of the 2020 carbon footprint. Purchased heat includes emissions from district heating and natural gas distributed through pipelines. Emissions from purchased heat can be decreased by reducing the need for heating energy or switching to buy district heat produced from renewable energy sources. Reducing heat consumption is possible by adjusting the energy equipment, recovering the waste heat, and minimizing the amount of heat escaping, for example by improving the insulation. Emission reductions related to heat are presented below if energy efficiency could be reduced by 10% by improving energy efficiency (Soininen 2021). The calculation assumes that the heat would be produced with the same energy sources as the heat purchased or burned in 2020. Decreasing the need for heat also reduces the need for electric heating, but its magnitude cannot be distinguished from other electricity consumption and has therefore been ignored. Subsidiaries that do not use heating or are heated by electricity are excluded from the table. Meaning that Ireland, China, Brazil and Uruguay are excluded from the table. The reduction of emissions from fuels burned in own boilers is marked in italics in the table. Their emission reductions are not included in the Scope 2 but in the Scope 1 category.

Table 20. Changes in emission if energy efficiency increasement would drop heat consumption by 10%.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD	-13.0	-0.2%	-149.2	-162.3	-33,500 €
Subsidiaries					
District heat	-78.9	-1.0%	-48.3	-128.2	-23,400 €
Burned fuels in own boilers	*-18.6*	-0.2%	*-1.8*	*-20.4*	*-5,300 €*

Another option is to switch to using heat produced with the lowest emission sources. In Finland, it is possible to buy district heat produced from 100% renewable raw materials, mainly wooden fuels. In Sweden, it is possible to purchase district heating, of which almost 1% is produced with fossil fuels (Rydegran 2021). This district heat is used for calculating reductions in Swedish offices. Table 21 below shows the changes in emissions if only district heat produced from renewable sources were used in Finland at the factory, sales and service and at Epec. In addition of which that earlier mentioned Swedish district heat change is taken account in the table. For subsidiaries, only those facilities for which it is possible to purchase renewable district heating have been considered in the calculation. For the factory, the calculations are more estimates, as the construction of the biogas plant in Vieremä would replace the remaining fossil fuels in the heating plant with biogas.

Table 21. Reductions when switching to purchase 100% renewable district heat.

[t CO_2-eq.]	Carbon footprint	% from 2019 footprint	Biogenic emissions	Absolute emissions	Annual savings/costs
Factory & RD	-101.7	-1.3%	+53.1	-48.6	-
Subsidiaries	-284.7	-3.1%	+323.6	+38.9	+1,600 €

As can be seen from the table, the change would not reduce absolute emissions in the subsidiaries but would have a significant impact on reducing the fossil carbon footprint. In addition, the annual cost of switching is low. Absolute emission reductions would also be achieved for the plant since the emission factors for biogas are considerably lower than for wood fuels. In addition, the amount of heat consumed by the plant is higher than the subsidiaries combined, which means that the lower emission factors for biogas are emphasized. The cost for this change in district heating at the factory cannot be estimated.

6.3.3 Changes independent of own actions

Currently, in Russia, the USA and China, the consumers have no possibility to choose the source of the electricity purchased, so they must consume what energy companies produce from the cheapest energy sources. The same thing is in Russia with district heat. Thus, reducing Scope 2 emissions is difficult in these subsidiaries, as more climate-friendly alternatives are not available. Emission reductions are affected a lot by countries' actions.

For example, the USA climate strategy has a goal of producing its electricity carbon-free by 2035 (The United States of America 2021, 3). Meaning the utilization of renewables and nuclear power. If the country achieves this target, Ponsse's subsidiary in the USA would reduce its carbon footprint and absolute emissions by up to 61 t CO_2-eq. without making any efforts towards reduction. Thus, the modification of energy production also affects companies' emissions. It will be interesting to see at that when the world is at the stage where most of energy is produced with renewable energy sources or carbon-freely.

On the other hand, the development of technologies will also have an impact with the reduction of emissions. New devices are becoming more energy efficient all the time, reducing the energy required to use them. However, the world is becoming more electrified, and it can be seen to be continuing, so the need for electricity will only increase in the future. In this case, the actions of countries and energy companies will have an even greater impact in the future than presented in the previous paragraph.

6.4 Roadmap

The aim of the work was to create two carbon neutrality roadmaps to Ponsse's operations – one for the parent company and one for all subsidiaries. The purpose of the presented carbon neutrality roadmaps is to reduce the fossil carbon footprint with the measures considered in this work and to compensate for the share that remains after the measures. The roadmaps summarize what actions should be taken and in what order to achieve the carbon neutrality goal. The emission reduction measures for the roadmaps have been selected considering the reduction potential, costs, and suitability for the company's use. Attempts have been made to schedule actions in such a way that they would be possible and realistic to make. The first step in order is to reduce consumption and thus emissions, and then to switch to use renewable energy sources. The roadmaps show the carbon footprint of the previous years and the reduction that can be achieved through actions. Below the measure, the emission reduction potential is presented in tons of carbon dioxide equivalent and as a percentage of carbon footprint of those companies in 2019.

Firstly, in the figure 7 below presents a carbon neutrality roadmap for the parent company, i.e., factory and RD. With the measures chosen, it is possible to reduce carbon footprint from

3,464.6 to amount 55.4 t CO_2-eq., which is 98.4% lower than in 2019. The largest emission reductions can be achieved by switching from heavy-duty road fuel to renewable diesel and by shortening test runs and changing test machines light fuel oil used to renewable one. Subsequent reductions would be achieved by switching the liquefied petroleum gas used in the paint shop to a renewable option, purchasing district heating made from renewable energy sources and changing light fuel oil to renewable in other uses. Before replacing vehicle fuels and district heating, their consumption should be minimized with other measures. The smallest effects on the carbon footprint are the exchange of refrigerants and the switching of passenger cars into electric hybrids vehicles. It is advisable to replace the cars in accordance with the current vehicle cycle and before taking them into use, to further investigate the adequacy of charging infrastructure in the area is needed, possibly Ponsse could also be actively building charging points for cars.

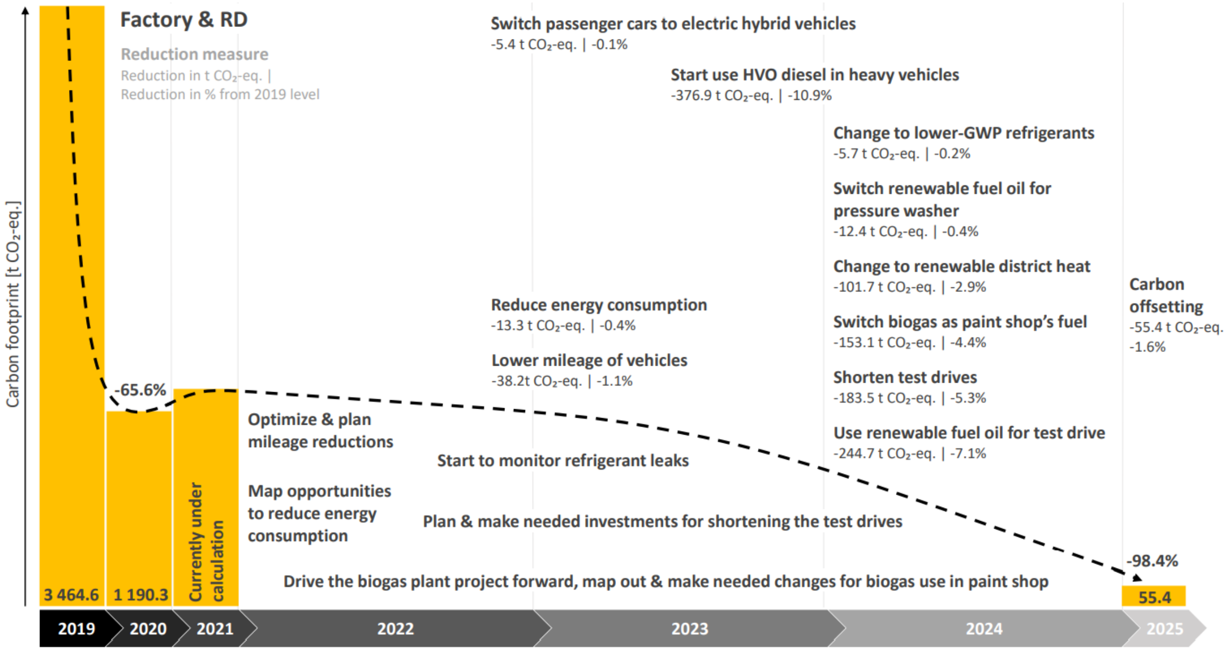

Figure 7. Roadmap towards carbon neutrality at Ponsse's factory and RD (parent company).

The target year in the roadmap is 2025, as Ponsse has set a target for the factory to be carbon neutral by 2025 (Appendix I.). The target is ambitious, with less than three years to go. As the roadmap shows, most of the actions are set for the last year. That why it is essential to start planning and implementing actions as soon as possible. For example, shortening test runs requires more accurate calculations, planning, and greater investment, including in the test track, before the action itself can be done. It is also important to be at the forefront and actively contributing that the biogas will be implemented in Vieremä, which would enable the change of the paint shop's liquefied petroleum gas to biogas and the greening of district heating in the area. The other alternative for paint shops fuel is liquefied biogas if the project is not completed in time in relation to target year. In addition, Vieremä does not currently have the opportunity to refuel with renewable diesel, in which case Ponsse itself will have to be a part of it in order to have one available in the locality. It is important part to achieve this goal, as there are currently no climate-friendly alternatives to heavy-duty vehicles other than renewable diesel.

The aim of the work was to create a second common carbon neutrality to all the subsidiaries. However, during the review of emission reduction measures quickly emerged that there are significant differences in emission reduction potential between countries. Below are the carbon footprints shown earlier in figure 6 by subsidiary and after the emission reduction measures. It also shows the percentage change from the 2019 carbon footprint. For Uruguay and Ireland, the percentages are positive, since the carbon footprint of these subsidiaries increased from 2019 to 2020, and after the actions made, the carbon footprint will remain still higher level than in 2019.

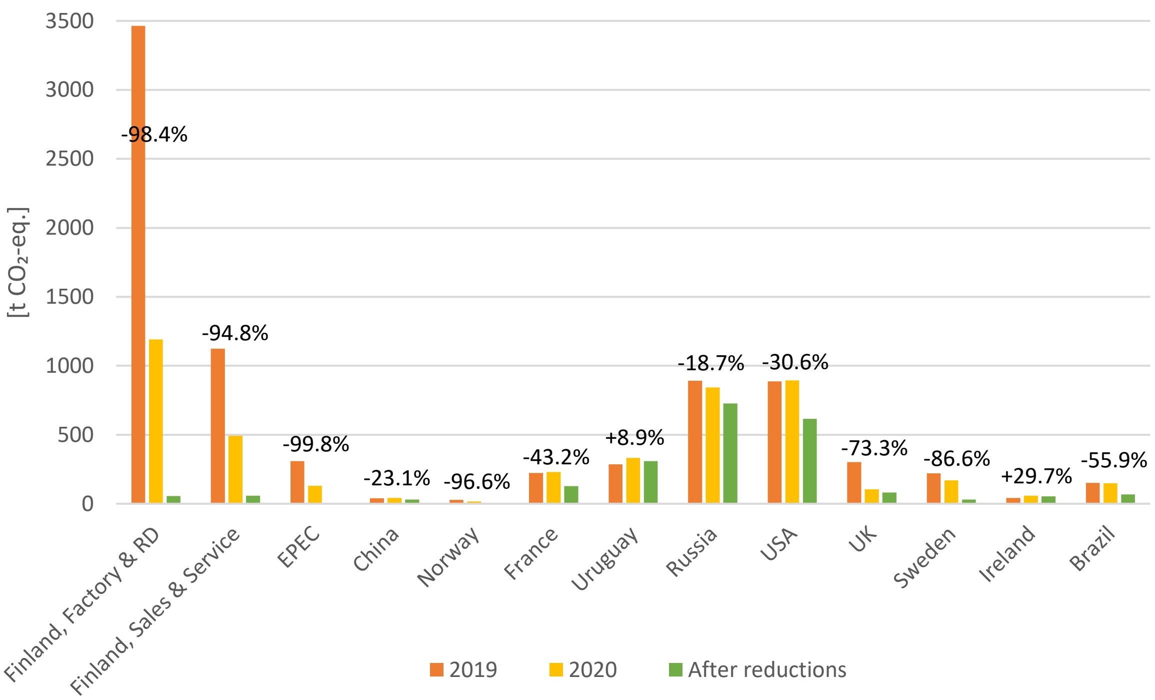

Figure 8. Carbon footprints after reduction measures and reduction percentage from year’s 2019 carbon footprint.

It can be seen from the figure that the reductions that can be achieved are clearly higher for companies located in the Nordic countries. Compared to the 2019 carbon footprint, the biggest reductions could be achieved by the parent company (factory & RD) Finland’s sales and service, Epec, Norway and Sweden, which could cut off from 86.6% up to 99.8% of the base year levels. Followed by those, the next largest emission reductions could be achieved in the subsidiary of UK, but in relation to the 2020 carbon footprint, impact would be significantly smaller, only 22%. For this reason, the subsidiaries are presented with two separate roadmaps for possible actions. The first is a common carbon neutrality roadmap for the Nordic subsidiaries, including sales and service in Finland, Epec, Sweden and Norway, and the second for the remaining subsidiaries. This is because the potential for emission reductions is much higher in the Nordic countries and can lead to significant emission reductions. While it is difficult to even find measures to reduce emissions in other subsidiaries, their roadmap contains fewer and very different measures compared to the Nordic ones.

Figure 9 shows a carbon neutrality roadmap for Ponsse's Nordic subsidiaries (sales and service in Finland, Epec, Sweden and Norway). The measures in the roadmap would make it possible to reduce the carbon footprint of these companies by 94.7% compared to the level of 2019, which means that 88.8 t of CO_2-eq would be left for offsetting. First, it is essential to identify and implement reductions in energy and fuel consumption. And only after that switch to using renewable diesel in heavy-duty vehicles and buying renewable district heat. In Finland, it is possible to buy district heating made from 100% renewable sources, and in Sweden there are alternatives where up to 99% is produced from non-fossil sources. In Finland’s sales and service, light fuel oil is used in wheel loaders and heating purposes, which could be replaced by renewable fuel oil. Alternatives to forklifts include switching to electric ones or renewable fuels such as diesel. The switch to electric forklifts should happen as soon as new ones are purchased and until then, old machines that are still operating normally could use renewable diesel. The same goes for changing the fuel in passenger cars, the change should keep pace with the current vehicle cycle and favor electric hybrids where those use is possible. In Sweden, for example, the annual mileage is so large that the suitability of electric vehicles must be examined before purchase. In heavy vehicles, the only fuel option is renewable diesel. The last small reductions will be obtained by switching to the purchase of renewable electricity in Norway and Sweden.

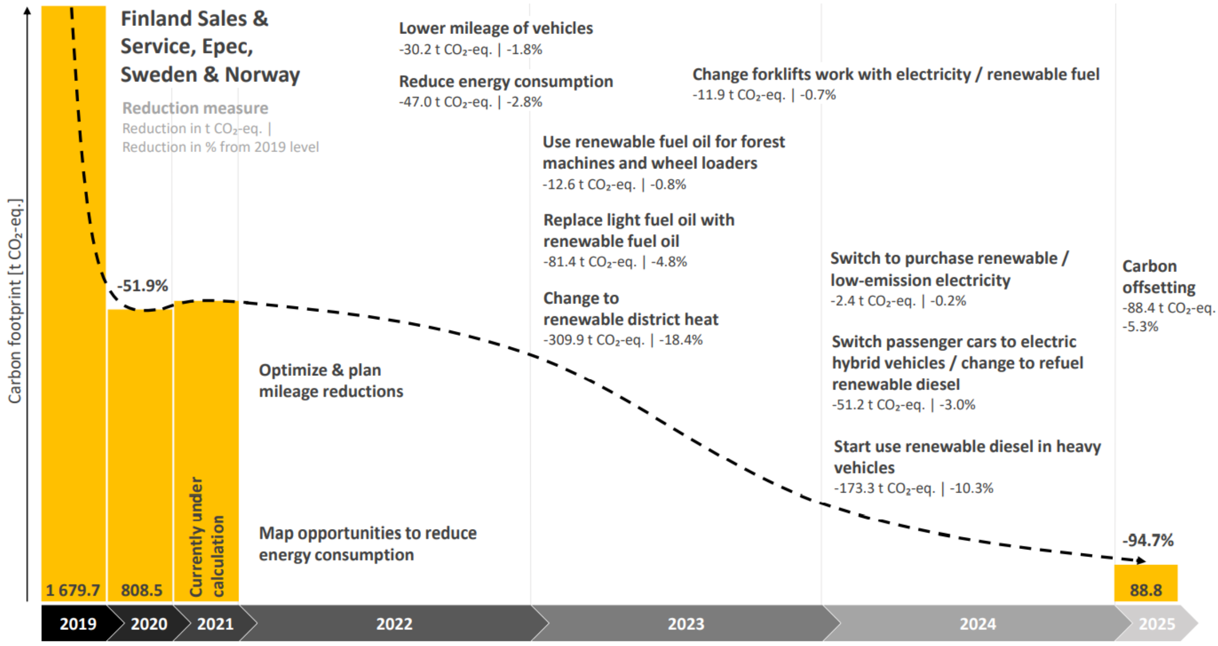

Figure 9. Roadmap towards carbon neutrality in Ponsse Finland's Sales & Service, Epec, Sweden and Norway.

In the roadmap for the Nordic subsidiaries the target year proposal is set to 2025, as all emission reduction measures are mainly the changing of energy sources to renewables and those are already available almost everywhere in these countries. By 2025, it could be possible to achieve carbon-neutral Nordic subsidiaries only with small changes. Achieving this goal seems easier than in the case of the factory and RD.

Lastly, figure 10 below includes subsidiaries in France, the UK, Ireland, Russia, China, the US, Brazil, and Uruguay. In this case it cannot be talked about a carbon neutrality map, but rather about the emission reductions that can be achieved with current measures. The actions studied in this work have the potential to achieve 28.7% emission reductions compared to the 2019 carbon footprint. After the reductions, the carbon footprint would be 2,022 t CO_2-eq. The measures are mainly limited to reducing consumption, switching passenger cars' fuel, and electrifying forklifts. Chancing to purchase renewable electricity is only possible in a few countries, so starting own electricity production, for example by solar panels, in the future should be considered as one of the emission reductions options. Renewable alternatives can be found in the UK for diesel used in pressure washer and propane burned in France. The option for passenger cars in Brazil is to switch to petrol-powered cars to ethanol vehicles, and in France and Russia to gas cars refueling with natural gas. In France and Russia, the annual mileage of passenger cars is so large that electric vehicles may not be suitable. In the case of Russia, these would be pure gas cars, and in France hybrids that could also run-on petrol. Electric hybrid vehicles are an alternative to passenger cars in other subsidiaries. The US subsidiary does not currently have any passenger cars in use instead of which they drive larger pick-ups. It is therefore essential to consider whether it is necessary. Replacing pick-ups with passenger cars would reduce emissions largely and, if continued to electric hybrids, significant emission reductions and cost savings would be achieved.

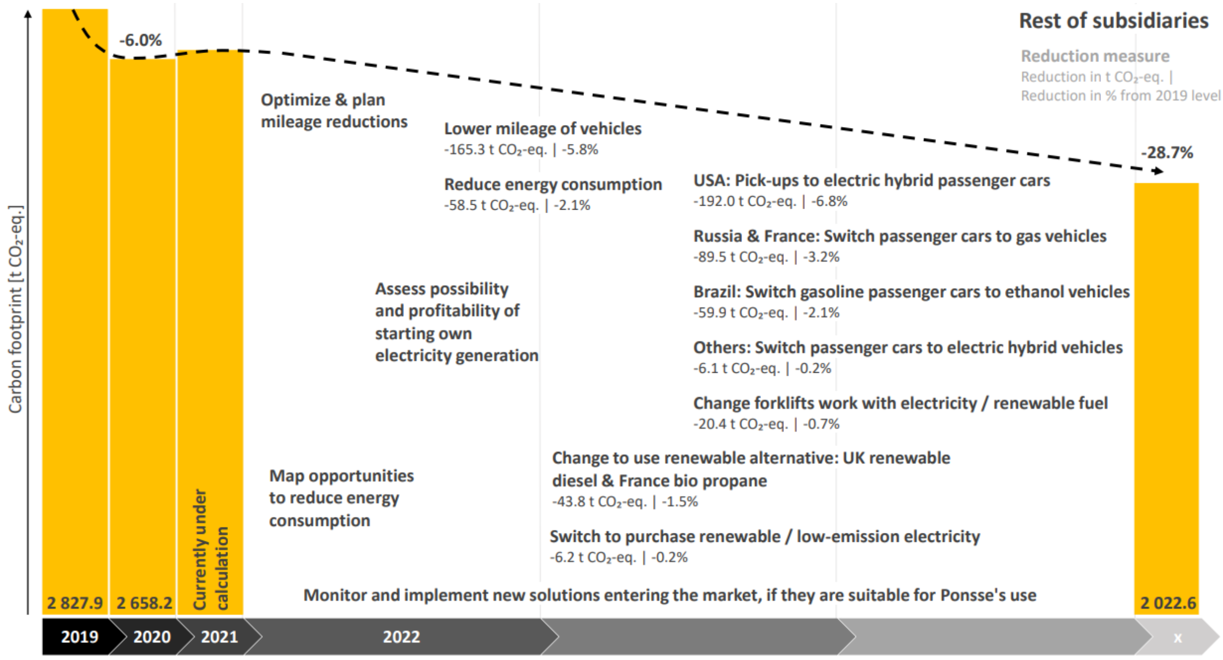

Figure 10. Possibilities to reduce the carbon footprint of other subsidiaries through measures considered in this study.

The exact timing of these actions needs to be assessed, as the number of charging points for example for electric cars varies widely from country to country. On the other hand, new, low-emission solutions may come available, which is why especially in these subsidiaries market penetration of new solutions should be monitored and introduced to use where possible. This also applies to the other two roadmaps presented earlier. Continuous improvement and review annually are essential in each three cases.

If all the measures presented in the roadmaps were implemented, the carbon footprint of the entire Ponsse concern would be reduced by 72.9% from 2019 levels to 4,657.0 t CO_2-eq. Reduction the fossil carbon footprint would increase biogenic emissions. Measures would still lead to a slight reduction in absolute emissions. Figure 11 shows that the biggest emitters after the actions taken are still vehicle use. The figure shows the development of the entire

Ponsse concern's carbon footprint and biogenic emissions if the measures presented in the roadmaps were implemented.

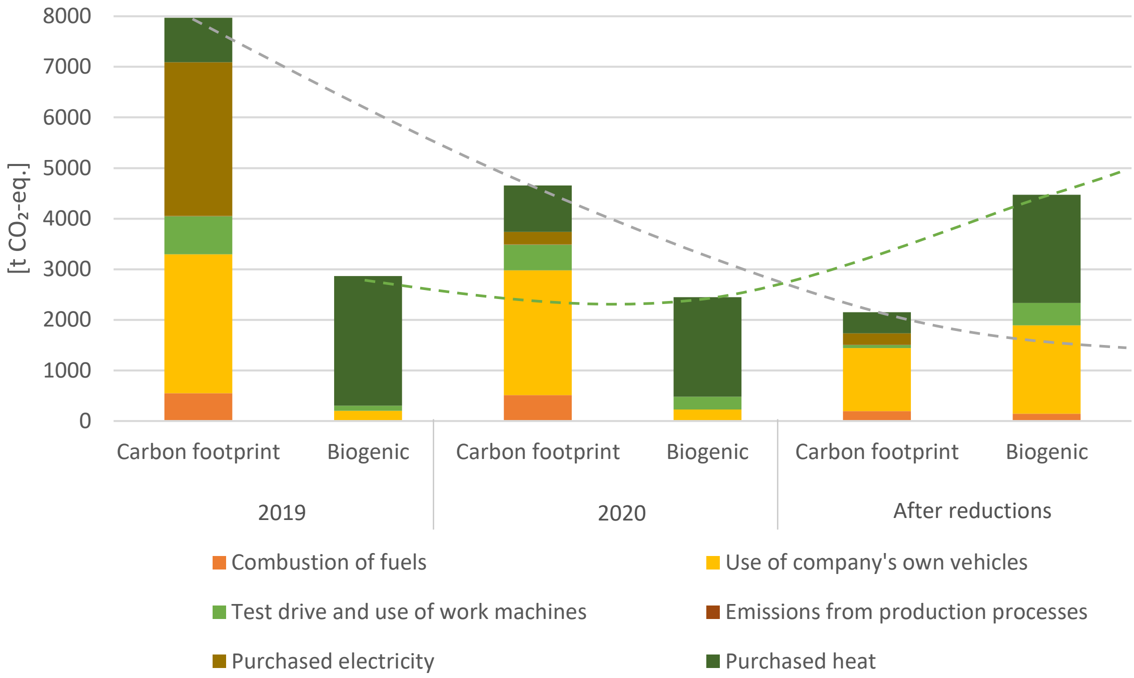

Figure 11. Functions affecting the carbon footprint and biogenic emissions after reductions, and trend of emissions.

All in all, there is a way to reduce carbon footprint and the number of solutions to be developed will certainly increase in the future. However, reducing absolute emissions is much more challenging. Biofuels must be used to reduce carbon footprint before new solutions are made, especially for heavy vehicles. The use of biofuels again increases biogenic emissions. They can be reduced by reducing fuel combustion, but this will require new solutions and technologies for, for example, heavy machinery and road vehicles.

Table 22 below shows the changes in annual energy and fuel costs if the actions outlined in the roadmaps were implemented. It does not set out the costs of the required investments, as those are difficult to estimate and require further review.

Table 22. Impact of roadmap actions on annual fuel and energy costs compared to 2020 levels.

	Factory & RD	Nordic subsidiaries	Rest of subsidiaries	**Total**
Change of combusted fuels	+51,200 €	+8,600 €	+2,700 €	**+62,500 €**
Reducing mileage and switch vehicle fuels	+2,300 €	-41,800 €	-197,000 €	**-236,500 €**
Shorten test drive and change to renewable fuels	-95,800 €	-	-	**-95,800 €**
Switching work machine fuels	+300 €	-2,000 €	+3,700 €	**+2,000 €**
Lower electricity usage and change to low-emission option	-24,900 €	+1,100 €	-3,900 €	**-27,700 €**
Decrease need of heating and switch to low-emission heat	-33,500 €	-21,800 €	-5,300 €	**-60,600 €**
Total	**-100,400 €**	**-55,900 €**	**-199,800 €**	**-356,100 €**

As can be seen from the table, the biggest savings come from reducing vehicle mileage and switching fuels, as well as shortening test drives and changing to use renewable fuels on test machines. There are also opportunities for savings by decreasing the consumption of heat and electricity and by purchasing low-emission forms of energy. Changing the fuels used in work machines and the fuels combusted in other applications have a cost-increasing effect. Nevertheless, each of the considered company entity would be able to significantly reduce its annual fuel and energy costs. In total, the Ponsse concern could achieve annual savings of around 360,000 € through roadmap measures. It should be noted that the table does not take side on investment costs. Greater investment would at least be associated with shortening test drives. The magnitude of cost savings could increase if energy and fuel prices continue to rise.

6.5 Measuring the progress and developing calculation

When emission reduction measures are started, their progress should be monitored. There are many ways to do this. One way is to monitor the size of your carbon footprint annually and compare it to a base year. For example, in the CDP, emission reduction targets are monitored as percentage reductions in emissions compared to base year emission levels. However, this practice does not consider changes within the company, such as an increase in production or the acquisition of new subsidiaries. Therefore, in addition to monitoring absolute emissions, it is advisable to proportionate the emissions per product, for example, or turnover. Alongside these, it is also important to monitor the development of energy consumption, as many emission reduction measures include the electrification of operations, which can significantly increase the need for electricity. It would be important to work to decrease energy consumption in addition to emission reduction measures.

In order to be able to target emission reduction measures more precisely, the measurement and monitoring of energy consumption at the manufacturing facility should be refined at the departmental level. In addition, the amount of driven mileage and fuel consumption for vehicles used in maintenance services should be improved to obtain accurate values, so no estimates needed to be made. The same applies to the number of working hours and fuel consumption of work machines, forklifts, and wheel loaders, used at the sites.

On the other hand, the reporting system needs to be developed, as in a global company, data processing in Excel alone is challenging and time consuming. In addition, the carbon footprint calculation process would be facilitated by clear responsibilities within the company as well as the employee resources assigned to the project, who would work mainly on the calculation and data collection during the project.

7 Conclusions

In this work, different options for reducing Scope 1 and 2 emissions from Ponsse 's operations were explored, on the basis of which two roadmaps towards carbon neutrality were proposed for operations in the parent company (factory & RD) and Nordic subsidiaries, meaning Finland sales and service, Epec, Norway and Sweden. In addition, emission reductions were identified for all the rest subsidiaries using the currently available actions. The roadmaps compared the emission reduction potentials, costs, and suitability of different measures in different subsidiaries. While looking at the different measures, it quickly became clear that there were significant differences between countries. In the Nordic countries, renewable and low-carbon alternatives were found for almost any fuel and purpose. The other extreme was in countries where there were no alternatives, making it difficult to come up with measures to reduce emissions. For this reason, the subsidiaries are divided into Nordic and others.

Differences between countries were already apparent when looking at their climate goals and actions. Each country had set a climate target and targets varied from carbon, climate and greenhouse gas neutrality, to net zero emissions and carbon dioxide remover. Often, however, the definition of the term is not opened, so it can really mean anything. In the table below, values for fossil carbon dioxide emissions in tons per capita in the country in 2020. This gives quite a good picture of the countries' greenhouse gas emissions in relation to each other, as most of the GHG emissions generated are mostly carbon dioxide. World’s average emission per inhabitant in 2020 was about 4.48 tons CO_2 (European Commission).

Table 23. Countries emissions compared their climate targets (European Commission).

Country	Emissions [Mt CO_2]	Emissions [t CO_2/capita]	Year	Goal
Uruguay	5.88	1.68	2030	CO_2 remover
Finland	40.70	7.29	2035	Carbon neutral
Sweden	42.30	4.18	2045	Net zero emissions
Norway	42.18	7.74	2050	Low-emission
France	279.99	4.26	2050	Carbon neutral
UK	313.73	4.66	2050[1]	Net zero emissions
Ireland	32.65	6.68	2050	Net zero emissions
Czechia	92.08	8.66	2050	Carbon neutral
USA	4,535.30	13.68	2050	Net zero emissions
Chile	84.56	4.58	2050	GHG neutral
Russia	1,674.23	11.64	2060	Carbon neutral
China	11,680.42	8.20	2060	Carbon neutral
Brazil	451.80	2.11	2060	Climate neutral

[1] Scotland have more ambitious target to have net-zero emissions by 2045.

As can be seen from the table, the years of the climate targets do not go linearly in relation to the country's absolute emissions or emissions per capita. Countries are moving towards the target by reducing their emissions as fast or slow as the target year is set. A good example is the Nordic countries, whose ambitious goals are always pursued through government action, where emissions reduction measures are well under way. These countries also have many opportunities and options for companies to reduce their emissions, as exemplified by extensive renewable fuel distribution networks. At the other end are countries with targets set up to 30 years later than the most ambitious ones, according to the table above. In these countries, emission reduction measures have often not even started yet, and there are no options for companies to reduce their emissions. It is therefore difficult to find ways to reduce the carbon footprint if the society around the company is currently unable to provide opportunities to do so. This was quickly noticed when mapping the emission reduction opportunities of Ponsse's operations. In some subsidiaries it is possible to achieve almost zero fossil emission, while in some other subsidiaries the only emission reduction measures are limited to reducing consumption without the possibility of using alternative energy sources.

In 2019 whole Ponsse concern's Scope 1 and 2 carbon footprint was 7,972 t CO_2-eq. and 4,657 t CO_2-eq. in 2020. More than half of Ponsse's 2020 carbon footprint came from road vehicles, followed by purchased heat. There are renewable alternatives for vehicles fuels and heat production that can significantly reduce the fossil carbon footprint. However, these do not reduce absolute emissions from operations. Reducing them will be achieved by abandoning incineration, but it will still require new solutions and technologies, for example for heavy machinery and road vehicles. The use of biofuels can therefore be seen as a mandatory transition to electrification and other low-emission solutions for the future. On the other hand, the constant increase in electrification increases the need for electricity, and in this case the source of electricity is in great importance. It will be interesting to see how electricity production develops in countries as the need for it increases – whether countries are able to increase renewable electricity production at the same pace as consumption.

The measures selected for the roadmaps would make it possible to reduce the parent company's (factory and RD) carbon footprint by as much as 98.4% and that of the Nordic subsidiaries by 94.7% from base year 2019. By the measures used in other subsidiaries, the reduction would be only 28.7%. The entire Ponsse concern could have decrease of 72.9% compared to 2019 carbon footprint. After the reduction measures taken, the largest source of emissions is still vehicles and, more specifically, heavy-duty vehicles. There are not yet many alternative fuels for these in addition to renewables. On the other hand, they are also moving towards gas and electric hybrids. There are already electric hybrid pick-ups and compressed natural gas vans on the market. In the use of these, however, the payload increased for Ponsse, which is currently insufficient in these alternatives. Indeed, emission reduction measures depend in part on the development of solutions and technologies.

The roadmap only deals with currently available emission reduction measures. It is therefore important to develop metering and reporting so that calculations can be refined, and actions can be better targeted in the future. Some of the calculations were based on coefficients found in the literature and it is worth making calculations based on more accurate values later. For example, measures to improve energy efficiency and optimize mileage can lead to higher emission reductions than those presented in this work. Continuous improvement of the roadmap and emission reduction calculations as new opportunities emerge is also essential. Scope 3 emissions can also be added to the roadmap in the future after baseline carbon footprint for those has been calculated. Looking at the carbon footprint of Ponsse's own operations, it is not difficult to predict that Scope 3 emissions will be the highest from all three categories. If in Scope 1 vehicle emissions cover half of the carbon footprint, then how large will the emissions in Scope 3 be when Ponsse manufactures thousands of forest machines each year which annual emissions are included in Ponsse's indirect emissions. It is clear that the biggest contributions and developments should be placed in the Scope 3 category.

It is also important to monitor annual developments in terms of both fossil carbon footprint and absolute emissions. Of these, it is essential to monitor totals, but also proportional changes, for example, emissions per turnover or production volumes. Total emissions will vary with the scale of operations – the Covid virus may be lowered quantity of operations and thus carbon footprint of 2020. On the other hand, as subsidiaries and outlets increase, emissions may even turn to growth in individual years. At present, lowering carbon footprint is mainly the change of fossil emissions to biogenic emissions. However, in the long term, efforts should also be made to reduce absolute emissions. For example, the SBT calls companies for a common goal to reduce the carbon footprint as well as biogenic emissions. When setting a carbon-neutral goal based on work, it is important to define what it means and what it covers below, so that there is no possibility of misunderstandings. The target setting should be ambitious, but at the same time consider the current emission reduction possibilities in different subsidiaries.

8 Summary

The purpose of this thesis was to compare different emission reduction opportunities for Ponsse's global operations and make two roadmaps towards carbon-neutral operations in Scope 1 and 2 emissions – one for the parent company (factory and RD) and one for the subsidiaries. The purpose of the roadmaps was to map out the ways in which the carbon footprint is currently being used. Emission reduction measures were compared in terms of the amount of emission reductions, costs and suitability in different subsidiaries.

In the theoretical part of the thesis, the terminology related to companies' climate work, the climate goals and actions set by states around the world, and the climate impacts of heavy machinery manufacturing and maintenance operations were opened. This information was utilized in the empirical part, where possible emission reduction measures were examined, and roadmaps were prepared. Roadmaps were developed to reduce emissions from Scope 1 and 2 categories. The reduction measures were presented by activity, not by subsidiary, as the structure of the activities of the subsidiaries and the emissions closely resemble each other.

The Scope 1 and 2 carbon footprint of Ponsse's entire concern in 2019 was 7,972 t CO_2-eq. The emission reduction measures examined in the work are those that highlighted in workshops and interviews. Making measures in the roadmaps would reduce the parent company's fossil carbon footprint by 98.4%, the Nordic subsidiaries by 94.7% and the other subsidiaries by 28.7% compared to base year levels. The most significant reduction measures are the conversion of heavy-duty fuel to renewable diesel, the shortening of test drives and the switching test machine fuels to renewables, and the change to use renewable district heating. Changing one's own habits also has a significant impact. An example is the replacement of large, high-consumption pick-up vehicles with smaller passenger cars.

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Appendix I – Held interviews and workshops

45-minute intervies about Ponsse's carbon neutrality target	
Date	**Name and job title**
23.8.2021	Katja Paananen, Sustainability Manager
30.8.2021	Juho Nummela, Chief Executive Officer (CEO)

1.5-hour workshops about carbon footprint results and emission reduction brainstorming	
Date	**Participated**
15.11.2021	Sweden and Norway's subsidiaries HSE and management team
16.11.2021	China's HSE and management team
17.11.2021	France's HSE and management team
17.11.2021	UK and Ireland's HSE team
18.11.2021	Epec's HSE and management team
18.11.2021	Russia's management team
22.11.2021	Ponsse Plc executive team
23.11.2021	Finland's service and logistic center operations' management team
24.11.2021	Global service management team
25.11.2021	Uruguay and Brazil's HSE and management team
26.11.2021	Factory's manufacturing management team
30.11.2021	The United States' management team

1-hour interviews about Ponsse's manufacturing processes	
Date	**Name and job title**
15.12.2021	Hannu Tarvainen, Surface Processing Specialist
15.12.2021	Arto Huttunen, Production Supervisor in Machining
16.12.2021	Mikko Tikkanen, Production Supervisor in Assembly
16.12.2021	Lassi Honkajärvi, Production Supervisor in Welding
16.12.2021	Tapio Honkanen, Logistics Manager
20.12.2021	Arto Virolainen, Manager in Ponsse Production System
27.1.2022	Tuomas Pasma, Quality Manager

Appendix II – Used sources in emission reduction calculations

Emission factors and fuel properties	
Source	**Data taken**
Alakangas, E., Hurskainen, M., Laatikainen-Luntama, J. and Korhonen, J. 2016. Suomessa käytettävien polttoaineiden ominaisuuksia. VTT Technology 25B. ISBN 978-951-38-8419-2.	Density of natural gas
Darment. Tietoa kylmäaineista. Webpage. Accessed 15 February 2022. Available at the https://darment.fi/kylmaaineinfo/	Alternative lower-GWP for refrigerants and GWP factors for refrigerants
Devecioğlu, A. and Oruç, V. 2015. Charasteristics of Some New Generation Refrigerants with Low GWP. Energy Procedia, Volume 75, 1452-1457.	
Euroopan parlamentti. 2018. Euroopan parlamentin ja neuvoston direktiivi (EU) 2018/2001, uusiutuvista lähteistä peräisin olevan energian käytön edistämisestä. Accessed 11 February 2022. Available at the https://eur-lex.europa.eu/legal-content/FI/ALL/?uri=CELEX%3A32018L2001	Energy content of bio propane
ESE. Rento, nuuka ja eko puu. Accessed 25 January 2022. Available at the https://ese.fi/fi-fi/lampo/rento-nuuka-vai-eko-puu/45/	Energy sources and prices for renewable district heating production compared to conventional in Finland
Infrastrukturdepartementet. 2021. Regeringens proposition: Reduktionslikt för bensin och diesel – kontrollstation 2019. Accessed 16 February 2022. Available at the https://www.regeringen.se/4981c9/contentassets/9f3163327e80462786efcd873945c1c8/reduktionsplikt-for-bensin-och-diesel--kontrollstation-2019-prop-202021180	Plan to increase the bio-share of diesel in Sweden
Jokela, A. Supervisor PDI Functions of Ponsse. Email, 1 February 2022.	Estimate of the proportion of trucks' mileage for transporting machines to forest test drive sites
Kuopion Energia. Muut kuin omakotitalokohteet – Kaukolämpöhinnasto. Accessed 25 January 2022. Available at the https://www.kuopionenergia.fi/wp-content/uploads/2021/11/ke_kaukolampo_hinnasto_A4_2022_muut_web.pdf	Energy sources and prices for renewable district heating production compared to conventional in Finland
LCA Consulting. 2021. Carbon Footprint Scope 1 & 2 Ponsse Plc. Ponsse's own final report and counting file from carbon footprint calculations	Coefficients and carbon footprints used in the carbon footprint calculations for 2019 and 2020.
LIPASTO. 2017. LIPASTO yksikköpäästötietokanta. Accessed 14 February 2022. Available at the http://lipasto.vtt.fi/yksikkopaastot/	Emission factors and consumption of vehicles and machinery.

	Method for calculating emission factors for electric hybrid vehicles.
Napapiirin Energia ja Vesi. Vihreä Lähilämpö on hiilidioksidivapaa kaukolämpötuote. Accessed 25 January 2022. Available at the https://www.neve.fi/vihrealahilampo	Energy sources and prices for renewable district heating production compared to conventional in Finland
Neste. 2021. Käyttöturvallisuustiedote – Neste uusiutuva polttoöljy. Accessed 11 February 2022. Available at the https://kauppa.lantmannenagro.fi/mwdownloads/download/link/id/3967/	Density for NesteMY renewable fuel oil
Neste. NesteMY #ReneableDiesel. Accessed 11 February 2022. Available at the https://www.neste.fi/sites/neste.fi/files/Neste_MY_uusiutuva_diesel_esite.pdf	Density of NesteMY renewable diesel
Oksanen, J. and Siitonen, V. 2015. Trukin valintaopas. 4th edition. Accessed 11 February 2022. Available at the https://www.rocla.fi/sites/default/files/rocla15_valintaopas.pdf	Forklift driving time on a single charge
Rydegran, E. 2021. Fjärrvärmens koldioxidutsläpp minskade 15,4 procent. Article in Energi Företagen. Accessed 15 February 2022. Available at the https://www.energiforetagen.se/pressrum/pressmeddelanden/2021/fjarrvarmens-koldioxidutslapp-minskade-154-procent/	The fuel distribution of district heating produced with only 1% fossil fuels in Sweden
SavonVoima. Kauko on nyt vihreää. Accessed 25 January 2022. Available at the https://savonvoima.fi/wp-content/uploads/2020/09/SV_Kauko_Vihrea_web.pdf	Energy sources and prices for renewable district heating production compared to conventional in Finland
Seinäjoen Energia. Kaukolämpöhinnastot. Accessed 25 January 2022. Available at the https://seinajoenenergia.fi/lampo/hinnastot/	
Skydel, S. 2014. Route Planning for Fuel Efficiency. Article in Fleet Equipment. Accessed 10 February 2022. Available at the https://www.fleetequipmentmag.com/route-planning-fuel-efficiency/#:~:text=%E2%80%9CThe%20typical%20results%20are%20mileage,to%20existing%20routes%20in%20progress.%E2%80%9D	Vehicle mileage reduction possibilities by optimization
Soininen, P. 2021. Kuusi yleisintä toimenpidettä, joilla parannetaan energiatehokkuutta. Article in TurkuEnergia webpage. Accessed 15 February 2022. Available at the https://www.turkuenergia.fi/valopilkku/energiatehokkuus/kuusi-yleisinta-toimenpidetta-joilla-parannetaan-energiatehokkuutta/	Reduction of electricity and heat consumption by increasing energy efficiency

Tilastokeskus. 2020. Polttoaineluokitus 2020. Accessed 14 February 2022. Available at the http://tilastokeskus.fi/static/media/uploads/tup/khkinv/khkaasut_polttoaineluokitus_2020_v2.xlsx	Fuels' calorific values, densities, and CO_2 emission factors
Toyota. Sähkökäyttöinen vastapainotrukki 1,5–2,0 t. Accessed 11 February 2022. Available at the https://media.toyota-forklifts.eu/published/21447_Original%20document_toyota%20mh.pdf	The maximum battery capacity and volts of a forklift with a lifting capacity of 1.5 tons
The United States of America. 2016. United States Mid-Century Strategy for Deep Decarbonization. Accessed 20 October 2021. Available at the https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf	Target to reach carbon-free electricity production by 2035 in USA

Energy, fuel and car prices	
Source	**Data taken**
Bouvin, M. HSE Coordinator of Ponsse Sweden. Email, 9 February 2022.	Fuel and energy prices in Sweden
Cardoso, E. Safety Technician of Ponsse Brazil. Email, 10 February 2022.	Fuel and energy prices in Brazil
Constable, N. Health, Safety and HR Manager of Ponsse UK and Ireland. Email, 9 February 2022.	Fuel and energy prices in UK and Ireland
Gasum. Maa- ja biokaasun hinnat tankkausasemilla. Webpage. Accessed 3 February 2022. Available at the https://www.gasum.com/yksityisille/tankkaa-kaasua/tankkaushinnat/	Natural and biogas prices for vehicles in Finland
Hotti, R. Accounts Payable Ledger of Ponsse. Email, 14 February 2022.	Price for purchased LPG for forklifts in Finland
Huang, Y. Finance Manager of Ponsse China. Email, 10 February 2022.	Fuel and energy prices in China
Huttunen, R. Production Supervisor of Ponsse USA. Email, 14 February 2022.	Fuel and energy prices in USA
Juutinen, R. Pohjolan Energiainsinöörit. Biogas price estimates for the paint shop and vehicle fuel if the biogas plan will be implemented. Email, 24 January 2022.	Biogas prices and needed changes in systems
Kaitasalo, L. Kosangas. Average price of Ponsse's purchased LPG in 2021. Email, 1 February 2022.	LPG price in Finland
Lavinen, T. Safety and Environment Manager of Ponsse Finland. Email, 10 February 2022.	Costs of purchased energy in Finland in 2021

Lizunkov, M. HSE Manager of Ponsse Russia. Email, 10 February 2022.	Fuel and energy prices in Russia
Mocellin, A. Aftersales Manager of Ponsse France. Email, 11 February 2022.	Fuel and energy prices in France
Nesset, M. Service Technician of Ponsse Norway. Email, 13 February 2022.	Fuel and energy prices in Norway
Neste. Neste MY Uusiutuva Diesel. Webpage. Accessed 3 February 2022. Available at the https://nestemy.fi/	The price difference between renewable diesel and normal diesel
Polttoaine.net. Webpage. Accessed 3 February 2022. Available at the https://www.polttoaine.net/index.php	Fuel average prices in Finland in 3.2.2022.
Veiste, T. 2008. Pulverimaalaus ja sen vertailu märkämaalaukseen. Lappeenrannan Teknillinen Yliopisto, Teknillinen Tiedekunta. Bachelor's Thesis. Accessed 13 December 2021. Available at the https://lutpub.lut.fi/bitstream/handle/10024/69185/nbnfi-fe201103301399.pdf?sequence=3&isAllowed=y	Energy costs in water and solvent paints
Tenembaun, F. Quality System Management of Ponsse Uruguay. Email, 9 February 2022.	Fuel and energy prices in Uruguay
Väre. Sähköauton lataus. Webpage. Accessed 3 February 2022. Available at the https://vare.fi/sahkoauton-lataus/	Prices for installing electric charging points in Finland
Winter, J. Global Sourcing Manager of Ponsse. Purchase prices of fuels from Neste. Email, 3 February 2022.	Prices of fuels in 31.12.2021 purchased from Neste