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DEVELOPMENT OF CLIMATE RESPONSIBLE ACTIONS FOR A PUMP MANUFACTURER

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TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
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Pumppujen ja muiden prosessiteollisuuden laitteiden valmistajien ilmastovastuullista toimintaa varten työssä kerättiin lainsäädäntöön, eri sidosryhmien huomioimiseen, ilmastovaikutusten laskentaan, ympäristönhallintajärjestelmiin sekä toimintaympäristöön liittyviä tietoja. Tärkeimmässä osassa oli pumppu- ja prosessilaitevalmistaja Sulzer Pumps Finland Oy:n ilmastovaikutusten tutkiminen.

Tieto oman organisaation hiilijalanjäljestä on prosessilaitteiden valmistajille nykyään entistä tärkeämpää, koska sitä kysytään usein, ja sillä on monesti ratkaiseva merkitys ostopäätöksen teossa. Sulzer Pumps Finland Oy:n hiilijalanjälki laskettiin tässä työssä ensimmäistä kertaa. Laskennassa käytettiin GHG Protocolin luomaa laskentakehikkoa, joka jakaa organisaation hiilijalanjäljen kolmeen eri osa-alueeseen, jotka ovat scope 1 (organisaation omasta toiminnan päästöt), scope 2 (ostetun energian päästöt) ja scope 3 (koko toimitusketjun ylä- ja alajuoksun päästöt raaka-aineiden hankinnasta myytyjen tuotteiden loppukäsittelyyn). Lähtötietojen keruussa havaittuihin ongelmiin ehdotettiin ratkaisuja tulevia laskentoja varten, ja hiilijalanjäljen pienentämismahdollisuuksia tutkittiin.

Tuotteen hiilikädenjäljellä tarkoitetaan sen pienentävää vaikutusta ostajan hiilijalanjälkeen. Työssä tarkasteltiin yhtiön päätuotteiden hiilikädenjälkipotentiaalia edistäviä tekijöitä. Lisäksi luotiin pohja tulevaisuudessa tapahtuvaa kyseisten tuotteiden hiilikädenjälki-laskentaa varten, hyödyntäen VTT:n ja LUT:n kehittämää kädenjäljen määrittämisprosessia.

ABSTRACT

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Development of Climate Responsible Actions for a Pump Manufacturer

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127 pages, 17 figures, 38 tables, and 4 appendices

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In this work, information concerning legislation, stakeholders' needs, calculation of climate impacts, environmental management systems, and operational environment was collected for climate responsible operation of companies manufacturing pumps and other equipment of process industry. In the main role was the examination of the pump and process equipment manufacturer Sulzer Pumps Finland Ltd's climate impacts.

The knowledge about own organization's carbon footprint is all the time more important for process equipment manufacturers because it is being frequently inquired, and in many cases, it is pivotal in making of purchase decisions. Sulzer Pumps Finland Ltd's carbon footprint was calculated for the first time in this work. A calculation framework created by the GHG Protocol was utilized in the calculation. It divides the carbon footprint of an organization into three different sectors, which are scope 1 (emissions from organization's own operation), scope 2 (emissions from purchased energy), and scope 3 (emissions of the whole supply chain from acquisition of raw materials to end-of-life treatment of sold products). Solutions were suggested for the problems that were faced in the collection of initial data, and possibilities to reduce the carbon footprint were examined.

A product's carbon handprint means its decreasing impact on its buyer's carbon footprint. Factors which improve carbon handprint potentials of the company's main products were discussed. A basis for carbon handprint calculation of these particular products was also formed based on the handprint quantification process developed by VTT and LUT.

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In Lappeenranta 5 April 2021

Tero-Ville Uimonen

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CFP	carbon footprint	[t CO_2e]
CHP	carbon handprint	[t CO_2e]
E	GHG emissions	[t CO_2e]
EF	emission factor	[t CO_2e/kWh]
LT	lifetime of an equipment	[h]
m	mass	[kg]
M	molar mass	[g/mol]
n	number	[1]
P	power of an equipment in use	[kW]
UR	use-rate of an equipment	[%]
V	volume	[m^3]
ρ	density	[kg/m^3]
Σ	sum	

Subscripts

1,i	of components in component category i
2,i	of components that have known weights in component category i
baseline	of the baseline
C2H2	of acetylene
C3H8	of propane
CO2	of CO_2
electricity	of used electricity
estimate	total of a raw material, estimated
input	input
MISON 18,gas	of MISON® 18 gas
offered solution	of the offered product or service
rm,i	of a raw material in component category i, known
use phase	of an equipment in its use phase
use phase,total	of all equipment in their use phases

Abbreviations

ACS	Attestation de Conformité Sanitaire
CDM	Clean Development Mechanism
CDP	the Carbon Disclosure Project
CPI	Cooperative Producers, Inc.
EPD	environmental product declaration
ErP	Energy-related Products
ESG	environmental, social, governance
EU	the European Union
GHG	greenhouse gas
GS	Gold Standard
GWP	global warming potential
HR	human resources
IT	information technology
IoT	Internet of Things
L&T	Lassila & Tikanoja plc
LCA	life cycle assessment
LPG	liquefied petroleum gas
Ltd	Limited Liability Company
LUT	Lappeenranta-Lahti University of Technology
LV	low voltage
MAG	metal active gas
MC®	medium consistency
MEI	the Minimum Efficiency Index
MV	medium voltage
MW	municipal waste
NFRD	non-financial reporting directive
NGO	non-governmental organization
NSF	National Sanitation Foundation
PCF	product carbon footprint
PCR	product category rule
PDCA	Plan-Do-Check-Act

PEEK	Polyether Ether Ketone
ppm	parts per million
RO	reverse osmosis
QESH	Quality, Environment, Safety, Health
SBTi	the Science Based Targets initiative
SEFI	Services Finland
SPFIN	Sulzer Pumps Finland Oy (Ltd)
UN	the United Nations
UNGC	the UN Global Compact
VCS	Verified Carbon Standard
VTT	Technical Research Centre of Finland Ltd
WEEE	waste electrical and electronic equipment
WRI	World Resources Institute
WWF	World Wide Fund for Nature

1 INTRODUCTION

Environmental impacts of products are paid increasingly attention to. Companies get inquiries about the carbon footprint of their products, for example. Minimizing environmental impacts is therefore a significant image factor, and if stakeholders are convinced that the matter is taken seriously, it can also be a competitive advantage.

The most commonly used indicator for environmental impacts is carbon footprint, which tells the amount of produced greenhouse gases as CO_2 equivalent, so how many kgs or tons of carbon dioxide would cause as big global warming potential (GWP) as all the greenhouse gases released from the examined target. The more complex a system is in question, the more challenging it is to determine its carbon footprint. The estimate gets more accurate when more factors which have impact on it are taken into account. Carbon footprint can be calculated, for example, for an individual, event, organization, or a product (Carbon Trust 2021). Carbon handprint is a newer concept, a way to quantify a product's or a service's positive environmental impacts for a customer (Pajula et al. 2021, 30). It can also be assessed for an organization or a project (Pajula et al. 2021, 30).

Footprint and handprint can as well concern other environmental impacts than GHG emissions. Water footprint measures negative water related impacts (impacts on water scarcity or quality), and water handprint tells an offered solution's positive impacts on water resources if a baseline product or service is replaced with it (Pajula et al. 2021, 8, 9, 19). Water footprint calculation is guided by the standard ISO 14046:2014 (Pajula et al. 2021, 10, 29). An umbrella term for several positive environmental impacts is environmental handprint (Pajula et al. 2021, 8).

The main topic of this work was the company-level carbon footprint (including production processes, purchased energy, and value chain before and after the production) of Sulzer Pumps Finland Oy (Ltd) (later on referred to as SPFIN), identification of current challenges in its calculation process, and suggesting possible solutions for them. Besides the company's carbon footprint, also its main product groups' carbon handprint potential was studied on a smaller scale, keeping in mind possible carbon handprint calculations in the future.

Since examination of environmental impacts was in this study limited to concern greenhouse gas (GHG) emissions, other environmental impacts and their measures (such as water footprint and handprint) were not included in it. The aim was also to collect knowledge about a process equipment manufacturer's, such as Sulzer, climate responsible operation, and how the operational environment affects achieving positive climate impacts. Climate responsible operation requires active responding to demands of legislation and different stakeholders. Different countries have different legislations and climate politics, as well as different emission factors of electricity production. All these circumstances have significance for achieving positive climate impacts on the market.

SPFIN is a part of the Swiss-based multinational Sulzer corporation, which produces several different products and services. Requirements and environmental footprints of these products and services are also different, so its business units and sites around the world assess their footprints and set their environmental impact reduction targets on their own (Sulzer 2021a). Site level financial and non-financial (environmental, HR, and health & safety) information is collected with a comprehensive reporting system (Sulzer 2021a). Sulzer corporation's products and services include many different types of pumps, agitators, compressors and aeration equipment, solutions for chemical industry, and maintenance and repairment of the products (Sulzer 2021b, Sulzer 2021c). Of these products, SPFIN manufactures pumps and pumping solutions, agitators, and turbocompressors, also providing accessories, spare parts, maintenance, and consultation for them (Haarala 2021a, 3). The products of SPFIN are used, for example, in pulp and paper industry, food industry, production of drinking water, and in sewage treatment.

SPFIN's carbon footprint was calculated following the standards developed by the Greenhouse Gas (GHG) Protocol. The GHG Protocol is a very common and well-known instrument for carbon footprint calculation and that is why it was utilized also in this work. The GHG Protocol has developed standards that show a company which things must be included in footprint calculation on corporate and product levels. These standards are:

- The Corporate Accounting and Reporting Standard (later referred to as "the Corporate Standard")

- The Corporate Value Chain (Scope 3) Accounting and Reporting Standard (later "the Scope 3 Standard")
- The Product Life Cycle Accounting and Reporting Standard (later "the Product Standard").

The carbon footprint calculation included emissions defined in the GHG Protocol's scopes 1 and 2, and selected emission categories from scope 3. The scope 1 includes direct emissions of the company's operation and scope 2 indirect emissions of all purchased energy. The selected scope 3 emission categories are those emission sources in upstream and downstream activities that are considered to be the most significant for SPFIN's carbon footprint. The final calculations were performed by the Finnish environmental consulting company Ecobio Oy (Ltd) based on the preliminary calculations done with collected data. When the carbon footprint of the company was calculated, the results and uncertainties of the calculation were reported and discussed. The emission scopes 1, 2, and 3, and different categories inside them, were compared and their significance for SPFIN was considered.

Carbon handprint potential of the SPFIN's main product groups (centrifugal process pumps, agitators and turbocompressors) was examined by comparing the significance of the products' different lifecycle phases concerning GHG emissions, and by identifying the products' current strengths and factors which have significant impact on their GHG emissions. The examined products from the mentioned product groups were SNS and AHLSTAR A pumps, SALOMIX™ SSF agitator, and HST™ turbocompressor. A four-stage handprint quantification process developed by VTT Technical Research Centre of Finland Ltd and LUT University was also utilized for creating a basis specifically for SPFIN's products' carbon handprint calculation in the future.

In the conclusions chapter, made choices concerning collection of information, used methods, and calculations were explained, faced challenges and possible solutions for them were presented, and ideas for further reducing the carbon footprint and developing the handprints were introduced. Also, future prospect of SPFIN and development of GHG emissions in a wider perspective were viewed. Finally, topics which are close to the area of this study or would logically follow it, were suggested for further studies.

2 SIGNIFICANCE OF CLIMATE RESPONSIBLE ACTS FOR A PROCESS EQUIPMENT MANUFACTURER

Climate responsibility is beneficial for companies in many ways in their operation. Factors that guide companies into climate friendly direction in their actions are national and international environmental legislation, and views of investors, customers, and other stakeholders. Filling these demands and even being proactive in it is an important challenge for a company in order to stay competitive on the market. These circumstances are viewed next.

2.1 Legislation

Companies should prepare for changing operational environment. According to the Finland Chamber of Commerce’s responsibility specialist Eero Yrjö-Koskinen, tightening norms as well as environmental protection taxes are becoming more common (Koskenranta 2020). Requirements of environmental legislation are becoming stricter due to decisions of the EU, national politics, and the Paris Agreement (Ilmastobisnes 2021a). Finland has set a goal of achieving carbon neutrality by 2035 (Ympäristöministeriö 2021). Besides Finland, also the EU and most part of the world’s economies are engaged in actions for guiding companies, households, and public sector into more climate friendly direction. This shows in many companies’ everyday operation as stricter environmental legislation and rising costs. As legislation is used for reducing the consumption of fossil-based fuels in traffic and energy production, companies have to think about substitutive energy sources. Emission reduction demands of legislation affect the whole value chain, because large companies have to set high requirements also for their cooperation partners. (Ilmastobisnes 2021b.)

A company can respond to the climate regulation either by adapting to it when the statutes get stricter and costs get higher, or by moving one step ahead and developing their operation so that the regulation doesn’t affect negatively. In the best case, the renewing will lead to getting competitive advantage in relation to other companies when legislation gets stricter, or the demand of the company’s climate-friendly products and services increases. (Ilmastobisnes 2021b.)

The European Green Deal is a program presented on December 11th 2019, of which targets are that the EU's greenhouse gas net emissions are zero by 2050, economic growth will be separated from resource use, and nobody and no area are left behind. On July 14th 2021, the European Commission adopted a number of proposals for making the EU's policies for climate, energy, transportation and taxation to support the reduction of net GHG emissions by 55% or more by the year 2030 from 1990 levels. This goal must be achieved in order to achieve the targets of the European Green Deal by 2050. (European Commission 2021a.)

To achieve climate neutral economy in 2050, the main target of the European Green Deal is to utilize the potential in global markets for producing sustainable products and services and for developing and using low-emission technologies (European Commission 2021b). This requires industry to be totally mobilized and all value chains have an essential role in it (European Commission 2021b). The process industry, including Sulzer, is regulated by several standards and directives which set demands for energy efficiency (Vanhala 2020, 2). One significant directive in that field is the EU's Energy-related Products (ErP) directive (2009/125/EC), which sets the minimum requirements for energy efficiency of water pumps (Vanhala 2020, 2). Same kind of directives are being created also outside of the EU (Vanhala 2020, 2).

Along with the regulation concerning the EU's own industry, the EU is planning to set carbon duties for products imported from countries which are not ambitious enough in their climate actions. This is done for preventing the EU's climate targets to cause the production to move from the EU to countries with less strict climate targets. (European Parliament 2021.) The carbon duties will most likely also affect Sulzer, since a large share of pumps' castings are manufactured in China.

The EU taxonomy is the EU's legal classification system for sustainable funding, which lists environmentally sustainable financial actions. The taxonomy is a robust and science-based tool for companies, investors, and the EU member states for planning transition into low-carbon, flexible and resource efficient economy. It offers criteria for assessing which kind of financial action significantly affects the targets of the European Green Deal. The criteria also give companies and investors a common language for credible communication about green action. (Björkqvist 2021.)

The taxonomy concerns companies operating on financial market, large companies which must deliver their economic data following the Non-Financial Reporting Directive (NFRD), and the EU member states. They must recognize economic action that can be classified as sustainable and identify this action according to the principles of avoiding significant harm (do-no-significant-harm). In addition to classification of functions, the EU taxonomy decree requires companies to follow changes in legislation and to show that the changes are complied with. (Björkqvist 2021.) SPFIN, unlike Sulzer corporation, is not currently affected by the EU taxonomy requirements since it has less than 500 employees.

The EU taxonomy decree came into effect in July 12th, 2020. The decree and the EU's strategy for sustainable funding were strengthened by publishing the funding package for sustainable development in April 21st, 2021. Companies must report according to the requirements of the decree by the first time before the end of 2022. The taxonomy decree is under constant development and it will concern also other sectors in the future. Therefore, all companies are recommended to prepare for following the requirements of the decree already beforehand. (Björkqvist 2021.)

2.2 Sustainability qualifications for funding and responding to stakeholders' needs

Legislation is not the only factor that guides companies to decrease their emissions. Customers and other stakeholders are also an essential driver which urges to act more responsibly toward climate and to proceed towards climate business. (Ilmastobisnes 2021a.) Environmental know-how and climate awareness affect a company's competitiveness and outlook, which in turn reflects into how interesting the company is for investors. Still, reputation or visions as such are not enough, investors are also interested in concrete emission reports and other indicators. Some investment funds focus only on companies of sustainable development. Also, when a company is going to be sold, comprehensive data about emissions and other environmental impacts of the company’s operation can be requested. (Ilmastobisnes 2021a.)

The further a customer company has advanced in its own environmental management, the more likely it is that it also demands its subcontractors to fill the environmental criteria. More often than before, an environmental standard or certificate can even be a requirement for discussing with customers or participating in competitive tendering. Also, public sector actors set strict energy and environment criteria for acquisitions in their offer requests. Consumers are all the time more interested about environmental impacts of products and services, and companies’ environmental image also affects their purchase decisions. Small but growing share of customers are also willing to pay more for low-emission products. (Ilmastobisnes 2021a.)

Climate responsibility arises in co-operation with other companies operating in the same eco-system. That is why many evaluate their partners from the perspective of how they are dealing with climate questions and what kind of reputation they have as environmental actors. Environmental know-how, climate responsibility, and the reflection of them into a company’s brand are nowadays often a way to stand out among the competitors and strengthen the company’s position on the market. (Ilmastobisnes 2021a.)

Employees prefer companies with values that they can stand for and which have a positive impact on society also from the environmental standpoint. Putting resources on climate business enhances the employer image especially among young experts. A company’s environmental responsibility interests strongly also the local residents, organizations, and decision makers. A good environmental reputation requires concrete actions, but also active communication and dialogue concerning them. Reporting of achieved results in environmental actions must not be misleading, because greenwash will turn quickly against itself. (Ilmastobisnes 2021a.)

In Table 1, there are important matters listed regarding different stakeholder groups. Recognizing and acting according to these helps to keep up good relations with the stakeholders, which is crucial for successful business.

Table 1. Different stakeholders and important things related to them. (VTT 2009)

Stakeholder	Important things for a company to recognize
Customers	- Customers' environmental demands should be considered already in planning and product development - Thoroughness and truthfulness are important in information sharing and marketing
Authorities	- Authorities grant environmental permits for companies - They have significant expertise in local environmental circumstances - A company should name a contact person who communicates with authorities in order to ensure good co-operation and meeting the requirements
Subcontractors/ suppliers	- Subcontractors and material suppliers should be kept informed about the demands of customers and the company's own wishes. This helps them to consider changing environmental circumstances in their development - Co-operation benefits environmental management of all actors in the supply chain
Competitors	- Development of competitors' environmental responsibility and its usage in their operation should be watched. Often the one who acts first can take the lead in the development and get the largest benefit
Neighbors	- Neighbors can have contradictory mental images about a company's environmental impacts, and they can be worried about possible health impacts and increasing traffic noise - Neighbors' inquiries should be answered thoroughly and truthfully - Finding and utilizing a working channel for conversation will help co-operation
Banks & insurance companies	- Identifying risks related to environment and the history of buildings helps to prepare for financial risks (especially in real estate sales) - Some (but not all) environmental risks can be controlled with insurances
Media	- A company should have working connections with media, so that sharing information about environmental matters through media is easier - If a company should defend its operation publicly, shared information must be clear and truthful because false information is difficult to get corrected

A document called EPD (Environmental Product Declaration) is one means to communicate a product's or material's environmental impacts or performance to customers in a transparent way. To get an EPD, a company must first collect all needed data, such as resource consumption and waste generation, and then implement an LCA (life cycle assessment) according to an appropriate PCR. (One Click LCA 2021.) PCRs (Product Category Rules) are documents which set requirements and give guidance for developing of EPDs for specific kind of products (The International EPD® System 2021). After the LCA, the company needs to prepare a background report, obtain a verification from an independent third-party verifier, and finally publish the EPD document via a program operator (One Click LCA 2021). With EPDs, a company can also get EPD or LCA credits for products in different certification systems. (One Click LCA 2021.) Sulzer has also obtained EPDs for some of its products in the past for communicating their environmental impacts, such as GWP and the natural resource use, but currently there are no valid EPDs available for the SPFIN’s products related to this work (Sulzer 2021d).

Another possibility worth mentioning to improve a company’s environmental image is to apply a permission to use the Climate Commitment sign from the Chamber of Commerce. The Climate Commitment System (Ilmastositoumusjärjestelmä in Finnish) was launched by the Finland Chamber of Commerce in late 2019. It is consistent with the Greenhouse Gas Protocol’s carbon footprint calculation for a company and it helps companies in committing to carbon neutrality and guides them in reliable reduction of emissions. (Koskenranta 2020.)

A company operating in Finland can apply a permission to use the Climate Commitment sign followingly. First, the target (carbon neutrality by 2035) must be set. For calculating a company’s carbon footprint, the Chamber of Commerce has a counter and instructions which are then downloaded from their website. Then, the company’s significant emission sources are identified and initial data and emission factors for them are collected. Next, the carbon footprint is calculated with the counter. After the calculation, a plan is made for actions that will reduce the emissions towards the target. When all this is done, the permission to use the sign can be applied. If the company is granted the permission, the staff, stakeholders, and customers should be informed about it. Realization of the emission reductions should be monitored and reported annually. (Keskuskauppakamari 2021.)

It must be noted that the Climate Commitment System is intended only for calculating carbon footprint of an organization, not a product or service. In addition to this, emissions of products purchased by the company are not included in the footprint calculation at this moment. Still, the counter can be applied and updated according to the company’s own needs. The counter also gives examples of how the company can monitor the emission reductions (for example, in respect of production volume or workforce). (Koskenranta 2020.)

Then there is also the Science Based Targets initiative (SBTi), a partnership formed by CDP, UNGC, WRI and WWF, which enables companies to reduce their emissions through setting of science-based targets. The SBTi shows companies the magnitude and speed of needed reduction in their GHG emissions for preventing the worst consequences of global warming. The SBTi also defines and furthers the best practices consistent with climate science, offers assistance and expertise, and assesses and validates the targets for companies. (Science Based Targets 2021a.) GHG emission calculation for the SBTi needs to be done following the GHG Protocol (Voutilainen 2021).

The targets are science-based if they according to current scientific knowledge help achieving the goals of the Paris Agreement; keeping global warming significantly under 2 °C above pre-industrial level and striving for limiting the warming to 1,5 °C. When SBTi has validated a company's target, the target needs to be communicated for stakeholders, and emissions and the target's progress must be reported yearly. (Science Based Targets 2021b.)

The SBTi is also the leading partner of the Business Ambition for 1,5 °C campaign for setting science-based net-zero targets to keep global warming under 1,5 degrees (Science Based Targets 2021a). With the help from many stakeholders and experts of different branches, The SBTi has developed first in the world the Net-Zero Standard for setting science-based net-zero targets. The standard emphasizes fast reductions of emissions and covers a company's whole value-chain (scopes 1-3). It requires a company to set both near-term target (decreasing emissions by 50% by year 2030) and long-term target (nearly zero emissions in 2050 and the remaining emissions shall be neutralized). The Net-Zero Standard is intended for companies with over 500 employees, but the SBTi also gives simplified instructions for smaller companies for setting net-zero targets. (Science Based Targets 2021c.)

Companies which have science-based targets validated by the SBTi have reported several benefits from it, including increase in profitability, better trust of investors, improved innovativeness, increased certainty about regulations, and stronger company image (Science Based Targets 2021d).

3 NEGATIVE AND POSITIVE CLIMATE IMPACTS AND THEIR ASSESSMENT AND MANAGEMENT METHODS

The concepts of carbon footprint and carbon handprint, and methods which are applied for SPFIN's carbon footprint calculation and assessment of selected product groups' carbon handprint potential, are introduced next. Principles of environmental management are also discussed.

3.1 Carbon footprint

Probably the most commonly used measure today for climate impacts is still carbon footprint. For as long as carbon footprint has been used in the public relations, different actors have striven to lower their own carbon footprint which can then be communicated to customers and other stakeholders. Carbon footprint is a part of life cycle assessment (LCA), concentrating only on GHG emissions (Pajula et al. 2021, 8). Life cycle assessment is guided by the standards ISO 14040-44:2006 and carbon footprint by ISO 14067:2018 (Pajula et al. 2021, 10, 29).

Product carbon footprint (PCF) can be partial ("cradle-to-gate") or full ("cradle-to-grave") PCF. A partial PCF includes GHG emissions between the life cycle phases from raw material acquisition through manufacturing till the phase where the product is ready to be transported for a customer. A full PCF covers also the use and disposal phases, ergo the product's complete life cycle. (Bio 2021, 2.)

For carbon footprint calculation and target setting, a very commonly used tool nowadays is the Greenhouse Gas Protocol framework (Koskenranta 2020). It would also be possible to apply ISO standards designed for the same purpose (Koskenranta 2020). Still, the Greenhouse Gas Protocol framework is selected as the carbon footprint approach of this work because it is now an established, clear, and rather solid system.

The Greenhouse Gas Protocol Initiative is a partnership of numerous stakeholders, including businesses, NGOs, governments and others congregated by the World Resources Institute, and the World Business Council for Sustainable Development, which is a coalition of 200 companies around the world. The story of the GHG Protocol began in year 1998, with the mission of developing international GHG accounting and reporting standards and guidelines with their global promotion. (World Resources Institute & World Business Council for Sustainable Development 2010, 2.) The standards developed by the GHG Protocol are introduced in the following sub-chapters.

3.1.1 The GHG Protocol's Corporate Standard

The Corporate Standard sets requirements for different kinds of organizations and companies for performing an inventory of corporate-level GHG emissions and guides them in it (Greenhouse Gas Protocol 2021). The Corporate Standard was originally launched in year 2001 and revised three years later, and it has been globally accepted by corporations and organizations as the international standard of GHG inventory development and reporting (Greenhouse Gas Protocol 2011a, 5).

The Corporate Standard divides the direct and indirect Greenhouse gas emissions of a reporting company into three sectors (scopes) and obligates companies to calculate and report their emissions in scopes 1 and 2. It does not obligate companies to report their scope 3 emission in any specific way, so it allows them to decide whether or not they include scope 3 in their GHG inventory and how. The three scopes are:

- Direct emissions from the company's operation (Scope 1)
    - GHG sources owned or controlled by the company, like facilities and vehicles
- Indirect emissions from energy purchased by the company (Scope 2)
    - Electricity, steam, heating, & cooling
- Indirect emissions from upstream and downstream activities (Scope 3)
    - Upstream: the goods and services bought by the company
    - Downstream: the goods and services provided by the company

(Greenhouse Gas Protocol 2011a, 5.)

The greenhouse gases which form the CO_2 equivalent emissions in scopes 1-3, are carbon dioxide, methane, N_2O, PFCs, HFCs, and SF_6 (Greenhouse Gas Protocol 2011a, 5). An overview of the scopes and emission categories inside them is presented in Figure 1.

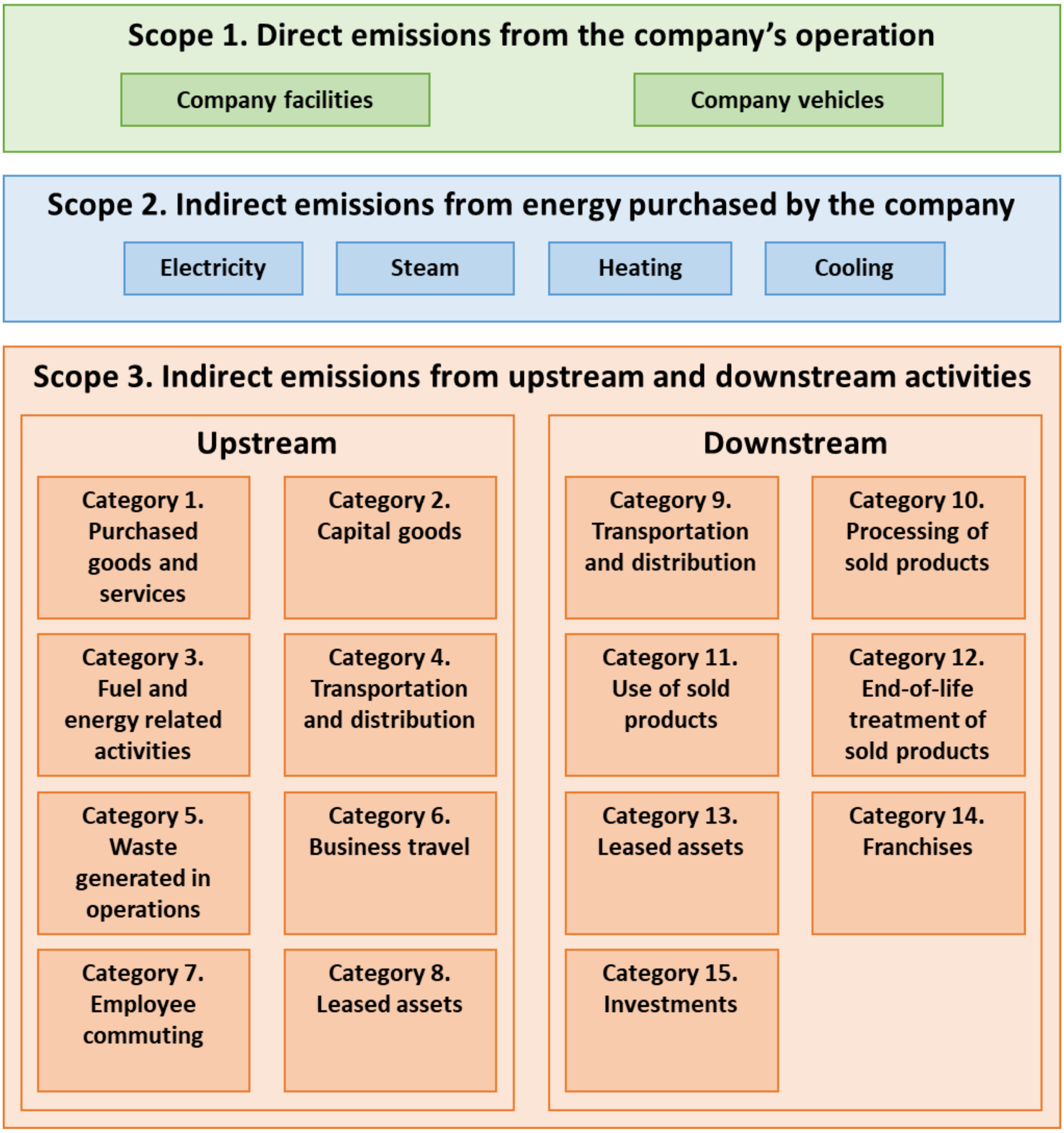


Figure 1. Overview of GHG Protocol scopes and emission sources across the value chain. (Greenhouse Gas Protocol 2011a, 5)

The Corporate Standard is the basis of scope 1 and 2 calculation. Beside the standard itself, its appendix F called Categorizing GHG Emissions Associated with Leased Assets, and an amendment for the standard called the Scope 2 Guidance, are used in calculation. (Voutilainen 2021.)

3.1.2 The GHG Protocol's Scope 3 Standard

Scope 3 activities often cause most of the GHG emissions of a company's operation, and when that's the case, they are also the best opportunity to reduce the emissions. An overall approach to measuring, managing, and reporting GHG emissions of scopes 1, 2, and 3 helps companies to identify the best reduction possibilities of emissions considering their whole value chain. This way companies can make more sustainable choices concerning their production, purchases, and the products they sell. (World Resources Institute & World Business Council for Sustainable Development 2010, 3.)

The Scope 3 Standard helps to make the examination and reporting of indirect emissions more consistent and complete (Greenhouse Gas Protocol 2021). It is grounded on and supplements the Corporate Standard and should be used together with the Corporate Standard's revised edition (2004) (Greenhouse Gas Protocol 2011a, 5).

So, companies have two options for reporting their corporate-level GHG emissions; either to follow only the Corporate Standard, in which case only scopes 1 and 2 are mandatory and scope 3 optional, or in addition to that follow the Scope 3 Standard which requires reporting of scope 3 emissions conforming its requirements (Table 2).

There is also a supplement for the Scope 3 Standard called Technical Guidance for Calculating Scope 3 Emissions (Voutilainen 2021).

Table 2. Corporate-level GHG Protocol reporting options. (Greenhouse Gas Protocol 2011a, 6)

	Reporting in conformance with the GHG Protocol Corporate Standard	**Reporting in conformance with the GHG Protocol Corporate Standard and the GHG Protocol Scope 3 Standard**
Scope 1	Required	Required
Scope 2	Required	Required
Scope 3	Optional: Companies can report any emissions of scope 3 they choose	Required: Companies must report emissions of scope 3 following the requirements of the Scope 3 Standard

3.1.3 Relationship between the GHG Protocol's standards

Besides the value chain, stakeholders are often asking for information about emissions of companies' products (Greenhouse Gas Protocol 2011b, 5). At the same time with the Scope 3 Standard, the GHG Protocol also developed the Product Standard. These standards complement each other in the accounting of value chain GHG emissions, even though they can be used also independently. (Greenhouse Gas Protocol 2011b, 6.)

The Product Standard is the GHG Protocol's answer for a globally established procedure for companies to measure and control the GHG emissions of their products and services (Greenhouse Gas Protocol 2011b, 3). The Product Standard helps to detect the best GHG emission reduction possibilities within a product's life cycle, therefore enabling a company to identify, which of its products have the biggest GHG decreasing potential (Greenhouse Gas Protocol 2011b, 6).

Because the Product Standard considers only GHG emissions and removals of a product (CO_2-removals are generally caused by photosynthesis), the analysis is simpler and stakeholders get clear results, but possible combined advantages of environmental impacts or trade-offs are not taken into account. Other environmental impacts, such as resource and ozone depletion, degradation of ecosystem, and human health, should also be considered in reduction of a company's overall GHG emissions based on product assessment results. The guidelines and methods of the Product Standard can be useful also outside the standard when assessing non-GHG impacts, which can be presented in addition to the GHG inventory results. (Greenhouse Gas Protocol 2011b, 7.)

Both scope 3 and product investigations utilize common data from suppliers and other actors which belong to the supply chain. Because of possible overlaps in the data, it can be beneficial to implement the corporate-level and product-level inventories side by side. All the above-mentioned standards can be used as integrated with each other. For example, if the Corporate Standard and Scope 3 Standard are applied to account for the total emissions of a company in scopes 1, 2, and 3, the results can be used to identify the products which have the biggest emissions. Then the Product Standard can be used for identifying the most effective possibilities to reduce the emissions within the life cycles of those products.

Product-level results from the use of the Product Standard can also be used for calculating scope 3 emissions related to selected products. (Greenhouse Gas Protocol 2011b, 6.)

The lifecycle emissions of all the products manufactured by a company together with emissions of certain scope 3 categories such as commuting, business trips, and investments, form the total corporate-level emissions of the company, which correspond to scope 1, 2, and 3 emissions combined. In practice though, it is not required that companies would implement life cycle inventories for separate products when they are accounting for their scope 3 emissions. (Greenhouse Gas Protocol 2011b, 6.)

The relationship of the Product Standard, the Scope 3 Standard, and the Corporate Standard is depicted in Figure 2. This simple example, where a company has just one product, shows how the corporate level emission scopes correspond with the product level life cycle phases.

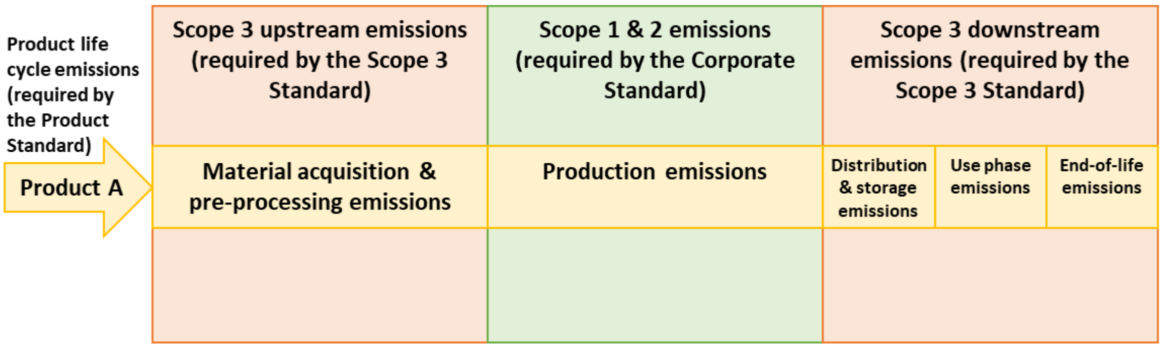


Figure 2. Relationship between the Product Standard, the Scope 3 Standard, and the Corporate Standard. (Greenhouse Gas Protocol 2011b, 7)

3.1.4 Organizational boundaries

A company's organizational boundaries for carbon footprint calculation of scopes 1 and 2 can be set either based on equity share (economic interest) or operational or financial control. In equity share based calculation, the company's greenhouse gas emissions of operations are calculated based on its equity share of each operation. If the calculation is based on control, the company takes into account all GHG emissions from the operations which it controls. This control can be operational or financial. Operational control means that the company or its subsidiary can independently make and implement operating policy decisions regarding an operation, whereas financial control means that the company can direct the operation's financial policies and benefit economically from it. (Greenhouse Gas Protocol 2004, 17-18.) These alternative approaches are illustrated in Figure 3.

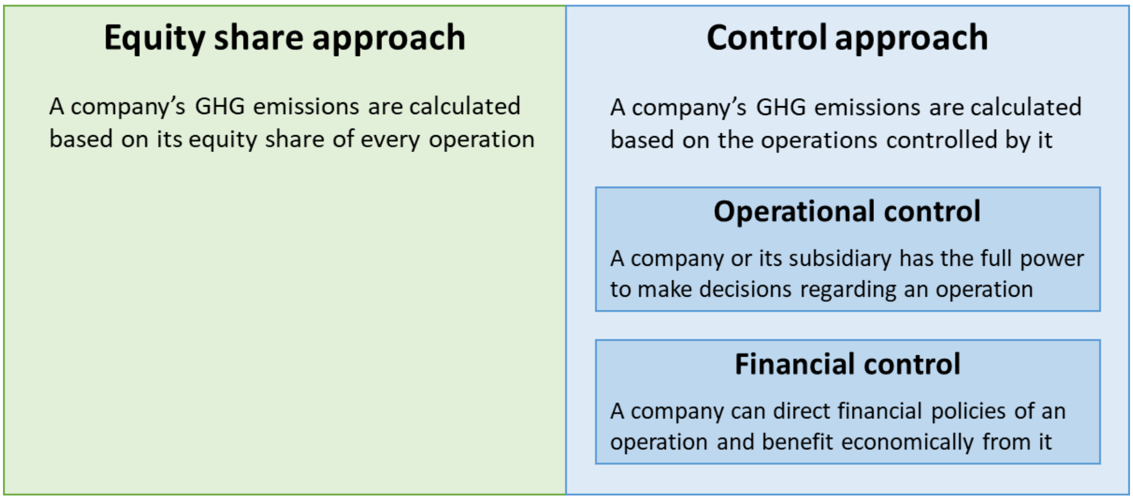


Figure 3. Options for organizational boundaries for GHG emissions. (Greenhouse Gas Protocol 2004, 17-18)

3.2 Carbon handprint and the handprint quantification process

Carbon handprint is becoming an important additional tool, side of carbon footprint. It tells how much GHG emissions will drop if an offered solution (a product or a service) replaces a baseline solution (Pajula et al. 2021, 8). Therefore, carbon handprint differs from carbon footprint in principle so that the handprint is used for decreasing other actors' footprint instead of one's own footprint (Pajula et al. 2021, 11). The difference of carbon footprint and carbon handprint is illustrated in Figure 4.

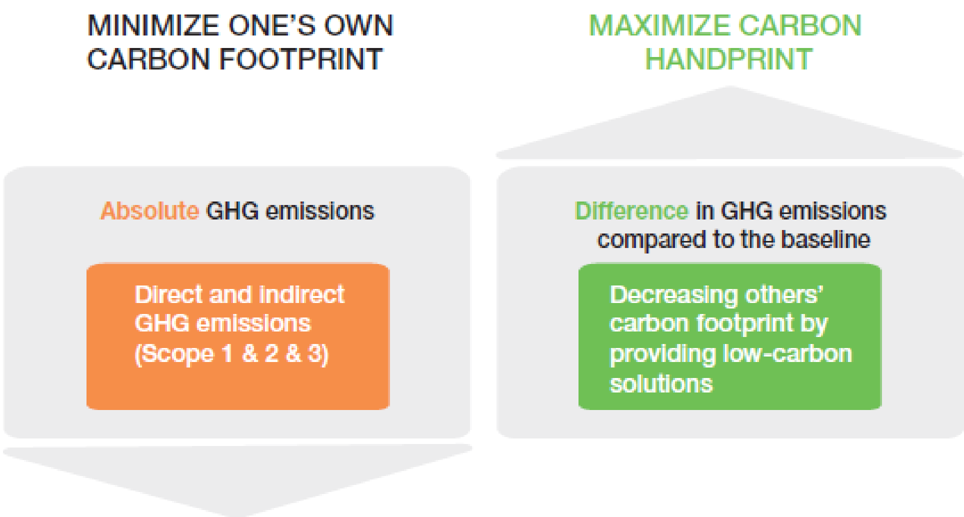


Figure 4. The principles of carbon footprint and handprint. (Pajula et al. 2021, 11)

Carbon handprint usually results from some or all of the following contributing mechanisms: more efficient use of materials and energy, longer lifetime and better performance, waste reduction, and carbon capture and storage (Pajula et al. 2021, 13). A handprint can be formed in two alternative ways. An offered solution can have lower footprint than the baseline solution, or the footprint of the user's processes can be decreased. A handprint can also be a combination of these, as Figure 5 shows. (Pajula et al. 2021, 14.) One solution that would have this kind of handprint is an insulating material that has lower cradle-to-gate emissions and is also more efficient insulator than a competitor's corresponding product.

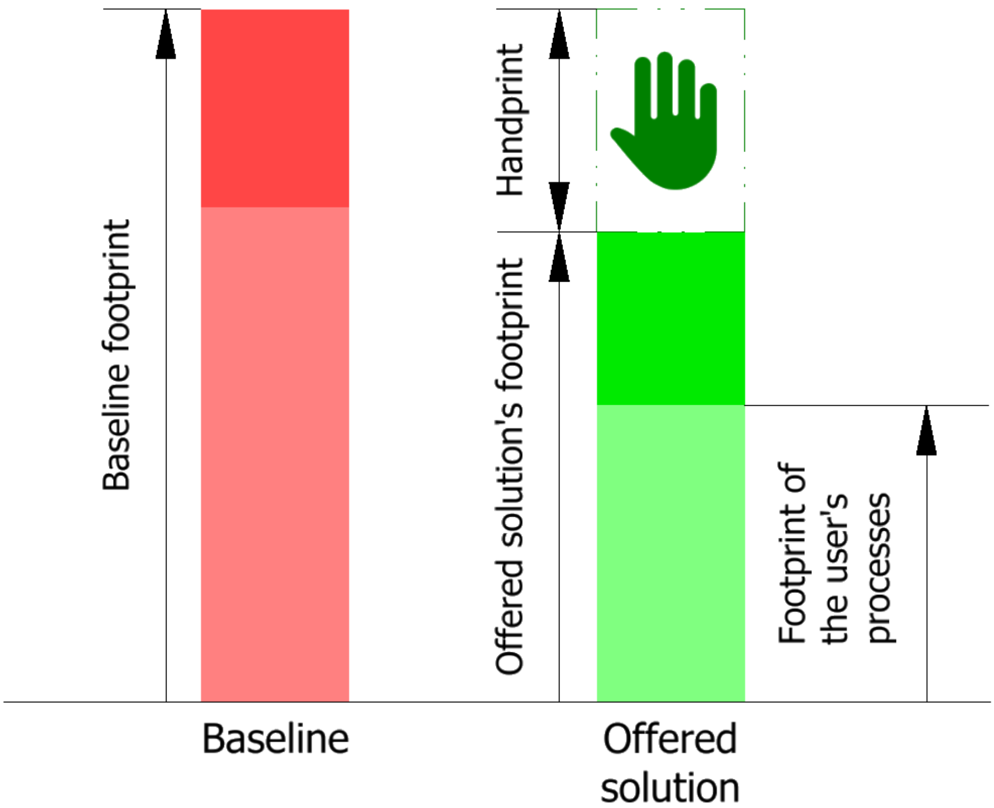


Figure 5. Formation of offered solution's handprint. (Pajula et al. 2021, 14)

When companies have presented different handprints to point out the beneficial environmental impacts of their actions, the problem has been that they have so different approaches to the topic that it complicates accountability. And when more environmental, social, or economic factors are included in the scope the quantification becomes more difficult. (Pajula et al. 2021, 10.) A consistent approach for handprint assessment developed by Finnish researchers was utilized in this work and will be introduced next.

The environmental handprint quantifying approach, which is closely related to the lifecycle assessment method, was developed in Finland by researchers of LUT University and VTT. The framework was formed based on observed similarities between separate cases that were introduced by many industrial partners from different business areas (Pajula et al. 2021, 10, 16). It has 13 steps which are in 4 stages. The first stage is included only in the calculation of a handprint. There, the concerned case's conditions are recognized and the baseline for the handprint calculation is defined. The steps in the following stages are normal LCA steps and footprint calculation. In the last stage, the handprint results are communicated in an appropriate way. Handprint calculation is basically an iterative process, meaning that steps might need to be updated because of the following step's results. (Pajula et al. 2021, 16.) The stages and steps of this process are presented in Table 3.

Table 3. Stages and steps of the handprint quantification process. (Pajula et al. 2021, 16)

Stage	Step
1. Handprint requirements	1. Definition of the offered solution's scope 2. Identification of potential handprint contributors 3. Identification of the relevant environmental impacts and potential indicators 4. Identification of the offered solution's users and beneficiaries 5. Definition of the baseline
2. LCA requirements	6. Definition of the functional unit 7. Definition of the system boundaries 8. Definition of needed data and sources for it
3. Quantification	9. Calculation of the footprints 10. Calculation of the handprint
4. Communication	11. Identification of the relevant indicators to be communicated 12. Consideration of the handprint's critical review 13. Communication of the results

In step 1, the scope of the offered solution is defined and described in detail. The offered solution can be a product, service, portfolio, or a project, that may have positive environmental impacts if the baseline solution is replaced with it. In step 2, the offered solution's possible benefits (contributors) compared to the baseline are identified. (Pajula et al. 2021, 18.) The environmental impacts which are identified in step 3 can relate either to climate change, resource use, water, nutrients, or air quality. For climate change, the obvious indicator is GHG emissions (carbon footprint). (Pajula et al. 2021, 17.) The environmental impacts of the offered solution depend on the situation (how, where, and when it will be used), so quantification of its handprint always requires identification of users and beneficiaries (step 4), which can be consumers, companies, or even society (Pajula et al. 2021, 21).

Next in the carbon handprint quantification process, a baseline needs to be defined (step 5). The baseline is a current or alternative solution with same functions, which the offered solution is supposed to replace. The carbon footprints of the baseline and the offered solution will be compared, in order to solve the offered solution's carbon handprint. But, if the offered solution is totally new to the market, it might have functions that do not exist yet in other products. In that case, the situation without and with this solution must be compared to quantify the handprint. (Pajula et al. 2021, 21.)

If the offered solution is not new and is meant to replace another solution, the following conditions must be filled. It and the baseline should both have the same function and purpose, be available, be used in the same time period and area, and be compared also otherwise in the same conditions and with the same criteria. The selected baseline must be well explained and clearly reported, because it affects a lot on the size of the handprint. (Pajula et al. 2021, 21.)

Figure 6 shows the whole baseline determination procedure. There are two important questions that guide the determination:

- Does the offered solution replace another solution, or is it completely new?
- If it replaces another solution, is it targeted for a certain user/beneficiary?

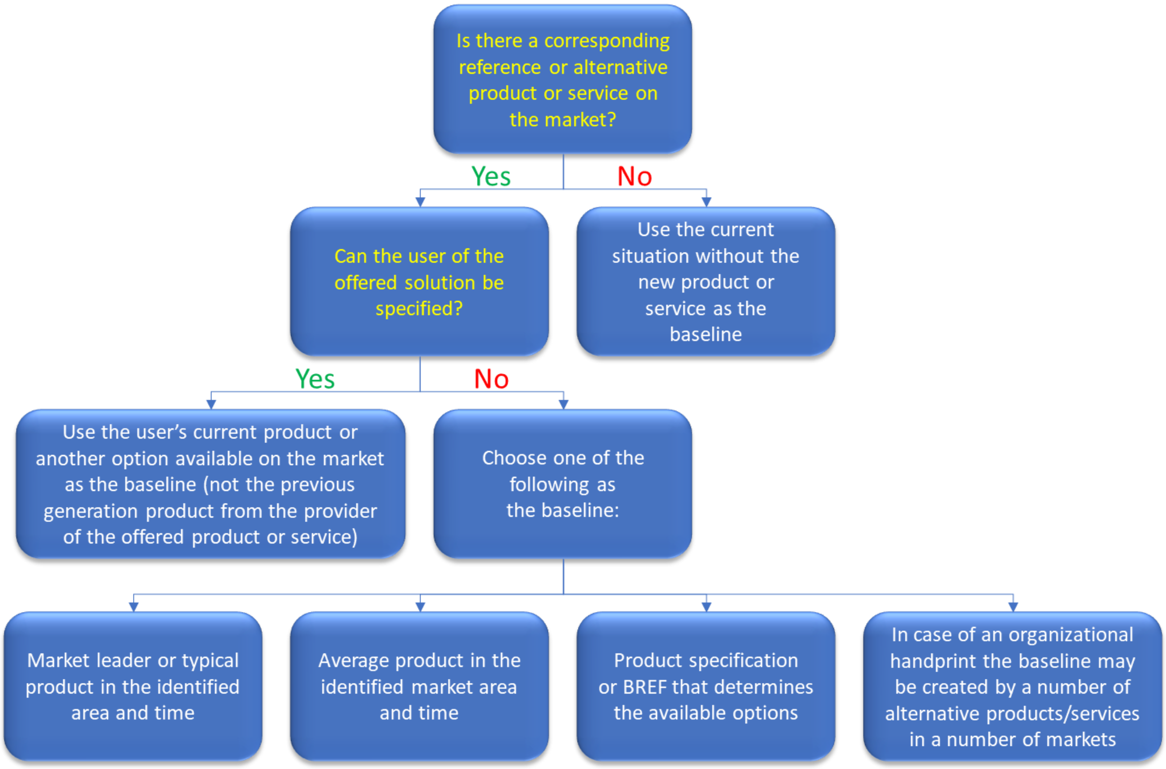


Figure 6. The baseline determination procedure. (Pajula et al. 2021, 22)

As said earlier, the steps in stages 2-4 are just normal footprint calculation. In step 6, the functional unit is defined. The compared environmental impact of the baseline and the offered solution must be associated with the same functional unit so that the comparison is possible. More information about this is in the ISO standards 14040-44. (Pajula et al. 2021, 23.) For process pumps, for example, the functional unit could be output pumping energy (output power * usage time) (kWh, MWh).

In step 7, the system boundaries are defined. This means determination of which unit processes are included in the assessment. In an ideal situation, inputs and outputs across the system boundaries are elementary flows between the system and its environment, but inputs, outputs, processes, or life-cycle stages that do not have real significance for the results can be excluded. Even so, the use phase of the assessed product's lifecycle should always be included in the system and usually also the end-of-life phase. The system boundaries must correspond to the ones of the baseline system and the objective of the assessment. If the assessment concerns an organization's handprint, the baseline system has corresponding products and services that the offered solution is meant to replace. It should also be explained, why the boundaries are set the way they are. Defining of system boundaries is introduced more in detail in the ISO standards 14040-44, 14046, and 14067. (Pajula et al. 2021, 24.)

Regarding step 8, the most up-to-date data that is available from the user should be utilized, if the intended user of the offered solution is known. In another case, if there are only potential users or beneficiaries, average or statistical data shall be used. According to ISO 14040-44, 14046, and 14067, the utilized data should be accurate and comprehensive regarding time and area. (Pajula et al. 2021, 24.)

In the footprint calculation of the baseline and offered solution (step 9), each chosen indicator (GHG emissions in case of carbon footprints) is calculated separately over the life cycles of these systems. When the carbon footprints are solved, the offered solution's possible carbon handprint can be calculated (step 10). Only if the footprint of the offered solution is smaller than the baseline footprint, the offered solution creates a handprint. (Pajula et al. 2021, 25.)

$$CHP_{\text{offered solution}} = CFP_{\text{baseline}} - CFP_{\text{offered solution}} \tag{1}$$

where $CHP_{\text{offered solution}}$ = Carbon handprint of the offered product or service [t CO_2e]
CFP_{baseline} = Carbon footprint of the baseline [t CO_2e]
$CFP_{\text{offered solution}}$ = Carbon footprint of the offered product of service [t CO_2e]
(adapted based on Pajula et al. 2021, 25)

A handprint can be communicated from business to business or from business to customer. In step 11 of stage 4, the relevant indicators for communication are identified. The most important indicators concerning the results are selected, and both positive and negative impacts are communicated in a transparent way. (Pajula et al. 2021, 26.)

After that, critical review for the handprint assessment and its results is acquired (step 12). Critical review is needed because it is required in the ISO standards 14040-44 when comparative claims are going to be made based on the results. ISO standard 14026 on the footprint communication also sets requirements concerning footprint comparison. Critical review helps to verify the calculations and their results and to fill the standards' requirements. Therefore, it is strongly recommended if the results of a handprint calculation are communicated to consumers, but it is useful also in business-to-business communication. The critical review can also be performed by an independent reviewer that is inside the organization which carried out the handprint assessment. (Pajula et al. 2021, 26.)

Finally, the results are communicated (step 13). In communication of the results a suitable communication unit needs to be decided. It can be the functional unit that is used in calculation, but some other unit can be chosen as well if it is more practical. (Pajula et al. 2021, 26.)

3.3 ISO 14001:2015 standard for environmental management systems

All Sulzer's production and service sites are ISO 14001:2015 certified (Sulzer 2021e). ISO 14001:2015 standard gives requirements and a framework for an effective environmental management system of any kind of company or organization. This standard provides certainty for the company management, employees, and stakeholders that the company measures and improves its environmental impacts. Over 300000 companies or organizations in 171 countries have ISO 14001:2015 certification. (ISO 2021a.)

The systematic environmental management approach of ISO 14001:2015 helps companies to prevent or reduce unwanted environmental impacts as well as reduce the environment's negative impacts on the company. This approach also helps a company to fulfill compliance responsibilities, improve environmental performance, prevent unintentional shift of environmental impacts from one stage to another inside its products' or services' life cycles, have a stronger position on the market, and communicate environmental matters to right stakeholders. Naturally, the standard does not affect any conditions of legislation. (ISO 2015.)

The approach of ISO 14001:2015 is based on the PDCA (Plan-Do-Check-Act) model that can be utilized for environmental management. It gives an iterative process for organizations to develop their operation continuously. Plan-phase includes establishment of environmental targets and processes needed for achieving wanted results. In Do-phase, the processes are implemented according to the plan. In Check-phase, the processes are monitored, their accordance with the environmental policy is checked, and the results are reported. In Act-phase, actions are taken to improve the results constantly. (ISO 2015.) The principle of PDCA and its relationship with the framework of ISO 14001:2015 is depicted in Figure 7.

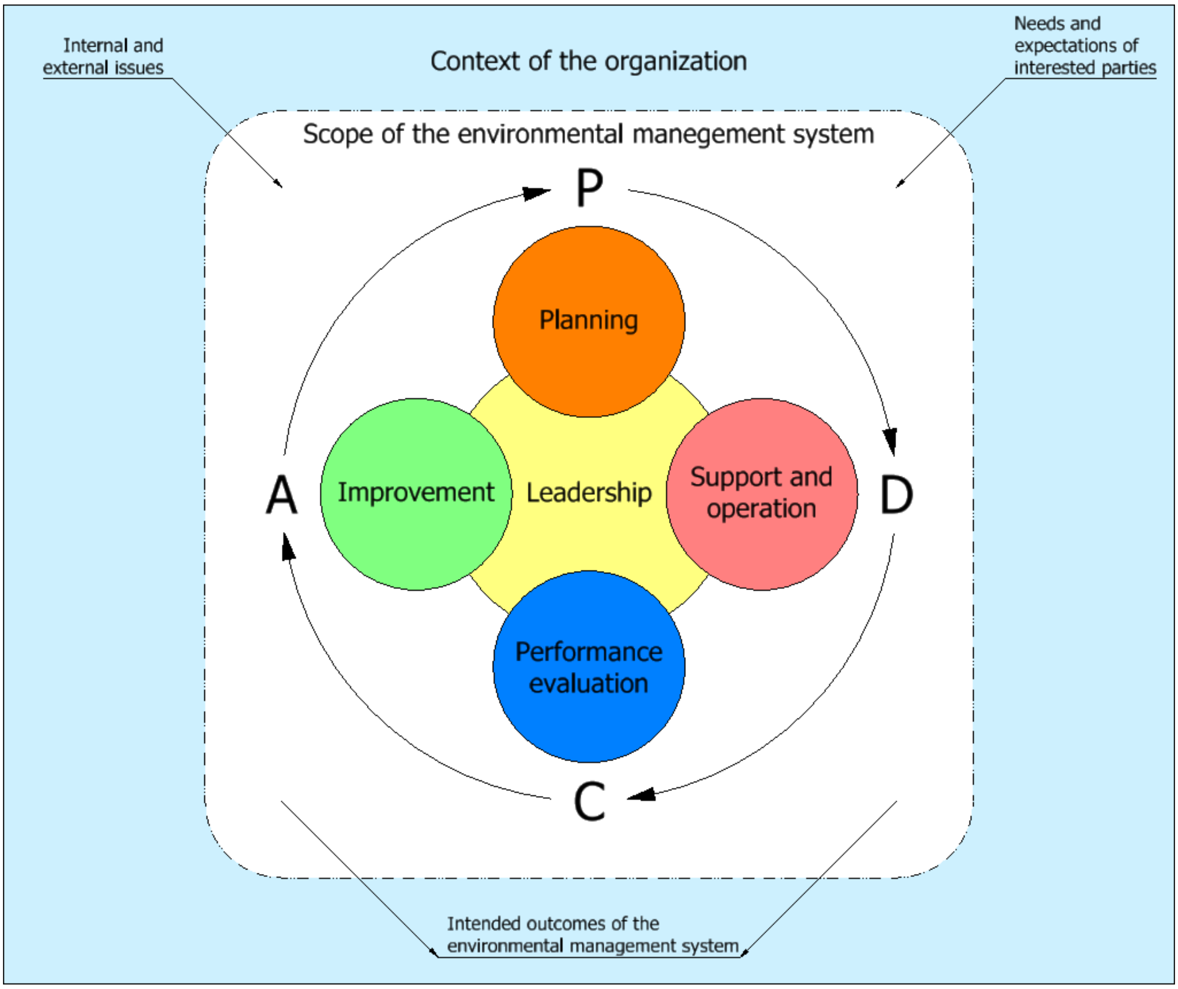


Figure 7. Relationship between PDCA and the framework in ISO 14001:2015 Standard. (ISO 2015)

4 SIGNIFICANCE OF OPERATIONAL ENVIRONMENT IN ACHIEVING POSITIVE IMPACTS

Because a major part of the life cycle GHG emissions of an electricity consuming industrial process equipment (such as a pump) is generated during its use phase, the location where it is operating affects its emissions significantly. This is due to variation in emission factors of produced electricity between different areas. Also, the choices of the equipment's user concerning the source of used electricity can make a big difference in certain areas. The location of the product's manufacturing facility (in SPFIN's case, Karhula or Mänttä) affects both the manufacturer's and the equipment's total emissions too through the emission factors of available energy source options in that area.

If there is environmental-friendly electricity available on the market and the equipment's user (or manufacturer) chooses to buy it, the emissions from the used electricity can even be zero or close to it. That is also the case if the equipment's user (or manufacturer) decides to produce electricity by itself with solar power, for example. The higher the region's basic mains current's emission factor is, the bigger is the significance of these choices. The equipment's user's choice of electricity source impacts on scope 3 downstream emissions, whereas the manufacturer's choices concerning used electricity, as well as purchased heating, cooling, or steam, impact on scope 2 emissions. Usually, the emission factor of electricity used by the equipment in the use stage has much more influence on its life-cycle emissions than the emission factors of electricity and other forms of energy used in the manufacturing stage.

Table 35 in Appendix I shows the mains current's production fuel mix factors in the countries to which SPFIN delivered equipment in 2019. The data in the table is from year 2019 except for those countries for which the factors were available only from year 2016.

A production fuel mix factor tells the average GWP of electricity production in a specific country based on the mix of fuels used by the country's power plants. A residual fuel mix factor means the average emission factor of available electricity, after electricity that is sold as generated from specific fuels (green or renewable energy which a customer can choose to buy), has been subtracted from the total electricity production. So, a production fuel mix factor can be used for location-based reporting and a residual fuel mix factor for market-based reporting when electricity is not bought from specific fuels. (Carbon Footprint Ltd 2022, 2.) If the energy sources of purchased electricity are specified, market-based reporting can be done by using an emission factor reported by the electricity supplier.

In Finland, for example, the difference between the production fuel mix and residual fuel mix factors is affected by the electricity that is imported from Russia (Energiavirasto 2021, 1). There are big differences also between the electricity production's emission factors of different countries. Of the European countries, Poland has the highest factors due to heavy use of coal in its electricity production (Eskola 2021). Then there are countries like Iceland and Norway which have a lot of renewable energy resources and they have harnessed them into their energy production. Iceland is largely using geothermal energy and Norway produces all its electricity from hydropower (Luukko 2017). Low emission factors of France result largely from the strong use of nuclear power; over 70% of France's electricity is produced with it (Vattenfall 2021).

An equipment's energy efficiency also has impact on the use phase GHG emissions; the higher emission factor the consumed electricity has, the more important the efficiency is. Countries have different legislations concerning, for example, minimum efficiency of water pumps. Sulzer's pump products fulfill the requirements of the EU's ErP directive, and hence also the looser requirements of other countries' legislations (Vanhala 2020, 2).

In addition to an equipment's use phase, scope 3 has many other emission source categories that depend on the operational environment of the equipment and/or its manufacturing plant. For example, emissions from the transport of materials and components to the manufacturing facility depend strongly on the distance from the subcontractors and available means of transportation. The same applies to transportation of products from the manufacturing plant to customers. Therefore, it is emission wise reasonable for a product's manufacturing company to use raw material sources and subcontractors which are as near as possible, and to use the least polluting available transportation options, if possible. And, if the company has more than one factory manufacturing similar products, it is also reasonable to deliver a product for a customer from the nearest possible factory. This is also the case with Sulzer's products; the pumps for Chinese customers are delivered for them from the Dalian factory in China rather than from the Karhula factory.

Other examples of scope 3's emission source categories that to some extent depend on the locations of a company's offices and plants, are upstream categories, 6 and 7 (business travel and employee commuting), and 5 (waste generated in operations); emissions of waste management can be very different depending on the location. In downstream, emissions from category 12 (end-of-life treatment of sold products) may also be different depending on the customer's local waste management system or whether the used products are sent back to the manufacturer for re-utilization.

5 SULZER AND ITS PRODUCTS

Next, fundamental information is presented about Sulzer corporation, Sulzer Pumps Finland Oy, and their operation and products.

5.1 Sulzer corporation

Sulzer is a multinational corporation which has its headquarters in Winterthur, Switzerland, and was founded in 1834 (Sulzer 2021f). It is a global leader of fluid engineering and specializes in pumps, agitators, and separation and application technologies concerning all kinds of fluids (Sulzer 2021b). Sulzer has approximately 15000 employees and 180 manufacturing plants and service centers around the world (Sulzer 2021g). In 2020, Sulzer generated sales of 3,3 billion Swiss francs (~3,1 billion €) (Sulzer 2021g).

Sulzer corporation's operation is divided into three divisions, which are Flow Equipment, Services, and Chemtech. Flow Equipment division delivers equipment for pumping, mixing, and treatment of all kinds of fluids. Services division provides upkeep and maintenance for Sulzer's equipment, and Chemtech division delivers high-quality chemical processing and separation technologies for chemical industry. (Sulzer 2021b.)

The Flow Equipment (until 2021 Pumps Equipment) division's products are: IoT and advanced analytics, axial flow pumps, axially-split pumps, multiphase pumps, radially-split multistage barrel pumps, radially-split multistage ring section pumps, radially-split one/two stage pumps, single stage end suction/overhung pumps, submersible pumps, lifting stations, progressing cavity pumps, sewage grinders, submersible dewatering pumps, vertical pumps, vertical sump pumps, agitators and submersible mixers, compressors and aeration, medium consistency (MC®) products, tower management systems, slurry pumps, vacuum pumps, and monitoring and controls (Sulzer 2021c, 17-19).

Products of the Flow Equipment division are manufactured and tested in the following sites: Bruchsal (Germany), Burgos (Spain), Cuautitlán Izcalli (Mexico), Dalian (China), Easley (USA), Jundiaí (Brazil), Karhula (Finland), Kunshan (China), Leeds (UK), Navi Mumbai (India), Portland (USA), Riyadh (Saudi Arabia), Santa Ana (USA), St. Quentin (France), Suzhou (China), Thimister-Clermont (Belgium), Vadstena (Sweden), and Wexford (Ireland) (Sulzer 2021c, 8-12).

For the sustainability management of the corporation, Sulzer has introduced ESG (Environmental, Social, Governance) metrics. Sulzer's ESG activity is led by the Board of Directors' Strategy and Sustainability Committee. With concentrated teamwork, reporting, and local initiatives, sustainability actions are monitored and implemented on global and local level. Sulzer strives to improve their environmental, social, and economical sustainability by reducing their environmental footprint in energy use, GHG emissions, and water use, developing waste management, offering a safe and healthy workplace and opportunities of professional development for employees, and by developing the products and services. (Sulzer 2021h.)

In addition to ISO 14001:2015 certification, all of Sulzer's production and service sites are also ISO 9001:2015 and ISO 45001:2018 certified (ISO 45001:2018 was preceded by OHSAS 18001) (Sulzer 2021e). ISO 9001:2015 standard gives requirements for a quality management system and helps to maintain products and services' high quality (ISO 2021b). ISO 45001:2018 is developed for improving safety of employees and reducing risks in workplaces (ISO 2021c).

The company aims at reducing its carbon footprint by 30% from 2019 level and becoming carbon neutral by 2050. Other targets are to accelerate shift towards cleantech and make every year improvements in all key indicators. (Sulzer 2021i.) By the end of 2020, 16 out of 17 Sulzer's sites in Britain were using only renewable energy, and the company is going to implement this on more sites across Europe during 2021. Sulzer also sets incentives and increasingly concentrates resources on research and development of sustainability. (Sulzer 2021a.)

5.2 Sulzer Pumps Finland Oy

SPFIN was born in year 2000 when Sulzer Pumps took over the Finnish pump manufacturer Ahlström Pumps (Sulzer 2021j). SPFIN's headquarters is in Kotka, Karhula (Fonecta 2021). In 2020, SPFIN had 467 employees and generated sales of 186,97 million € (Fonecta 2021).

Products of SPFIN include pumps (many different types) and related accessories, agitators (Salomix® product family), high-speed turbocompressors (HST and HSR), submersible aerator mixers (OKI), pumping stations, and spare part, maintenance, and consultant services (Haarala 2021a, 3). Of the many pump types manufactured by the Flow Equipment division, SPFIN makes single-stage process pumps (AHLSTAR and SNS series), multistage pumps (MBN, MBN-RO), axially-split pumps, vertical pumps, and medium consistency pulp pumps (Sulzer 2021c, 9). SPFIN also manufactures on demand so-called legacy products, which are obsolete product types but still used as replacement for old equipment that customers have been using to this day. A customer may want to buy a legacy product to avoid changes in the system surrounding the replaced pump, and hence saves in investment costs, even though also the customer is aware that a more modern and more energy-efficient product would become more cost-effective over time.

Uses of SPFIN's pumps and other products are various industrial and municipal processes (Sulzer 2021c, 9), such as pulp and paper production, food production, drinking-water production from sea water (multistage MBN-RO pumps in reverse osmosis facilities), and sewage treatment. SPFIN delivers pumps with needed certification (ACS and NSF 61 for drinking-water pumps, for example). The sales area of SPFIN is basically the whole world, but in practice not China, because Sulzer has a factory manufacturing similar pumps also there, in Dalian (Haarala 2021b).

SPFIN has the following functions in the following locations in Finland:

- Karhula:
    - Production (Karhula pump factory is a part of global production network)
    - Service and spare part center
    - Product development, research center
    - Sales (domestic, export, spare parts, tendering support), marketing

    - Functions of Industry business unit Strategy & Projects and business segments
    - Functions of global IT and procurement organization
    - Local management, administration and support functions
- Mänttä, Oulu, and Rauma: service centers
- Helsinki: Product development of turbo compressors, functions of the global IT organization
- Vantaa: Domestic sales (mainly Municipal water) and Water business unit service center

(Haarala 2021a, 3.)

For all the pumps which are manufactured in the Karhula factory, the plant has comprehensive testing systems, including a 1,5 MW MC® pump loop, a 0,5 MW general test station for other pump types, and a 2,7 MW test bed for multistage pumps (Sulzer 2021c, 9). SPFIN also subcontracts smaller pump sizes at Javasko Oy (Ltd), a machine workshop company in Mänttä, Complete pump assemblies including their accessories are then transported from the Karhula pump factory and Javasko Oy to HUB logistics Packaging Oy (Ltd) in Karhula, from where the packaged products are then sent to customers.

Maintenance and spare parts are essential during a product's life cycle. For this, SPFIN has five service centers in Finland. The main service center called the service and spare part center (SEFI) is located in Karhula. SEFI has the required machine tools and inspection & assembly areas for repair and basic maintenance. Needed spare parts are delivered for SEFI by Sulzer's worldwide delivery center network. (Sulzer 2021k.) Services provided by SEFI include:

- Spare parts and maintenance for pumps, agitators and high-speed compressors which are already sold to customers
- Reparation of products of these categories regardless of their manufacturer
- Capacity and material updates according to changing requirements
- Renovation
- Installation and troubleshooting on site
- Emergency duty around the clock

- Tailored design solutions to improve reliability and performance of equipment
- Long-term maintenance contracts
- PRE-owned products, which are products that have been in use but are repaired to correspond to a new product, in order to be sold again

(Sulzer 2021k, Hasko 2021.)

SPFIN has also smaller service centers for pumps and agitators in Mänttä and Oulu, for mechanical seals in Rauma, and for submersible pumps and agitators in Vantaa (Sulzer 2021l).

SPFIN supports the aforementioned sustainability targets of the parent company by implementing annual environmental improvement program. In 2021, the objects of this program concerned developing energy efficiency, and reducing and utilizing by-products. The Finnish company aims at reducing carbon footprint by decreasing direct energy consumption and examining what alternative energy sources (such as solar power as electricity source) could be used. SPFIN has taken energy saving measures as a part of complying with the Energy Efficiency Agreement of Technology Industries of Finland. The carbon footprint review is now being expanded to cover SPFIN's whole value chain including to certain extent also subcontractor companies and transportation. (Haarala 2021c.)

SPFIN's operation is also certified to the ISO standards 9001:2015, 14001:2015, and 45001:2018 (Haarala 2021a, 3). Regarding the management of the ESG efforts in SPFIN, environmental management (which is related to ISO 14001:2015 certificate) has mostly been done independently by the Finnish company rather than under the guidance of Sulzer corporation. SPFIN strives to constantly improve employee safety (ISO 45001:2018) and show proof of it. Governance in SPFIN has been handled with Sulzer's compliance program for several years now. (Haarala 2021b.)

6 CARBON FOOTPRINT OF SULZER PUMPS FINLAND OY

Carbon footprint of SPFIN consists of separate carbon footprints of its different production plants and offices. However, separate functions in the same locality are considered as one entity. Therefore, the pump factory, service and spare part center, and other functions in Karhula are addressed as Karhula, for example. The initial data was collected separately for each locality and these localities are Karhula, Mänttä, Oulu, Rauma, Helsinki, and Vantaa. A detailed list of the functions included in these localities was presented in the introduction of SPFIN (in chapter 5.2).

The purpose was to find out the magnitudes of emissions from different sources and scopes with the data that could be utilized and to create a basis for future assessments, rather than to get absolutely precise results at this point (all data that have impact on the results was not available). Precision of results can be increased in coming assessments based on the shortcomings in the availability of needed data that were now detected. Year 2019 was chosen as the time period for each scope's calculation because it was the last year not affected by the COVID-19 pandemic.

At first stage, SPFIN's company level carbon footprint was calculated covering the GHG Protocol scopes 1 and 2. In collection of initial data for the calculation, primary data was used whenever possible. Some data was not available exactly for year 2019, so then data that was as close to that period as possible (from year 2020 or from the period from October 2018 to September 2019) was used. In cases where data was not available at all, like for district heating in rented buildings, estimation was done. The data collection required doing some investigation inside and outside SPFIN. The data was acquired from SPFIN's annual reports, from electricity and district heat supplying companies, and from procurement people who have access to needed data sources. All the obtained information was then entered into a datasheet that was sent to the environmental consulting company Ecobio Oy. The mechanical calculation was performed by them.

Carbon footprint for scope 3 emissions was also calculated after scopes 1 and 2, and initial data for it was collected in the same manner. Accounting for emissions in scope 3 is more complex process than in scopes 1 and 2. This is because in scope 3, calculation of emissions requires consideration of which of the many emission categories should be included and from where reliable enough data for them can be obtained. It was already before the calculations quite clear that majority of the total emissions belong to scope 3 due to the long use phase of the products and acquisition of materials and components. Still, it was important to account for also scope 1 and 2 emissions, because they are not insignificant either and it is possible to reduce them in the future by optimizing the company's functions. SPFIN's carbon footprint calculation for scopes 1 and 2 was done based on operational control.

6.1 Scope 1 – direct emissions from manufacturing plants

Scope 1 includes all emissions that derive directly from the company's operation. In SPFIN's case, this covers emissions from facilities and vehicles which are under the company's control, because of the operational control approach.

6.1.1 Company facilities

Direct emission sources from SPFIN's facilities are the use of different gases (like welding gases) in production and potential refrigerant leaks. Data for gases that were purchased on each plant in year 2019 was obtained from Linde's customer portal through SPFIN's procurement department (Kemppainen 2021). Of all the gases that are used in the production, the ones that have global warming potential either as such or when combusted, are propane (C_3H_8), acetylene (C_2H_2), and MISON® 18. MISON® 18 is a MAG welding gas which contains for the most part argon but also 18% of CO_2 (Linde 2021, 20). Only the share of propane that is used in production is included here in company facilities. Propane that is used by forklifts in Mänttä and Vantaa is included in fuels used by company vehicles, and gases which do not have any GWP, such as air, argon, and oxygen, are left out of consideration.

Both in Karhula and in Mänttä, propane is used in production for heating parts when making interference fits (Laiho 2021, Tuominen 2021a). Acetylene together with oxygen are occasionally used in agitator installation, but not as a standard procedure (Laiho 2021). During year 2019, 403 kg of propane (LPG) was purchased to Karhula in 10 kg and 11 kg gas cylinders, of which 382 kg to the pump factory and 21 kg to SEFI (Kemppainen 2021). 10 kg of propane was also purchased for production in Mänttä (Kemppainen 2021), making the total amount of propane that was purchased for production 413 kg. Purity of the purchased propane is at least 95% (Linde 2021, 13). Since its possible impurities are not specified by the vendor, it is assumed to be 100% propane. One mole of propane produces three moles of CO_2 when burned. Hence, 1 kg of propane produces ~2,994 kg of CO_2 and 413 kg of propane ~1237 kg of CO_2:

$$m_{\mathrm{CO2}} = 3 \cdot \frac{M_{\mathrm{CO2}}}{M_{\mathrm{C3H8}}} \cdot m_{\mathrm{C3H8}} = 3 \cdot \frac{44{,}01\ \mathrm{g/mol}}{44{,}1\ \mathrm{g/mol}} \cdot m_{C3H8} \approx 2{,}994 \cdot 413\ \mathrm{kg} \approx 1237\ \mathrm{kg} \quad (2)$$

where m_{CO2} = mass of produced CO_2 [kg]

m_{C3H8} = mass of burned propane [kg]

M_{CO2} = molar mass of CO_2 [g/mol]

M_{C3H8} = molar mass of propane [g/mol]

8,4 kg of acetylene in total was bought to SEFI in Karhula, one 0,7 kg (5 l, 18 bar) and one 7,7 kg (40 l, 18 bar) container (Kemppainen 2021). The purchased acetylene contains the following impurities: ≤ 400 ppm of H_2O and ≤ 50 ppm of PH_3 (Linde 2021, 9), so its purity is ≥ 99,955%. One mole of acetylene produces two moles of CO_2 when burned. Calculated the same way as with propane, 1 kg of acetylene produces ~3,38 kg of CO_2 and 8,4 kg of acetylene ~28,4 kg of CO_2:

$$m_{\mathrm{CO2}} = 2 \cdot \frac{M_{\mathrm{CO2}}}{M_{\mathrm{C2H2}}} \cdot m_{\mathrm{C2H2}} = 2 \cdot \frac{44{,}01\frac{\mathrm{g}}{\mathrm{mol}}}{26{,}04\frac{\mathrm{g}}{\mathrm{mol}}} \cdot m_{\mathrm{C2H2}} \approx 3{,}38 \cdot 8{,}4\ \mathrm{kg} \approx 28{,}4\ \mathrm{kg} \quad (3)$$

where m_{CO2} = mass of produced CO_2 [kg]

m_{C2H2} = mass of burned acetylene [kg]

M_{CO2} = molar mass of CO_2 [g/mol]

M_{C2H2} = molar mass of acetylene [g/mol]

Beside Ar and 18% of CO_2, MISON® 18 contains 0,03% of NO, ≤ 10 ppm of H_2O, and ≤ 10 ppm of NO_2 (Linde 2021, 20). So, its climate warming impact comes from CO_2 in it. One 20 l and 200 bar MISON® 18 container was bought to Karhula's pump factory and a similar one to Mänttä (Kemppainen 2021). This kind of MISON® 18 container contains 4,7 m^3 of gas (Linde 2021, 20) and two of them 9,4 m^3, so the two purchased MISON® 18 containers together contain 1,692 m^3 (~3,4 kg) of CO_2, when released from the containers:

$$m_{\mathrm{CO2}} = 0{,}18 \cdot V_{\mathrm{MISON\ 18,gas}} \cdot \rho_{\mathrm{CO2}} = 0{,}18 \cdot 9{,}4\ \mathrm{m}^3 \cdot 1{,}98 \frac{\mathrm{kg}}{\mathrm{m}^3} \approx 3{,}4\ \mathrm{kg} \qquad (4)$$

where m_{CO2} = mass of CO_2 [kg]

$V_{\mathrm{MISON\ 18,gas}}$ = volume of MISON® 18 as gas [m^3]

ρ_{CO2} = density of CO_2 gas [kg/m^3]

The only greenhouse gas produced from these gases is CO_2. Table 4 shows the purchased amounts, emission factors, and emissions from them per site in year 2019.

Table 4. Types, amounts, emission factors, and emissions of purchased gases in year 2019. (Kemppainen 2021)

Gas type	Emission factor	Purchased amount		Emissions [kg CO_2e]		
		Karhula	Mänttä	Karhula	Mänttä	Total
Propane (C_3H_8)	2,994 kg CO_2/kg	403 kg	10 kg	1207	30	1237
Acetylene (C_2H_2)	3,38 kg CO_2/kg	8,4 kg	0 kg	28,4	0	28,4
MISON® 18		20 l	20 l	1,7	1,7	3,4
Total emissions from facilities (purchased gases) [t CO_2e]				**1,24**	**0,03**	**1,27**

Ideally, refrigerants are not supposed to leak into the air, but unless the devices using them are quite new, there is always a real risk for some leaks. SPFIN's buildings in Mänttä and Oulu have no heat pumps or other heating or cooling devices that have refrigerants (Tuominen 2021b, Ylitalo 2021). In Rauma's plant, there are relatively new heat pumps installed in early 2019 which have R410a refrigerant, but according to the maintenance, they have not had any leaks yet (Siivonen 2021). For Karhula's, Helsinki's and Vantaa's units, there was no data available about the refrigerant usage in them, so also their refrigerant leaks, and hence SPFIN's refrigerant leaks, are now assumed to be zero.

6.1.2 Company vehicles

SPFIN has on its control the following vehicles:

- Diesel using leased cars in Karhula, Mänttä, Oulu, and Vantaa
- Petrol using leased cars in Karhula, Mänttä, Oulu, and Vantaa
- One leased electric car
- Light fuel oil using forklifts in Karhula
- Liquefied petroleum gas (LPG) using forklifts in Mänttä and Vantaa
- Electric forklifts in Oulu and Rauma

(Haarala 2021d, Kosonen 2021a, 7-8.)

The initial data for fuels consumed by the company vehicles was collected from SPFIN's annual reports. Total consumption of diesel in SPFIN from October 1st, 2018 to September 30th, 2019 was 31415 l (Haarala 2021e). This amount was used in calculation, because Sulzer uses this kind of reporting period instead of calendar years, and it can be assumed that consumption in year 2019 is very close to the same. This applies also to the petrol consumption, which on the same period was 6585 l (Haarala 2021e).

SPFIN's different localities' shares of the company's diesel consumption in 2021 were 69,6% for Karhula, 8,27% for Mänttä, 16,47% for Oulu, and 5,66% for Vantaa (Haarala 2021d). Locality-specific shares or amounts of consumption were not available for year 2019, but it is presumable they have not changed significantly since then. That is why the above percentages were used for estimating the consumptions in 2019 in each locality, when SPFIN's total diesel consumption in 2019 is known to be 31415 l. The electric car is left out from the calculation since SPFIN did not have it yet in 2019.

Light fuel oil consumption of the forklifts in Karhula was 3380 l in the 10/2018 – 09/2019 period (Haarala 2021e). LPG consumption of the forklifts in Mänttä in 2019 was 121 kg (Kemppainen 2021). 2019 consumption data for forklifts in Vantaa was not available, but in 2020 the consumption there was 33 kg (Kosonen 2021a, 8), which is assumably close to the consumption in 2019, so these amounts were used in calculation. Electricity consumed by the electric forklifts in Oulu and Rauma belongs to total electricity consumption of those plants and is therefore included in purchased electricity in scope 2. Amounts of fuels consumed by SPFIN's vehicles, emission factors of the fuels, and corresponding emissions have been gathered into Table 5.

Table 5. Fuel consumptions of vehicles controlled by SPFIN, emission factors of the fuels, and emissions of the vehicles. (Haarala 2021e, Kemppainen 2021, Kosonen 2021a, 8, Ecobio Oy 2022a)

	Karhula	**Mänttä**	**Oulu**	**Rauma**	**Hki**	**Vantaa**	**Total**
Diesel used in leased cars [l]	21865	2598	5174	0	0	1778	31415
Petrol used in leased cars [l]	4583	545	1085	0	0	373	6585
Light fuel oil used in forklifts [l]	3380	0	0	0	0	0	3380
LPG used in forklifts [kg]	0	121	0	0	0	33	154
Emission f., diesel [kg CO_2e/l]	2,276						
Emission f., petrol [kg CO_2e/l]	2,077						
Emission f., light f.o. [kg CO_2e/l]	2,621						
Emission f., LPG [kg CO_2e/kg]	3,005						
Emissions, diesel [t CO_2e]	49,76	5,91	11,78	0	0	4,05	71,50
Emissions, petrol [t CO_2e]	9,52	1,13	2,25	0	0	0,77	13,67
Emissions, light f.o. [t CO_2e]	8,86	0	0	0	0	0	8,86
Emissions, LPG [t CO_2e]	0	0,36	0	0	0	0,10	0,46
Emissions from vehicles [t CO_2e]	**68,14**	**7,40**	**14,03**	**0**	**0**	**4,92**	**94,50**

6.2 Scope 2 – indirect emissions from purchased energy

Scope 2 includes all emissions that originate from different energy forms a company purchases. Usually the purchased energy is electricity, steam, heating, and/or cooling. The energy forms that SPFIN purchases are electricity and district heat.

6.2.1 Purchased electricity

The available consumption data of electricity was collected from SPFIN's annual reports. SPFIN's electricity consumption in 2019, excluding the Helsinki office, was 4658 MWh (Kosonen 2021b). Again, plant specific electricity consumptions for that year were not available, but in year 2020 the percentages of total consumption were 90,93% for Karhula, 3,35% for Mänttä, 1,99% for Oulu, 3,47% for Rauma, and 0,267% for Vantaa (Kosonen 2021a, 5). The consumption shares are assumed to have been nearly identical in 2019, so electricity consumptions of those plants or offices in 2019 were estimated based on the given percentages.

The Helsinki office's electricity consumption or supplier are not known as electricity is included in rent there. For the Helsinki office, the electricity consumption was estimated by Ecobio based on the office's area (1009 m^2) and the characteristic electricity consumption for offices (0,038 MWh/m^2) (Ecobio Oy 2022a). In any case, the Helsinki office's electicity consumption is minimal compared to SPFIN's total consumption.

For all other plants and offices than Helsinki, SPFIN has bought its electricity from Loiste Oy. On December 1st, 2021, the customers of Loiste Oy became customers of Lumme Energia Oy. So far, SPFIN has used the most economical electricity option. The emission factor of this uncertified electricity of Loiste Oy in 2019 could not be obtained despite many inquiries. So, the available year 2020 emission factor of Lumme Energia Oy's uncertified electricity (0,22 t CO_2e/MWh) was then used for market-based calculation for all plants and offices except Helsinki, for which the residual fuel mix factor of Finland (0,25 t CO_2e/MWh) was used. Lumme Energia's emission factor for their uncertified electricity, shares of used energy sources, and amount of generated nuclear waste per total amount of sold electricity in 2020 are shown in Table 6.

Table 6. Characteristics of uncertified electricity sold by Lumme Energia Oy in 2020. (Lumme Energia 2021)

Energy sources	
Nuclear power	49%
Fossil-based energy sources & peat	38%
Renewable energy sources	13%
Emission factor	0,22 t/MWh
Nuclear waste per sold electricity	1,41 g/MWh

Emissions from electricity consumption were also calculated using production fuel mix factor of Finland (0,135 t CO_2e/MWh) for location-based reporting (Ecobio Oy 2022a). For the Helsinki office, only this emission factor was used.

The estimated consumptions, used alternative emission factors, and calculated corresponding emissions per each plant in 2019 are presented in Table 7.

Table 7. Calculated electricity consumptions, emission factors, and emissions of SPFIN in 2019. (Kosonen 2021a, 5, Kosonen 2021b, Lumme Energia 2021, Ecobio Oy 2022a)

	Karhula	Mänttä	Oulu	Rauma	Hki	Vantaa	Total
Electricity consumption [MWh]	4235,52	156,00	92,70	161,60	38,34	12,44	**4696,34**
Emission factor 1 [t CO_2e/MWh]	0,22	0,22	0,22	0,22	0,25	0,22	
Emission factor 2 [t CO_2e/MWh]	0,135	0,135	0,135	0,135	0,135	0,135	
Market-based emissions [t CO_2e]	931,81	34,32	20,39	35,55	9,56	2,74	**1034,38**
Location-b. emissions [t CO_2e]	571,80	21,06	12,51	21,82	5,18	1,68	**634,05**

6.2.2 District heating

District heating is used in SPFIN's plants and offices in Karhula, Oulu, Helsinki, and Vantaa, while Mänttä and Rauma have direct electric heating which therefore belongs to purchased electricity. For Karhula, the district heat consumption data was obtained from SPFIN's annual reports. The district heat consumption in Karhula was 2860 MWh in year 2019 (Kosonen 2021b). Emission factor and used energy sources of Karhula's district heat were gotten from the heat supplying company, Kotkan Energia Oy. Characteristics of district heat that SPFIN purchased in Karhula in 2019 from Kotkan Energia Oy are shown in Table 8.

Table 8. Characteristics of district heat purchased from Kotkan Energia Oy in 2019. (Mellas 2021)

Product name of the purchased heat	Maltti
Emission factor [t CO_2e/MWh]	0,0836
Share of used fuels in production [%]	
Municipal waste	23,4
REF	3,4
Natural gas, own production	4,3
Natural gas from KotkaMills	5
Peat	14,8
Biofuels	49,1
Light fuel oil	0,04
Share of renewable fuels [%]	60,9

In Oulu, Helsinki, and Vantaa, the heat is included in rent and exact consumptions and emission factors are not known. Therefore, they had to be estimated. The heat consumption estimates of Oulu, Helsinki and Vantaa offices were calculated based on the buildings' known floor areas (Oulu 1422 m^2, Helsinki 1009 m^2, and Vantaa 1227 m^2 (Kemppainen 2021)) and the characteristic heat consumption of office buildings, which is 0,071 MWh/m^2 (Ecobio Oy 2022a).

The emission factors of bought district heat in Oulu, Helsinki, and Vantaa were estimated based on presumable heat suppliers, which are Oulun Energia Oy, Helen Oy, and Vantaan Energia Oy. These emission factors were used for market-based emission calculation. Also, location-based emission calculation was done with the average emission factor of Finnish district heat in year 2019. The known and estimated district heat consumptions and emission factors, and calculated emissions based on them, are listed in Table 9.

Table 9. District heat consumptions, emission factors, and emissions of SPFIN in 2019. (Ecobio Oy 2022a, Kosonen 2021b, Mellas 2021, Oulun Energia Oy 2021, Helen Oy 2020, Vantaan Energia Oy 2021)

	Karhula	Oulu	Hki	Vantaa	Total
Heat consumption [MWh]	2860,00	100,96	71,64	87,12	**3119,72**
Emission factor 1 [t CO_2e/MWh]	0,0836	0,2178	0,198	0,1335	
Emission factor 2 [t CO_2e/MWh]	0,152	0,152	0,152	0,152	
Market-based emissions [t CO_2e]	239,10	21,99	14,18	11,63	**286,90**
Location-b. emissions [t CO_2e]	434,72	15,35	10,89	13,24	**474,20**

6.3 Scope 3 – indirect emissions from upstream and downstream activities

After an upfront estimation about their relevance for SPFIN's total emissions, the emission categories 1, 2, 4, 5, 6, 7, 9, 11, and 12 of scope 3 were selected for the calculation. Calculation of emissions from them is described in the following sub-chapters.

6.3.1 Purchased goods and services (category 1, upstream)

This emission category was assumed to be among the most significant ones. The collection of initial data started with acquisition of lists from the procurement department about the pump products' main components and HST components which were purchased in year 2019. The obtained lists contained:

- castings purchased from Europe (the EU),
- baseplates, couplings, and motors,
- all parts (mainly cast parts) purchased from China, and
- HST-components.

The plan was to find out approximate total weights of steel and other raw materials in the purchased components. The GHG emissions of those materials could then be calculated with applicable emission factors. Table 10 shows the total number of pump components and motors purchased in year 2019 and numbers of them with and without known weights, and also how many different components where among them.

Table 10. Numbers of purchased pump components and motors and different components among them in year 2019. (Rongas 2022)

	Castings from the EU	**Components from China**	**Base-plates**	**Couplings**	**Motors**
No. of purchased components, $\mathbf{n_1}$	14629	89140	4110	3425	3484
No. of different components	3329	1805	1074	771	1300
Number of components with known weights, $\mathbf{n_2}$	13879	88454	4110	2851	2790
Different components	3213	1728	1074	562	1040
Components w/o known weight, $\mathbf{n_3}$	750	686 (442)	0	574	694
Different components	116	77 (72)	0	209	260

Castings from EU and China and baseplates had material codes in the exported SAP-report, and the castings could be allocated to steel, iron and titanium castings based on those codes. All baseplates are manufactured from steel, most from carbon steel with painting or hot-dip-galvanization, and a few from stainless steel. Couplings were estimated to be about 80% of steel, and 20% of flexible elastomer elements (Rex Viva couplings are the most used in SPFIN's products). Average composition of motors is estimated based on information obtained from ABB about their different sized motors (Kytömäki 2022a). Almost all SPFIN's motors come from ABB, some from Siemens, and a few also from other manufacturers.

One thing that should be mentioned about motors that were installed into the products, is that while most of them were purchased by SPFIN, also a significant number of them were so-called customer motors, which means that they were delivered to SPFIN by customers. The customer motors (776 motors in year 2019) are not included in the numbers of the Table 10, because SPFIN did not purchase them.

While most purchased components have weight information marked in Sulzer's SAP system, some do not. Therefore, the total weights of purchased raw materials were estimated followingly:

$$m_{\text{estimate}} = \sum_{i=1}^{n} m_{\text{rm},i} \cdot \frac{n_{1,i}}{n_{2,i}} \quad (5)$$

where m_{estimate} = estimated total weight of a raw material [kg]
$m_{\text{rm},i}$ = known weight of a raw material in component category i [kg]
$n_{1,i}$ = number of components in component category i [1]
$n_{2,i}$ = number of components that have known weights in component category i [1]

A significant part of the components bought from China that had no weight information were o-rings and other light elastomer components (244 out of 686) and the rest of them were metallic (442, consisting of 72 different components). Because the weight of those elastomer components is minimal compared to metallic parts, they were left out from calculation. So, in this case, $n_{1,i}$ in Equation 5 is the number of all components purchased from China minus 244 (the number of light elastomer components without weight information).

Shaft billets' weight is on average ~7,5% of the pump's weight in all AUP pump sizes, so the total weight of shaft billets was estimated to be 7,5% of the total weight of all castings from the EU and China (0,075 * (995918 kg + 1378064 kg) ≈ 178049 kg). All shaft billets were assumed to be of steel (no other used materials for shafts were found) and from Finland. Agitators are also almost completely made of steel. Their components' total weight was estimated followingly based on the number of agitators that were sold in year 2019. Components of vertical agitators are from Finland and there were 111 sold vertical agitators (types L and LV) in year 2019 (Tani 2022). Their weight information was obtained from their order specific drawings which are available in Sulzer's drawing archive. Their combined weight was 45045 kg. Horizontal agitators (several different types) are mainly of Chinese origin and 438 of them were sold in 2019 (Tani 2022). Their total weight then was estimated based on the weight of an average horizontal agitator (model SLB-125, ~1200 kg). So, their estimated total weight was 438 * 1200 kg = 525600 kg. The known and estimated weights of different raw materials in purchased non-HST-components from Finland/EU and China are presented in Table 11.

Table 11. Known and estimated weights of different raw materials in non-HST-components purchased by SPFIN in 2019. (Rongas 2022, Kytömäki 2022a)

	Steel [kg]	Iron [kg]	Ti [kg]	Al [kg]	Plain Cu [kg]	Other [kg]	Undef [kg]	Combi-ned [kg]	**Est. total [kg]**
Castings from the EU	808153	119034	0	0	0	2101	15571	944859	995918
Components from China	865142	502780	3014	0	0	276	0	1371212	1378064
Shaft billets from Finland	178049	0	0	0	0	0	0	178049	178049
Baseplates from Finland	789632	0	0	0	0	0	0	789632	789632
Couplings	49478	0	0	0	0	12370	0	61848	74300
Agitators from Finland	45045	0	0	0	0	0	0	45045	45045
Agitators from China	525600	0	0	0	0	0	0	525600	525600
Motors from EU (PL,DE,FI)	598134	684611	0	36032	122509	0	0	1441287	1799801
Total (known weights)	3859233	1306425	3014	36032	122509	14747	15571	5357532	5786408
Est. total weights	**4065972**	**1485664**	**3029**	**44995**	**152983**	**17352**	**16412**	**5786408**	
Est. from Finland/EU	**2611467**	**980372**	**0**	**44995**	**152983**	**2215**	**16412**	**3808444**	
Est. from China	**1395065**	**505292**	**3029**	**0**	**0**	**277**	**0**	**1903664**	
Est. from undef. source	**59440**	**0**	**0**	**0**	**0**	**14860**	**0**	**74300**	

Total weights of raw materials in purchased HST-components were also estimated based on the HST-products that were sold in 2019 and not on the list of purchased HST-components. There were a few reasons for this:

- About a half of purchased HST-component types in SAP (714 out of 1453) were lacking weight information.
- The structure and raw material composition of HST compressors are much more complex and diverse than the structure and raw materials of pumps and agitators.
- The accurate weights of all HST-compressor models are available in their technical datasheets.
- There is also a calculation Excel-table containing accurate weights and percentages of different raw materials in a HST30 compressor, made by Arttu Reunanen, the head of SPFIN's HST product development department. These weights and percentages are shown in Table 12.

Table 12. Weights and shares of different raw materials in a HST30 compressor. (Reunanen 2021)

	Alumi-nium	**Steel**	**Copper**	**Stainless steel**	**Perm. magnets**	**Lead**	**Plastics**	**Electro-nics**	**Total**
Weight [kg]	274	1143,5	166	1,5	4,5	10	52,2	40	1691,7
Share [%]	**16,20**	**67,59**	**9,81**	**0,09**	**0,27**	**0,59**	**3,09**	**2,36**	**100,0**

The raw material percentages are quite similar in other HST sizes besides HST30 as well. Therefore, the most reliable way to estimate the total weights of raw materials in purchased HST components was to account for the numbers of sold different sized HST compressors, find out the weights of different HST sizes, calculate the total weight of sold HSTs, and then multiply it by the percentages of raw materials shown in Table 12. The numbers of sold HSTs were obtained from a list of products delivered in 2019 (Tani 2022) and the weights of different HST sizes were collected from HST technical datasheets (Sulzer 2022p). In 2019, there were sold 361 HST compressors in total. The amounts, weights, and combined weights of sold HST-models are gathered into Table 36 in Appendix II.

Quite accurate weights of different raw materials that were in HST-components purchased by SPFIN in 2019 could now be calculated from the total weight of all complete HST-compressors that were sold in the same year (in the Table 36), using the percentages of Table 12. The results are presented in Table 13.

Table 13. Shares and weights of different raw materials in HST-components purchased by SPFIN in 2019.

	Alumi-nium	Steel	Copper	Stainless steel	Perm. magnets	Lead	Plastics	Electro-nics	Total
Share [%]	16,20	67,59	9,81	0,09	0,27	0,59	3,09	2,36	100
Weight [kg]	**80898**	**337523**	**48988**	**449**	**1348**	**2946**	**15430**	**11785**	**499368**

The machine workshop company Javasko Oy in Mänttä is a significant sub-contractor of SPFIN in machining and assembling SPFIN's products. Even though Javasko is an independent company with its own facilities, it works exclusively for SPFIN, so its emissions from purchased electricity and district heat are included as such in SPFIN's scope 3 category 1 emissions. In 2019 Javasko purchased its electricity from Vattenfall Oy and district heat from Mäntän Kaukolämpö ja Vesihuolto Oy. For district heat the emission factor for year 2019 was available but not for electricity. From the beginning of 2020, Javasko has bought electricity from Vaasan Sähkö Oy (their uncertified general electricity), and its emission factor was available, so it is then used for this calculation. Javasko's consumption of electricity and district heat, and their GHG emissions, are presented in Table 14.

Table 14. Javasko Oy's electricity and district heat consumptions, emission factors and emissions in 2019. (Luomi 2022, Mäntän Kaukolämpö ja Vesihuolto Oy 2022, Vaasan Sähkö Oy 2022)

	Electricity	**District heat**	**Total**
Consumption [MWh]	1541,957	599,85	**2141,807**
Market-based emission factor 1 [t CO2e/MWh]	0,156	0,11	
Location-based emission factor 2 [t CO2e/MWh]	0,135	0,152	
Market-based emissions [t CO2e]	240,54529	65,9835	**306,529**
Location-b. emissions [t CO2e]	208,1642	91,1772	**299,341**

Based on the total weights of the raw materials in Tables 11 and 13, and Javasko's electricity and heat consumption, the GHG emissions of purchased components and services were then calculated. These emissions are shown in Table 15.

Table 15. Emissions from purchased goods and services in 2019. (Ecobio Oy 2022b)

Material or service	**Emission factor:**	**Unit of the emission factor:**	**Emissions [t CO_2e]**
Castings from the EU (steel)	2,60	t CO_2e/t	2214,74
Castings from the EU (iron)	0,01	t CO_2e/t	1,49
Castings from the EU (other = iron)	0,01	t CO_2e/t	0,03
Castings from the EU (undefined = steel)	2,60	t CO_2e/t	42,67
Components from China (steel)	2,60	t CO_2e/t	2260,61
Components from China (iron)	0,01	t CO_2e/t	6,01
Components from China (titanium)	35,70	t CO_2e/t	108,14
Components from China (other = 50/50 Al and PEEK)	1,31	t CO_2e/t	0,36
Shaft billets from Finland (steel)	2,60	t CO_2e/t	462,93
Baseplates from Finland (steel)	2,60	t CO_2e/t	2053,04
Couplings from X (steel)	2,60	t CO_2e/t	154,54
Couplings from X (other = polyurethane)	4,20	t CO_2e/t	62,41
Agitators from Finland (steel)	2,60	t CO_2e/t	117,12
Agitators from China (steel)	2,60	t CO_2e/t	1366,56
Motors from EU (PL, DE, FI; steel)	2,60	t CO_2e/t	1941,98
Motors from EU (PL, DE, FI; iron)	0,01	t CO_2e/t	10,17
Motors from EU (PL, DE, FI; aluminium)	2,60	t CO_2e/t	116,99
Motors from EU (PL, DE, FI; plain copper)	0,50	t CO_2e/t	76,49
HST-components (aluminium)	2,60	t CO_2e/t	210,33
HST-components (steel)	2,60	t CO_2e/t	877,56
HST-components (copper)	0,50	t CO_2e/t	24,49
HST-components (stainless steel)	3,40	t CO_2e/t	1,53
HST-components (permanent magnets)	20,03	t CO_2e/t	27,00
HST-components (lead)	0,31	t CO_2e/t	0,91
HST-components (plastic)	3,12	t CO_2e/t	48,09
HST-components (electronics)	5,53	t CO_2e/t	65,16
Services from Javasco (electricity, district heat)	0,16, 0,11	t CO_2e/MWh	306,53
		Scope 3 category 1 total:	**12557,91**

6.3.2 Capital goods (category 2, upstream)

Capital goods which were purchased in year 2019 were different kinds of tools and equipment. The manufacturing QESH manager of Karhula pump factory estimated their total weight to be around 25000 kg, and they consist mostly of steel and iron (Laiho 2022). Without more precise data about them available, the GHG emissions caused by them were estimated to be 65 t CO_2e (Ecobio Oy 2022b).

6.3.3 Transportation and distribution (categories 4 & 9, upstream and downstream)

For these emission categories, the significant factors are

- Amounts of transported goods
- Transportation distances between the component suppliers and SPFIN
- Transportation distances between SPFIN and the customers
- Means of transportation.

Category 4 includes emissions from all transportation to SPFIN regardless of whether it is paid by SPFIN or the sender. It also includes those freights from SPFIN to customers that are paid by SPFIN. Category 9 then includes only those freights from SPFIN to customers that are not paid by SPFIN. (Greenhouse Gas Protocol 2011a, 45.) Figure 8 illustrates this.

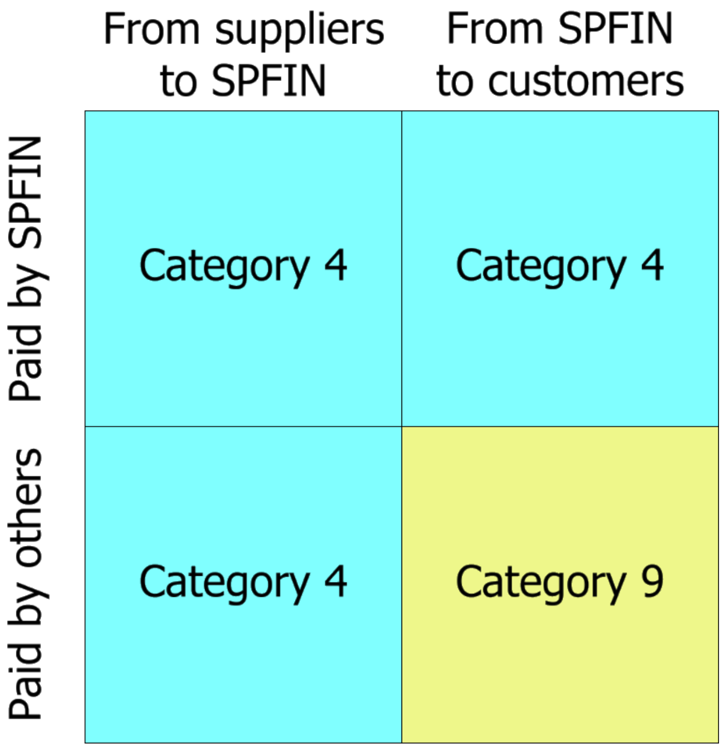


Figure 8. Relationship of scope 3 emission categories 4 and 9. (Greenhouse Gas Protocol 2011a, 45)

During this work it turned out, that a comprehensive analysis of transportation and distribution that is paid by SPFIN will be implemented later in 2022 as a separate project by a consulting company. This comprehends all other freights of category 4 but those that are paid by others (component suppliers) that SPFIN. Category 4 emissions are still estimated roughly already in this work.

One significant transport and logistics company that SPFIN uses is Danish DSV. Data for DSV’s freights in 2019 was not available, but for year 2021 a year report about all DSV’s freights to and from SPFIN was obtained via SPFIN’s logistics department. The amounts and GHG emissions of freights from different countries to SPFIN in 2021 are gathered from the year report to Table 16.

Table 16. DSV’s freights to SPFIN and their emissions in year 2021. (DSV 2022, Ecobio Oy 2022b)

Shipper country	Cargo moved [t]	Total distance [km]	GHG-emissions TTW [t CO_2e]	GHG-emissions WTW [t CO_2e]
Brazil	0,0035	15222	0,025	0,030
China	1794,392	2575940	900,265	1112,439
Germany	0,357	4768	0,066	0,082
India*	102,205	15760		24,16
Italia	7,708	22341	1,639	2,044
Portugal	2,098	25510	0,654	0,828
South Korea	5,102	25623	0,755	0,884
Spain	17,651	63973	16,274	20,034
Sweden	0,689	875	0,041	0,053
Turkey	0,720	2993	0,189	0,232
UAE	0,552	15619	0,059	0,067
Total (distance & emissions)	**1931,478**	**2768624**		**1160,85**

* Freights from India did not have emission data, so their GHG-emissions were calculated based on ton-kilometers and the distance between India and Finland (Ecobio Oy 2022b).

ABB, from which almost all SPFIN’s motors are purchased, orders and pays for the transportation of the motors (Kytömäki 2022b). Hence, they are not included in DSV’s reporting but are still a part of SPFIN’s scope 3 category 4 emissions. Since ABB organizes and covers the costs of motors’ transportation, it slightly rises the motors’ prices (Kytömäki 2022b). About 1,2% to 4% (rarely that much) of an ABB motor’s price consists of the transportation costs and adequate packaging of a motor (Kytömäki 2022b).

Almost all motors delivered from ABB to SPFIN are low voltage (LV) motors. Information about them was obtained from ABB for year 2021, but about medium voltage (MV) motors there was no information available. The purchased LV-motors were sent to SPFIN’s plants in Karhula and Mänttä from ABB’s factory in Vaasa, Finland, or from a factory in Poland (Kaarna 2022). The motors from Poland were first transported to ABB’s warehouse, CSE, in Germany, and from there to SPFIN (Kaarna 2022). All LV-motors were transported by truck (Kaarna 2022).

In 2021, the total weight of LV-motors delivered from Vaasa to SPFIN's plants was 603612 kg, and approximate GHG emissions from their freights were 18170,2 kg CO_2e (Kaarna 2022). For LV-motors which were transported to SPFIN from Poland via Germany, the total weight was 685950 kg and the GHG emission from freights were 200767,3 kg CO_2e (Kaarna 2022). Hence, the total weight of all LV-motors that were delivered from ABB to SPFIN in 2021 was 1289562 kg, and the total GHG emissions from transporting them were 218937,5 kg CO_2e. The difference between the total weight of LV-motors purchased from ABB in year 2021 (1289562 kg) and the estimated total weight of all motors purchased in year 2019 (1799801 kg, Table 11 on page 56) can be explained with these factors:

- The motors purchased in 2019 also include ABB's MV-motors and motors from other manufacturers like Siemens.
- There is always some variation between different years.

Regarding the MV-motors it is known that some portion of them come from China as air freight and the rest from Finland, but the amounts were not available (Kaarna 2022). What is known, is that the emissions per weight for motors brought from China (5,2 or 5,4 kg CO_2e/kg depending on whether they come straight to Finland or via Germany) are about 173…179 times higher than for motors from Finland (0,0301 kg CO_2e/kg) (Kaarna 2022). Because of this vast uncertainty concerning emissions from transportation of MV-motors, they are left out from the calculation for now. The same goes for other manufacturers' motors, so only the transportation emissions of ABB's LV-motors are included in this calculation. Hopefully in the future there will be available data also for the rest of purchased motors.

In 2019, according to the Tables 11 and 13, the total weight of purchased components and the total weight of sold products are both estimated to have been 5786408 kg (non-HST-components) + 499368 kg (HST-components) = 6285776 kg ≈ 6285,8 t, in the lack of more accurate information. 1799,8 t of it were motors (in the Table 11) and 4486,0 t were other components. The total weights of 2019 non-motor freights from different countries, and emissions from them, can then be estimated by scaling DSV's 2021 non-motor freights to SPFIN and their emissions with factor 4486/1931,478 (the divisor is from the Table 16 on page 61). So, the GHG emissions of all freights that were transported to SPFIN in 2019 (excluding ABB's MV-motors and other manufacturers' motors) were:

$$1160{,}85\ \text{t CO}_2\text{e} \cdot \left(\frac{4486}{1931{,}478}\right) + 218{,}94\ \text{t CO}_2\text{e} \approx 2915{,}10\ \text{t CO}_2\text{e} \tag{6}$$

Components and equipment are also transported daily between Karhula pump factory and Javasko workshop in Mänttä to both directions. Approximately one truck per day goes from Karhula to Mänttä and from Mänttä to Karhula. The distance between Karhula pump factory and Javasko workshop is 271,4 km and the emission factor of the partially loaded truck used for the transportation is estimated to be in highway driving 916,48 g CO_2e/km (Ecobio Oy 2022b).

And if the cargo is transported on 258 days in a year, the resulting emissions from it are:

$$2 \cdot 271{,}4\ \text{km} \cdot \left(0{,}00091648\ \text{t}\frac{\text{CO}_2\text{e}}{\text{km}}\right) \cdot 258 \approx 128{,}35\ \text{t CO}_2\text{e} \tag{7}$$

Weights of freights and numbers of separate items (equipment and individual parts) in them, which were delivered to customers in different countries in 2021 were obtained from SPFIN's logistics department as two separate lists. First list contained deliveries of new equipment and the second list spare part deliveries. This data is collected to Tables 37 and 38 in Appendix IV. In the new equipment deliveries, there were 12879 items, and their combined weight was ~4687,1 t. In the spare part deliveries, the number of items was 79384 and their combined weight was ~349,4 t, so total weight of all freights from SPFIN to customers in 2021 was 5036,5 t. Emissions of transportation from SPFIN to customers in 2019 can be estimated based on:

- The weights of freights transported to different countries in 2021 (in Tables 37 & 38)
- Assumed means of transportation
- The ratio of total weight of sold products in 2019 and the total weight of 2021 transports to customers (6285,8 t / 5036,5 t).

The result was 1183,08 t CO_2e (Ecobio).

Transportation of approximately 2/3 of the freights to customers was ordered and paid by SPFIN (Muuri 2022). So, 2/3 of emissions of transportation leaving from SPFIN are added to category 4 emissions, and the remaining 1/3 are then category 9 emissions (transportation ordered and paid by customers).

So, GHG emissions of category 4 were:

$$2915{,}10 \text{ t CO}_2\text{e} + 128{,}35 \text{ t CO}_2\text{e} + \frac{2}{3} \cdot 1183{,}08 \text{ t CO}_2\text{e} \approx 3832{,}17 \text{ t CO}_2\text{e} \quad (8)$$

And category 9 emissions were:

$$\frac{1}{3} \cdot 1183{,}08 \text{ t CO}_2\text{e} \approx 394{,}36 \text{ t CO}_2\text{e} \quad (9)$$

More accurate calculation can be carried out after the comprehensive analysis is implemented in the near future about transportation that was paid by SPFIN.

6.3.4 Waste generated in operations (category 5, upstream)

SPFIN’s waste management in Karhula and Helsinki is taken care of by the Finnish service company Lassila & Tikanoja plc (also known as L&T). In Mänttä’s plant, L&T handles only hazardous waste. The amounts of different waste types which were collected, transported, and processed from the plants and offices of Karhula and Helsinki in 2019, and GHG emissions from this activity, were found from L&T’s portal. Waste management data for offices and plants in Vantaa, Oulu, and Rauma was not available. So, the total amounts of waste and waste management emissions of Mänttä’s plant and these other three smaller service centers were estimated based on Karhula’s main service center SEFI’s numbers. The total amounts of collected waste, the characteristics of the waste management, and its GHG emissions in SPFIN and in its sites are presented in Table 17.

Table 17. L&T's Waste management data for SPFIN from year 2019. (Lassila & Tikanoja 2022a)

	Karhula	Helsinki	M/V/O/R*	SPFIN
Total amount of collected waste [t]	324,339	0,149	7,100	352,887
Recycling rate [%]	14	90	9	14
Utilization rate (hyötykäyttöaste) [%]	92	90	88	92
GHG emissions:				
Waste management [t CO_2e]	31,917	0,003	1,047	36,107
Collection and transportation [t CO_2e]	4,732	0,007	0,115	5,197
Total GHG emissions [t CO_2e]	**36,649**	**0,010**	**1,161**	**41,304**

* Recycling rate and utilization rate of service centers of Mänttä, Vantaa, Oulu, and Rauma are assumed the same as of Karhula's SEFI. The amount of collected waste and emissions from it are assumed to be 10% of Karhula's SEFI's amounts.

The amounts of SPFIN's different types of waste, the used treatment methods for them, and their shares are presented in Table 18 and Figure 9.

Table 18. SPFIN's waste distribution and waste treatment methods in year 2019. (Lassila & Tikanoja 2022a)

Waste type	**Hazardous waste**	**Treatment method**	**Amount [t]**			
			Karhula	**Helsinki**	**M/V/O/R**	**SPFIN**
Clean wood	No	Other	200,52		4,38	218,06
Energy waste, rec. Kymenlaakson Jäte Oy	No	utilization	16,86		0,45	18,66
Energy waste, receiver L&T, Kotka	No		9,84			9,84
Brown cardboard and carton, loose	No	Recycling	17,82			17,82
Data protection material	No	and	9,82	0,13	0,30	11,15
Bio waste	No	reuse	7,44		0,25	8,44
Other WEEE	No		5,41		0,04	5,56
Assorted waste paper, loose	No		2,69		0,08	3,00
Used lubrication oil, water content < 10%	Yes		1,26			1,26
Mixed sheet metal	No		0,50			0,50
Heavy metal battery waste	Yes		0,11		0,00	0,12
Lead battery waste	Yes		0,08			0,08
Fluorescent tubes	Yes		0,01	0,01		0,01
Mercurial waste, liquid/solid	Yes		0,00			0,00
Mixed waste, receiver L&T	No	Combustion in	21,86		0,74	24,81
Mixed waste, receiver Kotkan Energia Oy	No	power plant	4,68			4,68
Mixed waste, receiver L&T, Tuusula	No	End treatment		0,02		0,02
Emulsion waste, liquid	Yes		15,58			15,58
Alkaline washing water waste, liquid	Yes		6,69		0,67	9,36
Oily waste, solid/paste	Yes		2,45		0,16	3,09
Aerosol waste, solid	Yes		0,57		0,02	0,64
Paint waste, solid	Yes		0,16		0,01	0,20
Alkaline waste, solid	Yes		0,00			0,00
		Total:	**324,34**	**0,15**	**7,10**	**352,89**

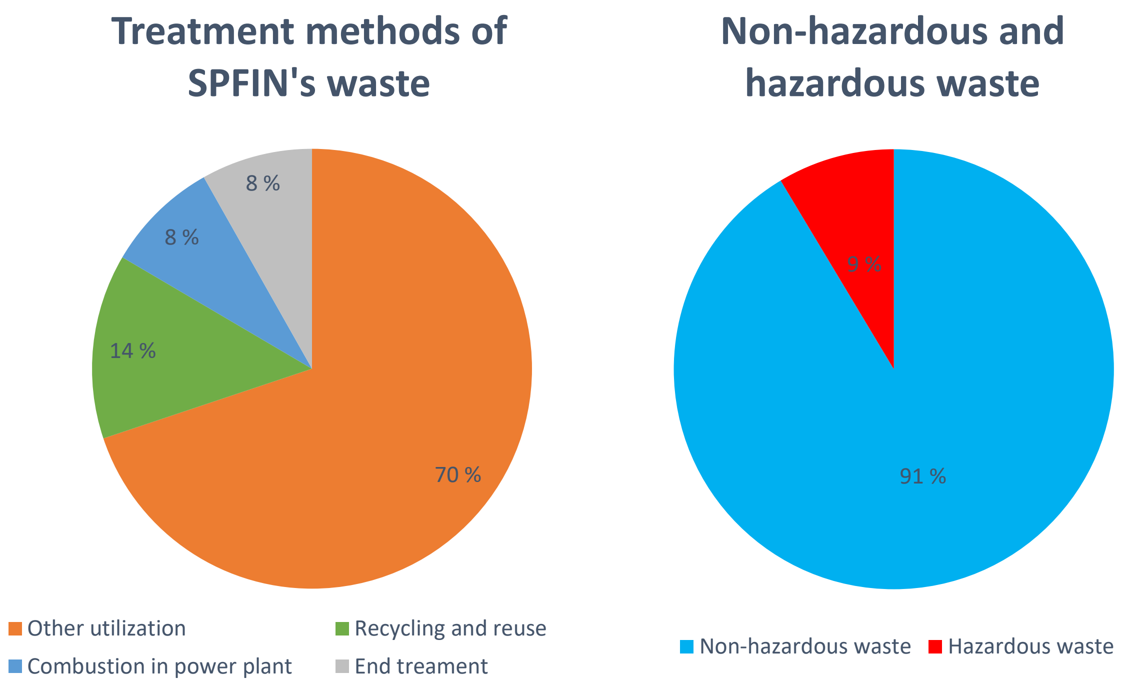


Figure 9. Shares of SPFIN's waste's treatment methods and hazardous waste. (Lassila & Tikanoja 2022a)

In 2020, there was also produced 141,25 tons of metal waste in SPFIN's Karhula's plants and offices that wasn't collected by L&T, but instead it was recycled by Stena Recycling Ltd and/or Kuusakoski Group Ltd (Haarala 2022). For year 2019 or for other SPFIN sites, there was no data available for metal waste that was disposed outside L&T, but presumably the amount in 2019 was quite similar. The amounts of metal waste produced in the sites of Mänttä, Vantaa, Oulu, and Rauma were estimated to be 5% of Karhula's amount, and zero in the Helsinki office. The calculated GHG emissions from treatment of this metal waste were:

$$\left(141{,}25\ \mathrm{t} + 4 \cdot \frac{5}{100} \cdot 141{,}25\ \mathrm{t}\right) \cdot 0{,}20861\ \mathrm{t\ CO_2e/t} \approx 35{,}359\ \mathrm{t\ CO_2e} \qquad (10)$$

where 0,20861 t CO_2e/t = emission factor of recycling of mixed metals (Ecobio Oy 2022b)

And so, total emissions from collection, transportation, and management of all waste generated by SPFIN in 2019 were:

$$41{,}304\ \mathrm{t}\frac{\mathrm{CO_2e}}{\mathrm{t}} + 35{,}359\ \mathrm{t}\frac{\mathrm{CO_2e}}{\mathrm{t}} \approx 76{,}66\ \mathrm{t\ CO_2e} \tag{11}$$

6.3.5 Business travel (category 6, upstream)

Lists of made business trips were gotten from traveling management. According to them, means of transportation used on SPFIN's business trips in 2019 were:

- Own or leased car
- Airplane
- Public transportation (train, bus), taxi, or rental car

Over half of SPFIN's business trips were taken in own cars, naturally in Finland (Rintala 2022a). Leased cars were also used on business trips inside Finland (Rintala 2022a). Emissions from traveling in leased cars are already included in scope 1 emissions, so they are left out from calculation here. Amounts, average lengths, and combined lengths of these trips taken in own and leased cars are presented in Table 19.

Table 19. Amounts and lengths of business trips taken in own or leased car in year 2019. (Rintala 2022a)

Car type	Trips	Average trip length [km]	Combined length [km]
Own car	3496	143	500962
Leased car	874	217	189291

Then the GHG emissions from business trips in own cars were:

$$500962\ \mathrm{km} \cdot 171{,}48\ \frac{\mathrm{g\ CO_2e}}{\mathrm{km}} \approx 85{,}90\ \mathrm{t\ CO_2e} \tag{12}$$

where 171,48 g CO_2e/km = emission factor of an avg. car with unknown fuel type (Ecobio Oy 2022b).

Amounts, approximate lengths, combined lengths, and GHG emissions of SPFIN's two-way business flights to different destinations, leaving from and returning to Helsinki-Vantaa airport in Finland, are listed in Table 20. Here one flight means one two-way flight of one person.

Table 20. Amounts, approximate lengths, combined lengths, and GHG emissions of SPFIN's two-way business flights in year 2019. (Rintala 2022b, Ecobio Oy 2022b)

Destination	Number of flights	Length [km] (two-way)	Combined lengths [km]	Emissions [t CO_2]
Atlanta USA	18	15540	279720	30,98
Dublin, Ireland	48	4060	194880	24,94
Istanbul, Turkey	35	4300	150500	17,09
Madrid, Spain	36	5900	212400	27,19
Melbourne, Australia	1	30460	30460	2,64
Moskow, Russia	9	1780	16020	2,05
Mumbai, India	26	11860	308360	26,61
Beijing, China	43	12660	544380	46,97
Doha, Qatar	34	8780	298520	33,90
Rovaniemi, Lapland	36	1400	50400	6,45
São Paulo, Brazil	19	22640	430160	42,58
Stockholm, Sweden	34	800	27200	3,48
Zürich, Switzerland	252	3560	897120	114,83
Total	**591**		**3440120**	**379,70**

Taxies and public transportation were used both in Finland and abroad mainly for going to and leaving from airports. Rented cars were used abroad. Unfortunately, kilometers travelled in these transportation means are not known, but some kind of estimation could be made. There were 460 trips taken by public transportation, 627 trips by taxi, and 117 trips in a rental car, so 1204 trips combined, which is a little bit over 2 (2,04) trips per one two-way flight (there can of course be one or more people in the same taxi or rented car). It was assumed that an average length of one drive by public transportation or in a taxi was 100 km (the distance between Karhula and Helsinki-Vantaa airport for example is ~130 km, but there were also a lot of shorter trips taken). With rented cars it was assumed that an average driven mileage per a renting time was 2 * 100 km = 200 km. This means 46000 km by public transportation, 62700 km in taxies, and 23400 km in rental cars. Emissions from these trips and used emission factors are presented in Table 21.

Table 21. Traveled distances, used emission factors, and emissions of trips taken by public transportation, taxi, or rental car in year 2019. (Ecobio Oy 2022b)

Type of travel	Distance of travel [km]	Emission factor [t CO_2e/km]	Emissions [t CO_2e]
Public transport	46000	0,00011	4,91
Taxi	62700	0,00021	13,06
Rental cars	23400	0,00017	4,01
Total	**132100**		**21,98**

Thus, GHG emissions from SPFIN's business traveling in 2019 were:

$$85{,}90\ \mathrm{t\ CO_2e} + 379{,}70\ \mathrm{t\ CO_2e} + 21{,}98\ \mathrm{t\ CO_2e} = 487{,}58\ \mathrm{t\ CO_2e} \tag{13}$$

6.3.6 Employee commuting (category 7, upstream)

Emissions from daily commuting of employees between home and workplace were estimated based on the following information and assumptions. The number of SPFIN's employees was 467. 64% of all employees in Finland commuted in a car as a driver and 4% as a passenger, and 12% used public transportation (bus or train) (Pastinen 2018). The average distance between home and workplace of those employees who commuted in a car was approximately 19 km (Keva 2020), which makes their total distance of daily commuting as 38 km. The number of normal workdays per year was assumed to be 210 on average. Hence, SPFIN's employees' supposed total mileage of commuting in a car per year was:

$$467 \cdot 0{,}64 \cdot 38\ \mathrm{km} \cdot 210 \approx 2385062\ \mathrm{km} \tag{14}$$

And in a bus or train (if the distance between home and workplace remains the same):

$$467 \cdot 0{,}12 \cdot 38\ \mathrm{km} \cdot 210 \approx 447199\ \mathrm{km} \tag{15}$$

In Table 5 on page 50, there were total fuel consumptions of SPFIN's diesel and petrol using leased cars. Their total mileage during that year can be calculated approximately with average consumptions of diesel and petrol cars in Finland, which in year 2020 were 5,9 l/100 km for diesel cars and 6,9/100 km for petrol cars (Moottori 2021). Then the approximate total mileage of leased cars was:

$$\frac{31415\ \mathrm{l}}{5{,}9\ \mathrm{l/100\ km}} + \frac{6585\ \mathrm{l}}{6{,}9\ \mathrm{l/100\ km}} \approx 627892\ \mathrm{km} \tag{16}$$

Because the total mileage of business trips taken in leased cars was 189291 km (Table 19 on page 67), the remaining mileage of leased cars was then 627892 km – 189291 km = 438601 km. This residual mileage is here assumed to be daily commuting in SPFIN's leased cars, and its emissions are already included in scope 1 emissions. So, when it is reduced from the total mileage of commuting in any passenger car (2385062 km), the result is the total mileage of employees' commuting in their personal cars (or at least in other than SPFIN's leased cars): 2385062 km – 438601 km = 1946461 km. The total GHG emissions from commuting in other than SPFIN's leased cars were therefore:

$$1946461\ \mathrm{km} \cdot 171{,}48\ \frac{\mathrm{g\ CO_2e}}{\mathrm{km}} \approx 333{,}78\ \mathrm{t\ CO_2e} \tag{17}$$

where 171,48 g CO_2e/km = emission factor of an avg. car with unknown fuel type (Ecobio Oy 2022b).

Commuting by public transportation to SPFIN happens almost completely by bus, because of the long distance from the nearest train station, so its emissions are assumed to be:

$$447199\ \mathrm{km} \cdot 102{,}27\frac{\mathrm{g\ CO_2e}}{\mathrm{km}} \approx 45{,}74\ \mathrm{t\ CO_2e} \tag{18}$$

where 102,27 g CO_2e/km = average emission factor of traveling by bus (Ecobio Oy 2022b).

So, total emissions from SPFIN's employee commuting in year 2019 were:

$$333{,}78\ \mathrm{t\ CO_2e} + 45{,}74\ \mathrm{t\ CO_2e} = 379{,}52\ \mathrm{t\ CO_2e} \tag{19}$$

6.3.7 Use of sold products (category 11, downstream)

It was already beforehand quite clear that this emission category will be the most significant of all scope 3 categories and bigger than scopes 1 and 2. The calculation process of category 11 started with finding out the following characteristics of SPFIN's sold products:

- input powers in use [kW]
- product groups
  - Pump
  - Agitator
  - HST
  - Other
- segments of the end-users
  - Food
  - Pulp & Paper
  - CPI/Fertilizers
  - Water/MW/dewatering
  - RO applications
  - Metals & Mining
  - Power
  - Biofuels
  - Other
- average use-rates [%] and lifetimes [h] of the products
- countries where the products are used and average emission factors of electricity production in those countries

Sulzer's product orders have an order number and a position number, which means that one order number can have several position numbers, and each position is a separate product. So, each product order is numbered followingly: "XXXXXX/YYY", where "XXXXXX" is an order number and "YYY" is a position number.

A list of SPFIN's products that were delivered in year 2019 was obtained from the management of the company. The list included all sold products' order and position numbers, information of type and model of each product, and end-users and their countries. However, powers and end-user segments of the products were not in the list. Therefore, an Excel-report with power and segment information needed to be exported from SPFIN's SAP-system using the order numbers from the list. More challenge for that came from the fact that in different product types the power is entered in different places in the products' SAP-structures, and in some products the given power information is the maximum power of motor and not the real use power. Also, some of the products do not have the power information entered at all, and some have the power in hp (horsepower) instead of kW.

The list of delivered products included 6773 rows which had 6638 individual products (for some reason, 123 products had two rows), and in those 6638 products, there were 2117 different order numbers ("XXXXXX"). There were 672 different product models and 79 different product types (which include those 672 models) in the list. The relationship of the terms "product group", "product type", and "product model" is illustrated in Table 22.

Table 22. An example of product groups, product types, and product models.

Product group	Pump				Agitator			
Product type	AUP		SNS		SLN		SSA	
Product model	A10-32	A71-500	SNS1-100	SNS4-80	SLH-100	SLG-160	SSA60-80B	SSA100-130B

The location of power information needed to be searched for each 79 product types (for some of them the information was in the same location of course). There was found 38 different locations ("characteristics") of which 24 were use (input) powers and 14 were maximum motor powers. With these 2117 order numbers and 38 power characteristics, a report with power and end-user segment information was exported from SAP. The segment information which came into the report was not clear, so when the products in the report were then divided into the above-mentioned end-user segments, the made segment choices were given to experts for checking. The products were also divided into the product groups (pump, agitator, HST, or other).

When the report was exported, it also included products that were not delivered in year 2019 but had the same order number ("XXXXXX") than those products that were in 2019 deliveries. Those surplus products needed to be removed from the report first, by comparing it to the list of delivered products. After that, each product's power in the report needed to be converted into the same form (from motor power to use power with estimated coefficients, from hp to kw, and so on), and missing powers needed to be estimated based on powers of other same type of products.

Products' average use-rates and lifetimes were estimated be experts of those products. With agitators and HSTs, use-rate and lifetime do not depend on segment, but with pumps they do. The estimated lifetimes and use-rates are presented in Table 23.

Table 23. Average lifetimes and use-rates of SPFIN's product groups. (Paro 2022, Röberg 2022, Mikkola & Vanhala 2022)

Product group	Lifetime [a]	Use-rate [%]
Agitators	30	95
HST:s	20	50
Pumps, end-user segment:		
Food	15	70
Pulp & Paper	20	90
CPI, Fertilizers	5	80
Water, MW, dewatering	30	90
RO applications	15	95
Other	15	80
Metals & Mining	5	80
Power	25	92
Biofuels	20	90

Luckily the end-user countries of the products were gotten from SAP into the report with no problems. Numbers of products sold to 90 different countries are listed from largest to smallest in Table 24:

Table 24. Numbers of products sold to different countries.

FI	515	US	193	GB	111	NO	59	UA	33	UZ	16	PK	8	PH	5	MR	2
DE	500	CN	190	MX	106	NL	57	SG	30	FO	15	CD	7	GR	4	NC	2
RU	485	BG	179	BE	95	AR	52	HU	27	NZ	15	CG	7	RO	4	BO	1
ES	303	TR	172	PL	88	DZ	49	BA	25	HR	14	JO	6	RS	4	FJ	1
FR	294	SK	167	ID	85	JP	44	CH	22	SM	14	MT	6	IL	3	GT	1
SE	283	BR	150	PE	81	CA	40	PT	22	DJ	11	BH	5	LU	3	PY	1
SA	262	ZA	147	MA	71	AE	39	CO	19	CY	10	IE	5	RE	3	SN	1
AT	260	IN	146	BY	66	TH	39	TN	17	EE	10	KR	5	ZW	3	TZ	1
IT	203	CL	130	KZ	65	LT	34	ZM	17	IQ	10	MG	5	HK	2	UY	1
EG	202	CZ	123	AU	64	DK	33	DO	16	TW	9	MY	5	LA	2	VN	1
																TOTAL	6638

Average emission factors of electricity production (production fuel mix factors) of these countries were then searched from the database of Our World in Data. In carbonfootprint.com's year report, there were also individual 2019 emission factors available for different states of USA and Australia, and for provinces of Canada, but factors of many needed countries were missing. So, to keep the calculation coherent, only the emission factors of Our World in Data were utilized, including national average factors of USA, Canada, and Australia which were estimated to give accurate enough results. The gathered production fuel mix factors of different countries are in Table 35 in Appendix I.

Now, when known or estimated use power, product group, end-user segment, estimated use-rate and lifetime, end-user country, and emission factor of used electricity for each product were in the same columns of the report, GHG emissions of each product's use phase could be calculated followingly:

$$E_{\text{use phase}} = P_{\text{input}} \cdot UR \cdot LT \cdot EF_{\text{electricity}} \tag{20}$$

where $E_{\text{use phase}}$ = GHG emissions of an equipment in its use phase [t CO_2e]
P_{input} = input power of an equipment in use [kW]
UR = use-rate of an equipment [%]
LT = lifetime of an equipment [h]
$EF_{\text{electricity}}$ = emission factor of used electricity [t CO_2e/kWh]

When each of the products in the report had their calculated use phase GHG emissions in the same column, the total use phase GHG emissions of all products delivered in 2019 could be solved as their sum:

$$E_{\text{use phase,total}} = \sum E_{\text{use phase}} \approx 10747390{,}46 \text{ t CO}_2\text{e} \tag{21}$$

where $E_{\text{use phase,total}}$ = GHG emissions of all equipment in their use phases [t CO_2e]

The result seems to be surprisingly high (almost 10000 times the location-based emissions of scope 2), but the number of sold products in 2019 and their decades long running time put it into perspective. Emissions of SPFIN's average product during one year in its use phase are ~92,35 t CO_2e. The header row and the first 50 of all 6638 products in the report/ calculation chart are presented in Figure 17 in Appendix III.

6.3.8 End-of-life treatment of sold products (category 12, downstream)

Emissions of disposal were estimated for all products that were delivered for customers in 2019. The reason for this is, that all sold products will eventually be disposed at some point, so this is a clear and logical way to calculate those emissions. The estimation was done based on the total amounts of raw materials in those products (they are assumed to correspond the total weights of raw materials in the components that were purchased in 2019, shown in Table 11 on page 56 and Table 13 on page 58). It was assumed that in the disposal process all the products will be completely disassembled so that almost all of their parts can be recycled, and the rest are combusted. The raw materials, their treatment methods, emission factors of the treatment, amounts of materials in different product categories, and emissions from their treatment are presented in Table 25.

Table 25. Characteristics and emissions of disposal of SPFIN's products which were sold in 2019. (Ecobio)

Component material	Treatment method	Emission factor [t CO_2e/t]	Product category	Amount [t]	Emissions [t CO_2e]
Steel	Recycling	0,20861	Pump/Agit./Other	4082,38	851,6261
			HST	337,97	70,50439
Iron	Recycling	0,20861	Pump/Agit./Other	1485,66	309,9244
Titanium	Recycling	0,20861	Pump/Agit./Other	3,03	0,63188
Aluminium	Recycling	0,03628	Pump/Agit./Other	45,00	1,632419
			HST	80,90	2,934966
Plain copper	Recycling	0,16326	Pump/Agit./Other	152,98	24,976
			HST	48,99	7,997781
Perm. magnets	Recycling	0,20861	HST	1,35	0,281268
Lead	Combustion	1,41	HST	2,95	4,154242
Plastic	Rec. and comb.	1,16096	HST	15,43	17,91416
Electronics	Recycling	0,06	HST	11,79	0,707105
Other	Rec. and comb.	1,16096	Pump/Agit./Other	17,35	20,14498
				Scope 3 category 12 total:	**1313,43**

6.4 Results and uncertainties

The total GHG emissions of scope 1 are presented in Table 26 and Figure 10. As can be seen, emissions from vehicles dominate the scope 1 emissions strongly compared to emissions from facilities, which in SPFIN's case originate entirely from purchased gases. The scope 1 emissions from gases used in production and from the company vehicles could be calculated quite accurately and reliably because their consumptions were well-reported.

Table 26. SPFIN's total scope 1 GHG emissions.

	Karhula	**Mänttä**	**Oulu**	**Rauma**	**Hki**	**Vantaa**	**Total**
Emissions from facilities [t CO_2e]	1,24	0,03	0	0	0	0	**1,27**
Emissions from vehicles [t CO_2e]	68,14	7,41	14,03	0	0	4,92	**94,50**
Scope 1 total emissions [t CO_2e]	**69,38**	**7,44**	**14,03**	**0**	**0**	**4,92**	**95,77**

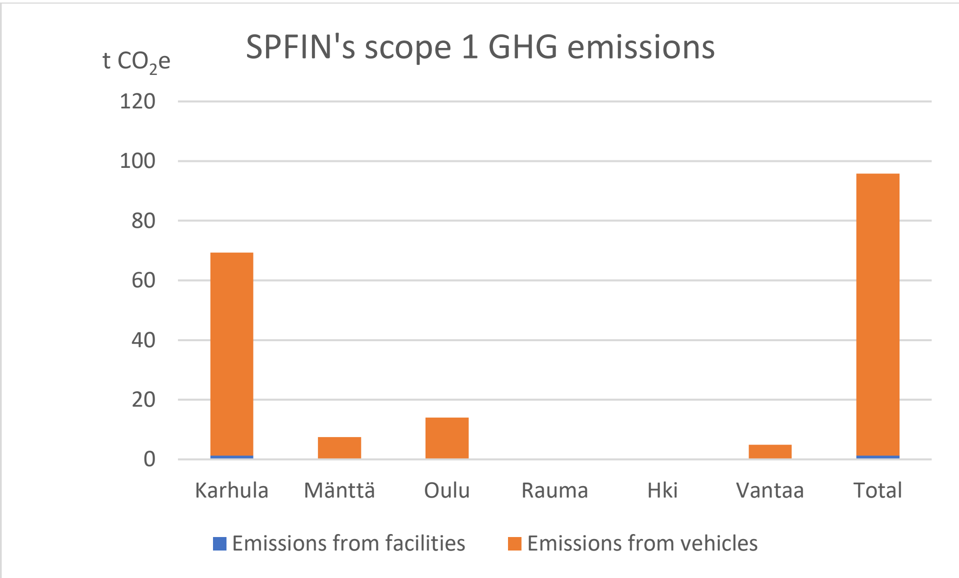


Figure 10. SPFIN's total scope 1 GHG emissions.

The biggest uncertainty concerning scope 1 emissions probably comes from the use of 2021 percentages for calculating different localities' diesel consumption, though it does not affect the total diesel consumption of 2019. Therefore, this uncertainty only concerns the local consumptions. Some uncertainty concerning the total consumptions of diesel, petrol, and light fuel oil in 2019 comes from the fact, that the used consumption data is from October 1st, 2018 to September 30th, 2019, not precisely from year 2019. Also, LPG consumption data of Vantaa plant was from year 2020 instead of 2019. One uncertainty is also related to possible refrigerant leaks, because there was no data available about the use of refrigerants in plants and offices of Karhula, Helsinki and Vantaa.

The total market-based and location-based GHG emissions of scope 2 are presented in Table 27 and Figure 11. Market-based emissions are closer to the reality, because they are calculated mainly with known or probable emission factors of the electricity and district heat suppliers. Consumptions and emissions of the dominating Karhula plant could be calculated quite reliably. Market-based scope 2 emissions are about 19 times bigger and location-based about 12 times bigger than scope 1 emissions.

Table 27. SPFIN’s total market-based and location-based scope 2 GHG emissions.

		Karhula	Mänttä	Oulu	Rauma	Hki	Vantaa	Total
Market-based emissions [t CO_2e]	Electricity	931,81	34,32	20,39	35,55	9,56	2,74	**1034,38**
	District heat	239,10	0	21,99	0	14,18	11,63	**286,90**
	Total	**1170,91**	**34,32**	**42,38**	**35,55**	**19,36**	**14,37**	**1321,28**
Location-based emissions [t CO_2e]	Electricity	571,80	21,06	12,51	21,82	5,18	1,68	**634,05**
	District heat	434,72	0	15,35	0	10,89	13,24	**474,20**
	Total	**1006,52**	**21,06**	**27,86**	**21,82**	**16,07**	**14,92**	**1108,24**

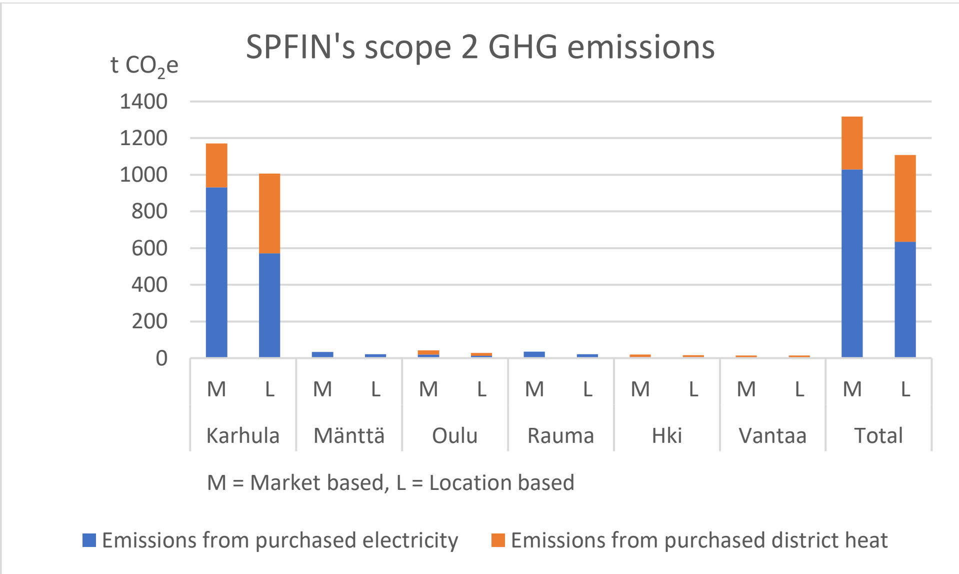


Figure 11. SPFIN’s total market-based and location-based scope 2 GHG emissions.

Some uncertainty to scope 2 emission calculation comes from the use of year 2020 emission factor of Lumme Energia’s electricity, as 2019 emission factor was not available. Besides that, the rest of uncertainties concern the smaller offices' heat consumptions and their district heat's emission factors which were estimated by Ecobio. For Helsinki office, both heat and electricity consumptions were estimated based on assumptions made by Ecobio.

In scope 3, the category 11 (Use of sold products) emissions were in different magnitude than emissions of any other category in scopes 3, 2, or 1, as was expected. The emissions of scope 3 categories are presented in Table 28 and Figure 12. Emissions of category 11 are also shown as annual emissions of SPFIN's average product in its use phase. 6638 products were sold in year 2019.

Table 28. SPFIN's scope 3 GHG emissions.

Emission category	Emissions [t CO_2e]
1. Purchased goods and services	12557,91
2. Capital goods	65
4. Transportation & distribution (upstream)	3832,17
5. Waste generated in operations	76,66
6. Business travel	487,58
7. Employee commuting	379,52
9. Transportation & distribution (downstream)	394,36
11. Use of sold products (all products sold in 2019, whole usage time)	10747390,46
(11. Use of sold products (an average product, annual emissions))	(92,35)
12. End-of-life treatment of sold products	1313,43
Scope 3 total:	**10766497,09**

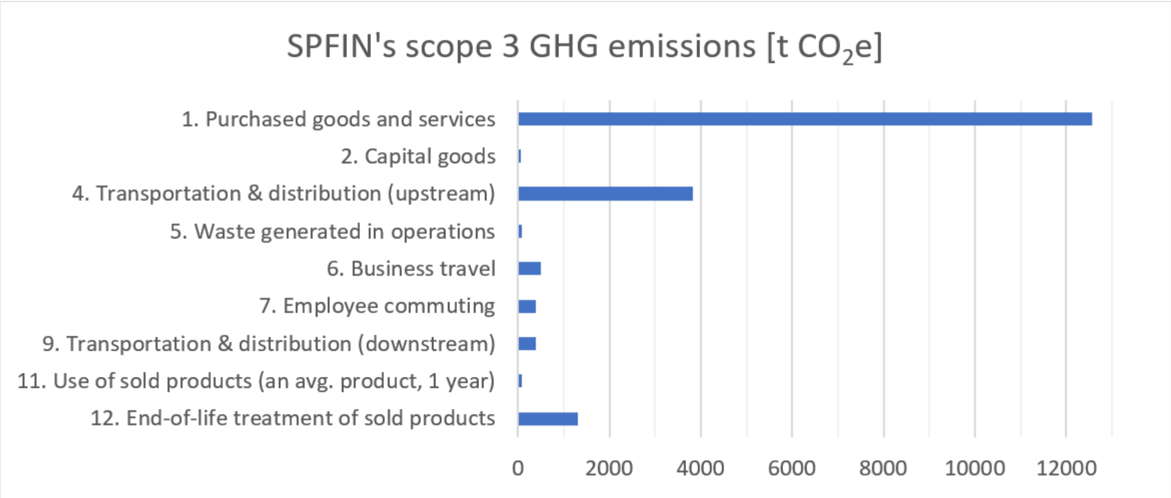
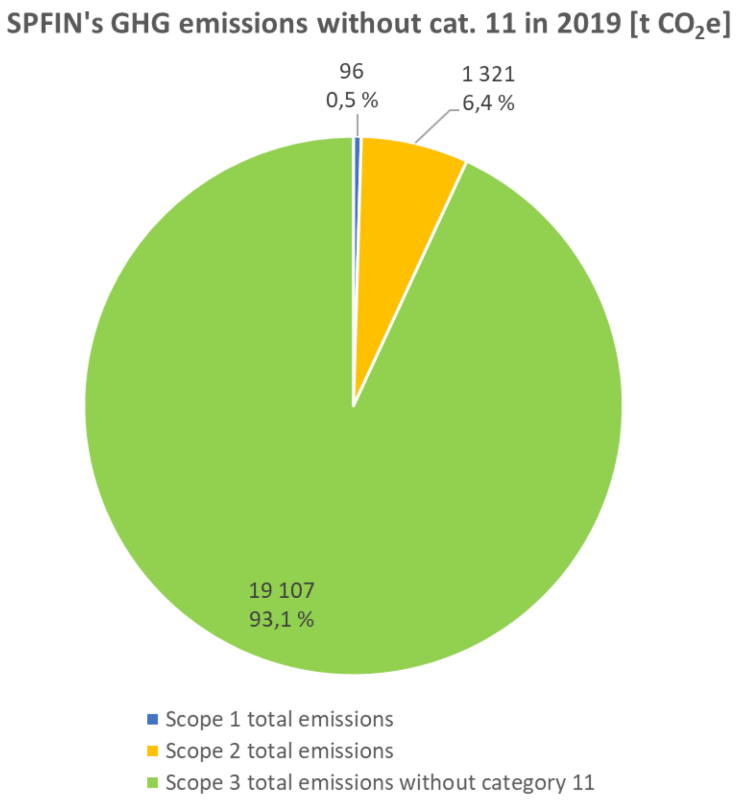


Figure 12. SPFIN's scope 3 GHG emissions (category 11 presented as annual emissions of one average product in its use phase).

Uncertainties in the selected scope 3 emission categories are:

- Category 1 (Purchased goods and services)
    - Missing weight information of some of the component items in SAP-system
    - Materials that were under the titles Other and Undefined
    - Calculation was done only based on the main components
    - Material percentages
- Category 2 (Capital goods)
    - Total weight of purchased tools and machines is a rough estimation, because precise information was not available
- Categories 4 and 9 (Transportation and distribution)
    - Emissions of imported freights were scaled from DSV's data, which was only a little over half of all imported freights excluding motors
    - Only ABB's LV-motor freights were taken into account because of the lack of information
    - Share of category 9 from all exported freights is based on estimation (1/3)
- Category 5 (Waste generated in operations)
    - Based only on L&T:s data about the amounts of waste collected from Karhula's and Helsinki's premises and on the reported amount of metal waste from Karhula. Numbers for other premises are estimated based on them.
- Categories 6 and 7 (Business travel and employee commuting)
    - Many assumptions had to be made
- Category 11 (Use of sold products)
    - Many equipment's use powers had to be estimated
    - Use rates and lifetimes of all equipment are assumptions, albeit of experts
    - Average emission factors of electricity production were not available for some countries where sold equipment are used, so the international average was used for equipment sold to those countries
- Category 12 (End-of-life treatment of sold products)
    - Based on the assumption that all parts of the products will be recycled or disposed otherwise properly in different countries

The results of scopes 1, 2, and 3 are compared in Figures 13 – 15.



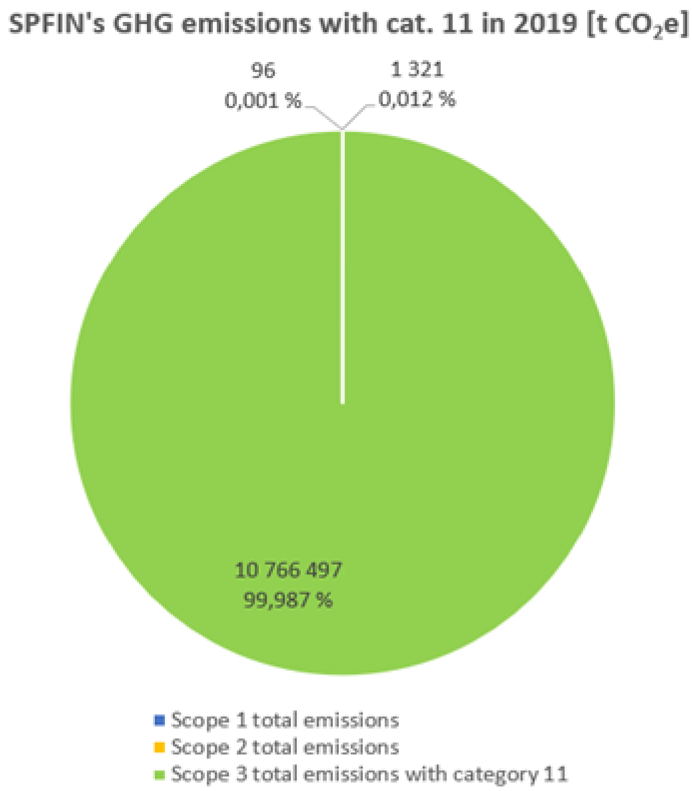


Figure 13. GHG emissions of SPFIN in 2019 without and with category 11 of scope 3.

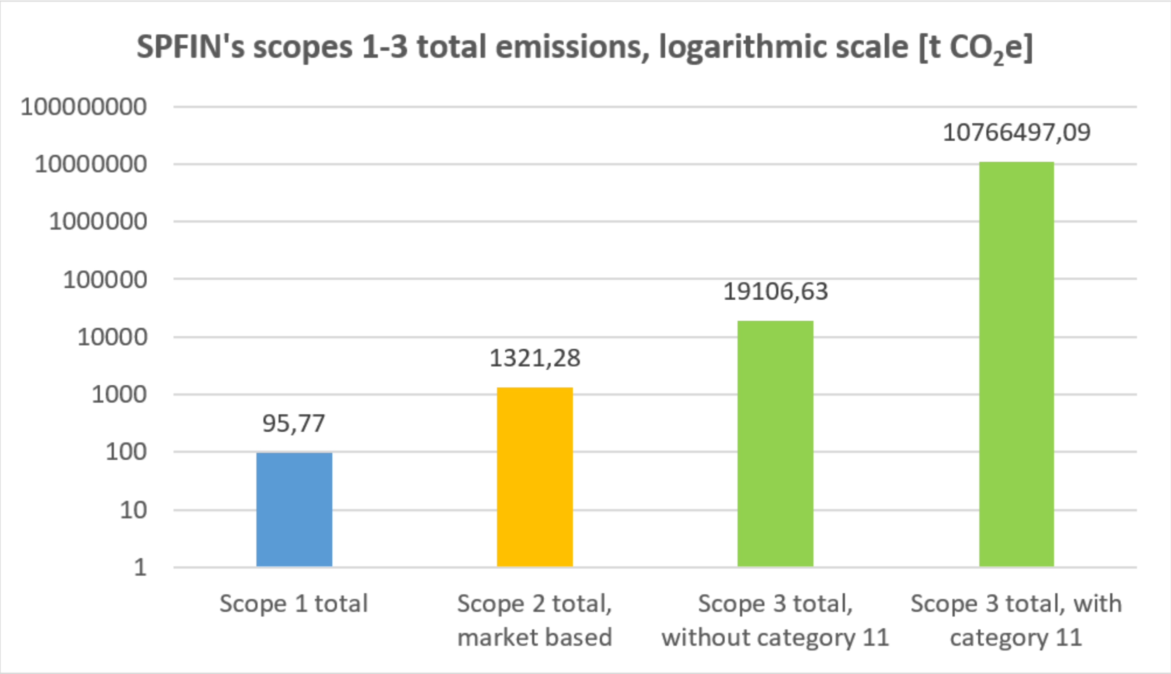


Figure 14. Comparison of scopes 1 – 3 on a logarithmic scale.

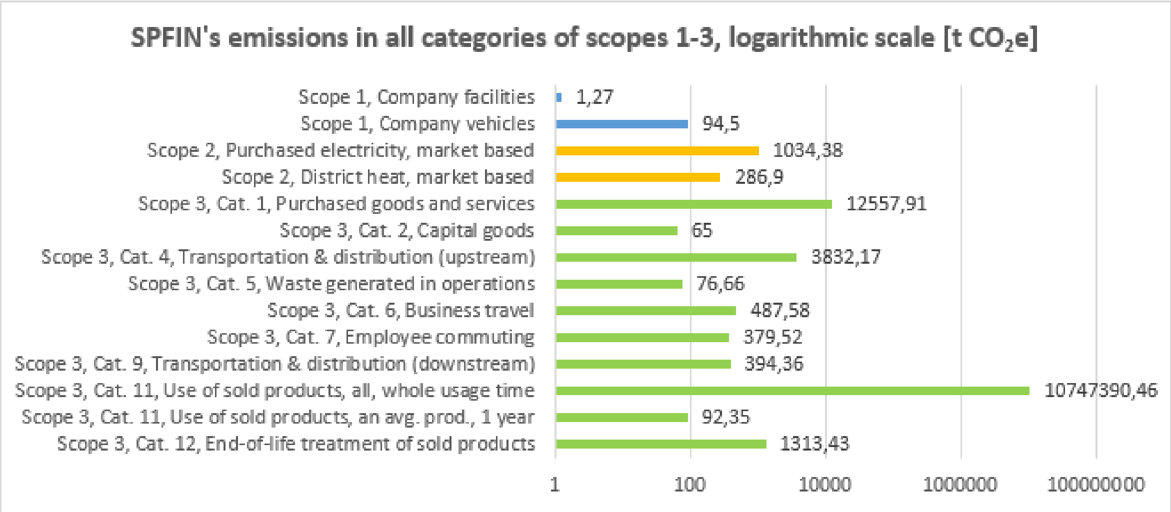


Figure 15. Comparison of all categories of scopes 1 – 3 on a logarithmic scale.

Finally, emissions of all categories of scopes 1 – 3, total emissions of each scope, and total emissions of SPFIN (scopes 1 – 3 combined, with and without category 11 emissions) are gathered into Table 29.

Table 29. Summary of SPFIN's all GHG emissions in 2019.

Scope	Emission category		Emissions [t CO_2e]
1	1. Company facilities		1,27
	2. Company vehicles		94,50
	Scope 1 total		95,77
2	1. Purchased electricity	Market-based	1034,38
		Location-based	634,05
	2. District heating	Market-based	286,90
		Location-based	474,20
	Scope 2 total	Market-based	1321,28
		Location-based	1108,25
3	1. Purchased goods and services		12557,91
	2. Capital goods		65,00
	4. Transportation & distribution (upstream)		3832,17
	5. Waste generated in operations		76,66
	6. Business travel		487,58
	7. Employee commuting		379,52
	9. Transportation & distribution (downstream)		394,36
	11. Use of sold products	All, whole usage time	10747390,46
		An avg. prod., 1 year	92,35
	12. End-of-life treatment of sold products		1313,43
	Scope 3 total	With category 11	10766497,09
		W/o category 11	19106,63
SPFIN scopes 1-3 total (market-based emissions in scope 2)		**With cat. 11 of scope 3**	**10767914,14**
		W/o cat. 11 of scope 3	**20523,68**

7 CARBON HANDPRINT POTENTIALS OF SPFIN'S PRODUCTS

As an addition to the assessment of SPFIN's carbon footprint, product-level carbon handprint potential of SPFIN's products was considered. Instead of calculating handprints compared to competing products on the market, factors that have impact on potential carbon handprints of these products were identified. The earlier introduced handprint quantification process was also used in a preliminary manner for creating a basis for SPFIN's products' carbon handprint calculation in the future. Possibilities to improve the products' carbon handprint potentials from their current state were also discussed in conclusions.

7.1 Significance of different lifecycle phases for the products' carbon handprint potentials

According to GHG Protocol's Product Standard (illustrated in Figure 2 on page 28), lifecycle of a product can be divided into the following phases:

- Material acquisition & pre-processing
- Production
- Distribution & storage
- Use phase
- End of life

(Greenhouse Gas Protocol 2011b, 7).

Even though product-level carbon footprints were not calculated in this work, some conclusions about them and the significance of different lifecycle phases for them can be made based on the results of the company-level carbon footprint. The products' carbon footprints interact with the company's carbon footprint's emission categories, as the Figure 2 shows.

If the emission categories of SPFIN's carbon footprint (except for commuting, business travel and capital goods) are allocated into the above-listed lifecycle phases and summed up inside each lifecycle phase, the significance of these phases for a product's carbon footprint can be seen. And if those emissions are then divided by the number of products which were sold in 2019 (6638), the gotten results are per an average product of SPFIN. The allocation of the emissions into the lifecycle phases and the emissions per one average product are shown in Table 30 and Figure 16.

Table 30. The allocation of different emissions into a product's lifecycle phases and emissions per product.

Lifecycle phase	Included emissions categories	Emissions [kg CO_2e]
Material acquisition & pre-processing	- Purchased goods and services (scope 3 category 1) - Transportation & distribution, upstream (scope 3 category 4) - Waste generated in operations (scope 3 category 5)	2481
Production	- Scope 1 - Scope 2 (market-based emissions)	213
Distribution & storage	- Transportation & distribution, downstream (scope 3 category 9)	59
Use	- The whole usage time (scope 3 category 11)	1619071
End-of-life	- End-of-life treatment of sold products (scope 3 category 12)	198

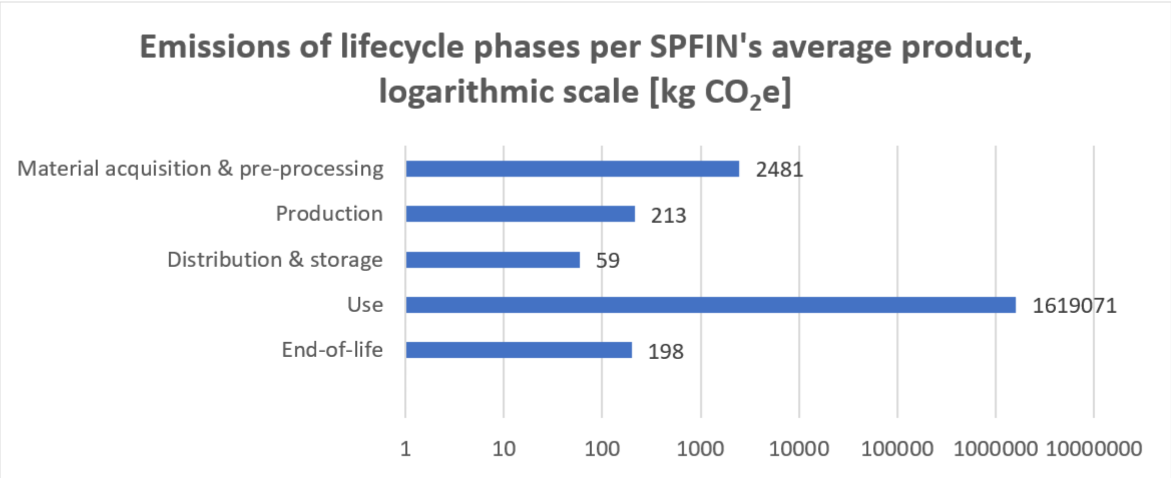


Figure 16. Significance of different lifecycle phases for the carbon footprint of SPFIN's average product.

As the table and figure show, the use phase generates by far the largest emissions also in the products' carbon footprints and hence it is also the most important lifecycle phase in the products' carbon handprints. Far below the use phase, the importance order of lifecycle phases regarding SPFIN's products' carbon footprints and potential carbon handprints is: material acquisition & pre-processing, production, end-of-life, and distribution & storage. It is important to notice that in this kind of allocation only scope 3 category 9 emissions are in distribution & storage phase, while category 4 is in material acquisition & pre-processing.

7.2 The main products and important factors of their carbon handprint potentials

The dominating importance of the use phase makes the products' energy efficiency the most important factor that the manufacturer can affect, because the emissions of the use phase are almost entirely from the electricity use of the products. The emission factor of the used electricity is of course also very essential, but the product's manufacturer cannot decide what kind of electricity the product's user purchases. One thing that should be considered, is that paradoxically, the longer lasting an equipment is, the larger its carbon footprint during its lifecycle is, when the use phase becomes longer. Nevertheless, durability also reduces the need for spare parts and postpones the need for acquiring next replacing equipment, so in that way it reduces the users own carbon footprint. On the other hand, if the energy efficiency of new products improves little by little, at some point it could be emission wise justified to buy a new equipment just because it has so much better energy efficiency than the equipment currently in use, regardless that the current equipment would still last for many years in use.

SPFIN's main products' energy efficiency and durability are already on a very high level, but because their effect on the products' carbon footprints and potential carbon handprints is so significant, it is worthwhile to aim at developing them even further. And that is what SPFIN's product development is doing constantly; energy efficiency, durability, and recyclability are among the main criteria in their projects. Other factors are far less significant for generation of GHG emissions, but nonetheless also they are worth of developing.

The product categories and products selected for the carbon handprint survey were pumps (AHLSTAR and SNS), agitators (SALOMIX™ SSF), and turbocompressors (HST™), because they are SPFIN's most sold products. AHLSTAR and SNS are both end-suction single-stage centrifugal process pumps (covered by the international standard ISO 5199). Different AHLSTAR models can be used, with applicable construction materials, for pumping basically any kind of liquid (hot liquids, abrasive and erosive fluids such as mud, coating pigments, lime milk, or slurry, and liquids containing large solids). (Sulzer 2021m.) SNS does not have as many alternative construction materials as AHLSTAR due to SNS's higher standardization level, but nevertheless it is applicable for pumping many different kinds of fluids (clean, slightly contaminated, and viscous liquids and fibrous slurries) (Sulzer 2021n). SNS provides higher hydraulic power, flow, and head than AHLSTAR and other more conventional pumps, and it has the highest energy efficiency among process pumps on the market (Sulzer 2021n).

Energy efficiency of pumps depends mainly on their hydraulic design, shaft sealing, and bearing. Sulzer's SNS process pump has an outstanding energy efficiency; it has the highest efficiency on the process pump market. It has exceeded minimum efficiency index MEI 0.7 level, thus making a new record. It also meets the energy-related products' ErP 0.4 criteria. SNS has a rigid, compact, long-lasting, and leak-free bearing construction, which reduces the consumption of lubricant. The structure of SNS pumps is highly standardized, so they use common components and modules, and the number of different parts in them has been reduced, which increases their reliability. (Sulzer 2021n.) This decreases the need for spare parts and lengthens SNS's lifetime. AHLSTAR A is an older pump model than SNS, but it is still SPFIN's most sold pump product, because of its versatile applicability for different pumping applications due to many different material, shaft sealing, and bearing lubrication options (Sulzer 2021o). It also has a very competitive energy efficiency and high reliability because of the mentioned various options (Sulzer 2021o).

Different types of SALOMIX™ agitators are applicable for demanding industrial liquid mixing and agitation applications (Sulzer 2021p). There are side-mounted horizontal and top-mounted vertical models with gear drives and belt drives (Sulzer 2021p). Components which affect agitators' energy efficiency significantly are propeller, gear, and bearing. SALOMIX™ SSF agitator's high energy efficiency results from EX3 type propeller that has adjustable blades and a large axial thrust, integrated gear box, condition monitoring, and compatibility with many different motor options. Among the integrated gear box and condition monitoring, the construction that is entirely of stainless steel and easy maintenance are factors that improve the SSF agitator's durability and therefor lengthen its lifetime. (Sulzer 2021q.) An average lifetime of SPFIN's agitators is approximately 30 years (Röberg 2022).

Turbocompressors manufactured by SPFIN are equipped with magnetic bearings and can provide low-pressure air to almost all kinds of industrial processes which need aeration (wastewater treatment, food and beverage production, pulp and paper industry, and so on) (Sulzer 2021r). HST™ turbocompressor's energy efficiency is excellent mainly because of the magnetic bearings. This kind of structure effectively prevents power from getting lost. HST's motor is always driven with a frequency converter that is integrated into the compressor. (Sulzer 2021s.) HST can cost about three times the price of the cheapest alternative device, but on the other hand, HST saves energy at least 1/3 compared to the cheapest alternative (Paro 2022). Running multiple HST turbocompressors together further improves energy efficiency and lowers GHG emissions (Sulzer 2021s).

HST turbocompressor is also very reliable and durable because the technology it uses is wear-free, lubrication-free, vibration-free, and pulsation-free, and it requires very little maintenance (Sulzer 2021s). HST turbocompressors are designed to run for 20 years (Paro 2022). The first HSTs were delivered in October 1996, and some of them are still in use (Paro 2022). Some small components such as filters and some fans that have roller or ball bearings need to be changed every 5 to 10 years, and the main capacitors of the frequency converter last at least for 10 years (Paro 2022).

So, recognized factors related to the products use phase (energy efficiency, reliability, and durability) which are beneficial for these products' carbon handprint potential and marketing, are:

- For SNS pumps:
    - The highest energy efficiency on the process pump market (breaking of all records (MEI 0.7 level), meeting the ErP 0.4 criteria)
    - Low lubricant consumption due to leak-free bearing construction
    - High reliability and durability, and therefore long lifetime, due to high standardization level of the structure and reduced number of components
- For AHLSTAR A pumps:
    - High energy efficiency and long lifetime due to excellent hydraulic design and many alternatives for construction materials, shaft sealing, and bearing lubrication

- For SALOMIX™ SSF agitators:
    - High energy efficiency and long lifetime (~30 years) due to EX3 type propeller, integrated gear box, condition monitoring, compatibility with various motor types, stainless steel structure, and easy maintenance
- For HST™ turbocompressors:
    - Excellent energy efficiency due to magnetic bearings (energy savings compared to the cheapest comparable product are 1/3 or more)
    - No need for lubrication
    - Long lifetime due to the technology that is free of wearing, vibration, and pulsation, and has minimal need for maintenance (HSTs are designed for 20 years of use, some of the first HSTs from October 1996 are still running)

Besides the factors that affect the products' GHG emissions in the use phase, effective factors of other lifecycle phases as well are listed in Table 31.

Table 31. Factors that affect GHG emissions in different lifecycle phases of SPFIN's products.

Lifecycle phase	**Factors affecting GHG emissions**
Material acquisition & pre-processing	Component and component supplier choices Proper waste management
Production	Type and consumption of purchased electricity Type and consumption of purchased heat Company vehicles (use and used fuels) Company facilities (used substances and consumption of them)
Distribution & storage	Means of transportation and used fuels
Use	Energy efficiency Reliability/durability Emission factor of used electricity (depends on available options at the location and the user's choice regarding them)
End-of-life	Recycling/reuse rate

7.3 Basis for SPFIN's products' carbon handprint quantification in the future

Even though carbon handprint quantification of the products was not included in this work, the handprint quantification process could be preliminarily applied to SPFIN's products. So, next, the steps of the process are studied without actual quantification of carbon handprints or making of comparative claims. If carbon handprints of the products will be quantified in the future, the quantification can follow the contents of the steps as guidelines.

In step 1 of stage 1 (handprint requirements), the product's scope is defined in detail (Pajula et al. 2021, 18). For a centrifugal process pump, the scope consists of a device which transfers a liquid from one point to another with a certain pressure and flow. An agitator's scope includes a device that mixes a liquid (usually in a vessel) with a certain power, and a turbocompressor's scope includes a device that produces a certain constant air flow with a certain pressure.

In step 2, the selected products' possible carbon handprint contributors are identified (Pajula et al. 2021, 18). With SPFIN's products, the contributors are related to the emission categories used in the company's footprint calculation, which were emissions directly from the facilities and vehicles owned or controlled by the company, emissions from purchased electricity and heat, and emissions from scope 3 categories 1, 2, 4, 5, 6, 7, 9, 11, and 12. The most significant contributors in this case are related to scope 3 categories 11 (especially), 1, and 4. The rest of the categories are not insignificant either and some of them can be improved quite easily, like purchased electricity and heat.

In the case of carbon handprint, climate change (global warming) is identified as the only considered environmental impact in step 3, and the indicator which is used for it is GHG emissions in CO_2 equivalent. SPFIN's pumps', agitators' and turbocompressors' users and beneficiaries defined in step 4 are several companies of process industry around the world. The basic use of these products is everywhere the same (pumping or mixing a liquid and producing air flow), but the geographical market can affect the carbon handprint potential due to different emission factors of electricity used for running the equipment.

In carbon handprint calculation, it is possible to specify specific users for offered SPFIN's products, and the products that the users are currently using or other corresponding products can be set as baselines in step 5 (Pajula et al. 2021, 22). For marketing purposes though, the most useful choice for a baseline might be an average corresponding product on the market, because there are lots of potential customers with many corresponding products currently in use. Also, in many areas, Sulzer's products are market leaders or at least typical products in their categories, and an average product is commonly used in comparative studies, which would also support choosing an average product as a baseline. But if a competing product is known to be the market leader in some areas, it is also well justified baseline choice.

In step 6 of stage 2 (LCA requirements), a logical choice for the functional unit for pumps would be output pumping energy (output power * usage time) (kWh, MWh), for agitators output mixing energy (kWh, MWh), and for turbocompressors output energy of produced air flow (kWh, MWh).

The system boundaries which are set in step 7, should in the case of pumps, agitators, and turbocompressors include all life-cycle stages from acquisition of materials to the end-of-life treatment. This is because during the products' life cycles the use phase is the most important emission source and the acquisition of materials is also an important one, and the use phase should be included in any case (Pajula et al. 2021, 24). The end-of-life phase is usually also included (Pajula et al. 2021, 24). The flows across the system boundaries are then all needed material and energy flows of SPFIN's operation (functions of scopes 1 and 2, and scope 3's selected categories) per the examined product.

In step 8 (definition of data needs and sources), if carbon handprints are calculated for specified users, the user's most recent primary data should be utilized if possible (Pajula et al. 2021, 24). Then again, if the carbon handprints are calculated for potential users, average or statistical data must be used (Pajula et al. 2021, 24). For the examined SPFIN's products (process pumps, agitators, and turbocompressors), the data are collected inside SPFIN, from product brochures, possibly available and valid EPDs, and departments of procurement, sales, and product development.

The carbon handprints of the chosen products are then calculated in stage 3 (quantification), which includes steps 9 (calculation of the footprints of an offered product and a baseline product) and 10 (calculation of the handprint (Equation 1 on page 34)) (Pajula et al. 2021, 25). The offered products' and the baseline products' global warming impacts (t CO_2e) can be divided by the functional units defined in step 6 of stage 2 (output pumping energy, for example), so that the GHG emissions of the products are comparable.

As pointed out in step 3 of stage 1, climate change is the only considered environmental impact in carbon handprint and used indicator for it is GHG emission in CO_2 equivalent. Hence, GHG emission is also the indicator chosen in step 11 (identification of the relevant indicators to be communicated) of stage 4 (communication). Critical review (step 12), which verifies the calculation, its results, and its consistency with appropriate standards, could be done by an outside consulting company or by a competent, independent reviewer inside Sulzer. When the results are then communicated (step 13), it would be logical to use the earlier defined functional units also as communication units.

The above-described steps and suggestions for them regarding SPFIN's products' carbon handprint quantification in the future are listed in Table 32.

Table 32. Steps for carbon handprint quantification of SPFIN's products. (Pajula et al. 2021, 16 – 26)

Stage 1. Handprint requirements	
Step 1. Definition of the product's scope	- For pumps: a device which transfers a liquid from one point to another with a certain power (= pressure * flow) - For agitators: a device that mixes a liquid in a vessel with a certain power - For turbocompressor: a device that produces a constant air flow with a certain power
Step 2. Identification of potential handprint contributors	- Energy efficiency, reliability, need of maintenance and spare parts, and lifetime of sold products - Emissions from purchased components - Sources of purchased components, destinations of sold products, and means of their transportation
Step 3. Identification of the environmental impacts and their potential indicators	- For carbon handprint, the only considered environmental impact is climate change, and the indicator for it is GHG emission in CO_2 equivalent
Step 4. Identification of the users and beneficiaries of the product	- Industrial companies around the world
Step 5. Definition of the baseline	- If the products' carbon handprints are quantified for specific users, the baselines can be the products that the users are using at that time or some other corresponding products. For common marketing, the baselines can be specific or average corresponding products
Stage 2. LCA requirements	
Step 6. Definition of the functional unit	- For pumps: output pumping energy (kWh or MWh) - For agitators: output mixing energy (kWh or MWh) - For turbocompressors: output energy of produced air flow (kWh or MWh)
Step 7. Definition of the system boundaries	- The system boundaries include all life-cycle stages from acquisition of the materials to the end-of-life treatment

Continues on the next page.

Step 8. Definition of data needs and sources	- The user's most recent primary data for the main handprint contributors should be used if possible. - If the carbon handprint is calculated for potential users instead of a specific user, average or statistical data will be utilized. - For SPFIN's products, data are obtained from SPFIN's internal sources (product brochures, EPDs, product development, procurement, and sales)
Stage 3. Quantification	
Step 9. Calculation of the carbon footprints	- The offered products' and the baseline products' global warming impacts are divided by the defined functional units, so that the GHG emissions are comparable.
Step 10. Calculation of the carbon handprint	- Equation 1 on page 34
Stage 4. Communication	
Step 11. Identification of the relevant indicators to be communicated	- Climate change is the only considered environmental impact, and its indicator is GHG emission in CO_2 equivalent
Step 12. Consideration of critical review of the handprint	- Critical review can be done by an outside consulting company or by a competent, independent reviewer inside Sulzer.
Step 13. Communication of the results	- The functional units defined in step 6 can be used also as communication units.

8 CONCLUSIONS

Most of this work dealt with the calculation of SPFIN's carbon footprint and climate responsible operation from the perspective of a pump manufacturer. The carbon footprint was calculated by following the framework of the GHG protocol. Emissions from scopes 1 and 2, and from selected categories of scope 3, were included in the calculation, the scope 3 being the widest area in it. During the research, current problems and challenges in the process were identified, so the process can be developed in respect of them. About the climate responsibility, knowledge was gathered concerning legislation, sustainability qualifications for funding, environmental management, and impacts of operational environment. Applying the concept of carbon handprint to SPFIN's products was also examined in a precursory manner and a basis for carbon handprint calculation of specifically SPFIN's products was developed for the future. This was done based on the handprint quantification process developed by researchers of LUT and VTT.

8.1 Made choices

Climate responsibility was approached from the viewpoint, that complying with legislation, following standards, getting funding, and taking into account the features of the operational environment are all necessary for a company to be able to operate in a sustainable way and to achieve positive climate impacts.

For carbon footprint calculation, the GHG Protocols framework was chosen as a basis mainly because nowadays it has become a very commonly used tool, and also because it is quite intuitive and clear means for implementing this kind of assessments. Applying the GHG Protocol was also recommended by Ecobio, who performed the final calculations based on the gathered initial data and preliminary calculations given to them.

For scopes 1 and 2, the calculations were done based on operational control. It is the most common way of setting organizational boundaries when the organization's operation is focused on production (Voutilainen 2021). This way, emissions from leased cars and rented buildings, for example, can be included in scopes 1 and 2, which seems more logical than including them in scope 3. Scopes 1 and 2 can be seen as an organization's "front yard" and scope 3 as “back yard” (Voutilainen 2021). If an organization focuses more on investments, then a different boundary setting can work better (Voutilainen 2021).

The scope 3 emission categories which were left out from the calculation, and reasons for that, were:

- Category 3 – Fuel and energy related activities (upstream)
  - This is quite negligible in SPFIN’s case
- Category 8 – Leased assets (upstream)
  - Leased cars are included in scope 1, and electricity and heat of the rented offices in scope 2, because of the organizational boundaries based on operational control
- Category 10 – Processing of sold products (downstream)
  - SPFIN’s products are not processed after they are sold
- Categories 13…15 – Leased assets, Franchises, and Investments (downstream)
  - SPFIN does not have these kind of investments or activities

Even though only scopes 1 and 2 must be included in carbon handprint calculation and emission categories of scope 3 can be chosen freely, it is reasonable to also include at least the most relevant ones of them in the calculation, in order to understand the whole picture. Then all the most important emission sources can be seen, and some of them will probably be in scope 3 as can be seen from SPFIN’s emissions.

Utilization of the handprint quantification process was also a clear choice for the SPFIN’s products’ carbon handprint potential survey. At the time of this work, there were no other as comprehensive handprint quantification methods commonly known. The main focus of this work was on the company level carbon footprint calculation though, which is why the handprint potential was examined more concisely.

The examined product categories and products (pumps: AHLSTAR A and SNS, agitators: SALOMIX™ SSF, and turbocompressors: HST™) were selected for the carbon handprint survey because they represent SPFIN’s business activity best. AHLSTAR is applicable for many different kinds of pumping solutions and its A model is the most multipurpose one

(Sulzer 2021o). SNS has less wide selection of different construction materials but is has a superior energy efficiency and higher hydraulic power than AHLSTAR (Sulzer 2021n). For those reasons they are, together with SALOMIX^{TM} SSF agitator and HST^{TM} turbocompressor, SPFIN's most sold models in their product categories.

Since Sulzer is a multinational corporation, SPFIN is just one of many companies Sulzer has around the world. Now there has also started a corporation level GHG emission calculation project at Sulzer's headquarters in Winterthur, concerning only Sulzer's scope 3 emissions. This SPFIN's carbon footprint calculation started before the corporation level calculation. The made choices and results of this thesis work can be utilized also in the corporation's emission calculation in Winterthur, so there should not be overlapping that would cause the same work to be done more than once.

If emission calculations are done separately in different subcompanies and/or headquarters of Sulzer, they should follow the same strategy and choices so that their results will be comparable. There are advantages both in doing separate calculations in different subcompanies or doing one centralized calculation concerning the whole corporation. One centralized calculation project including all scopes from 1 to 3 in the same extent as in this work would certainly be solid in a way that emission calculation of all subcompanies would follow the same principles. On the other hand, separate calculations done locally in subcompanies can be in some ways more reliable. This is because there are differences between local systems and customs of different subcompanies, and certain employees on the spot usually have the best knowledge about their local company and where important data might be found. Also, there can be better conditions for potential innovations on a local level because of the local knowledge. It is yet to be seen whether more carbon footprint calculation projects like this will be implemented in other subcompanies of Sulzer as well or will there be a corporation level calculation done in a similar fashion. In any case, this work can be utilized as a framework for them.

8.2 Challenges in the carbon footprint calculation process and its development for the future

Most challenges during the process were related to obtaining relevant information and data. Acquiring of needed information and data took quite some time, and they had to be collected from various sources and people. Some of the searched information was not even available, so many assumptions and estimations had to be made.

In scope 1, the following problems were faced. For the facilities in Mänttä, Oulu, and Rauma, refrigerant leaks could be verified as zero, but for Karhula, Helsinki, and Vantaa, there was no information available, so their leaks were also assumed to be zero. The reporting system should be developed for the future assessments. There should be named persons who document all made refills of refrigerants, and the reports should be available in a defined place. Data for welding gases and for gases used in other production processes in year 2019 was available without any major problems.

Data for total diesel and petrol consumption of cars and light fuel oil consumption of forklifts controlled by SPFIN was not available exactly for year 2019, but for the period of October 1st, 2018 – September 30th, 2019, so it had to be used. Data for LPG consumption of Mänttä's forklifts in 2019 was available, but for forklifts in Vantaa, there was only data from year 2020. Luckily the consumed amounts of LPG were small, and it is presumable they have not changed significantly from year 2019 to 2020. The obtained consumption data of light fuel oil and LPG, which were used only in forklifts, was plant specific. However, diesel and petrol consumptions were only available as SPFIN's total consumptions, so the plant specific consumptions were then estimated with the plants' percentages of total consumptions in year 2021 which happened to be available.

In scope 2, only the total amount of electricity consumed in SPFIN in 2019, excluding Helsinki office, was available, but plant specific amounts were not. Again, the plant specific consumptions in 2019 were estimated with the percentages of year 2020 consumption which were known. On top of that, the emission factor of purchased electricity in 2019 was not obtained from Loiste Oy (Ltd), which was SPFIN's electricity supplier until December 1st, 2021, when the customers of Loiste Oy became customers of Lumme Energia Oy (Ltd). Therefore, emission factor of Lumme Energia's uncertified electricity in year 2020 was used. Electricity consumption and supplier for the rental office in Helsinki are not known. Its electricity consumption had to be estimated by Ecobio based on the office's area and the characteristic electricity consumption of offices. Because the electricity supplier was not known either, Finland's residual fuel mix factor was used as the emission factor of electricity used in that office.

As for the used district heat, only Karhula plant's district heat consumption and emission factor in 2019 were obtained (from Kotkan Energia Ltd). Plants of Mänttä and Rauma are known to have direct electric heating, but plants and offices in Oulu, Vantaa, and Helsinki have district heating, so their heat consumptions were estimated based on their areas and the characteristic heat consumption of such spaces. The used emission factors for them were the emission factors of the assumed local district heat suppliers.

In category 1 (purchased goods and services) of scope 3, one problem was that about 2,4% of all non-HST-components that were purchased in 2019 had no weight information in Sulzer's SAP system. Therefore, the total weights of different raw materials in them had to be estimated by scaling with the quantities of all certain type components and those of them that have the weight information. Even larger share of HST-components did not have weight information, but with them it was not a problem for calculation of the total weights of raw materials, because the accurate weights of all sold HST-compressors could be obtained from their datasheets in Sulzer's intranet. But otherwise, it would be better if as many components as possible had their weight in the SAP system.

One challenge came also from the observation that some of baseplates, castings and HST-components were included both in their own lists and in the list of Chinese components, so the duplicates had to be removed. Quite many assumptions and estimations had to be made also in this emission category, such as the material composition of couplings and motors, and the total weights of shaft billets and agitators. If more accurate data for the mentioned component categories, and time resources for collecting it, will be available in the future, also more accurate results will be available. The same would apply also to Javasko's data that was used this time (emission factor of electricity and scope 1 emissions which were not obtained for this assessment project), but during the next couple of years, Javasko's manufacturing will be moved to Karhula's new production line (so called Eagle project), so then Javasko will not be a part of SPFIN's production chain anymore.

Emissions of category 2 (capital goods) were calculated based on a very rough estimation. The problem was that for a more precise calculation of this category the purchased tools and equipment should have been weighed in practice, and this was not possible at the moment. Quite precise weights of a grinding machine in Rauma and a milling machine in Oulu were found out, but the weights of the rest of the purchased items were assumptions. And of course, there are also some amounts of other materials in them besides steel and iron. If this category will be seen important in the future assessments, weights and materials of purchased equipment and tools should be documented by a designated person whenever something is acquired. Large acquisitions can also be allocated for more than one year. Still, the emissions from this category seem to be so minimal beside other emissions, that it might not be necessary to include it at all.

Calculation of category 4 emissions will become more accurate with the analysis of all transportation paid by SPFIN, which is planned to take place later in 2022. Still, the analysis will not include those freights from component suppliers to SPFIN that are paid by the senders. In this work, the emissions from the freights from suppliers around the world to SPFIN were estimated based on the known total weight of purchased components in 2019 and DSV's report of imported freights (paid by SPFIN) in year 2021. If more reports from other transport and logistics companies had been available, the reliability of the result for this emission category would be higher. One minor deficiency in the DSV's report was that freights from India did not have emission data, so some extra calculation was needed. The biggest issue with GHG emissions from transportation of motors was that the needed information was available only for ABB's low voltage motors but not for medium voltage motors or other manufacturers' motors. In the future, the calculation can become more accurate if data also for them will be available.

The daily transportation between Karhula and Javasko in Mänttä will also stop in the near future because of the mentioned new production line of Karhula. Thus, it will not be a part of category 4 calculation after that, which also reduces some uncertainty. The logistics department's Rami Muuri delivered two reports containing total weights of freights (new equipment and spare part deliveries) sent from SPFIN to different destinations in 2021, because these data were available (though there were also some minor estimates done among them). Again, the emissions of the freights from SPFIN to customers were estimated by scaling the year 2021 freights to correspond the total weight of imported and exported material in year 2019. Category 9 emissions were calculated based on the rough estimation that they were 1/3 of the emissions of all leaving freights. This will not of course affect the combined emissions of categories 4 and 9, but when the mentioned analysis of all transportation paid by SPFIN will be done, also more exact size of category 9 will be found out. When subsequent carbon footprint calculations will be done in the future, the calculation process will be somewhat simpler and the results will become more accurate, if all initial data will be available for the selected year.

The problem with emission category 5 was, that waste management data was only available for plants and offices in Karhula and Helsinki, and partly for Mänttä (hazardous waste) via L&T's reports. So, for the service centers in Mänttä, Vantaa, Oulu, and Rauma, the amounts of waste and emissions from it had to be estimated from Karhula's service center's numbers. Another uncertainty was related to the metal waste that was not collected by L&T. Its weight information was available only for Karhula, and even there only for year 2020 but not for 2019.

In category 6 (business travel), emission information or general information (amounts and lengths) about SPFIN's business flights in 2019 was inquired from Egencia, the company which books all SPFIN's flights, but clear and coherent data was not obtained via many intermediaries. Therefore, the flights were allocated from SPFIN's own reporting. Kilometers travelled by taxi, public transportation, or rental car were not available, only the numbers of trips taken by them, so assumptions for the lengths of made trips had to be used again. In category 7 (employee commuting), average data of Finland was utilized regarding the distances between home and the workplace and the shares of different means of transportation used in daily employee commuting. In the future, if more accurate information about SPFIN's commuting is needed, an inquiry could be arranged for the employees.

The biggest challenge of the most important emission category, category 11 of scope 3, was the missing of the products' input powers in the list of products delivered in 2019, and also that the powers could not be easily exported from SAP into one column of the Excel report. In addition to that, some of the powers in SAP were motor maximum powers instead of the product's input power, some powers were in hp instead of kW, and every product did not even have any kind of power information. If all or at least more products than now had their input powers in SAP, and the powers could in some way be gathered automatically, it would save a lot of time and work in the total power calculation in the future. The solution could be a new SAP transaction (a subprogram) or an external macro, designed especially for this purpose, together with entering the input powers for new product orders in normal order processing whenever possible.

Another thing which could be developed regarding the products' data in SAP, if GHG emission calculation is wanted to be faster and more convenient in the future, is the end-user segment information (these segments were listed on pages 71 and 73 (in Table 23)). This too could be solved with the new SAP transaction or macro.

The excel chart for calculating scope 3 category 11 GHG emissions which was developed as a part of this work (represented in Appendix III), can be used also as a basis in the subsequent carbon footprint calculation projects.

The faced challenges and improvement suggestions for them are gathered into Table 33.

Table 33. Challenges of SPFIN’s carbon footprint calculation process and possible solutions for them.

	Challenges	Possible solutions for the future
Scope 1		
Company facilities	- No information available about the use of refrigerants in Karhula, Helsinki, and Mänttä.	- Named persons who document all made refills, the reports available in a defined place.
Company vehicles	- For forklifts in Vantaa, there was only data from year 2020, but not from 2019.	- In the subsequent carbon footprint calculations, more recent year to be selected as the examined period.
	- Diesel and petrol consumptions only available as SPFIN’s total consumptions, but not as plant specific consumptions.	- Development of SPFIN's reporting.
Scope 2		
Purchased electricity	- Plant specific electricity consumptions were not available for year 2019.	- More recent year to be selected as the examined period in the future.
	- Emission factor for 2019 not available.	- The same as above.
	- Helsinki office's electricity consump-tion and its emission factor not known	- Inquiry attempts.
Purchased heat	- District heat consumptios and emission factors of Oulu, Vantaa, and Helsinki not available.	- Development of SPFIN's reporting.
Scope 3		
Category 1	- Some components do not have weight information in Sulzer's SAP system.	- A project for fixing them.
	- Duplicate items in the lists of purchased components.	- More accurate filtering in the composition of the lists.
	- Material composition of couplings and motors.	- More work and time for investigating them. More accurate data about them, if possible to get.
	- Weights of shaft billets and agitators. Possibly also of smaller components, such as coupling guards and riser blocks.	- The same as above.
		- Lists also for the smaller components, if possible and worthwhile.
	- Javasko's scope 1 emissions and emission factor of used electricity.	- Will not be needed in the subsequent calculatios, because the manufacturing moves to Karhula (new production line).
Category 2	- Exact weights and materials of purcha-sed capital goods were not known.	- Documenting these data of every new purchased item by a designated person.
		- EPDs of the purchased items.
		- Weighing.
Categories 4 & 9	- Complete reporting of all freights to and from SPFIN in year 2019 was not available. Assumptions and scaling of emissions were needed.	- The analysis of all transportation paid by SPFIN (scheduled for later in 2022).
		- Documentation of freights not paid by SPFIN (ABB motors, possibly others too)
		- More recent year to be selected as the examined period in the future.

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Category 5	- Waste management data was not fully available via L&T for plants and offices in Mänttä, Vantaa, Oulu, and Rauma.	- Closer investigation of these plants' waste management system, if seen necessary.
	- Amount of recycled metal waste was reported only from Karhula and for year 2020 but not for 2019.	- The same as above & more recent year to be selected as the examined period in the future.
Category 6	- Clear and coherent data about SPFIN's flights was not obtained from Egencia.	- More effective inquiries, acquisition of necessary permissions (confidentiality).
	- Kms travelled by taxi, public transportation, or rental car were not available	- Development of SPFIN's business travel reporting system
Category 7	- Average data of Finland was used for daily employee commuting.	- A work trip inquiry for the employees (length and means of transportation).
Category 11	- Products' input powers were not in the list of products delivered in 2019.	- Automatized system; possibly a new SAP transaction (subprogram) or macro.
	- All products do not have input power information in SAP.	- Entering the input powers manually into saler orders in order processing.
		- Automatized system which uses motor powers and estimated coefficients.
	- Some products that have input power in SAP, only have it in hp and not in kW.	- Automatized system which makes the conversion from hp to kW.
	- Summing different products' input powers from SAP into an Excel report.	- Automatized system (a SAP transaction or a macro).
	- Products' end-user segments were not available straight from SAP.	- The same as above.

8.3 Carbon footprint and carbon handprint potential – utilization and improvement possibilities

The current environmental advantages of SPFIN's products and their factors that were identified in the carbon handprint potential survey can and should be utilized in marketing as selling points, even if carbon handprints have not been calculated yet.

SPFIN's products' market is the whole process industry around the world (which is also the only realistic market for them), with of course the exception of those countries which are under sanctions, Russia and Belarus being the latest additions at this moment. Therefore, there are no real possibilities to choose the markets where the impact of potential carbon handprints would be most effective. SPFIN's focus on the market will not probably change in the near future, and products are sold whenever and wherever possible. Still also the strategic aspect of market selection should be recognized if circumstances should change in the future. So, at the moment, the focus should be mainly on the emissions of the products during their lifecycle. If carbon handprints will be calculated at some point, then also comparative claims can be made based on the results, after they have been verified. The handprint contributors which are related to the use phase of sold products, especially the products' energy efficiency and durability, contribute to the products' carbon handprints by lowering the carbon footprints of the customers' processes. The other contributors lower the products', and the company's, carbon footprints.

Next, possibilities to improve SPFIN's carbon footprint and thus also the products' carbon handprint potentials are discussed.

In scope 1, emissions from the company facilities are not easy to get lower, because in SPFIN they come only from the use of welding and heating gases in production processes and possible refrigerant leaks, which there were none reported. Still, that does not mean that the leaks are not possible. The best thing that can be done for preventing refrigerant leaks is to take care of the condition of refrigerant using equipment. It is also recommendable to choose the kind of equipment that use refrigerants which have lower global warming potential (for example, propane instead of fluorocarbons), if possible. With the gases which have global warming potential that are used in production processes (propane, MISON® 18, and acetylene), leaks should also be avoided. The most realistic way to reduce emissions of the company vehicles (cars or forklifts) is purchasing an electric vehicle whenever a new one needs to be acquired. Biofuels could also be used in the existing non-electric forklifts.

In scope 2, more significant reduction of GHG emissions is possible, as the scope 2 emissions were almost 14 times the emissions of scope 1. The most simple and effective thing that could be done, is to change both the purchased electricity and district heat to carbon-neutral alternatives. Kotkan Energia, for example, has a completely emissionless district heat product called Toivo, of which 84% is produced with wood and 16% with biobased waste (Mellas 2021). Other possibilities are development of own energy production with solar panels, wind turbines, and geothermal heating. Proper insulation of the used buildings is also essential in respect of energy consumption.

In scope 3 category 1, GHG emissions can be decreased through the comparison and selection of purchased components (especially their construction materials), their suppliers, and foundries that manufacture the casting parts. The same applies to purchased capital goods in category 2. In categories 4 and 9 (transportation and distribution) the fundamental factors of GHG emissions are the locations of component suppliers and SPFIN's customers, means of transportation, and used fuels. So, in practice, emissions of transportation can be impacted by the comparison and selection of component suppliers, different transport options and logistics companies. Emissions of waste management in category 5 are possible to get to zero by changing the current contract with L&T to an emission compensated option which also L&T has in their selection (Lassila & Tikanoja 2022b).

In category 6 (business travel), the most effective and recommendable way to reduce emissions is avoid unnecessary travelling. The COVID-19 pandemic has actually advanced this development significantly. Still, business travel has not stopped completely. With the still ongoing travelling, the most effective means of emission reduction is to buy flights of which GHG emissions are compensated. The emissions of the flights can be compensated via airlines, organizations, or private enterprises, though there is a lot of uncertainty in finding out the exact emissions of the flights and also in the effectivity of the compensation itself (Yle 2018). In category 7 (employee commuting), probably the most effective way to decrease emissions is to motivate the employees to travel their work trips more by cycle, by foot, or by public transportation.

As already pointed out, for category 11, which is the most important one, the two crucial factors regarding GHG emissions and reduction of them are the energy efficiency of the products and the emission factor of the electricity used for running them. Longer lifetime of the products through developing durability is also desirable, even though it ostensibly increases the products' and the company's carbon footprints. In reality, it also reduces the user's carbon footprint and through that increases the product's carbon handprint, which is important to recognize in reporting and communication. So, what SPFIN should do regarding category 11, is to keep on developing energy efficiency and durability of their products (and this is what the product development department is doing all the time), even though they are already at excellent level. Different motor types (reluctance motor, for example) are also worth examining for this purpose. The importance of the emission factor of the electricity consumed during the products' use should also be communicated to customers, as well as the proper recycling of SPFIN's products at the end of their lifecycle (SEFI receives old products and repairs them to correspond to new products (PRE-owned products)), which affects emissions of category 12.

The final means to reduce the carbon footprint of a company when the target is carbon neutrality, is compensation of emissions (carbon offsetting). A company's actions for reducing their own emissions should always come first and should not be neglected under the pretext of carbon offsetting. But when everything else is done, voluntary market-based emission compensation makes it possible for companies to compensate such emission that cannot otherwise be avoided. If a company that has not yet purchased any carbon credits from the emission trading market purchases them to the extent that they equal to its GHG emissions, the company becomes carbon neutral. Many companies nowadays even strive at net negativity, meaning that they purchase more carbon credits than what their emissions are, and some have also begun to offset their earlier GHG emissions. By purchasing carbon credits, a company invests in projects which aim at standardized reduction of emissions or removal of CO_2 from the air in a nature-based or technical way. These options are presented in Table 34. (Nordic Offset 2022.)

Table 34. Different types of projects for carbon offsetting. (Nordic Offset 2022)

Emission-reducing projects	Projects for removing CO_2 from the air	
	Nature-based	Technical
- Energy efficiency in industry, households, and societies	- CO_2 sequestration into soil	- Removal of CO_2 directly from the air with technology
- Small scale renewable energy	- CO_2 sequestration into trees aka afforestation	- Sequestration of CO_2 by mineralization
- Forest conservation	- Biochar	- Sequestration of CO_2 into the oceans
- Reduction of industrial gases	- Restoration of ecosystems	
- Low-emission transportation and agriculture	- Removal of CO_2 from biomass	
- Waste management		

If offsetting is utilized, the purchased emission reduction units should always be real, additional, permanent, and authenticated with a valid baseline. The compensation projects that are selected need to have a globally recognized standard, such as GS, VCS, or CDM, for reliable calculation and other sustainability benefits. The climate impact calculation must be so reliable that the impact will not be counted more than once and not for more than one actor. Emission compensation funding is used for such climate projects that would not otherwise happen because of political or financial reasons, and the projects are implemented in locations where they have most desired effect with the invested funds. All voluntary climate actions, like uncertified planting of trees in Finland, cannot be counted as valid compensation of emissions, even though they might be climate friendly deeds as such. Ecological and social sustainability of the projects should always be assessed before choosing them. The UN's Sustainable Development Goals are useful in the assessment of the projects' sustainability. (Nordic Offset 2022.)

For now, there are not official rules for which emission categories should be included in carbon neutrality, so companies can choose whether they want to be carbon-neutral only concerning scope 1 and 2 emissions, or if they want to include also scope 3 emission categories in it. In any case, communication should be as transparent as possible. It is probably easiest to do emission reductions first to scope 1 and 2 emissions and compensate the rest of them (in scopes 1 and 2). Then stakeholders can be informed, that the company's scope 1 and 2 emissions have been decreased close to zero with other actions that should be taken care of before compensation and the rest of them have been compensated. Scope 3 emissions can be decreased one emission category at a time if wanted, and for example category 11 emissions can be left out of consideration in the company's own carbon-neutrality target, again with transparent communication. But if the company decided to commit to Science Based Targets initiative, for example, then also category 11 emissions should be included, although there might be some flexibility for offsetting such categories. (Kärppä 2022.)

8.4 Future prospects

During the next couple of years, the production of smaller pump sizes is going to be moved from Javasko in Mänttä to Karhula pump factory. The reason for this is the new Eagle production line which is just going to be ready. This is going to affect emissions in the following emission categories (the combined emissions will probably decrease):

- Scope 1
    - Company facilities (Those industrial gases and possible refrigerants which are now used in Javasko will probably be needed also in the new production line in Karhula)
    - Company vehicles (Emissions of leased cars will decrease, because business trips between Karhula and Mänttä will be needed much less (there will still be the service center in Mänttä). Also, forklifts will not be needed for the new production line of Karhula, because there will be electric automated guided vehicles, which save energy and decrease emissions)
- Scope 2
    - Purchased electricity and heat (The new Eagle production line increases electricity and heat consumption in Karhula)

- Scope 3
    - Category 1 (Javasko's scope 1 and 2 emissions will not belong to SPFIN's scope 3 category 1 anymore)
    - Category 4 (Transportation of goods between Karhula and Mänttä will be needed much less)
    - Category 6 (Business trips between Karhula and Mänttä by other means of transportation than leased cars will also decrease)

Remote working has become new normal with the COVID-19 pandemic. In 2019, it was still quite rare in SPFIN. Now, when most employees have been working remotely for two years, it seems probable that there is no return to the previous practice where almost everybody come daily to the office building. It is likely that also after the pandemic at least significant number of employees will continue remote working or change to some kind of hybrid model, which is partially remote work and partially traditional office work. So, commuting between home and the company's offices will most likely stay also in the future much lesser that it was still in 2019.

Besides reduced emissions from commuting, remote working affects also other emission sources. For example, emissions of electricity that is consumed by a remotely working employee's work computer are included to company's GHG emissions (Voutilainen 2021). This kind of factors need to be taken into account in the subsequent carbon footprint and handprint calculations. Though remote working has come to stay, SPFIN has recently started to support financially acquisition of work bicycles for employees, which for its part might further reduce emissions of scope 3 category 7, because there will always be some commuting.

One significant change that is inevitably happening, is the global decreasing of emission factors of electricity and heat production, which will of course reduce the category 11 emissions over the course of years. But how much and how fast, is then another subject. And of course, it will decrease GHG emissions of most energy consumers and companies in the world along with SPFIN.

8.5 Possible topics for further study

A logical subject for coming studies would be more product-oriented research, meaning calculation of carbon footprints and carbon handprints of specific products, where the basis for SPFIN's products' carbon handprint calculation might be utilized. The handprint approach will probably become more and more of interest among customers and different stakeholders in the next few years. Water footprints and handprints of the company and its products might be relevant topics as well.

A closer examination of environmental impacts of foundries from which SPFIN currently purchases their cast parts could be beneficial for the selection of cast suppliers in the future. There are serious attempts going on for reducing the climate impacts of foundries (Green Foundry LIFE 2022). And of course, it would be good to consider possibilities and financial chances to replace the use of distant (Chinese) foundries with closer ones, since transportation is a significant emission source.

Also, the challenges which were identified regarding weight information of components, and input power and end-user segment information of products in the SAP system, and possibilities to develop those areas, would be worth examining.

9 SUMMARY

This work dealt with climate responsibility of process equipment manufacturers, calculation of Sulzer Pumps Finland Ltd's (SPFIN) carbon footprint in year 2019, and carbon handprint potential of their main products, which are single-stage centrifugal process pumps, agitators and turbocompressors. The subject of climate responsibility was approached by collecting essential information about legislation and climate politics, how to take into account the needs of different stakeholders, and how operational environment affects accomplishing wanted positive results. By recognizing these aspects, a company in a stronger actor on the market environmentally but also financially.

For calculation of the carbon footprint of SPFIN, the GHG Protocol's framework was used, as it has become a common methodology in that area. Scopes 1 and 2 (direct emissions from the company's operation and indirect emissions from purchased energy), and selected emission categories from scope 3 (indirect emissions from upstream and downstream activities in the supply chain) were included in the calculation. The organizational boundaries of SPFIN's carbon footprint calculation were set based on operational control, so also emissions of leased cars and rented offices were included in scopes 1 and 2.

The carbon handprint potential of SPFIN's main products was studied without calculation of the handprints. Factors that have significance for their carbon footprints, and through that also for their potential carbon handprints, were identified, and the significance of the products' different lifecycle phases was examined. The handprint quantification process developed by LUT University and VTT Technical Research Centre of Finland Ltd was also utilized for composing a compilation of suggested procedures specifically for SPFIN's products if their carbon handprints will be calculated in the future. The handprint quantification process was also a natural choice for this purpose.

The GHG emissions which are generated by the process equipment's electricity consumption during their use phase are overwhelmingly the largest of all emissions of these products. This applies also to the products' manufacturer's carbon footprint, when scope 3 category 11 (use of sold products) emissions are included in it. All other emission categories are far less significant in respect of SPFIN's and its products' total emissions. In fact, the category

11 emissions (10747390 t CO_2e) cover approximately 99,8% of SPFIN's carbon footprint (10767914 t CO_2e). Of the other emission categories, the next largest are categories 1 (purchased goods and services, 12558 t CO_2e) and 4 (upstream transportation and distribution, 3832 t CO_2e) of the scope 3. After them, very close to each other, are scope 2 market-based emissions (1321 t CO_2e) and scope 3 category 12 (end-of-life-treatment of sold products, 1313 t CO_2e), followed by the rest of the emission categories.

In scope 1, emissions from the company facilities were minimal (1,27 t CO_2e), as they come only from gases that are used in the manufacturing processes (burning of propane and acetylene, for example). Emissions from vehicles controlled by the company were about 74 times as high (94,50 t CO_2e), but still very small compared to many other emission categories. Scope 2 emissions were over 10 times higher than scope 1 emissions (1321 t CO_2e (market-based) or 1108 t CO_2e (location-based) versus 96 t CO_2e). Within the scope 2, market-based emissions from purchased electricity were 3,6 times as high as the market-based emissions of district heating (1034 t CO_2e versus 287 t CO_2e), but with location-based emission factors the ratio is only around 1,3 (634 t CO_2e versus 474 t CO_2e). The market-based emissions are the most accurate in this case because they are based on the emission factors that were announced by the supplier companies.

When comparing the significance of different lifecycle phases for the products' carbon footprints and therefore also for their carbon handprints, the use phase obviously turned out to be the single most important phase. It is followed by material acquisition & pre-processing, production, end-of-life, and distribution & storage, with the allocation of different emission categories into the lifecycle phases that was used in the comparison.

There are uncertainties in the carbon footprint calculation results, because a lot of the searched initial data was not available, so many assumptions and estimations had to be made. But the magnitude of different emission categories could be clearly found out, which was the aim in this project. The deficiencies in the used data and other challenges in the process were identified and solutions for them were suggested, so that they could be solved for the subsequent carbon footprint calculations. The missing data concerned, for example, weight information of some components in Sulzer's SAP-system, which then required some scaling for estimation of the total weights of purchased components. Other significant data deficiencies were in the information for input powers and end-user segments of sold products, which are also SAP-related issues, in exact material composition of motors, and in logistics companies' reporting of freights from component suppliers to SPFIN. Minor issues, but still such that should be solved, were consumptions of electricity, heat, and fuels at some of SPFIN's sites, some emission factors of used electricity and heat, possible refrigerant leaks, waste management of other plants besides Karhula and Helsinki, and more exact flight and travel data in terms of emissions.

The most important factor of process equipment's operational environment that affects their manufacturer's potential to gain positive climate impacts on different locations is the emission factor of locally available electricity. It has a huge impact on the emissions in the category 11 of scope 3. However, the equipment's manufacturing company cannot decide what are the emissions of electricity available in different countries or the decisions of their products' owners. Still, the significance of the choice of used electricity can be informed to customers. Apart from that, the most important thing for the manufacturer to do is to aim at increasing their products' energy efficiency, as SPFIN's product development department is constantly doing, along with improving the products' durability. When products stay longer in use, it postpones the need to acquire new products, thus saving natural resources. But of course, if energy efficiency of new product models improves significantly over time, it complicates the question whether a longer lifetime of a product is always beneficial with respect to climate impacts.

Even though emissions of other categories are very small compared to the category 11, it is worthwhile to aim at also reducing them. For example, concerning categories 1 and 4, potential foundries and other component suppliers can be compared, and suitable options may be located closer to the company's production plants that the current ones. The materials of currently used components might not be the most climate friendly options either. Emissions of category 4 (as well as category 9, downstream transportation and distribution) depend not only on the transport distances but also on the used means of transportation and fuels. As long as SPFIN buys the transportation from outside logistics companies, the only way to have some influence on these two factors is to compare logistics options and choose the most ecological ones of those that are available.

Regarding the scope 2 (indirect emissions from purchased energy), in SPFIN’s case, the current suppliers of electricity and heat have also more climate friendly alternatives available. Own production of carbon-neutral energy with solar panels, wind turbines, or geothermal energy is also worth considering. This kind of changes are relatively easy to make and not necessarily even financially unprofitable. Emissions of category 6 (business travel) can be best decreased by taking only those business trips which are absolutely necessary. During the COVID-19 pandemic this has already become the prevalent practice. Emissions of those flights that still need to be taken can be compensated already when booking them. Category 7 (employee commuting) emissions can be lowered by motivating the employees to prefer carbon-neutral ways to move between their homes and workplaces. In category 12, customers ought to be informed about the correct recycling of the products when they are no longer used. SPFIN’s service and spare part center SEFI renovates used products so that they can be sold again as PRE-owned products which correspond to new products.

Emissions of scope 1 and categories 2 (capital goods) and 5 (waste generated in operations) of scope 3 were the lowest (95,77 t CO_2e, 65 t CO_2e, and 76,66 t CO_2e respectively). Scope 1 emissions, which are almost entirely from company vehicles (94,50 t CO_2e), can be reduced, for example, by purchasing an electric car whenever a new car needs to be bought. The rest of the scope 1 emissions (1,27 t CO_2e) came mainly from burning of propane and acetylene in manufacturing. It is of course recommendable to avoid the leaks. Emission from capital goods can be very different in different years depending on what kind of tools and machines are acquired. Their manufacturers may have information about their carbon footprints. For the waste management, there are also carbon-neutral options, even in the currently used waste management company’s (L&T) selection.

Emissions of SPFIN’s products’ different lifecycle phases naturally also depend on the above-mentioned factors. The most important of them are energy efficiency, durability, and emission factor of consumed electricity in the use phase and purchased components’ materials and suppliers in the material acquisition and pre-processing phase. The energy efficiency and durability of the SPFIN's products that were examined seem to be already on a very good level. So, even though any product-level carbon footprint or carbon handprint calculations have not been done yet, the identified characteristics can be used as selling points, while at the same time developing them even better.

If a company aims at becoming carbon-neutral, those emission which cannot be avoided can be compensated by buying carbon credits. This means should be used only when everything else has been done to lower the company's emissions. There is variation in the reliability of compensation. For example, the actual climate impact of the purchased offset is not always clear. Therefore, the purchased emission reduction units must be verified, and the chosen compensation projects must comply with an internationally recognized standard.

In the near future, the new Eagle production line will start its operation in Karhula pump factory replacing the production of Javasko workshop, which reduces the need of daily transportation between Karhula and Mänttä. The new production line will be equipped with automated guided vehicles, so forklifts will not be needed either. Other change compared to the year 2019 which was the period of examination, is that remote working has become the new normal because of the COVID-19 pandemic, and it seems to continue this way also after the pandemic, at least as some sort of hybrid model.

The company's carbon footprint's calculation process that was presented and implemented here, is supposed to be further developed based on the identified challenges and suggested solutions. Other justifiable topics for following studies could be carbon handprint calculation of the main products of SPFIN based on the suggestions presented in the carbon handprint potential survey, calculation of water footprints or handprints, and comparison and choices of foundries and component suppliers from the perspective of GHG emissions.

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Table 35. Production fuel mix factors [kg CO_2/kWh] of electricity production in different countries. (Our World in Data 2021, Carbon Footprint Ltd 2022, 6-9)

AE	0,11	CL	0,19	FO	0,19	JP	0,21	NZ	0,15	SM	0,19*
AR	0,17	CN	0,27	FR	0,12	KR	0,19	PE	0,17	SN	0,29
AT	0,16	CO	0,17	GB	0,17	KZ	0,34	PH	0,26	TH	0,17
AU	0,23	CY	0,23	GR	0,17	LA	0,18	PK	0,24	TN	0,25
BA	0,26	CZ	0,21	GT	0,2	LT	0,2	PL	0,27	TR	0,22
BE	0,13	DE	0,19	HK	0,12	LU	0,21	PT	0,16	TW	0,21
BG	0,2	DJ	0,1	HR	0,19	MA	0,26	PY	0,03	TZ	0,16
BH	0,15	DK	0,16	HU	0,18	MG	0,19	RE	0,34	UA	0,24
BO	0,15	DO	0,23	ID	0,27	MR	0,22	RO	0,2	US	0,2
BR	0,14	DZ	0,24	IE	0,2	MT	0,04	RS	0,24	UY	0,09
BY	0,21	EE	0,19	IL	0,2	MX	0,2	RU	0,2	UZ	0,23
CA	0,15	EG	0,21	IN	0,28	MY	0,24	SA	0,2	VN	0,23
CD	0,05	ES	0,16	IQ	0,36	NC	0,25	SE	0,07	ZA	0,32
CG	0,13	FI	0,14	IT	0,19	NL	0,16	SG	0,05	ZM	0,12
CH	0,12	FJ	0,11	JO	0,19	NO	0,09	SK	0,18	ZW	0,23

States of USA**

AK	0,46612	FL	0,41823	LA	0,39391	NC	0,37159	OK	0,35005	VA	0,30312
AL	0,37453	GA	0,41999	MA	0,37216	ND	0,69007	OR	0,18979	VT	0,02445
AR	0,53773	HI	0,74784	MD	0,35217	NE	0,60338	PA	0,36177	WA	0,14257
AZ	0,41633	IA	0,41065	ME	0,10177	NH	0,12213	RI	0,40629	WI	0,58777
CA	0,18462	ID	0,10078	MI	0,48308	NJ	0,25989	SC	0,25671	WV	0,92735
CO	0,63456	IL	0,34601	MN	0,41998	NM	0,63256	SD	0,23462	WY	0,98638
CT	0,22755	IN	0,77906	MO	0,76221	NV	0,35245	TN	0,3358	avg.	0,42394
DC	0,38033	KS	0,42605	MS	0,39922	NY	0,18037	TX	0,43542		
DE	0,33922	KY	0,84888	MT	0,60196	OH	0,59227	UT	0,76367		

Provinces of Canada**

AB	0,67	NB	0,27	NT	0,2	PE	0,002	YT	0,111
BC	0,0197	NL	0,029	NU	0,9	QC	0,0015	avg.	0,12
MT	0,0013	NS	0,81	ON	0,03	SK	0,71		

States of Australia**

Australian Capital Territory	0,87	South Australia	0,42	avg.	0,84
New South Wales	0,87	Tasmania	0,18		
Northern Territory	0,605***	Victoria	1,06		
Queensland	0,92	Western Australia	0,65***		

* Emission factor for electricity production in Italy

** For USA, Canada, and Australia, national average factors were used for calculation instead of state- and province-specific factors, so that all used factors could be taken from Our World in Data's database.

*** Factors of Australia's Northern Territory and Western Australia are mean values of two different factors.

Table 36. The amounts, weights, and combined weights of sold HST-models. (Tani 2022, Sulzer 2022p)

HST-model	No. of sold products	Product weight [kg]	Wt. of sold products [kg]
HST20-4500-1-125-40	41	1265	51865
HST20-4500-1-150-40	28	1265	35420
HST20-6000-1-125-40	10	1305	13050
HST20-6000-1-150-40	41	1305	53505
HST20-6000-1-150-40-F	1	1305	1305
HST20-6000-1-190-40	28	1350	37800
HST20-6000-1-190-40-F	1	1350	1350
HST20-6000-1-190-69	2	1350	2700
HST20-6000-1-U200-48	4	1305	5220
HST20-6000-1-U250-48	10	1349	13490
HST20-6000-1-U250-58	5	1349	6745
HST30-36-1-190-40	13	1570	20410
HST30-36-1-250-40	2	1600	3200
HST30-46-1-190-40	6	1600	9600
HST30-46-1-250-40	9	1630	14670
HST30-46-1-300-40	20	1675	33500
HST40-300-1-H-6	4	1900	7600
HST40-300-1-L-4	9	1900	17100
HST40-300-1-L-5	1	1900	1900
HST40-300-1-L-6	5	1900	9500
HST40-350-1-H-4	10	1915	19150
HST40-350-1-L-6	2	1915	3830
HST40-400-1-H-4	8	1985	15880
HST40-400-1-H-6	1	1985	1985
HST40-400-1-L-6	2	1985	3970
HST40-U400-1-L-48	5	1873	9365
HST40-U450-1-H-48	3	1905	5715
HST40-U500-1-L-48	7	1905	13335
HST2500-1-69-40-F	1	800	800
HST2500-1-83-40-F	3	800	2400
HST2500-1-A-4	19	800	15200
HST2500-1-H-4	1	800	800
HST2500-1-L-4	18	800	14400
HST2500-2-H-5	2	800	1600
HST2500-2-L-4	2	800	1600
HST2500-U100-1-L-48	4	816	3264
HST2500-U120-1-H-48	4	816	3264
HST6000-2-H-4	3	1500	4500
HST6000-2-H-6	3	1500	4500
HST9500-200-1-H-4	3	1300	3900
HST9500-200-1-L-4	5	1300	6500
HST9500-250-1-H-4	7	1440	10080
HST9500-250-1-L-4	2	1300	2600
HST9500-U250-1-L-58	2	1800	3600
HST9500-U350-1-H-48	4	1800	7200
Total number of all HSTs sold in 2019:	**361**	**Total weight of all HSTs sold in 2019 [kg]:**	**499368**

Order number	Position	Product group	Product type	Product model	Use power (If not known then estimated from motor power) [kW]	SO Application Code	End-user segment	Product's lifetime [h]	Product's use-rate [%]	End-user country	US/CA/AU state or province	Emission factor of electricity (production fuel mix factor) [kg CO_2e/kWh]	Use phase emissions [t CO_2e] (total in yellow field)
													10747390,46
346014	10	Pump	ATM	WPP53-100	72,8	15435	CPI, Fertilizers	43800	80	MA		0,26	663,23712
346014	20	Pump	ATM	WPP53-200	149	15435	CPI, Fertilizers	43800	80	MA		0,26	1357,4496
346014	30	Pump	ATM	WPP55-300	247	15435	CPI, Fertilizers	43800	80	MA		0,26	2250,2688
346014	40	Pump	AUP	A53-250	298	15435	CPI, Fertilizers	43800	80	MA		0,26	2714,8992
346014	50	Pump	ATM	WPP22-50	3,3	15435	CPI, Fertilizers	43800	80	MA		0,26	30,06432
346014	60	Pump	ATM	WPP22-50-S	5,1	15435	CPI, Fertilizers	43800	80	MA		0,26	46,46304
349174	280	Pump	AUP	A53-250	407	4202	RO Applications	131400	95	AE		0,11	5588,6391
349174	290	Pump	AUP	A53-250	407	4202	RO Applications	131400	95	AE		0,11	5588,6391
349174	300	Pump	AUP	A53-250	407	4202	RO Applications	131400	95	AE		0,11	5588,6391
349174	310	Pump	AUP	A53-250	407	4202	RO Applications	131400	95	AE		0,11	5588,6391
349174	320	Pump	AUP	A71-300	565	4202	RO Applications	131400	95	AE		0,11	7758,1845
349174	330	Pump	AUP	A71-300	565	4202	RO Applications	131400	95	AE		0,11	7758,1845
349174	340	Pump	AUP	A71-300	565	4202	RO Applications	131400	95	AE		0,11	7758,1845
349174	350	Pump	AUP	A71-300	565	4202	RO Applications	131400	95	AE		0,11	7758,1845
349174	360	Pump	AUP	A71-300	565	4202	RO Applications	131400	95	AE		0,11	7758,1845
350419	50	HST	HST	HST40-350-1-L-6	302,2	14112	Water, MW, dewatering	175200	50	DE		0,19	5029,8168
350419	60	HST	HST	HST40-350-1-L-6	302,2	14112	Water, MW, dewatering	175200	50	DE		0,19	5029,8168
364863	10	Pump	AUP	A31-100	102	4202	RO Applications	131400	95	AE		0,11	1400,5926
364863	20	Pump	AUP	A31-100	102	4202	RO Applications	131400	95	AE		0,11	1400,5926
364863	30	Pump	AUP	A31-100	102	4202	RO Applications	131400	95	AE		0,11	1400,5926
364863	40	Pump	AUP	A31-100	102	4202	RO Applications	131400	95	AE		0,11	1400,5926
364863	50	Pump	AUP	A31-100	102	4202	RO Applications	131400	95	AE		0,11	1400,5926
364863	60	Pump	AUP	A31-100	102	4202	RO Applications	131400	95	AE		0,11	1400,5926
364863	70	Pump	AUP	A21-65	2,6	4202	RO Applications	131400	95	AE		0,11	35,70138
364863	80	Pump	AUP	A21-65	2,6	4202	RO Applications	131400	95	AE		0,11	35,70138
364863	90	Pump	AUP	A21-65	2,6	4202	RO Applications	131400	95	AE		0,11	35,70138
364863	100	Pump	AUP	A21-65	2,6	4202	RO Applications	131400	95	AE		0,11	35,70138
364863	110	Pump	AUP	A21-65	2,6	4202	RO Applications	131400	95	AE		0,11	35,70138
364863	120	Pump	AUP	A21-65	2,6	4202	RO Applications	131400	95	AE		0,11	35,70138
364863	130	Pump	AUP	A51-400	99,9	4202	RO Applications	131400	95	AE		0,11	1371,75687
364863	140	Pump	AUP	A51-400	99,9	4202	RO Applications	131400	95	AE		0,11	1371,75687
364863	150	Pump	AUP	A51-300	248	4202	RO Applications	131400	95	AE		0,11	3405,3624
364863	160	Pump	AUP	A51-300	248	4202	RO Applications	131400	95	AE		0,11	3405,3624
364863	170	Pump	AUP	A51-300	248	4202	RO Applications	131400	95	AE		0,11	3405,3624
364863	180	Pump	AUP	A11-50	21,3	4202	RO Applications	131400	95	AE		0,11	292,47669
364863	190	Pump	AUP	A11-50	21,3	4202	RO Applications	131400	95	AE		0,11	292,47669
364863	200	Pump	AUP	A11-50	21,3	4202	RO Applications	131400	95	AE		0,11	292,47669
364863	210	Pump	AUP	A31-125	15,8	4202	RO Applications	131400	95	AE		0,11	216,95454
364863	220	Pump	AUP	A31-125	15,8	4202	RO Applications	131400	95	AE		0,11	216,95454
375210	10	Pump	AUP	A10-32	2,8	5599	Pulp & Paper	175200	90	JP		0,21	92,71584
375210	20	Pump	ATM	EPP31-100	14,1	5599	Pulp & Paper	175200	90	JP		0,21	466,89048
375210	30	Pump	ATM	APP22-80	3,8	5599	Pulp & Paper	175200	90	JP		0,21	125,82864
375210	40	Pump	ATM	APP11-40	3,7	5599	Pulp & Paper	175200	90	JP		0,21	122,51736
375210	50	Pump	ATM	APP21-65	3,8	5599	Pulp & Paper	175200	90	JP		0,21	125,82864
375210	60	Pump	AUP	A33-100	90,7	5599	Pulp & Paper	175200	90	JP		0,21	3003,33096
375210	70	Pump	AUP	A33-100	90,7	5599	Pulp & Paper	175200	90	JP		0,21	3003,33096
375210	80	Pump	AUP	A33-80	53	5599	Pulp & Paper	175200	90	JP		0,21	1754,9784
375210	90	Pump	AUP	A33-80	53	5599	Pulp & Paper	175200	90	JP		0,21	1754,9784
375210	100	Pump	AUP	A22-80	9,5	5599	Pulp & Paper	175200	90	JP		0,21	314,5716
375210	110	Pump	AUP	A60-500	148	5599	Pulp & Paper	175200	90	JP		0,21	4900,6944

Figure 17. Calculation chart of use phase GHG emissions of the products delivered in year 2019.

Table 37. Freights of new equipment from SPFIN to different countries in 2021. (Muuri 2022)

Ship-to country	Sum of Gross weight [kg]	Sum of Delivery quantity [1]	Ship-to country	Sum of Gross weight [kg]	Sum of Delivery quantity [1]
AE	103495,36	140	JO	1723	5
AO	125	1	JP	10694	21
AR	9014	22	KR	17368	13
AT	73839,01	173	KZ	25437	78
AU	54300,46	170	LB	672	2
AZ	798	2	LK	2394	7
BA	13384	24	LT	1610	4
BE	25542	77	LU	540	2
BG	12111	30	LV	360	2
BH	3990	8	MA	76469	53
BR	103228,395	699	MR	1128	4
BY	13289	23	MT	4331	5
CA	19159	58	MX	23892	59
CD	18492	14	MY	4052	8
CG	23140	36	NE	4390	8
CH	26266	32	NL	9001,6	70
CL	81453	175	NO	115592	199
CN	173211,24	2386	NZ	3197,5	6
CO	1092,14	11	OM	4788	7
CU	630	2	PE	4788	10
CY	7685	42	PH	5974	15
CZ	35976	137	PK	5424	19
DE	380265,98	757	PL	165377	267
DK	57148,421	104	PT	20410,8	51
EC	798	1	QA	8464	28
EE	1218	4	RE	6231	11
EG	112974	135	RO	14670	25
ES	151445,18	401	RS	798	3
FI	406037,241	770	RU	415833,32	684
FR	200383,04	466	SA	64655	123
GB	91019,222	210	SE	596845,37	1980
GE	1596	3	SK	15787	38
GP	610	2	SN	9458	8
GR	20747,04	33	TH	2772	10
GT	798	2	TM	2440	4
HK	0	2	TN	798	1
HR	4915	7	TR	200463,02	331
HU	83858	150	TW	3192	6
ID	40879,01	83	UA	13524	21
IE	1235	2	US	131681,66	605
IL	50128	30	UY	68058	120
IN	54979	114	UZ	2240	1
IQ	29071	17	VN	2394	7
IS	4788	7	ZA	26761	56
IT	78700,427	317	ZM	16628	23
			Total	**4687120,44**	**12879**

Table 38. Freights of spare parts from SPFIN to different countries in 2021. (Muuri 2022)

Ship-to country	Sum of Gross weight [kg]	Sum of Delivery quantity [1]	Ship-to country	Sum of Gross weight [kg]	Sum of Delivery quantity [1]	Ship-to country	Sum of Gross weight [kg]	Sum of Delivery quantity [1]
AE	900,52	131	GR	500,32	43	PK	90,66	19
AO	5,92	3	HK	0,08	10	PL	2986,86	599
AR	1547,99	158	HR	398,43	127	PT	5206,28	255
AT	6924,39	861	HU	1024,78	5829	QA	346,85	73
AU	2147,13	441	ID	14067,44	6319	RE	33,43	10
BA	342,88	35	IE	472,36	2	RO	181,04	82
BE	2195,39	319	IL	243,49	37	RS	26,6	2
BG	2207,49	176	IN	603,46	77	RU	19651,9	1157
BH	206,34	17	IQ	73,45	13	SA	4091,2	278
BO	169,7	28	IT	6806,79	697	SE	20869,91	12627
BR	12934,56	1622	JO	4,8	7	SG	86,17	41
BY	1297,4	39	JP	4236,3	398	SI	18,81	11
CA	2105,92	250	KR	256,71	98	SK	3014,31	179
CD	560,75	156	KW	11,32	9	SM	5	1
CG	7538,49	1943	KZ	596,6	44	SN	296,41	14
CH	1136,31	305	LA	722,31	14	SZ	8,8	2
CL	8502,57	2450	LT	47,85	14	TH	517,06	76
CN	5663,79	552	LY	3,6	2	TM	3	2
CU	70,94	4	MA	939,11	67	TN	18,9	6
CY	13,36	27	MD	0,04	1	TR	2463,8	306
CZ	3739,47	201	MG	0,01	2	TW	73,32	13
DE	21433,1	1750	MR	21,75	6	TZ	3,86	3
DJ	3,2	4	MT	0,25	1	UA	236,79	27
DK	2780,74	314	MX	428,4	24	UK	214,82	31
DO	22,36	1	MY	157,95	36	US	45264,08	5589
DZ	39,55	10	NE	0,5	2	UY	2279,73	75
EE	279,17	42	NL	6837,41	748	UZ	28,66	5
EG	767,56	298	NO	2386,96	389	VN	27,71	8
ES	26921,56	2739	NZ	1531,82	107	ZA	10090,86	641
FI	48689,18	24557	OM	28,55	56	ZM	835,58	131
FR	15628,22	1355	PE	297,76	67	ZW	28,65	4
GB	10289,5	1022	PH	620,36	61	**Total**	**349387,46**	**79384**