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ENVIRONMENTAL SUSTAINABILITY STRATEGY IN PRODUCT DEVELOPMENT

Case: Sandvik Mining and Construction Oy

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Abstract

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Abstract

Environmental sustainability is an ongoing and constantly evolving topic of discussion in all fields of business. This thesis was commissioned by Sandvik Mining and Rock Technology (SMRT), BU Stationary Crushing and Screening R&D, Stationary Screens and Feeders R&D team (Lahti) to answer the following questions: how does a company-wide sustainability strategy affect the work of design engineers in the R&D team, and what contributions can the R&D team make towards achieving company-wide sustainability targets?

Theoretical research was carried out through literature review on topics such as sustainable investing, circular economy, life cycle assessment, and environmental standards and certifications. Company personnel were interviewed, previous work experience was reflected on, and gathered information was used to draw conclusions about possible next steps. Targets were also evaluated through theoretical calculations.

Research findings were compiled into initiatives Screens and Feeders R&D can incorporate into their work and initiatives the entire company needs to consider to reach current targets. Suggestions include environmental performance assessment, circular material sourcing, data collection, involved management, etc. Results were complicated by the connection between strategy and current environmental standards.

Gathered results suggest that the current targets laid out in Sandvik's sustainability strategy need more refinement before definitive action can be taken. Based on findings, company personnel need more guidance on the environmental aspects of the strategy. The authors recommend training all staff on environmental issues related to Sandvik's business area and conducting further research on topics such as life cycle assessment, certification standards, supply chain structure, and data collection.

Keywords

Sustainable development, ecological sustainability, product development, carbon footprint

Tiivistelmä

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Tiivistelmä

Ekologisesti kestävä kehitys on oleellinen aihe jokaisella liiketoiminnan osa-alueella. Sandvik Mining and Rock Technology (SMRT), BU Stationary Crushing and Screening R&D, Stationary Screens and Feeders R&D team (Lahti) tilasi tämän opinnäytetyön vastatakseen seuraaviin kysymyksiin: miten koko yrityksen kattava kestävän kehityksen strategia vaikuttaa suunnitteluyksikön työhön ja mitä juuri suunnitteluyksikkö voi tehdä edistääkseen strategian tavoitteiden saavuttamista?

Opinnäytetyön teoriapohja toteutettiin kirjallisuuskatsauksena. Tietoa etsittiin mm. ympäristölähtöisestä sijoittamisesta, kiertotaloudesta, elinkaariarvioinnista ja ympäristöstandardeista ja sertifikaateista. Lisäksi yrityksen työntekijöitä haastateltiin, aiempaa alan työkokemusta reflektoitiin ja yrityksen kehitysstrategiaa arvioitiin laskelmien avulla. Kerätyn tiedon avulla suunniteltiin mahdollisia jatkotoimenpiteitä.

Tutkimustulokset jaoteltiin ideoihin, joita seulojen ja syöttimien suunnitteluyksikkö pystyy hyödyntämään työssään sekä koko yritystä koskeviin ideoihin, jotka mahdollistavat strategian tavoitteiden saavuttamisen. Ehdotukset liittyvät mm. ympäristövaikutusten seurantaan, kestävään materiaalien hankintaan, tiedonkeruuseen ja ympäristöjohtamiseen. Tulosten jäsentelyä hankaloitti strategian ja nykyisten ympäristöstandardien yhteensovittaminen.

Tulokset osoittavat, että nykyisen kehitysstrategian tavoitteita täytyy tarkentaa ennen kuin niiden eteen pystytään tekemään konkreettisia toimenpiteitä. Henkilöstö tarvitsee lisäksi enemmän strategian ympäristötavoitteita koskevaa opastusta. Jatkotoimenpiteiksi suositellaan mm. koko henkilöstön kouluttamista Sandvikin toimintaan liittyvissä ympäristöasioissa sekä elinkaariarvioinnin, ympäristösertifioinnin, toimitusketjun rakenteen ja tiedonkeruun syvällisempää tutkimista.

Asiasanat

Kestävä kehitys, ekologinen kestävyys, tuotekehitys, hiilijalanjälki

CONTENTS

LIST OF ABBREVIATIONS

BU – Business unit

CF – Carbon footprint

EHSQ – Environment, health, safety, and quality

GHG – Greenhouse gasses

LCA – Life cycle assessment

MTS – Make the SH/FT

PCF – Product carbon footprint

PLC – Product life cycle

PLM – Product lifecycle management

R&D – Research and development

SMRT – Sandvik mining and rock technology

S&F – Screens and feeders

TBL – Triple bottom line

1 INTRODUCTION

The objectives of this thesis are to investigate the state of environmental sustainability at Sandvik Mining and Rock Technology (SMRT), BU Stationary Crushing and Screening R&D, Stationary Screens and Feeders R&D team (Lahti), clarify how Sandvik's company-wide sustainability strategy affects the work of engineers at S&F R&D, and research ways S&F R&D and the entire company can work towards achieving the goals set in the strategy. The strategy includes the goals to halve all CO_2 emissions and achieve 90% circularity by the year 2030. The strategy was released in 2019.

Sandvik Mining and Construction Oy Lahti site is part of the larger organization of Sandvik Group. Sandvik is a global engineering group founded in 1862. The company employs 42 000 workers globally and deals mainly in mining, rock-excavation, metal-cutting, and materials technology. (Sandvik 2020a.)

The aim of this thesis is to examine the company structure and processes to assess the current state of environmental sustainability practices and standards. Based on this information, research is conducted to find ways to bring new practices into the business process to meet the emission goals outlined in the sustainability strategy. Proposed suggestions vary between ones that can be implemented right away, ones that require some changes in production practices, and ones that require large scale reform or investments in new practices.

Theoretical research is conducted mainly through literature review and analysis. Information about company practices is gathered by interviewing employees and investigating company materials, as well as reflecting on previous work experience as a design engineer at Sandvik. The goals of the strategy and potential sustainability assessment methods are elaborated on by conducting experimental calculations.

The improvement methods provided in this thesis are preliminary suggestions based on general information and require more in-depth research prior to application. This approach was chosen to enable the research of multiple methods of improvement instead of focusing on a few precise details. The research focuses on the actions of S&F R&D, although the structure and practices of the entire company are looked at as well, as they affect the work of S&F R&D.

2 ENVIRONMENTAL SUSTAINABILITY

2.1 Definition

Arguably one of the most often cited definitions of sustainable development comes from the United Nations World Commission on Environment and Development (1987) report titled Our Common Future:

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

The report, published in 1987, was composed to address long-term environmental concerns and to propose strategies for dealing with the issues as a global community. (World Commission on Environment and Development 1987.) Despite being over thirty years old, the definition sees wide use even today.

UNESCO (2019) makes a distinction between sustainability and sustainable development. It refers to sustainability as the long-term goal and sustainable development as the methods by which the world can achieve sustainability. These methods include e.g. education, good government, and sustainable production and consumption.

Sustainability is a broad concept. It is often divided into three categories: social, economic, and environmental. These categories can be represented as pillars or overlapping circles (Figure 1). Because of this overlap, it is difficult to discuss environmental sustainability without also considering the social and economic aspects, as all categories greatly influence each other.

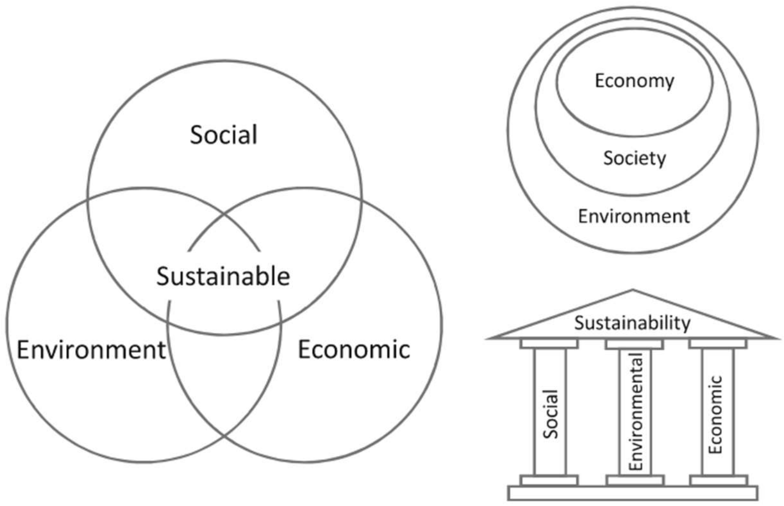


Figure 1 The three components of sustainability (Purvis, Mao & Robinson 2018, 682)

In a business context, these categories are often referred to as the triple bottom line or TBL. The first bottom line is to make profit for the company, the second bottom line is to create products that enhance the lifestyles of other people, and the third bottom line is to achieve environmental sustainability. While the first bottom line is easily measured via currency, the second and third are more difficult to measure, and tracking their impacts requires more expertise from the company. (Johnson & Gibson 2014, 19.)

Sometimes more than three aspects are included in the categorization of sustainability. UNESCO (2019) refers to a fourth sphere of sustainability called culture, whereas O'Connor (2006, 2) argues for the existence of the political sphere, which exists primarily to regulate the social, economic, and environmental spheres.

The United Nations (2015) 2030 agenda for sustainable development lists 17 sustainability goals to strive for by 2030. These goals, while not sorted under specific categories, are related to the same social, environmental, and economic spheres. The agenda includes goals such as ending poverty in all its forms and ensuring sustainable production and consumption patterns.

2.2 Importance

Although the world started waking up to the need for international environmental law in the early 1900s, the first international agreements were mainly concerned with protecting wildlife. From the 1950s to the 1970s, the focus was mainly on environmental problems caused by oil and nuclear energy. It wasn't until the late 1960s that mainstream environmental concerns really started to broaden. (Brown Weiss 2011, 2–4.)

The 1960s gave rise to literature concerning environmental hazards such as pesticides and air pollution. Hardin (1968) wrote in his essay of the issues of pollution, distribution of resources, and overpopulation. He argued that the resolution to these problems would not be found in technology, but in the restriction of personal freedoms.

The 1970s were a defining moment for environmental action. Hardin's essay was followed by The Limits to Growth, a computer-aided simulation and subsequent report of the exponential growth of human population and industry and the problems they would eventually cause (Meadows, Meadows, Randers & Behrens 1972). The first United Nations conference on the environment was held the same year in Stockholm.

Many arguments have been made for the importance of environmental sustainability. Climate change is predicted to cause drastic loss of biodiversity all over the globe. Eco-systems rely on biodiversity to function, and the loss of animal species will have a negative impact on both the environment and human societies. For people, it might mean the loss of important food sources or income from tourism, leading to poverty. Loss of biodiversity might also reduce carbon sinks, leading to more rapid global warming and even worse environmental problems. (Pigot & Trisos 2020.)

2.2.1 Economic impact

Due to the way economies and the environment are linked, economics play a significant role in the evolution of environmental sustainability. Capitalism is currently built on the concepts of continuous economic growth and ever-growing gaps in wealth, which are both unsustainable in the long run. Not only are they destructive from an environmental standpoint, they will also cause worsening social problems. (Elkington 2004, 10.)

Elkington's (2004, 1–3) idea of the triple bottom line is one of many concepts of corporate sustainability. The term has been around since 1994 and was invented to better appeal to businesses. SustainAbility, the consulting group he co-founded in 1987, also coined the 3Ps of people, planet, and profits. The concepts were meant to bring attention to the environmental and social value corporations add or remove.

Elkington (2018) has later criticized the way TBL has been used in the business world. He claims the term has been diluted by accountants and is rarely used in the radical way he intended when he first coined it. Elkington's goal with TBL was to push for systematic change and the transformation of capitalism. While corporate leaders do their best to ensure they hit their profit targets, the same effort is still rarely given to the people or the planet.

2.2.2 Societal impact

The people suffering from social injustices such as poverty or food scarcity are often also the ones suffering most from climate change and environmental depletion (The University of Manchester 2020). Multiple factors such as dependency on imports and exports or amount of foreign investments can also increase a country's vulnerability to the impacts of climate change, while wealth often acts as a mitigating factor. Both direct and indirect climate impacts should be considered due to globalization and the interdependencies between countries. (Benzie, Hedlund & Carlsen 2016, 14–32.)

The amount of carbon dioxide in the earth's atmosphere has been steadily rising since the start of the industrial revolution, correlating with the increase in human emissions (Figure 2). The current amount of atmospheric CO_2 is projected to double by the end of the century if the growing global energy demand keeps being met with fossil fuels (Lindsey 2020).

A growing body of research suggests that large amounts of emissions have a negative impact on people’s perceived happiness, while the presence of nature has a positive effect on both physical and mental wellbeing (Ferreira, Brereton, Cuñado, Martinsson, Moro & Ningal, 2013; MacKerron & Mourato 2013; Zhang, Zhang & Chen 2017). Not acting sustainably or striving to reduce emissions can therefore have an adverse effect on a society’s wellbeing.

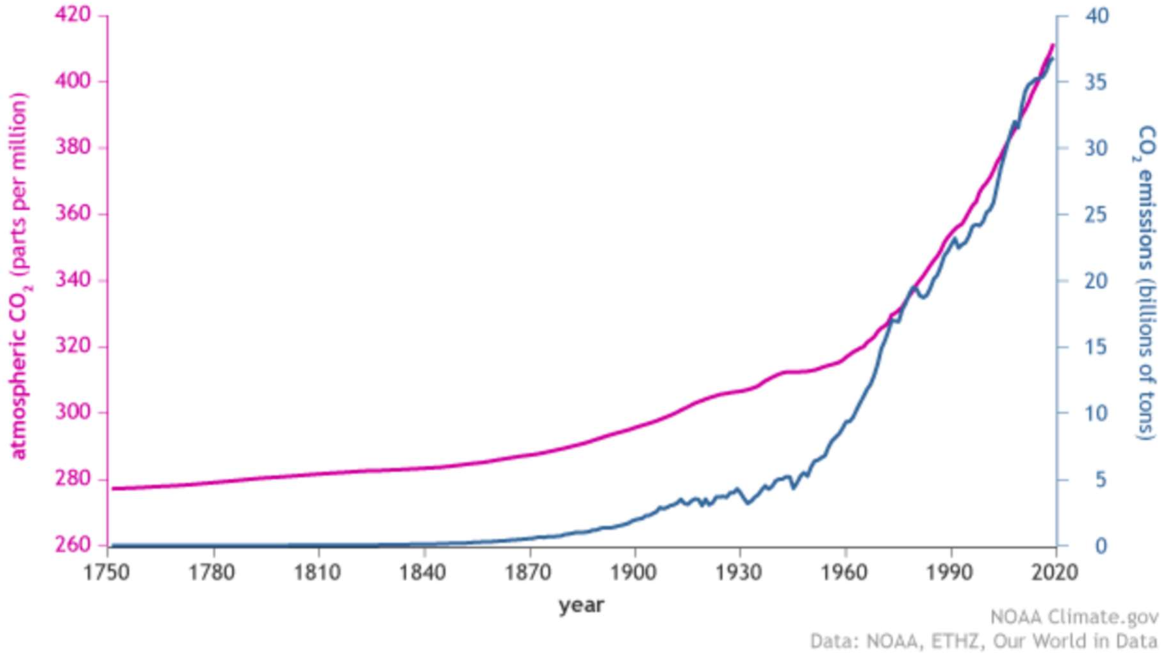


Figure 2 CO_2 in the atmosphere and annual emissions 1750–2019 (Lindsey 2020)

3 DEVELOPING ENVIRONMENTALLY SUSTAINABLE TECHNOLOGY

3.1 Sustainability in corporations

Corporations must strive to fully integrate sustainability into their day-to-day performance and decision-making to make an impact. Without identifying, measuring, and reporting the present and future impacts of their activities, processes, products, and services, the promise of sustainability merely looks like a move to improve public relations. (Epstein & Rejc Buhovac 2014, 44.) Because sustainability is currently such a prevalent trend among businesses and consumers alike, a company might be tempted to declare itself sustainable without truthfully considering the impact their actions have on their long-term business, society, and the environment.

To be considered environmentally sustainable, a company should at least fully comply with all local and global regulations and industry standards for emissions and waste. They should also commit to minimizing their use of energy and natural resources and their production of waste and emissions. A sustainable company should additionally attempt to maximize the recyclability and durability of their products. (Epstein & Roy 2003, 27.) Doing the bare minimum becomes less acceptable as our understanding of the importance of environmental sustainability grows.

Elkington (2004) compares sustainable corporations to honeybees. They have clear ethical business principles and an innovative and sustainable business model and they manage natural resources in a strategic and sustainable way. Moreover, they work together with others, form symbiotic partnerships, and moderate the impacts of less sustainable corporations in their supply chain. Like honeybees, these corporations work in sustainable and even regenerative ways, improving the world around them.

3.2 Sustainable investing

Investing in sustainable growth is a concept wherein a company's capital is evaluated by the standards of the triple bottom line. This evaluation drives the economy by affecting the value of companies' shares. Evaluation is performed by numerous institutes, each specialized in different fields of business and forecast mechanics. (Slaper & Hall 2011.)

The Dow Jones Industrial Average (DJIA) is an umbrella institute that summarizes companies' stock prices to calculate an average factor. It is one of the most highly respected indexes of modern economy, recording the performance of industrial growth across the globe. The DJIA index is maintained by S&P Dow Jones Indices (DJI) that is owned by

Standard & Poor's Financial Services LCC (S&P Global), a publicly traded corporation of financial information and analytics. (S&P Dow Jones Indices 2020.)

RobecoSAM is the section of DJI that specializes in sustainable investing indices. RobecoSAM has developed the means to measure an individual company's performance on sustainable development and publicly ranks companies based on these evaluation methods with scores ranging from 1 to 100. Sandvik's ranking as of 22.10.2020 is 79. Investors base their decisions on these indices to mitigate risk and expect profitable returns for their investments. (RobecoSAM 2020.)

3.2.1 Drivers

Legislation and policies are some of the biggest drivers for developing environmentally sustainable business. Environmental policies can drive businesses towards innovative technologies either explicitly or implicitly. Explicit methods include introducing tighter emission limits and technical standards while implicit methods include strategies like pollution taxation. (Marin, Marzucchi & Zoboli 2015.)

New innovations are driven not only by existing regulations, but by the anticipation of future policies. (Carrillo-Hermosilla, del González, Könnölä 2009, 43.) As research progresses and knowledge of environmental issues grows, recommendations get turned into regulations. It is vital for companies to ensure they are prepared for future changes to avoid getting caught off guard by demands.

Porter and van der Linde (1995, 98–105) argue that competitive advantage comes from a company's ability to continuously innovate and improve. By developing environmental innovations before competitors, companies can gain an early-mover advantage in the markets. This is especially true for international companies, as environmental legislation develops at different paces in different regions.

A resource-based view suggests that companies themselves can drive sustainability forward within their business. Doing so will accrue whole new resources and an edge over rivals and therefore be economically profitable as well. (Berrone 2009, 52–54.) These benefits can be referred to as innovation offsets. They offset the costs of investing in green technology by lowering the costs of production, waste disposal, material handling, etc. and by raising productivity and product quality. (Porter & van der Linde 1995, 101.)

3.2.2 Barriers

Barriers refer to factors that make the adoption of environmental innovations and strategies more difficult. Barriers often depend on factors such as the country of operation, the sector of business, and the type of innovation. From a company's perspective, they can also be divided into external barriers, company barriers, and eco-innovation related barriers. (Carrillo-Hermosilla et al. 2009, 28.)

External barriers come from outside the innovating company. They include consumers, policymakers and organizations, and they often make innovating harder by not providing the company with the necessary policies, laws, or pressures to develop more ecological practices. Some of these barriers might also be referred to as a lack of drivers. (Carrillo-Hermosilla et al. 2009, 31.)

The United Nations Stockholm Conference held in 1972 kicked off an era of international environmental agreements and treaties. However, it wasn't until the Rio Conference 20 years later that non-governmental organizations and the business sector really started working to shape environmental law through voluntary codes of conduct and environmental policies. (Brown Weiss 2011, 6–12.)

Sometimes barriers come from within the company itself. Perhaps the most obvious barrier is a lack of financial resources. Companies might also lack the technological know-how needed to adopt or develop these innovations. Sometimes the lack of innovations is merely due to prioritization, meaning the company decision-makers simply do not consider environmental issues important enough to invest in. (Carrillo-Hermosilla et al. 2009, 31.)

The last barriers are related to environmentally sustainable innovations themselves (Carrillo-Hermosilla et al. 2009, 31). New technologies or practices might for example be too expensive or too difficult to implement into existing processes. There might also simply not be enough information or research behind them to support investing in them yet, especially since environmental technologies are currently evolving at incredible speed.

4 CURRENT STATE OF SANDVIK

4.1 Environmental sustainability

Currently Sandvik publishes environmental performance reports on a quarterly basis using Scope 1 and 2 methods of reporting. Scope 1 includes the direct emissions of company-owned facilities while Scope 2 includes the indirect emissions caused by e.g. bought heating and electricity (World Resources Institute & World Business Council for Sustainable Development 2004, 25).

Sandvik has initiated an environmental sustainability strategy to recognize and minimize the environmental impacts of their business. This strategy was launched in 2019 and named Make the SH/FT (MTS). MTS includes the goals of increasing the business's circularity rate to 90%, reducing CO_2 emissions by 50%, improving safety to zero incidents, and improving inclusion by acting according to the highest ethical standards. Sandvik expects to reach these goals by 2030. (Sandvik 2020b.)

The focus of this thesis is on the circularity and CO_2 reduction goals. The goal to halve CO_2 impact includes the following targets:

- CO_2 reduction is included in all product development projects.
- Value propositions to customers always include verified CO_2 reduction potential.
- The CO_2 footprint from Sandvik's own production is halved.
- The CO_2 footprint for the transportation of people and products is halved.
- Key suppliers are required to halve their CO_2 footprint. (Sandvik 2020c.)

The goal to achieve more than 90% circular business includes the following targets:

- Material and resource efficiency improvement is included in all development projects.
- Business models for recycling and circularity are developed for customers.
- All products and packaging material will have at least 90% material circularity.
- The amount of waste from production processes is halved.
- 90% circularity is required from key suppliers. (Sandvik 2020d.)

Studying the targets set in the climate goals reveals that the objectives are beyond the scope of current reporting. Preliminary calculations suggest that a screening product's carbon footprint is mostly formed in sourcing and operating (Appendix 1).

Another important detail in the goals is the target to provide customers with verified reduction potential. Verified potential could be interpreted as providing emission data from products by using ISO 14040 and ISO 14044:2006 standards and requirements for external communication and reporting. ISO 14064-3 determines the requirements and processes for product emission verification. It includes a third-party verifier to ensure that evaluations meet the standards of set scope and boundaries. (SFS-EN ISO 14064-3:2019.)

4.1.1 Entire company

Sandvik is a global company with multiple business areas. Business areas differ from each other widely, and there are no unified tools for tracking the environmental sustainability of individual departments across the company. Environmental sustainability tracking currently consists of site-specific energy consumption being reported by the standards of Scopes 1 and 2. (Interviewee 3 2020.)

Some business areas have produced product emission calculations, but the results are currently for internal use only. Comprehensive enough data is not yet available to expand reporting to the standards of Scope 3 across the entire company. Scope 3 reporting would also require site-specific calculations for all products.

4.1.2 Screens and Feeders R&D Lahti

Screens and Feeders research and development is a key contributor to Sandvik's products' life cycle impacts. Currently S&F has no objective strategy for how they can contribute to the company's goals of reducing emissions and increasing circularity. Initiative has been taken to improve performance in the form of this thesis.

Sandvik Screens & Feeders offers a vast product range in stationary equipment with approximately 170 screening products that can be fitted with additive equipment options and 100 feeder products. S&F products are mostly custom engineered to meet customer-specific needs. Manufacturing of S&F products occurs in multiple countries, providing products and reliable delivery worldwide. Considering the variety of products, customized solutions, and changes between manufacturing locations, there could be thousands of scenarios to evaluate for environmental performance. (Sandvik 2020e.)

Improvements in environmental sustainability have recently been achieved in the development of a new production campaign. The campaign's focus is on optimizing products from a production efficiency perspective and improving customer satisfaction and after-sales support. The campaign also improves on environmental sustainability to some degree, but impact on environment has not been measured to assess whether the direction of development is equally optimal from an environmental standpoint. (Interviewee 1 2020.)

4.2 Measuring environmental impact

Tracking is an important part of developing environmental sustainability further, as it is difficult to start improving without a baseline. Having information on the amount of emissions different products and processes produce helps with determining priority of development subjects. The scope of tracked sustainability data needs to be understood and communicated clearly to avoid misinformation and potential abuse of methodology.

The simplest and most common way to measure company emissions is to track energy consumption within the company and calculate the CO_2 equivalent produced in the process. This way of measuring is adequate for some reporting purposes, but the information is not detailed enough to evaluate the full environmental impact of the entire business. (Klemeš 2015.)

Every product has a life cycle, from the sourcing of raw materials to the end of life. Emissions are created during every step of products' life cycles, and these life cycle emissions cumulate into a complete calculation of the environmental impacts of a business's activities.

Tracking the emissions of the products and services of a company is a widespread endeavour. It requires detailed policies to determine how the emissions are calculated and reported. There are also grey areas that need to be clarified in scope, e.g. when the product is no longer the company's direct responsibility and the ways an individual employee contributes to the evaluation. (Pelletier, Allacker, Manfredi, Chomkhamsri, de Souza 2012, 24-27.)

4.2.1 Emission tracking scopes

Emission tracking can be divided into different levels of data collection. These levels are commonly referred to as Scopes 1, 2, and 3 (Figure 3). As mentioned in chapter 4.1, Sandvik currently uses Scopes 1 and 2 only.

Scope 1 includes the direct emissions of used energy and water. Direct emissions cover emissions produced within the company. Examples of these emissions include the combustion fuels and water consumed in production processes. (World Resources Institute & World Business Council for Sustainable Development 2013.)

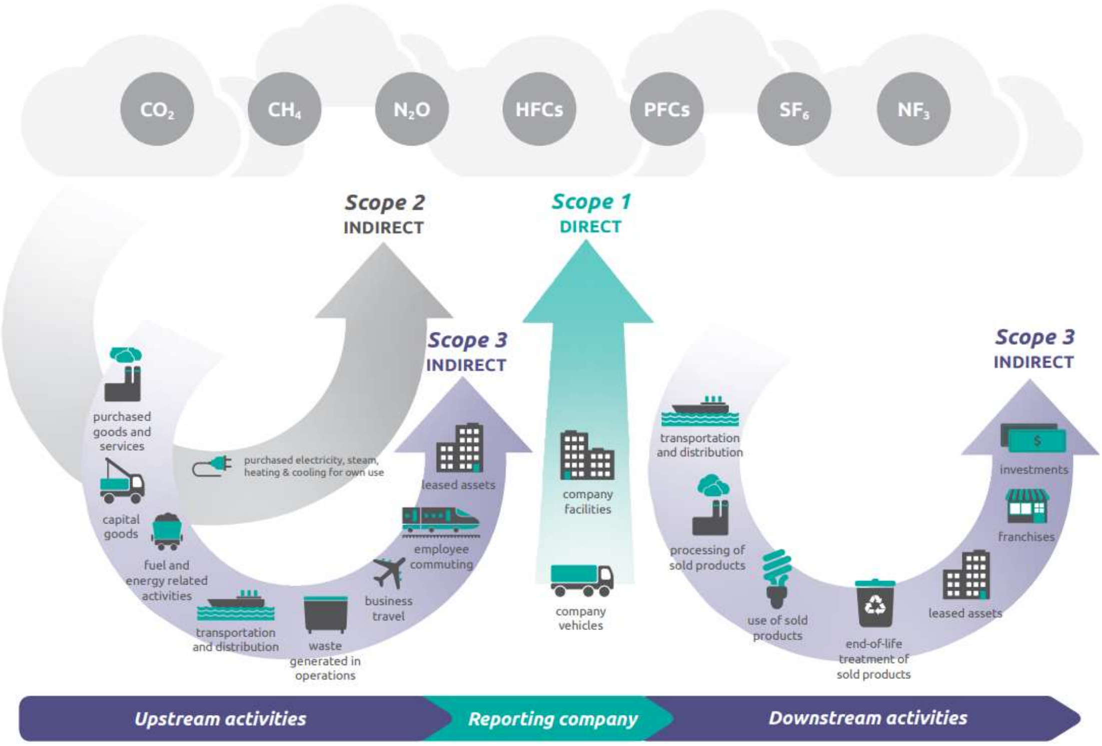


Figure 3 Overview of GHG Protocol scopes and emissions across the value chain (World Resources Institute & World Business Council for Sustainable Development 2013)

Scope 2 includes the indirect emissions of used energy and water. This includes all the bought energy used in production, for example the electricity used to operate machinery and heat the property. For these emissions, the companies providing the energy provide details for converting energy units into CO_2 equivalents. (World Resources Institute & World Business Council for Sustainable Development 2013.)

Scope 3 includes the emissions formed from transportation, employees, and communications. It also includes the domestic and international sources of the corporate value chain. Scope 3 can be considered a complete assessment of the emissions produced by the operations of a company. This level of tracking requires advanced tools to be measured accurately. (World Resources Institute & World Business Council for Sustainable Development 2013.)

4.2.2 Circularity tracking

Currently there is no data for tracking circularity within Sandvik, but there are initiatives to research and evaluate the circularity of the business. The data is needed to make a systematic approach to improving circularity. Tracking circularity may be difficult as there is no unified method of measurement for circularity and the current best practices are still under development (Linder, Sarasini & Van Loon 2017).

A goal of 90% circularity suggest that only 10% of material used in products are not recycled material from a sourcing and end-of-life perspective. Circularity depends highly on suppliers' and customers' commitment to sustainability, making co-operation within the production chain all the more important.

4.2.3 Life cycle assessment

Life cycle assessment is a method of measuring greenhouse gas emissions and other environmental impacts defined by ISO 14040 and ISO 14044:2006. Currently there are no practices within Sandvik to provide LCA reports since the method is regulated by standards and requires extensive research and auditing to compile. Some streamlined LCA calculations have been made for internal use to provide initial insight into emissions at different departments.

4.2.4 Sustainability goals

Sandvik's MTS program includes the goals to halve CO_2 emissions and achieve 90% circularity. Understanding the variety in methods of measurement makes these goals debatable. Goals set by company headquarters need to be interpreted individually in each department of the company to assess the necessary steps to achieve them. (Ernst & Young France & Quantis 2010.)

The strategy of these goals needs to be clarified within the management level to have a clear understanding of which methods are to be used in the future. As Sandvik operates globally, global standards would drive company-wide strategies. This would reduce the autonomy of local departments. A decentralizing approach would yield local standards and provide departments with more autonomy but may result in duplicated functions or compatibility issues. (Epstein & Rejc Buhovac 2014, 100.)

4.3 The life cycle of Sandvik Screens and Feeders technology

Sandvik's Screens and Feeders product area provides equipment for mining and construction industries. The products are used to process the rock and mineral outputs of their customers' operating sites. Equipment are either sold as catalogue standards or engineered to meet a customer's specific needs. There are currently no systems in place for the retrieval of products after use, but all products are shipped with maintenance and disposal instructions.

The variety of products and production sites makes environmental performance assessment more complicated. Suppliers and manufacturing efficiency change depending on the customer's geological position, delivery schedules, and local standards. Currently S&F does not have measuring tools or accurate data collection for the environmental performance of the products they produce. Research is needed to develop practices for measuring environmental performance that can be implemented for the entire range of products.

During the writing of this thesis, S&F launched a new campaign to deliver higher performance screening for customers. The campaign was developed to reduce the number of variations in product families by making them as modular as possible. The aim of the campaign is to provide more versatility and flexibility in the product range, offer faster response times on replacement parts, and reduce overall manufacturing costs without compromising quality. These properties also support sustainable production principles.

An estimation of an average screening unit's carbon footprint has been conducted for demonstrative purposes as part of this thesis (Appendix 1). The estimated carbon footprint of an average screening unit is 78 tCO_2e over 5 years or 15 000 hours of operation (Figure 4). This estimation has high uncertainty factors due to used methods but will provide some insight into the possible division of emissions during the product's life cycle. The company can use this demonstration to discern which parts of the process should be prioritized for further research.

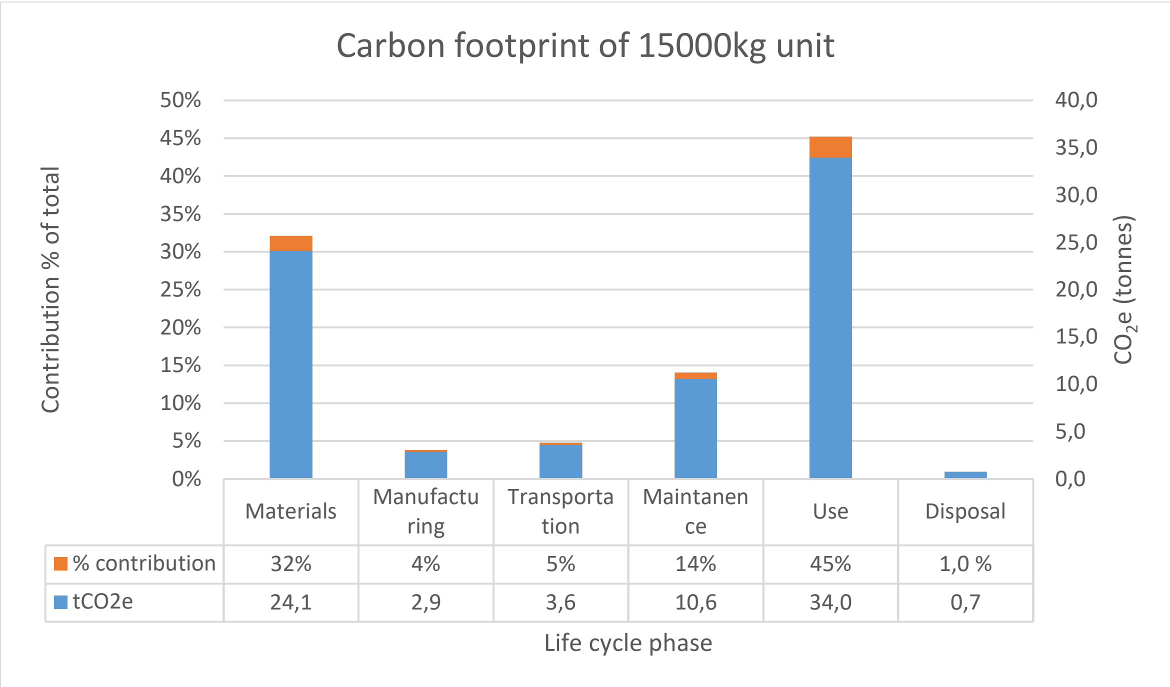


Figure 4 Estimated carbon footprint of a screening unit (Appendix 1)

5 PROPOSALS FOR SANDVIK R&D LAHTI

5.1 Design efficiency

Research and development has a key role in achieving the goals set in the MTS program. It is suggested that over 80% of a product's life cycle costs and environmental and societal impact is influenced by the design and development phase of the product (Charter & Tischner 2001, 120). R&D should include environmental impact analysis as part of their processes to improve internal performance and provide customers with solutions for reducing their environmental impacts.

Design approaches toward sustainability depend on company policies and chosen solutions affect the practices of other departments. New design approaches should be discussed with stakeholders to assess best practices. Training on sustainability principals may be required to provide stakeholders with equal insight before decisions are made, as the level of knowledge may vary greatly among individuals.

5.1.1 Screening life cycle assessment

A product's environmental impact is determined based on data provided by suppliers, the manufacturing site, transportation, the customer, and the product's end-of-life. Collecting data for accurate calculations would hinder the process of the design phase and potentially slow development. With screening LCA, R&D could make a quick assessment of the design's environmental impacts by using secondary data inputs and expert estimations (Jensen, Hoffman, Møller, Schmidt, Christiansen, Elkington & van Dijk 1997, 31).

Investing in the tools for conducting screening LCA would give design engineers insight into how certain changes affect the carbon footprint of a product. Screening calculation results may vary based on the goals and scope defined by company policy.

5.1.2 Design for 4R

Engineers in product development need to be mindful of various aspects of product manufacturing. Traditionally the focus in product development has been on economic potential, i.e. delivering a product that meets the customer's needs while having the lowest possible manufacturing costs. Customer satisfaction includes ease of operation, reliability, maintainability, and operation costs. Profitability can be increased by e.g. reducing material costs, man-hours needed, and storage space needed for components.

Engineers should also include end-of-life as part of a product's design when improving environmental performance. Sustainable disposal value (SDV) could be introduced as part of material sourcing to further improve the economic and environmental performance of manufacturing. A common SDV technique is 4R, which stands for recycle, reuse, repair, and reduce. (Johnson & Gibson 2014, 88.)

Reduce

Reducing is the most effective way to improve a product's environmental performance. Optimizing designs will reduce the materials needed for the product as well as the energy needed for manufacturing and transportation. Reduction is also perceived as effective from an economic standpoint and is therefore emphasized by process policies. (Johnson & Gibson 2014, 96.) Material reduction is discussed further in chapter 5.3.

Repair

Reparability of a product prolongs its lifetime in use, providing customer with more operating hours per purchase. Deterioration of a product should be considered part of the product's properties during the design phase. In most cases, repairing an existing product is more cost effective than making a new product or component. Some simpler components such as bearings and seals are designed to be sacrificial to protect more valuable components. Engineers should be mindful of designing the product to provide easy access to these sacrificial components. (Johnson & Gibson 2014, 92.)

Reuse and refurbish

A product enters its end-of-life phase once it has fulfilled the need of the customer. End-of-life has traditionally been considered waste production. However, from an environmental and economical viewpoint, the reuse or refurbishment of a product may be more profitable if the product or components are still in serviceable condition. Reclaiming the product from the customer would reduce manufacturing costs and the environmental impact of a refurbished product in comparison to manufacturing a product from new materials. (Johnson & Gibson 2014, 89-91.)

Customers can benefit from refurbished products financially, as their manufacturing costs are lower. Providing refurbished products would however require researching demand and logistical costs and possibilities. Designing the products and their components to be compatible across product ranges would contribute to the feasibility of refurbishing significantly. (Johnson & Gibson 2014, 91-93.)

Recycle

End-of-life recycling is considered the least favourable of these four options, but it has its uses when other options are no longer feasible due to economic or practical disadvantages. In this context, recycling of materials refers to the process of extracting used materials and converting them into raw materials. (Johnson & Gibson 2014, 89.) On average, 95% of the products designed by S&F are made from steel, which is a fully recyclable material. The remaining 5% is rubber and other materials which are also recyclable to some degree.

Currently the circularity of S&F products does not meet the goals of the MTS program. However, increasing the circularity rate of products through improvements in the supply chain is possible. On average, recycled scrap used in steel manufacturing is at 56% in Europe (The European Steel Association EUROFER 2020). Based on interviews, around 25% of steel raw material in S&F products is from circular sources.

The circularity rate of components could be estimated by using a simplified calculation method combining Material Reutilization Score (MRS) or recycled content percentage and Material Circularity Indicator (MCI) or recycling collection rate (Formula 1). The circularity rate of S&F products decreases when introducing non-steel components that are also subject to abrasive wear and need to be replaced as part of maintenance. Consumption of polymer-based parts causes a rapid decline in circularity evaluation, leading to an estimated rate of 51%. (Appendix 1.)

$$\frac{Recycled\ input\ \%}{2} + \frac{Recyclable\ output\ \%}{2} = Circularity\ rate\ \%$$

Formula 1 Simplified circularity rate formula (adapted from Niero & Kalbar 2019)

5.1.3 Modularity

Modularization can improve the sustainability performance of products by reducing the variation of components across products and providing opportunities to reuse components for new purposes or refurbished products. From an economic standpoint, modularization reduces the manufacturing costs of customized products and increases reliability of delivery in replacement parts. (Johnson & Gibson 2014, 300–302.) Modularity may affect the emissions of materials as explained in chapter 5.3.

5.1.4 Integrated evaluation tools

Various tools integrated within CAD or PLM software may help the design phase evaluate the environmental impacts of specific decisions. Using built-in software tools to make environmental impact assessments requires design engineers to be trained on the subject, as it is important to apply correct values to each scenario for accurate results. (Morbidoni, Favi & Germani 2011.)

Many companies have previously developed calculation tools for their own needs. The methods vary and results may not meet international standards, but they can act as guiding tools in inspecting certain aspects of process chains. These screening evaluation tools meet the needs for environmental performance development temporarily. In the long term they must be replaced or developed further to meet the standards of external communication. (Means & Guggemos 2015.)

An integrated approach to environmental impact analysis of product development would shed additional light on design decisions. Integrated tools can also provide accurate data for product comparisons to a limited degree. In addition to integrated engineering tools for environmental analytics, organizational tools would be required to identify potential compatibility issues with the rest of the development process. (Ait-Kadi, Ameknassi & Keivanpour 2016, 1461-1465.)

Most evaluation tools require an extensive array of input values due to their intended use of providing standardized and transparent quantitative results for communications. Setting these parameters for each part used in product assembly would extend the library of information exponentially if the software were to be used to provide verifiable calculations, as it would need to accommodate every scenario in the production chain. Verifiable measurement was set as one of the MTS program’s CO_2 reduction targets and should be kept in mind when choosing evaluation methods and tools.

5.1.5 Management

The role of management is crucial in achieving set sustainability goals as management is responsible for setting the principles and practices that enable sustainable development (Epstein & Rejc Buhovac 2014, 71). Management can also encourage employees to participate in researching sustainable solutions within existing processes or considering the prospects of new business models (Johnson & Gibson 2014, 143).

Tracking performance is the most effective tool management has for identifying key factors within the process chain. Without measurement tools, it is difficult to take action and without actions there are no results to evaluate. Measurement methods and solutions are discussed further in chapter 6 (Johnson & Gibson 2014, 119).

Product development management could introduce environmental performance improvement as part of product requirements. This would challenge the development team to investigate possible solutions, data gathering, and techniques to meet the requirements. It would also provide management with information on possible bottlenecks and technological challenges that restrict the development team from achieving requirements. Debriefing during the development process gives the team a chance to explain the challenges met during development stages. (Johnson & Gibson 2014, 130–137.)

5.1.6 Collaboration

R&D has a central role in providing sustainable products, as 80% of triple bottom line performance is determined during the design phase (Charter & Tischner 2001, 120). As decisions to improve sustainability are made, the production chain should also be made aware of the objectives to ensure targets are met. Communication between stakeholders could also help R&D develop practices that improve overall sustainability performance.

The relationship between stakeholders and R&D can be described as follows (Figure 5). R&D, purchasers, and suppliers develop best practices on sourcing materials and components. R&D and manufacturing engineers discuss best practices for producing components and products. R&D then designs products that are optimized for usage, maintainability, and disposal to provide sustainable solutions for customers' needs. R&D should utilize the expertise of stakeholders to develop best practices for product design.

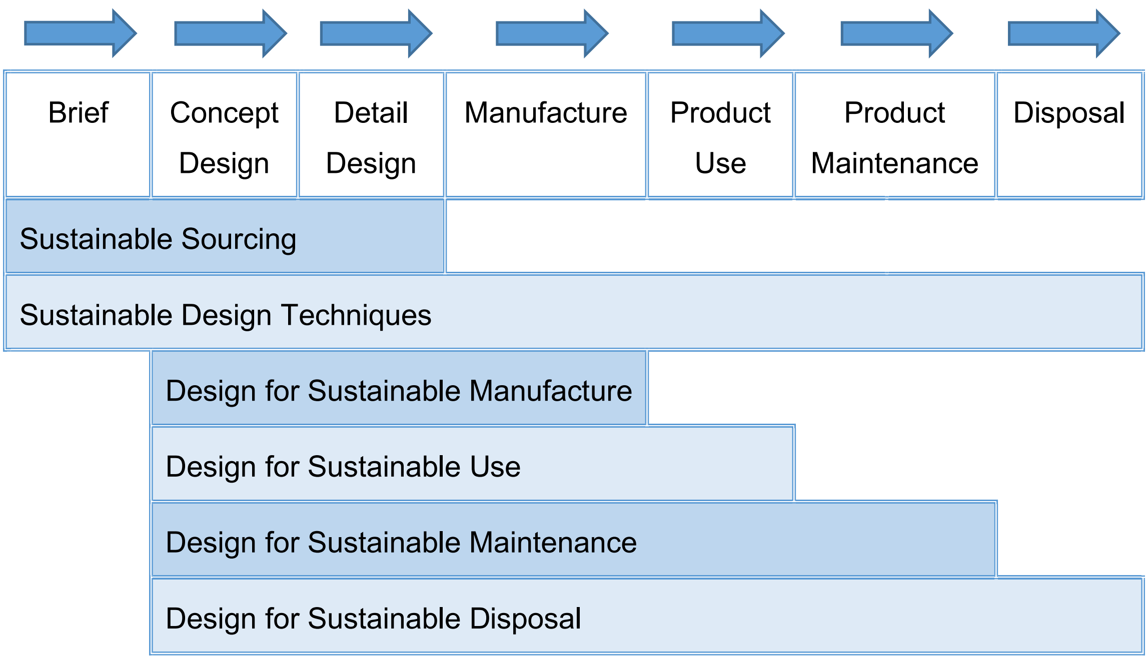


Figure 5 The Sustainable Engineering Design Whole-Life Model (adapted from Johnson & Gibson 2014, 73)

5.1.7 Training

Sustainability principles may be a foreign concept for many stakeholders. Knowledge also comes from various sources at varying levels. Training employees and stakeholders is essential for future development of sustainable solutions. The content of sustainable design training must be considered carefully to emphasize the short- and long-term goals and to ensure that requirements are met, and workflow is not hindered.

Training design engineers successfully may be challenging for management, as there are many ways to introduce sustainable solutions into processes. Management may need training or external consultation on how to introduce compatible, scalable, and flexible methods that suit current practices and future goals.

5.2 Product energy consumption

SMRT S&F use electric motors that qualify for premium efficiency IEC 60034-30-1 classification as standard equipment. This may wary based on the client's specified needs. A majority of delivered equipment is fitted with IE3 classified electric motors.

Based on demonstrated estimations (Appendix 1), the energy consumption of an average screening unit causes the majority of emissions during the product's life cycle and is the largest contributor to its carbon footprint. Reduction of energy needed to operate the unit is beneficial for both the customer and the environment.

Fitting screening units with IE4 classification electric motors may reduce their emissions and operating costs by 2% (Appendix 1). In quantitative measures these reductions equal 1 tCO_2e and 400€ per one unit's life cycle (Eurostat 2019). These results are based on averages and are subject to change depending on geological location and amount of primary data from testing.

Electric motors commonly contain neodymium magnets. These are unsustainable components, and their recycling is still so inefficient that they are considered unrecyclable waste. (Yang, Walton, Sheridan, Güth, Gauß, Gutfleisch, Buchert, Steenari, Van Gerven, Jones & Binnemans 2017, 123.) Electric motors that do not contain rare-earth materials are available, but their availability and cost efficiency need to be considered. For example, ABB has developed magnet-free low voltage motors that also meet the IEC standard efficiency rating of IE4.

The operational characteristics of higher efficiency rating motors differ from previous IE3 category motors. Adopting higher efficiency motors would require extensive testing and possible changes to motor controllers. Motor control units affect the calculations of power consumption and theoretical calculations may therefore differ from practical use. Conducting in-depth research on the performance of higher efficiency rated motors for screening units is recommended.

5.3 Reduction of material

According to preliminary estimations, the materials used in the production of an average screening unit contribute to 32% of the total carbon footprint of a unit. Impact is largely affected by the recycling rate of raw materials. In quantitative measures, materials produce 24 tCO_2e and depend on geological location and the amount of recycled material used to produce new material. (Appendix 1.)

The most efficient way to reduce the environmental impact of materials is to increase the circularity rate. Reducing the percentage of virgin raw material can reduce the carbon footprint of materials used by up to 39% (Appendix 1). Recycling rate is controlled by suppliers and is therefore based on demand.

Material reduction should be included in the design process, as minimizing the material costs for products should be the basis of engineering. Measures should be taken to research over quality and material selection. Re-evaluation of material selection and fastening methods in current products can reveal costly overdesign that has persisted from the early stages of development. (Johnson & Gibson 2014, 315.)

Products designed at S&F are developed upon previous models and material selections carry on throughout the years if no structural issues occur. Material production methods and standards have developed tremendously during the past few decades. During discussions at S&F R&D, some concerns were raised about the steel grade not being optimized and mostly being based on current and past standards (Interviewee 1 2020).

Studies suggest that a higher grade of structural steel reduces the material mass needed for a structure (Nordenstam & Svantesson 2016, 38). Reducing mass is directly related to the reduction of carbon footprints since the manufacturing method is relatively similar regardless of the grade of steel produced. Reducing the mass of materials can also reduce manufacturing costs of products depending on availability of materials.

One of many critical material properties for screening products is Young's modulus, which indicates cracking resistance under a vibrating load. Young's modulus varies between structural steel grades, but only nominally. Studies suggest that the stated 200Gpa elasticity modulus of structural steel may be inaccurate, and determining the accurate value is complicated. Elasticity modulus increases as material thickness is reduced. The error in definition may affect the results of finite elements method (FEM) analysis. Engineers define materials according to FEM analysis results and therefore the elastic modulus may deviate in practice. (Sadowski, Rotter, Reinke & Ummenhofer 2015, 14.) Material selection and fastening methods could be re-evaluated to reduce the carbon footprint and manufacturing costs of products.

5.4 Summary of suggested initiatives

The proposals from chapter 6 have been summarized below (Table 1). We encourage S&F R&D to do further research on the following suggestions, as their suitability depends on how well they can be integrated into current practices and the resources S&F R&D has at their disposal.

Table 1 A summary of suggested initiatives for S&F R&D

Initiative	Need	Gain	Limitations
Screening assessment of products	- Uncertainty of products' environmental performance	- Initial insight into contributors on products' environmental impacts	- Data not available - Margin of error is high
Design for 4R - Reuse and refurbish as part of modularity	- Increase of circularity and reduction of emissions	- Reduction of manufacturing costs and emissions - Increase of circularity	- Use cases require logistics investments and reliable condition evaluation - Customers' motivation to participate
Integrated evaluation tools	- Lack of information on products' environmental performance	- Ability to compare solutions' environmental performance in the design phase	- Scarcity of available data - Database administration - Unclear scope, methodology and trade-off criteria - User training
Management - Stakeholder collaboration and objectives	- Clarify the objectives of individual departments - Needs and barriers of measuring environmental performance	- Provide alternative solutions to improve environmental performance of product manufacturing - Reduce emissions through product life cycle - Recognition of obstacles for sustainable solutions	- Increases workload and expertise requirements - Absence of unified standards - Varying level of knowledge and interest in environmental impacts

6 COMPANY-WIDE PROPOSALS

6.1 Sustainability servicing opportunities

SMRT provides equipment for material sourcing and excavation processes that are inherently unsustainable. SMRT could therefore have a major role in minimizing the environmental impact of the mining industry by providing more sustainable equipment and services. This extended product responsibility could come in the form of e.g. providing customers with tailored solutions to mitigate their environmental impact or tools to track environmental performance.

Environmental sustainability is likely to create new business opportunities. Providing customers with more efficient processes and tools to operate in continually tightening legislation is a logical next step. Examples of services include maintenance as service, equipment and process optimization, automated performance data output, and consultation for environmental impact analysis.

6.2 Sustainable material sourcing

Currently a lack of information from the supply chain and knowledge of sustainability principles across the supply chain pose a challenge in making the entire business more sustainable. Although secondary data can be used to make assumptions about a product's carbon footprint, a calculation made this way cannot be considered an accurate evaluation of the product.

Accurate primary data is required when a company decides to publish results externally (SFS-EN ISO 14044:2006). To provide customers with data, the company must require its suppliers to provide data first, as a product's carbon footprint accumulates from material sourcing to end-of-life.

6.3 Circular economy and recyclability

Circularity plays an important role in environmental sustainability. Circular economy has the potential to reduce GHG emissions significantly while also increasing profitability (Ellen MacArthur Foundation 2013, 10). It is a simple concept, although in practice the methods of measuring circularity are still under development.

The constant development in the field of circular economy leads to different approaches in methodology. A good example is the difference in circularity rate between a refurbished product and a product manufactured from purely recycled material. A refurbished product has a smaller circle than a product made from recycled materials, but depending on calculation methods, both can theoretically have the same circularity rate. (Linder, Sarasini & Van Loon 2017, 548.)

Circularity also faces some marketing challenges. Manufacturers need to assure customers that remanufactured products or products with a high content of recycled materials deliver equal quality when compared to the traditional linear production method. (Koistila 2020, 19–20.) Due to varying sustainability awareness, some customers are more open to the idea of remanufactured products than others.

The goal of 90% circularity given in the MTS program dictates that only 10% of a product's materials can be either virgin or waste material. The rest cannot be disposed of in landfills or by incineration. Given that S&F products are estimated to be 95% recyclable, only 15% of the materials used in manufacturing could therefore be from non-circular sources. These calculations exclude the impact of energy consumption and emissions on circularity assessment.

Sandvik has previously conducted a circularity case study on mining transportation equipment. Conclusions and propositions were evaluated with the intent to increase circularity in set business areas. With further research, some of these practices could also be applied to other business areas.

6.4 Life cycle accounting

Conducting a complete life cycle assessment from the scope of the entire company would yield the best possible information on the environmental performance of current business practices. Data collection for LCA would require a vast amount of resources and be demanding towards suppliers and customers.

Life cycle accounting might be the optimal practice for improving environmental performance at the current state of operations. Product life cycle (PLC) accounting is standard in tracking the performance of production chains. It differs from LCA in methodology by focusing only on the impact of the individual product's carbon footprint.

PLC accounting is easier to measure that LCA since the data collection can include secondary data inputs. However, due to the nature of databases, the results do not meet the ISO 14044 standard for external communication and therefore are not viable for making public environmental sustainability claims for products. (European Commission JRC-IES 2010, 31.)

PLC accounting overlaps with Scope 3 reporting and it can therefore be mutually beneficial to implement both practices. PLC accounting data can be used to compile Scope 3 reporting for stakeholders and overall performance indication. (World Resources Institute & World Business Council for Sustainable Development 2011.) The benefits of PLC accounting include tools for decision-making in management and development of more environmentally sustainable products and practices. Accounting also drives suppliers to provide more precise data to evaluate best practices of material sourcing.

The limitations of PLC accounting are connected to the possibility of using secondary data inputs, as results might include misinterpreted data that should not be used for external communications. PLC accounting measures only the quantitative emissions and gives only partial information on environmental impacts. The company could investigate PLC accounting programs and consider the benefits of Scope 3 reporting as a means of improving environmental performance.

6.4.1 Sustainability goals

The goals set by Sandvik in the MTS program provide initial targets for the company. There is still uncertainty among employees on how to approach these targets due to variations in methodology, terminology, scope, and legislation. Consensus on methods is needed to assess sustainability in all the various business areas within Sandvik. (European Commission JRC-IES 2010.) Goals and scope also need to be re-evaluated as progress is made within the company and knowledge, tools, and methods evolve. A heuristic piloting approach may be an effective means of achieving insight into viable practices.

The MTS goal of reaching 90% circularity is complicated to achieve, as the methods of measuring circularity are still being debated and developed. Circularity and sustainability are closely intertwined, so this goal is a crucial driver in improving the company’s environmental performance. However, circularity percentage may not necessarily indicate optimal environmental performance. It is thus important that goals be clarified before measurement methods are chosen. (Linder, Sarasini & Van Loon 2017, 547.)

Emissions should be reported as metric tons of carbon dioxide equivalent (tCO_2e) by using the latest global warming potential index (SFS-ES ISO 14064-1:2019, 18). The letter e in tCO_2e stands for equivalent and is an important detail in reporting. The terminological difference between carbon dioxide (CO_2) and carbon dioxide equivalent (CO_2e) is significant, as using CO_2 can be interpreted as the exclusion of other GHG emissions. The MTS goal to halve CO_2 emissions should therefore be re-evaluated.

6.4.2 Assessment methods

Screening LCA can be conducted in the initial development phase to make rough estimations of how emissions are distributed throughout the production process. Screening LCA does not have to follow the ISO standards for LCA and should be treated as an estimation to point out potential issues in the process. Screening LCA can be done by using simple tools that a company can develop or purchase with relatively low resources. (European Commission JRC-IES 2010, 13.)

Simplified LCA is a more robust study of the production process, and it provides detailed enough information to make conclusive decisions. Simplified LCA follows the principles of ISO standards but consists of secondary data when primary data is not available. With simplified LCA, a company can measure the impact of individual parts of multifunctional processes. The term simplified is slightly misleading, as simplified LCA is a complicated structure constructed by using simple input-output nodes. Conducting simplified LCA may require specialized tools to compile data into an informative presentational form. (Jensen et al. 1997, 30-31.)

Complete LCA is currently the only method that meets the ISO 14000 series standards for providing product-related environmental impact results for external communications (SFS-EN ISO 14063:2020, 22–27). Complete LCA is defined by ISO 14040 and ISO 14044 standards as providing calculations of the environmental impact of a product's life cycle from sourcing to end-of-life. As evaluations are made based on a complete history of the company and its suppliers, the amount of research needed is vast and reaches even beyond the company's control. Complete LCA is also considered the only method to provide verified claims on environmental impacts. (SFS-EN ISO 14021:2016, 14.)

6.5 Standards, certifications, and environmental management

ISO is the most common globally used international standard. ISO 14000 series provides standards on environmental impacts and is part of the Sustainable Development Goals (SDGs) set by the United Nations. ISO standards are mostly used as is in the European Environment Agency (EEA). ISO 14001 certification can be acquired through a third-party auditing program and is similar in process to ISO 9001 certification. (ISO/TC 207/SC 1 2020.)

The United States Environmental Protection Agency (EPA) has different levels of standards for federal, national, and international use. Environmental standards in the EPA are based on ISO 14000 series standards. Another competing standard for ISO is the British

Standards Institution (BRI) Publicly Available Specification (PAS). The PAS standard differs slightly from ISO, although they are mostly uniform. Some nations have also adopted environmental legislation designed to protect the environment by law instead of voluntary standards.

Certification is offered by various third parties. The CarbonNeutral certification is based on CO_2 calculations and is administered by a third-party assessor. The method of certification is based on the GHG protocol Scope 3 or PAS 2050 calculation standards. (Natural Capital Partners 2020.)

EU Ecolabel promotes circular economy and encourages companies to develop durable products that are maintainable and recyclable. Ecolabel follows the ISO 14024 standard of labelling. There are no definitive criteria for certification, which enables companies to apply for certification with various standards that are verified by the Ecolabel committee individually. (European Commission 2020.)

The Carbon Trust company has multiple certifications and has different criteria to follow depending on the chosen label. Carbon Trust's criteria for carbon footprints are aligned with the BRI PAS 2050, ISO 14067 and GHG protocol standards. (Carbon Trust 2020.)

6.6 Flexible work policies

A company can reduce work related emissions by enabling flexibility in working practices. Encouraging employees to work from home and reducing the necessity to commute between home and office daily will reduce the emissions caused by commuting and may even reduce the need for office space long term.

According to latest estimations, the average distance between home and office in Finland is 16km. An estimated 64% of Finns commute to work by passenger car, excluding rideshares. (Finnish Transport and Communications Agency Traficom 2018.) Commuting between home and office by passenger car emits roughly 5kg of CO_2 per round trip (Finnish Transport and Communications Agency Traficom 2020; Formula 2).

$$vehicle\ CO_2\ emissions\ \times\ daily\ commute = daily\ commute\ CO_2\ emissions$$

Formula 2 Finnish average commute CO_2 emissions per workday for passenger cars

With 228 workdays per year, an average Finnish employee produces an annual total of 1,1 tCO_2 while commuting by passenger car. Multiplied by Sandvik's 42 000 employees and the estimated 64% that commute by passenger car, it creates a total of 30 500 tCO_2 (Formula 3). Actual statistics may differ from this estimation, as Sandvik is a global entity.

$$daily\ commute\ CO_2\ emissions\ \times\ workdays\ \times\ employees\ \times\ passenger\ car\ commuter\ factor\\ = annual\ company\ CO_2\ emissions\ from\ employee\ passenger\ car\ commutes$$

Formula 3 Annual company emissions from employee passenger car commutes

Commuting is not tracked in the current scope used at Sandvik, but it would be tracked in Scope 3. Most employees’ job descriptions do not currently allow for working from home. Their work schedules could be researched and modified by e.g. increasing the duration of their shifts and reducing their number of workdays.

A potential for misinformation in enabling employees to work from home is that the current scope of reporting tracks the energy consumption in company-owned facilities only. The energy consumption of work computers would therefore shift from a tracked to an un-tracked source and yield misleading results in reports. Scope 3 reporting may be essential in tracking the performance impacts of new work policies.

6.7 Training the staff

Sandvik has 42 000 employees and a vast array of expertise in different fields of study and practical knowledge. Coordinating extensive and useful training for all employees with targeted content that provides all the necessary education will be challenging. This training may be necessary to produce scientifically approved results and properly examine the goals the company has set for the MTS program. Extensive training may also inspire employees to come up with new innovations, as the company provides all employees, from janitors to executive managers, with the means to participate.

Sandvik may already have employees that have the expertise or desire to improve the state of environmental sustainability. These individuals could prove to be an asset in future development. Further education could be acquired to train interested individuals for new job descriptions related to sustainable development.

6.8 Summary of suggested initiatives

Suggested initiatives from chapter 6 have been summarized below (Table 2). There are a multitude of ways to improve the environmental sustainability of a business, and the following are only a handful of suggestions based on information gathered so far. The company could further research these methods to determine their suitability for company processes and goals.

Table 2 A summary of suggested initiatives for the entire company

Initiative	Need	Gain	Limitations
Sustainable equipment solutions	- Provide customers solutions to reduce their environmental impacts	- Recognition as a provider of sustainable solutions	- Framework for communication on environmental impact improvements unclear
Sustainable material sourcing	- Material sourcing is a key element in achieving 90% circularity	- Improve products' circularity rates significantly	- Price and availability
Life cycle inventory	- Provide accurate information of product CO_2e impact for internal use - Accurate circularity metrics	- Provide accurate quantitative for carbon footprint and life cycle assessment	- Variety of data sources and accounting tools depending on methodology
Data collection and databases	- Verifiable improvements require data collection	- Provide insight on the environmental impact of each individual process in the manufacturing chain	- Only primary data is acceptable for external communications - Determining margin of error requires extensive research
Environmental sustainability training	- Equalize understanding of sustainability principles, goals and obstacles	- Encourage participation and critical view on what decisions could be beneficial	- Scope, standards and methodology too unclear to answer all questions

7 THEORETICAL CARBON FOOTPRINT CALCULATIONS

7.1 Today, tomorrow, and in the future

The intent behind the following calculations is to demonstrate how some of the previously mentioned proposals may affect the carbon footprint of manufacturing a product. Estimates were calculated based on available secondary data and combined with information given through interviews. The materials and components used are rough estimations of what an average product consists of. Results may provide insight into key elements that should be studied further.

Of the demonstrated product, 93% of total mass is steel, 4% is polymers and 3% is other components, e.g. electric motor and fluids. Maintenance was estimated to consume 3 metric tons of steel and polymers over a 5-year life cycle. The total distribution of material mass was therefore set to 81% steel and 17% polymers. Crude steel production emissions are on average 2tCO_2e per metric ton of steel (Hasanbeigi, Arens, Rojas Cardenas, Price & Triolo 2016). Polymers were assumed to be rubber for the sake of simplifying the calculation, making their production emissions 1,5tCO_2e per metric ton of material (Vidanagama & Lokupitiya 2018).

The estimation for the manufacturing phase was calculated by using data provided by one of the manufacturing units. This data contains unsorted pollutants and might not include e.g. energy consumption. Manufacturing phase calculations are site specific and may vary significantly for the same product made at different locations. The emissions of the manufacturing phase must be measured on site using the inventory method to provide accurate calculations.

Transportation emissions were estimated by using simplified lorry emissions of 900gCO_2/km and multiplying by 4000km, which is the estimated combination of supply chain transportation and product delivery. Factors such as the weight of transported items or empty running were not included. Accurate measurements of transportation in the supply chain need to be calculated to provide conclusive information.

The maintenance phase was estimated by using emission data provided by one of the screening unit manufacturing sites. The data contained annual SO_2, NO_x, CO, and unsorted inorganic and organic emissions. Emissions were converted into tCO_2e using 100-year global warming potential conversion factors from the IPCC's fourth assessment report. Unsorted emissions were converted into unweighted averages for inorganic and organic emissions respectfully. (Forster, Ramaswamy, Artaxo, Berntsen, Betts, Fahey, Haywood, Lean, Lowe, Myhre, Nganga, Prinn, Raga, Schulz & Van Dorland 2007, 212-215.)

Combined annual tCO_2e was then divided by the number of produced units to form average emissions of 4,6 tCO_2e per unit.

The use phase of the product was calculated using an estimated average motor and load rate provided by interviewees. Emissions for the use phase are based on European average emissions for electricity multiplied by the runtime during the demonstrated product's life cycle. A runtime of 12 hours per workday was chosen for the demonstration. The emission reductions of motor efficiency upgrades were calculated by reducing input electricity while using output power as a constant.

The disposal phase represents the impact of end of life for the product. Emissions were calculated by using average recycling rates of used materials and multiplying the recycled mass of each category by their respective waste management factors: 6,8kgCO_2e/ton for steel and 150kgCO_2e/ton for polymers (Damgaard, Larsen & Christensen 2009, 11; Lokupitiya & Vidanagama 2018). The disposal phase has high uncertainty factors since the emissions of disposal depend on geological location and disposal methods.

End-of-life potential was excluded from this demonstration since the practices of reusing and refurbishing do not exist at S&F yet. End-of-life potential would give the calculations a negative value to compensate for life cycle emissions. This potential value exists at the boundary of two products and should be calculated carefully to avoid double accounting.

Today

Current carbon footprint and circularity rate are estimated based on literature sources of materials' CO_2e averages and average recycling rates. The circularity rate is calculated based on European average statistics and information provided by the current supplier. The total estimated carbon footprint for an average 15t unit is 78,04 tCO_2e, with a circularity rate of 51% (Figure 6).

The recycling rate for structural steel is 97,5% (Bowyer, Bratkovich, Fernholz, Frank, Groot, Howe & Pepke 2015, 3). The recycling rate of polymers is on average 2,6% (Eurostat 2017). This is largely due to the fact that there are no viable solutions for using scrap material in the production of polymer-based products (SusChem Materials Working Group 2018, 25).

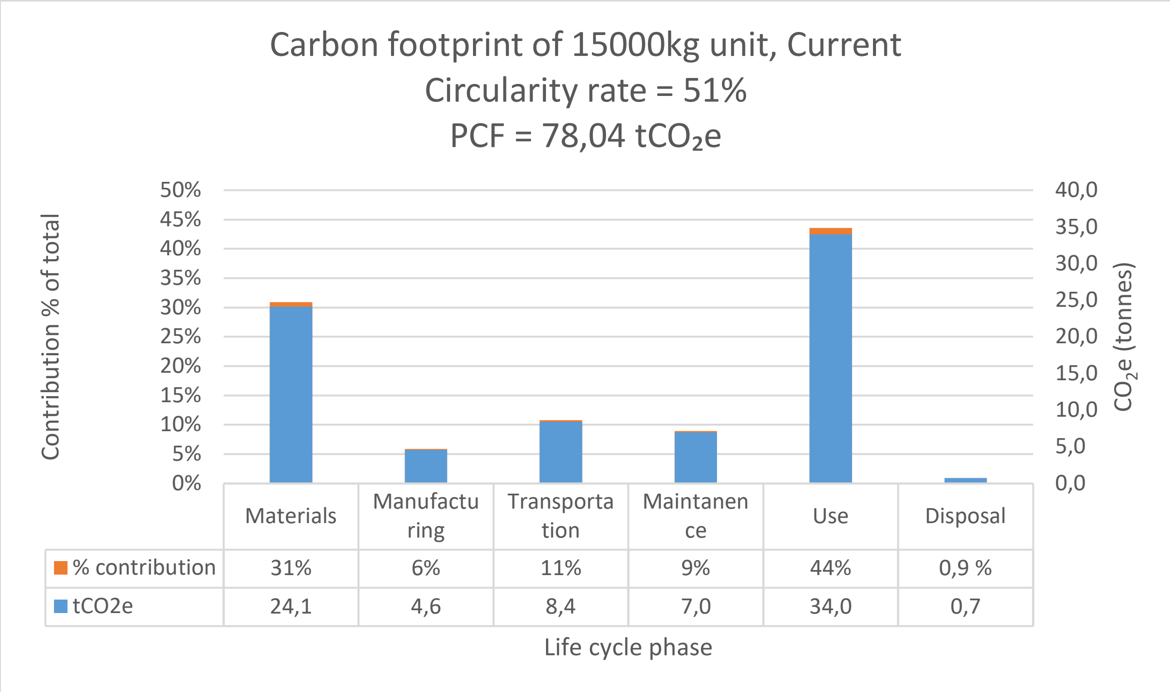


Figure 6 Carbon footprint calculations for a theoretical screening unit today (Appendix 1)

Tomorrow

The following scenario contains an estimation of the carbon footprint of the same product while including viable sustainability solutions to reduce environmental impact. The circularity rates of materials have been increased to current estimated averages, and calculations have been modified to include a higher efficiency motor.

The recycled scrap content used for steel parts is at 56%, the reported average of scrap used in EU steel production (The European Steel Association EUROFER 2020). The recycling rate of polymer materials is unchanged since there are currently no solutions for recycling it. Operation emissions have also been reduced by 0,7 tCO_2e by using a higher efficiency motor. The total estimated carbon footprint for an average 15t unit in this scenario is 69,38 tCO_2e, with a circularity rate of 63% (Figure 7). The carbon footprint is therefore reduced by 11% in comparison to today's product.

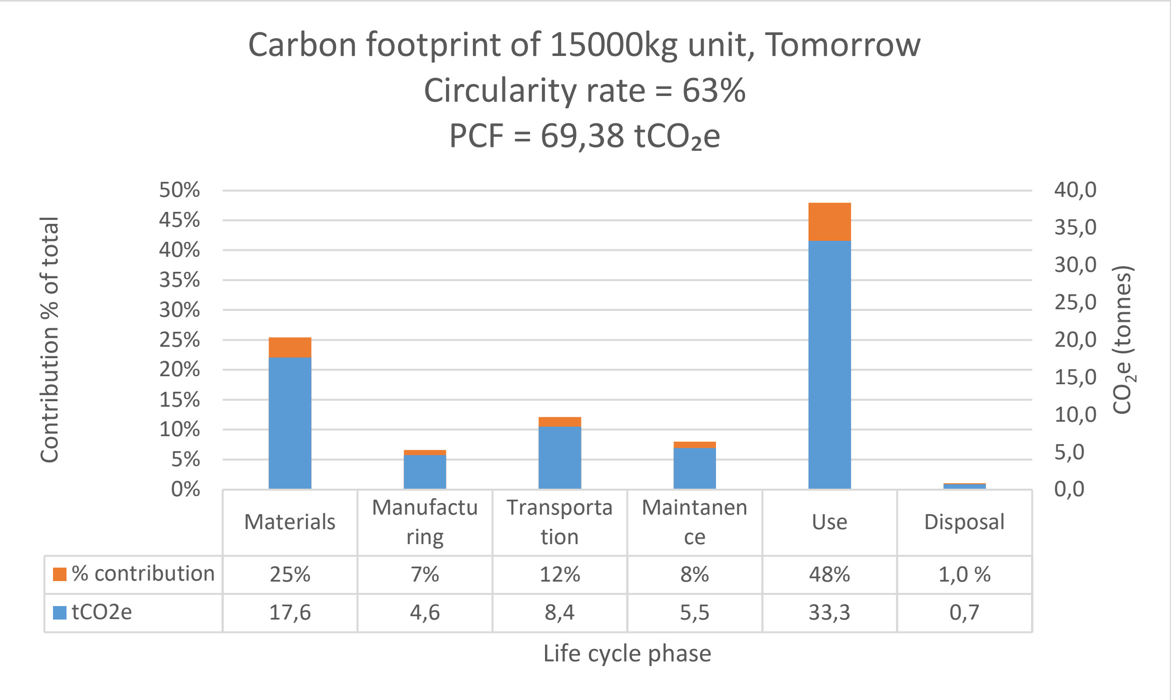
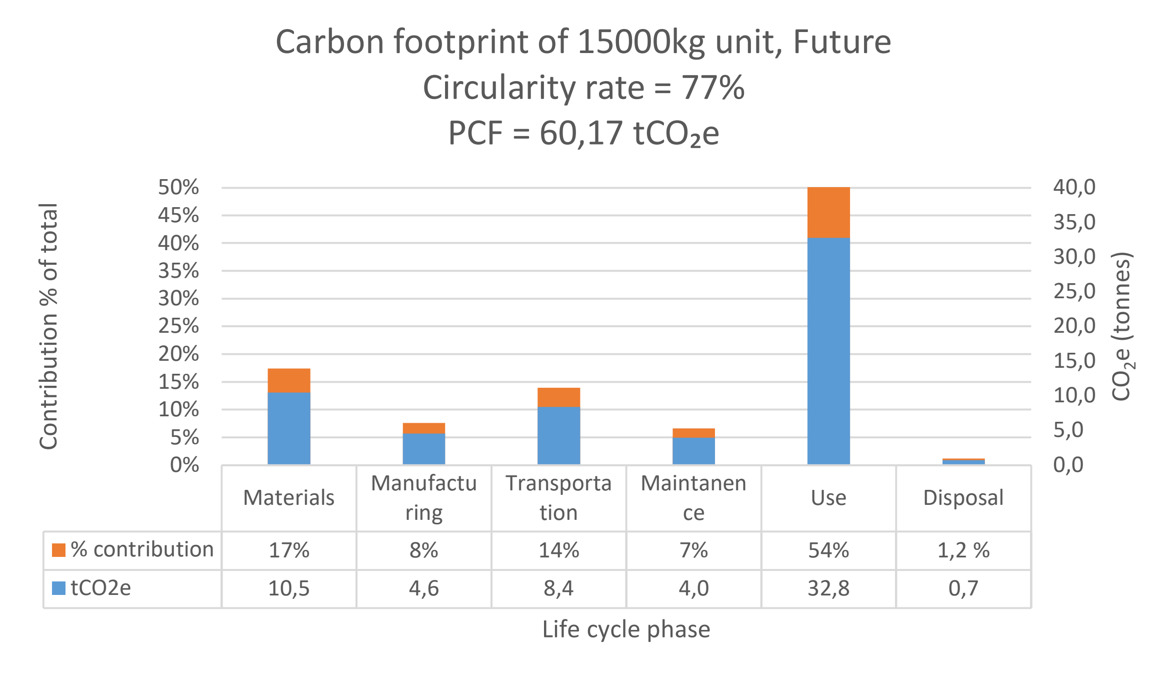


Figure 7 Carbon footprint calculations for a theoretical screening unit with minor improvements (Appendix 1)

Future

In the future scenario, the highest feasible measurements achievable by optimizing material use were included in the estimation. The recycling of steel material in this scenario is 97,5% in disposal, and 100% of new material is procured from circular sourcing. Polymer material circularity has not been changed. Operation power consumption has also been reduced by including an even higher efficiency rating motor that reduces energy consumption by 2%.

Even in this most optimistic scenario the total estimated carbon footprint for an average 15t unit is 60,17 tCO_2e and the circularity rate is 77% (Figure 8). This calculation reduces the carbon footprint by 23% in comparison to today's product. More development needs to be done to achieve the 90% circularity rate and 50% carbon footprint reductions targeted in the MTS program.



	Materials	Manufacturing	Transportation	Maintanence	Use	Disposal
% contribution	17%	8%	14%	7%	54%	1,2 %
tCO2e	10,5	4,6	8,4	4,0	32,8	0,7

Figure 8 Carbon footprint calculations for a theoretical screening unit with major improvements (Appendix 1)

Achieving goals

Meeting the goals and targets set by the MTS program is not impossible. In the final scenario, all the steel used is 100% recycled or repurposed and 20% of non-steel materials are from circular sources. In the end-of-life phase, 97,5% of steel is repurposed or recycled and 95% of non-steel materials are repurposed or recycled.

Transportation emissions are reduced by 30% by using natural gas vehicles to transport products. Major reductions are achieved in the use phase by replacing the emissions of energy consumption with the average value of 100% wind power. This reduces the emissions of electricity by 97% compared to the European average. With these changes 90% circularity is achieved, and the carbon footprint could be reduced by up to 67%, resulting in a 22,94 tCO_2e footprint for the average 15t unit (Figure 9).

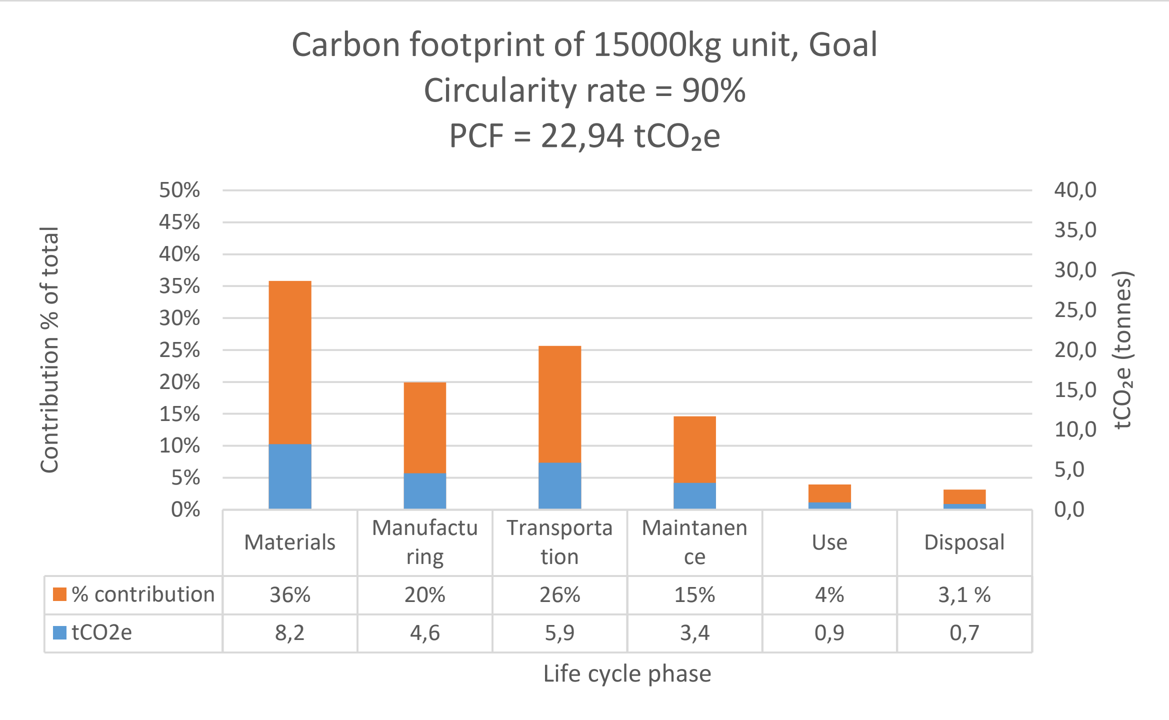


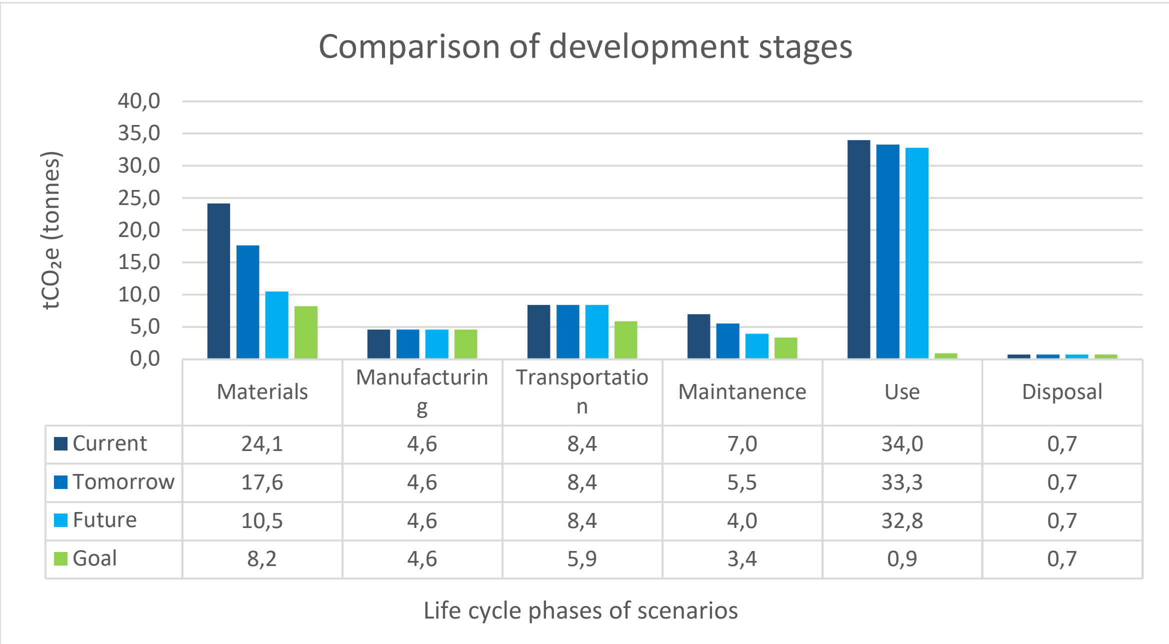
Figure 9 Carbon footprint calculations for a theoretical screening unit that meets the targets set by Sandvik (Appendix 1)

Comparing development

From this demonstrative setup, observation can be made on how different decisions may reduce the carbon footprint of a product (Figure 10). There is however still some uncertainty in phases that are more complex to evaluate. The manufacturing phase may have a significantly larger impact on a product's carbon footprint than evaluated in this demonstration. Transportation distances should also be calculated accurately, and manufacturing emissions should be measured on site to provide accurate data to re-evaluate the footprint.

The results of the goal scenario provide examples of issues in methodology and communication across extended product responsibility. Use phase emissions can be reduced significantly by the customer but are effectively beyond the control of the product provider. It is debatable whether the reductions of emissions achieved by customers' actions are part of producers' environmental impacts.

Carbon footprint also does not provide enough information to evaluate other sustainability issues or gains that would be achieved by reducing the demand on natural resources. One of these issues is rare earth magnet consumption in electric motor manufacturing. Consumption of rare earth elements increases worldwide due to a high demand for electric motors, which are a low emissions power source. (Yang et al. 2017, 125.)



	Materials	Manufacturing	Transportation	Maintanence	Use	Disposal
Current	24,1	4,6	8,4	7,0	34,0	0,7
Tomorrow	17,6	4,6	8,4	5,5	33,3	0,7
Future	10,5	4,6	8,4	4,0	32,8	0,7
Goal	8,2	4,6	5,9	3,4	0,9	0,7

Figure 10 A comparison of the carbon footprints of screening units in different scenarios (Appendix 1)

Conclusions

This demonstration can be used to determine which parts of a product's carbon footprint can be reduced and what data still needs to be gathered to make more accurate evaluations. Fairly accurate assumptions can already be made with the data available for material sourcing and electricity consumption.

Manufacturing phase evaluations are highly uncertain without accurate data from sites, and emissions may be significantly higher than what has been demonstrated. Maintenance and transportation also lack data and therefore yield highly uncertain results. The disposal phase is uncertain because it depends on customer activity. With the data currently available, achieving 90% circularity and 50% emissions reduction is highly unlikely for this type of unit without extensive research into materials and customer behaviour.

7.2 Largest sources of emissions

Based on the demonstrated carbon footprint for the average screening unit, the highest sources of emissions are material sourcing and electricity consumption in use. Material sourcing is relatively easy to solve by requesting a higher scrap percentage from steel material suppliers. Using 100% recycled scrap metal would effectively reduce emissions by up to 76% for an average unit's sourcing phase. The emissions related to non-steel materials are more complex. They have to withstand heavy wear, may be replaced frequently, and produce a higher carbon footprint since polymer-based materials are less recyclable.

Electricity consumption in the use phase may be the single highest source of emissions during a product's life cycle depending on the customer's needs. In the demonstration, the 15 000 hours of operation during the product's life cycle equalled 12 hours of daily operation for 5 years and produced 45% of all life cycle emissions. Reducing use phase emissions can be achieved by introducing more energy-efficient motors, but reductions achieved that way are minimal compared to a customer's decision to use purely wind-based electricity. A higher-efficiency motor may also be justified to reduce overall operating costs for the customer if the purchasing price is not significantly higher.

8 SUSTAINABILITY TRAINING

There are several key aspects to address in compiling sustainability training material for a company. Training should contain the principles of environmental sustainability as part of the TBL model, which acts as a basis for further development. Emphasizing the drivers of sustainable development is important, as it may be a crucial part of a company's competitiveness in the future. Comparing TBL principles with the company's own sustainability strategy may help identify possible deviations or complex issues that require more explanation to understand.

The creation of sustainability training material should follow the principles of human resources management methods. Utilizing various methods in sustainability training, such as mentoring and consulting, may provide more effective results. (Karim, Huda & Khan 2012, 147.)

Training should aim to provide employees with the capability to identify and address non-optimal practices based on the company's methods of measuring environmental sustainability. Used methods should be made clear in the training while openly discussing their possibilities and limitations. Training should acknowledge that means of measurement are imperfect and that methods will most likely be developed and refined over time. (Albareda-Tiana, Vidal-Raméntol, Pujol-Valls & Fernández-Morilla 2018, 16.)

Long-term goals are set in the company's strategy, and training should provide advice on how to move towards them by setting smaller goals. Small steps of improvement are easier to comprehend, and they help increase understanding of TBL principles. Setting the framework for sustainable development through strategy and training encourages employees to start evaluating their own daily practices and developing alternative solutions to improve TBL performance. Encouraging individuals in critical thinking and creativity may yield sustainable innovations in company operations. (Albareda-Tiana et.al. 2018, 5.)

9 CONCLUSIONS

The objectives of this thesis were to assess current environmental performance at Sandvik Mining and Rock Technology (SMRT), BU Stationary Crushing and Screening R&D, Stationary Screens and Feeders R&D team (Lahti), clarify how the company's sustainable development strategy affects the work of S&F R&D, and provide suggestions for how S&F R&D can do their part in achieving company goals. To fulfil these objectives, it was also necessary to clarify terminology and expand on what environmental sustainability means and the various ways it can be measured.

The environmental strategy introduced by Sandvik is a step towards improving environmental sustainability in all business areas of the company. However, there is still uncertainty in translating the strategy into practice and figuring out the next steps towards achieving the goals.

Environmental performance has already been improved by a variety of initiatives across all business areas. Initiatives include e.g. reduction of facility energy consumption and improved waste management. Improvements are mostly limited to a facility level and have not yet fully seeped into product development. Improvements have also been made in product manufacturing by researching circular business models. This research was done in the form of a master's thesis by Riccardo Losa from Lund University.

During this project, it was discovered that environmental education is needed to clarify how the Make the SH/FT program affects each department within the company. Providing education and clarification would require the company to decide which standards and methods to use in evaluating and tracking environmental sustainability. These standards and methods are key factors in successful sustainability development as they determine how different decisions affect results.

Deciding which methods to use can be a risk for the company due to the fact that there is currently no method in use that is internationally compatible between all supply chains. It seems that decision-making for methods is at a standstill around the globe, with many companies waiting for the announcement of a unified standard to follow. Despite the lack of clarification on methodology, studies can be carried out using screening methods. They will provide initial insight on product environmental impact as demonstrated in this study.

Research and development has a key role in reducing the environmental impact of business operations, as the decisions they make affect most parts of the product life cycle. Measuring the impact of decisions is difficult due to strict regulations on the quality of communication and requires collaboration with stakeholders across the product's life cycle. Engineers may have to be more involved beyond the traditional job description of providing manufacturing documents. In any case, design engineers should be aware of how different design approaches affect the environmental performance of the company.

The thesis presents improvement suggestions for research and development and for the entire company, as company policy determines the extent of measurement. Improvement suggestions are mostly intertwined. For example, measuring the carbon footprint of purchased materials is possible through training, but methodology needs to be established before training can happen. Before methodology can be established, compatible standards have to be declared, and the standards used depend on the participation of suppliers. This web can be challenging to unravel, but difficulty should not be used as an excuse to do nothing.

The company's current focus should be on reducing the uncertainty factors related to sustainable development. Knowledge gaps exist in all areas as the research on methods is incomplete and conveying an understanding of incomplete complex matters to employees poses major challenges. Training material was requested by management to provide training for all employees at the production site. The aim of the training was to clarify the complexity of environmental impact assessment and encourage participation in development by gathering promising ideas and initiative. Further training targeted at specific units and job descriptions is also required.

This thesis aims to provide the company with a better overall understanding of how to incorporate environmental sustainability into product development and the engineering phase. However, as this is a preliminary study of a complex subject, giving definitive answers is difficult. The thesis has revealed new questions the company must answer, thus providing multiple topics for further research. Topics include product carbon footprint calculation, product structure and analytics re-evaluation, stakeholder training, supply chain structure, viability of integrated measuring tools, manufacturing emissions inventory, database and partnership procurement needs, demand for low-carbon solutions, motor efficiency and alternatives and feasibility of remanufacturing.

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APPENDICES

Appendix 1 Emission calculations for a theoretical screening unit

Product Carbon Footprint of theoretical Screening machine

Carbon footprint of 15000kg unit

%	kg	Component	wearparts/lc	Life expectancy	Operation hours	Replacement frequency (operating hours)	Transport emissions (1)
67 %	10000	Frame		5 years	12 per day	3000 media	2,1 kg/km
20 %	3000	Mechanism			256 monthly	5000 wearplates	Low emission lorry (1)
4 %	600	Media	3072		3072 annually		1,47 kg/km
7 %	1000	Wearplates	3072		15360 lifetime		
3 %	400	motor 15kWh					Motor manufacturing emissions
							500kg/unit
100 %	15000	Total weight	21144	-> Steel 17072 81 %	Rubber 3672 17 %		

Operation	Operation	Operation	Wind power (6)	Transport emissions (1)	Steel recycled emissions savings (2)
15 kW rated	15 kW rated	15 kW rated	15	2,1	1,5 tCO2e/cst
50 % operating power	49 % operating power	48 % operating power	48 %		
7,5 kW input power	7,341 kW input power	7,23 kW input power	7,23	Low emission lorry (1)	Steel recyling emissions (3)
92,1 effiency (IE3)	93,9 effiency (IE4)	95,2 effiency (IE5)	95,2	1,47	0,0068 tCO2e/t
6,9 kW output power	**6,9 kW output power**	**6,9 kW output power**	**6,9**		
0,295 kgCO2 /kWh	0,295 kgCO2 /kWh	0,295 kgCO2 /kWh	0,0082	Motor manufacturing emissions	Rubber recycled emissions savings (4)
6,7968 tCO2e/y	6,65270784 tCO2e/y	6,5521152 tCO2e/y	0,18	500kg/unit	0,15 tCO2e/cst

Emissions of materials and manufacturing		Crude steel emissions	Rubber emissions	Transportation
		2 tCO2e/t	1,5 tCO2e/ t	4 tkm
Steel components	tonnes			
Frame	10	14 cst	0,6 media (t)	2,1 tCO2/tkm
Mechainsm	3			
Wearplates	1	0,1 Machinery factor	0,1 Machinery factor	
	14 total	30,8 total	0,99 total	8,4 total

Screening Lifecycle assessment

	steel	rubber
in - Circularity	25 %	2,6 %
Recovery	97,5 %	0,0 %
Daily runtime (h)		12

Carbon footprint of 15000kg unit
Circularity rate = 51%
PCF = 78,04 tCO_2e

Current

	Materials	Manufacturing (5)	Transportation	Maintanence	Use	Disposal
	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
steel	22,75		8,4	5,6064	33,984	
rubber	0,87894			1,350035		0,71609
std comps	0,5					
	Materials	Manufacturing	Transportation	Maintanence	Use	Disposal
tCO_2e	24,1	4,6	8,4	7,0	34,0	0,7
% contribution	31 %	6 %	11 %	9 %	44 %	0,9 %

Circularity rate =	
51 %	
PCF =	tCO_2e
78,04	
change	0 %

Screening Lifecycle assessment

	steel	rubber
in - Circularity	56 %	2,6 %
Recovery	97,5 %	0,0 %
Daily runtime (h)		12

Carbon footprint of 15000kg unit
Circularity rate = 63%
PCF = 69,38 tCO_2e

Tomorrow

	Materials	Manufacturing (5)	Transportation	Maintanence	Use	Disposal
	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
steel	16,24		8,4	4,17792	33,263539	
rubber	0,87894			1,350035		0,71609
std comps	0,5					
	Materials	Manufacturing	Transportation	Maintanence	Use	Disposal
tCO_2e	17,6	4,6	8,4	5,5	33,3	0,7
% contribution	25 %	7 %	12 %	8 %	48 %	1,0 %

Circularity rate =	
63 %	
PCF =	tCO_2e
69,38	
change	-11 %

Screening Lifecycle assessment

	steel	rubber
in - Circularity	90,0 %	2,6 %
Recovery	97,5 %	0,0 %
Daily runtime (h)		12

Future

	Materials	Manufacturing (5)	Transportation	Maintanence	Use	Disposal
	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
steel	9,1		8,4	2,6112	32,760576	
rubber	0,87894			1,350035		0,71609
std comps	0,5					
	Materials	Manufacturing	Transportation	Maintanence	Use	Disposal
tCO_2e	10,5	4,6	8,4	4,0	32,8	0,7
% contribution	17 %	8 %	14 %	7 %	54 %	1,2 %

Carbon footprint of 15000kg unit
Circularity rate = 77%
PCF = 60,17 tCO_2e

Circularity rate = 77 %

PCF =	tCO_2e
60,17	
change	-23 %

Screening Lifecycle assessment

	steel	rubber
in - Circularity	100,0 %	20,0 %
Recovery	97,5 %	95,0 %
Daily runtime (h)		12

Goal

	Materials	Manufacturing (5)	Transportation	Maintanence	Use	Disposal
	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
steel	7		5,88	2,1504	0,910633	
rubber	0,72234			1,205712		0,71609
std comps	0,5					
	Materials	Manufacturing	Transportation	Maintanence	Use	Disposal
tCO_2e	8,2	4,6	5,9	3,4	0,9	0,7
% contribution	36 %	20 %	26 %	15 %	4 %	3,1 %

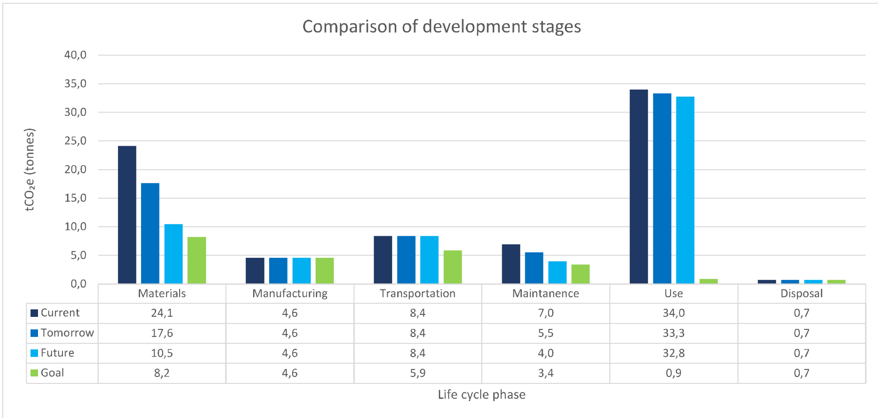
Carbon footprint of 15000kg unit
Circularity rate = 90%
PCF = 22,94 tCO_2e

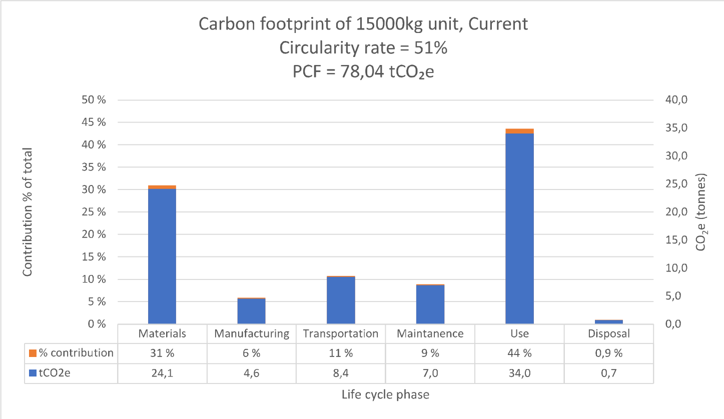
Circularity rate = 90 %

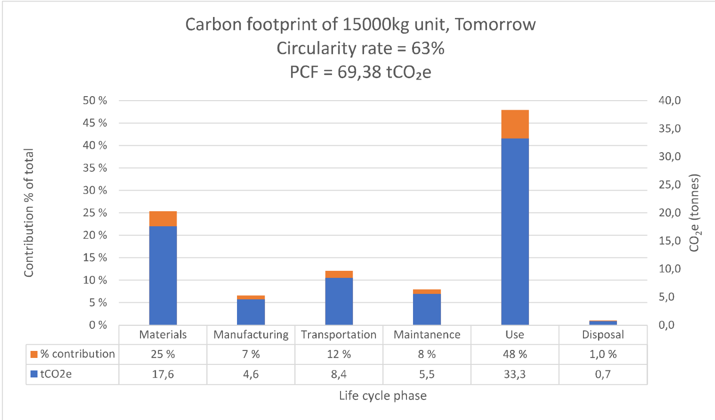
PCF =	tCO_2e
22,94	
change	-67 %

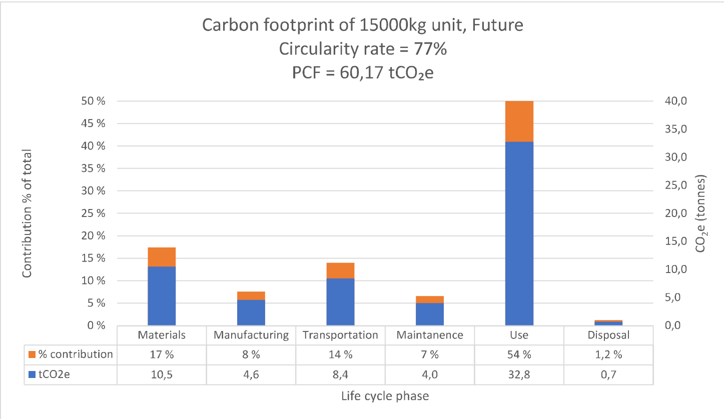
Comparison

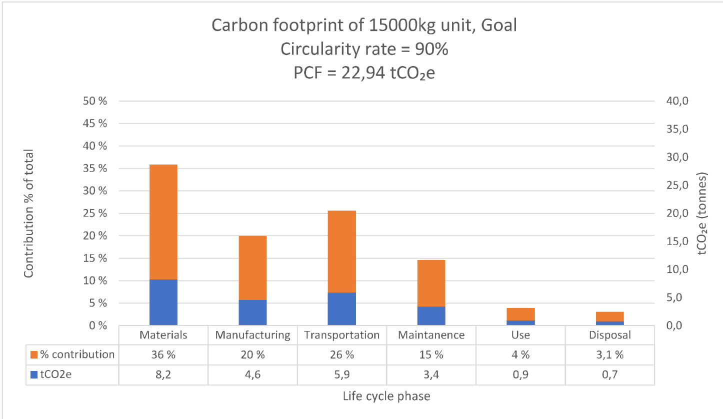
	Current	Tomorrow	Future	Goal
Materials	24,1	17,6	10,5	8,2
Manufacturing	4,6	4,6	4,6	4,6
Transportation	8,4	8,4	8,4	5,9
Maintanence	7,0	5,5	4,0	3,4
Use	34,0	33,3	32,8	0,9
Disposal	0,7	0,7	0,7	0,7











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