Assessing Environmental Performance of a Circular Business Model using Business Model Life Cycle Assessment

A Case Study of a Sharing Service for Power Tools

Master's Thesis in Industrial Ecology & Management and Economics of Innovation

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Abstract

Climate change is becoming more and more inevitable and the pressure to act is higher than ever. While facing a growing world population and increasing consumption, production, and consumption patterns must become more sustainable. To counteract climate change, there is a need for business models that separate resource use and economic profit. One such type of model is the circular business model. By looping the resources in a non-finite system characterized by reuse and recycling, we can achieve decoupling.

Circular business models can however be difficult to quantify and thus the actual climate impact compared to a linear counterpart becomes difficult to estimate in many cases. LCA is a tool that has been used in recent years to calculate the climate impact of a product's total life cycle. To apply this measurement method to an entire business model, BM-LCA was developed, which includes the use phase in the calculation and then relates the environmental impact to the profit. In this study, a BM-LCA is conducted on a case company that provides a subscription-sharing service for power tools. The BM-LCA is focused on one of the products, a percussion drill, and the locker depot holding all the tools. The method of the study consisted of information-gathering meetings with the case company as well as a literature study of relevant theory.

It was found that the locker depot had a significant environmental impact and that a change in its material would have a significant effect on the emissions per profit. Additionally, the lifetime of the product was found to be significant as well as the user behavior which was found to be hard to estimate. Lastly, it was concluded that the BM-LCA did highlight valuable hot spots in the business model and that some changes could have a large impact on the final climate footprint of the product service offering. The study resulted in the following recommendations for the case company: *Increase the lifetime of the product, reduce the weight and consider another material for the locker depot, increase the number of subscribers, consider partnerships with other actors in the ecosystem, lobby for a change in consumer behavior and consider how the inconveniences related to sharing can be overcome.*

Keywords: BM-LCA, circular economy, circular business models, consumption, sharing economy, business model assessment, life cycle assessment, product-service-system, production

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Frida Holzhausen & Linn Troedsson, Gothenburg, June 2023

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BM-LCA	Business Model Life Cycle Assessment
BF-BOF	Blast Furnace-Basic Oxygen Furnace
DRI-EAF	Direct Reduced Iron-Electric Arc Furnace
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
Scrap-EAF	Scrap-Electric Arc Furnace
SDG	Sustainable Development Goals
PSS	Product Service System

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1 Introduction

The world is facing increased environmental crises due to climate change and the UN states that action needs to be taken across the globe to prevent global warming. In 2021, energy-related CO2-emissions increased by the highest level up to now of 6% and temperatures continued to rise unreduced resulting in more extreme weather (United Nations, 2022).

In order to tackle social, economic, and environmental threats to the earth and humanity, the United Nations formulated 17 goals where Climate Action is one (United Nations, 2022). Goal 12, Climate Action, is about ensuring sustainable consumption and production patterns, which is key to sustaining the livelihoods of current and future generations (United Nations, 2023). Unsustainable patterns of consumption and production are root causes of the triple planetary crises of climate change, biodiversity loss, and pollution. These crises, and related environmental degradation, threaten human well-being and achievement of the Sustainable Development Goals (United Nations, 2023). Governments and all citizens should work together to improve resource efficiency, reduce waste and pollution, and shape a new circular economy (United Nations, 2023).

Extraction and processing of resources make up 90% of biodiversity loss and water stress, 50% of total greenhouse gas emissions, and a third of health effects caused by particulates (The European Commission, 2020a; Johansson, 2021). In order to mitigate climate change, environmental degradation needs to be decoupled from economic growth (OECD, 2002) and a shift towards a circular economy would result in lower climate impact (Ellen MacArthur Foundation, 2019). With a growing population, unsustainable consumption and production practices represent a major challenge (Martin et al., 2021) While consumers are typically seen as playing a crucial role in making sustainable choices, the focus has shifted to highlight the potential for companies to reduce their environmental impact through more efficient production methods and innovative business models that offer alternatives to traditional products sales (Martin et al., 2021).

1.1 Aim

This report aims to explore a circular business model consisting of a product service system for renting appliances. It will also discuss the potential use of BM-LCA and evaluate the method and the implications it may have for circular companies and stakeholders.

1.2 Background

1.2.1 Decoupling

If companies keep the resources in use they can decouple economic profit from the consumption of raw materials (Ellen MacArthur Foundation, 2019). This decoupling would mean that the bond between environmental degradation and economic growth would be broken (OECD, 2002) and the Gross Domestic Product (GDP) would thus increase without an increasing environmental impact (Ward et al., 2016). Decoupling can be either absolute or relative, where absolute decoupling refers to the state where the environmental impact is stable and the economic growth is positive while relative decoupling is when the environmental impact is increasing but not at as high a rate as the economic growth (OECD, 2002). In order to achieve this decoupling, consumption and production patterns need to be changed by for example introducing more efficient resource use (OECD, 2002).

1.2.2 Circular Economy

A shift towards a circular economy is a vital part of reaching the climate targets (Ellen MacArthur Foundation, 2019). The concept of circular economy has gained popularity in recent years from both government and companies and is characterized by the determination of maximizing the use of materials and resources, minimizing the social and environmental impacts and avoiding natural resource depletion (Bocken et al., 2018). The concept means implementation of three dimensions; designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen MacArthur Foundation, 2019). In a The circular economy, waste is thus designed out of the supply chain and the materials are kept in use instead (Ellen MacArthur Foundation, 2019). The circular economy is supported by the transition towards sustainable energy and the increasing use of renewable materials and the aim is to decouple economic growth from the consumption of natural resources (Ellen MacArthur Foundation, 2019). The financial sector and public sector have a role in scaling the transition to a circular economy through their control of financial means and regulatory frameworks (Ellen MacArthur Foundation, 2020).

1.2.2.1 The R:s of circular economy

The concept of circular economy has become increasingly popular among scholars and professionals and the concept is typically depicted with the 4R framework that covers activities related to 'Reduce', 'Reuse' and 'Recycle' (Kirchherr et al., 2017). Further, frameworks that expand on the 4R framework have been proposed, including the 6R framework and the 9R framework. The framework is a hierarchical approach, with three individual hierarchical approaches for closing the material loops, and takes an economic and systemic perspective on circular economy (Kirchherr et al., 2017). EU:s categories for circular projects are related to and contribute to activities related to the 9R model (The European Commission, 2020b). However, it is acknowledged that not all projects that relate to the 9R strategies are circular (The European Commission, 2020b). The different stages in the model are described in Table 1.1.

Table 1.1: The 9R Model

Stage	**Description**
Refuse	Discontinue a product's use by either abandoning its function or replacing it with a completely different (e.g., digital) product or service.
Rethink	Explore alternative methods of product utilization to increase its intensity of use, such as implementing product-as-a-service models, reusing and sharing models, or offering multi-functional products.
Reduce	Enhance the efficiency of a product's manufacturing or usage by consuming fewer natural resources and materials throughout its entire lifecycle.
Reuse	Extend the lifespan of a functional product by reusing it for the same purpose for which it was initially conceived and designed, provided it is still in good condition and not considered waste.
Repair	Restore the functionality of a defective product through repair and maintenance, allowing it to continue to be used for its original intended purpose.
Refurbish	Bring an old or outdated product up to current quality standards through restoration and renovation.
Remanufacture	Utilize parts of a discarded product to create a new product with the same function and condition as if it were new.
Repurpose	Use parts of a redundant product in a new product with a different function, allowing for extended product utilization and minimizing waste.
Recycle	Recover materials from waste and reprocess them into new products or substances, either for their original purpose or for other uses, excluding energy recovery and reprocessing materials for use as fuels or backfilling.

1.2.2.2 The RESOLVE Framework

The RESOLVE framework is a tool that describes different circular strategies by categorizing them into six business models: Regenerate, Share, Optimize, Loop, Visualize, and Exchange which are presented in Table 1.2 (McKinsey & Company, 2015b).

Regenerate is about the transition towards renewable materials and energy, share

Table 1.2: The RESOLVE Framework (Horvath et al., 2019)

Stage	Description
Regenerate	• Use sustainable resources and materials • Retain, restore, and reclaim ecosystems • Return recovered biological resources to the biosphere in order to restore ecosystem health
Share	• Share assets (eg. cars, rooms, appliances) • Reuse • Prolong life through maintenance, design for durability, upgradability etc
Optimize	• Increase performance/efficiency of product • Remove waste in supply chain • Leverage big data, automation, remote sensing and steering
Loop	• Remanufacture products or components • Recycle materials
Virtualize	• Use digital technologies to dematerialise d
Exchange	• Replace old with advanced non-renewable materials • Apply new technologies (eg. 3D printing)

means to reuse and share products and optimize is about increasing the efficiency of a product (McKinsey & Company, 2015b). To loop implies the remanufacturing of products and recycling of materials (McKinsey & Company, 2015b). Virtualize is about delivering utility in a virtual way while exchange circles around replacing old materials with advanced non-renewables as well as introducing new technologies in manufacturing (McKinsey & Company, 2015b).

1.2.2.3 Circular Economy in the EU

The new circular economy action plan, adopted by The European Commission in 2020, constitutes one of the building blocks of Europe's agenda for sustainable growth. The package of policies is summarized in the European Green Deal and was approved in 2020. The Green Deal outlines a strategy for achieving a resource-efficient, climate-neutral, and competitive economy, and circular economy is considered to be among the most critical areas for achieving climate neutrality and ensuring competitiveness within the EU (The European Commission, 2020b).

The transition to a circular economy across the EU has the potential to create around 700 000 new jobs and increase the EU:s GDP by 0.5% by 2030. For the individual firm, adopting a closed-loop model can shelter from resource price fluctuations and increase profitability. This is especially relevant for manufacturing companies, that on average spend about 40% on materials (The European Commission, 2020a).

An implementation of a circular economy would have multiple benefits for Europe, both social, economic, and environmental (McKinsey & Company, 2015a). Resource productivity could increase by 3% annually which would result in a primary resource benefit of €0.6 trillion per year by 2030, as well as €1.2 trillion in non-resource and externality benefits (McKinsey & Company, 2015a). McKinsey & Company further states that the Gross Domestic Product (GDP) for Europe could increase by seven percentage points and that job opportunities would increase. The implementation of a circular economy would also result in lower costs for mobility, food, and built environment (McKinsey & Company, 2015a).

The Circular Economy Action Plan builds on circular economy actions and presents an agenda that aims to accelerate the transformation, outlined by the European Green Deal. The action plan presents more than 150 measures that address the critical challenges of accelerating the circular economy (Johansson, 2021). The focus has shifted from waste management to establishing a market for consumers that receive and use secondary products and resources. This entails ensuring access to reuse and repair services, as well as implementing design requirements for circularity, standardization, and reducing complexity (Johansson, 2021).

To understand the development of elements of the circular economy over time, it is crucial to monitor key trends, progress and patterns in the transition toward a circular economy (The European Commission, 2018). Monitoring serves as a foundation for setting new priorities and assessing the effectiveness of actions taken toward the long-term goal of a circular economy. The European Commission (2018) has developed a monitoring framework that covers dimensions of the stages of the life cycles of products, services, and resources. The stages include (1) production and consumption, (2) waste management, (3) secondary raw materials and (4) competitiveness and innovation. In addition, The Bellagio Declaration, is developed through a collaboration between ISPRA and EEA, and outlines principles for monitoring the transition to a circular economy. The declaration is aligned with the implementation of the European Green Deal and the Circular Economy Action Plan.

1.2.3 Circular Economy Business Models

In order to combat climate change, the whole economy needs to change fundamentally and the way value is created needs to shift from today's take-waste-disposal system to a system where value comes from regeneration and restoration (Ellen MacArthur Foundation, 2019). Business models have traditionally been linear and the value of the product has been lost after being used (Centobelli et al., 2020). Circular economy business models have three dimensions; value creation, value transfer, and value capture, (Centobelli et al., 2020) and the aim is to slow down and close material loops (Bocken et al., 2018). In a circular economy, value creation focuses on benefits for the whole society (Ellen MacArthur Foundation, 2019). One specific sustainable business model included in the circular economy is the product-service system (Bocken et al., 2018).

The Value Hill framework is developed as a result of a demand for circular business models and strategies and provides a tool for companies that wish to position their business and develop a strategy that aligns with a circular context (Achterberg et al., 2016). The model is used as a guidance to identify projects that can contribute to the circular economy as part of the implementation of the European Green Deal and the Circular Economy Action Plan (The European Commission, 2020b). The model illustrates the process of adding value uphill through circular strategies and keeping products for as long as possible, in contrast to the linear scenario of destroying value downhill (Achterberg et al., 2016). This emphasizes the importance of developing long-lived products that can be maintained and repaired, for the purpose of slowing resource loops.

1.2.4 Product as a Service

Product as a service (PSS) implies a shift in business paradigm from selling specific products to delivering a function, through a mix of products and services, thereby incentivizing resource efficiency as well as user satisfaction (Kjaer et al., 2016; Tukker, 2004). By increasing availability, while reducing the number of products on the market, it is possible to extend the usage time and reduce the amount of resources that would be needed for additional production to meet the demand for additional products (Martin et al., 2021). Strategies that have the potential to lower the environmental impact of a PSS are summarized in Table 1.3. In a PSS system, the ownership stays with the provider, and the product is made available for the customer through
i) product lease,
ii) product renting/sharing,
iii) or product pooling (Tukker, 2004).

Renting, sharing and pooling allow for products to be more intensively used and the impact reductions are particularly high in the case of the production being the main phase causing environmental degradation (Tukker, 2004). It is however important to note that not all product service systems will reduce environmental impact and a holistic perspective that quantifies the environmental performance of product service systems compared to conventional systems is needed (Kjaer et al., 2016).

Table 1.3: Strategies that have the potential to lower the environmental impact of a PSS (Kjaer et al., 2016).

Type of PSS	Environmental Strategy
Product-oriented systems	• Supporting efficient use of the product • Extending the lifetime of the product • Reducing waste and optimizing end-of-life processes
Use-oriented systems	• Increasing the utilization of products • Promoting the implementation of clean technology • Implementing strategies on the demand side in order to reduce resource consumption, such as material efficiency services.

1.2.5 Life Cycle Assessment

A life cycle assessment (LCA) is a comparative analysis and assessment of ecological burdens and the impact on human health of products, processes, and activities through a complete life cycle of a product (Klöpffer, 2014). The method accounts for all steps using the lifecycle of a product, including extraction of raw materials, production of materials, components, and products, as well as operation and finally recycling and managing the waste of the product (Klöpffer, 2014). The 'cradle-to-grave'-perspective enables the assessment of the entire system from which products are derived and allows comparing different product systems, or 'functional units', which are goods or services that fulfill the same or similar functions (Klöpffer, 2014). The method can be used for decision support and guide decisions regarding process optimization, supply chain management, or eco-designs (Zhang et al., 2018).

When conducting an LCA, the whole product system is assessed (Baumann and Tillman, 2004). It is typically conducted on an individual product system and the combination of product and service inputs that constitute a product-service system makes the use of LCA to evaluate such systems challenging (Kjaer et al., 2016). In addition, Böckin et al. (2020) highlight that the conventional LCA fails to account for economic aspects, which would be useful for companies that wish to make decisions which are both environmentally and economically grounded (Böckin et al., 2020)). In addition, studies that aim to address business models mainly account for value creation and delivery activities, which translates to resource efficiency and circular measures, rather than examining the environmental impact of the business model strategy.

1.2.6 Business Model Life Cycle Assessment

Business model life cycle assessment (BM-LCA) is a newly developed method that expands on the conventional method for LCA and quantifies the environmental impact of a business model by including the economic performance as a functional unit (Böckin et al., 2022). The method provides opportunities to further develop the LCA with business competitive advantage by coupling the environmental flows with the monetary. Moreover, Böckin et al. (2022) state that the development of BM-LCA is based on the realization that LCA does not include the impact from the entire business model and thus misses what is not connected to the product itself. BM-LCA thus becomes an overall assessment for the entire business model; both economically and environmentally.

1.2.7 User Behaviour and Customer Acceptance

The environmental performance of a product service systems depends on the user behaviour to a large extent (Mont, 2004) and changes in customer behaviour represent a challenge when evaluating the environmental performance of a product-service system, making comparison of the situation before and after implementation difficult (Goedkoop, 1999). For instance, product lease may lead to less responsible use and sharing can lead to higher environmental impact if the impact is mainly related to the use of the product (Tukker, 2004). This can be compared to renting, which discourages usage through the cost that the customer has to pay for using the product. The uncertainties when evaluating the environmental performance of a product service system are further stressed by Martin (2018), who points out that there is a lack of studies that review behaviour changes that follow the increasing implementation of sharing services.

Successful implementation depends on user acceptance, and potentially induced rebound effects (Kjaer et al., 2016). This is further highlighted by Rexfelt and Hiort Af Ornäs (2009), illustrating that the socio-cultural setting represents an important factor when it comes to customer acceptance and illustrating that a product-service system may have unexpected effects on other products systems (Goedkoop, 1999). Rexfelt and Hiort Af Ornäs (2009) points out that there are a number of preconditions to consider when designing a PSS for customer acceptance. First, the solution should provide an advantage relative alternative solutions. This require knowledge about the customer groups and how the PSS will affect their lives and habits. Second, how the customer perceives the the PSS will affect the acceptance and adoption. Communication is important and motives, competency and intentions should be clear. Third, the strategy should be flexible enough to allow for changes in customer preferences and needs. The authors further stress the importance of prototyping and testing the business model at an early stage in order to gain insights from customers and to understand customer needs. In addition, the alternatives to adopting the PSS should always be considered.

A study on sharing services in Sweden, by Hunka and Habibi (2023), conclude that the concept of sharing is a niche market in a system that is dominated by sole ownership of physical product. Their study highlight a number of factors that will determine the success of sharing services. First of all, the demand for a sharing service is mainly determined by price and the authors conclude that a subscription fee above 129 SEK implies a sharp drop of customers. However, the loss of customers are assumed to be higher in the range between 49 SEK and 129 SEK and lower in the range above 129 SEK. The second most important factor that determines the demand is the distance to the sharing point. The optimal location will depend on its content and a sharing housing and garden tools can be attractive for customers that live in neighborhoods with smaller gardens. Also, inconveniences related to sharing instead of owning can be accepted if this is reflected in the subscription fee. These include distance to sharing point, booking in advance and time limits. Beyond this, accounting for the entire business ecosystem, such as manufacturers, service providers, insurance companies, as well as repair and maintenance companies, is suggested. In addition, this approach has an effect on financial risk and validation of the business model. Lastly, understanding customer preferences is described as vital for successful implementation of sharing services.

A similar study has been conducted on a sharing service for renting power tools in Sweden (Martin et al., 2021). The study concludes that the environmental impact is highly dependent on user transportation, emphasizing the risk of transportation-related emissions outweighing the potential environmental benefits of product sharing. This highlights the importance of considering the broader customer system and user behaviour. As suggested by Hunka and Habibi (2023), the authors emphasize that the location of the sharing point represents an important consideration.

1.2.8 Conclusion of background

According to the review, the assessment of business model environmental performance is an area that is not as well-developed as the assessment of product or function environmental impact. The most used tools for evaluating environmental performance do not include economic measures. Furthermore, assessments of business models' environmental impact often focus on the functional or societal perspective, neglecting the implications for the companies themselves.

Given the rising market for sharing services, it would be appropriate to conduct a study on business model environmental performance for such a case. Such a study could make use of existing product LCAs and investigate the feasibility and usability of a tool known as BM-LCA, which was developed specifically for assessing business model environmental performance. This tool might be useful from a company perspective but has only been tested on a few cases so far. Therefore, there is a need to conduct further BM-LCAs on more cases and evaluate its effectiveness.

As circular economy business models become more popular, there is a need to evaluate the actual environmental benefits compared to linear models. To do this, it is necessary to investigate the total environmental load for a product in a business model as well as the economic implications. The success of a product-service system depends, to a large extent, on customer acceptance, which is determined by sociocultural factors. In addition, the environmental load of user behavior that follows the implementation of a product-service system remains uncertain.

2

Method

The aim of the study is, as mentioned in the introduction, to evaluate a specific circular business model. This will be done by exploring the environmental performance in relation to financial values. Since quantification of circularity is difficult, this study will be using a new tool developed specifically for this. This tool is called BM-LCA and will be presented further below.

This chapter describes the method used in the study. It begins with an overview of the research strategy and the used materials, followed by an explanation of the BM-LCA and the implementation of the used LCA methodology respectively. Lastly, ethical issues and considerations are covered.

2.1 Research strategy

The study is done through a combination of quantitative and qualitative research methods.

A literature review on related and relevant subjects, e.g. circular business models and user behavior, was initially pursued. This part covered an examination of existing research on relative subjects, as well as theories and concepts, in order to gain knowledge on the field and to be able to evaluate the BM-LCA tool in relation to the current situation for circularity. Online databases were used as a source for academic journals, which could be identified using relevant keywords. Further, additional literature was identified through following up citations.

A case study was conducted on a company pursuing a circular business model applied on a sharing service. More specifically, the business model is to provide a locker depot with power tools to either the public or a specific group with users paying a subscription fee. For this study, one product was chosen to be investigated: a percussion drill. Data was extracted through a quantitative approach and additional qualitative elements were collected through information-gathering meetings with the company. Additional data was gathered from credible websites. The study was followed by a sensitivity analysis where different scenarios and parameters were investigated, with the purpose of identifying areas of improvement. First, different scenarios related to the product and the physical sharing infrastructure were analysed. Second, financial parameters were analysed. The results of the sensitivity analysis and their implications were then discussed and reflected upon. The study can be argued to take an interpretive approach, where knowledge is developed through an iterative process of moving between theory and empirical phenomena.

2.2 BM-LCA

A BM-LCA will be conducted on the business model for renting out tools. The assessment will be based on the method for BM-LCA presented in the article "Business model life cycle assessment: A method for analyzing the environmental performance of business" by Böckin et al. (2022). The steps of the methodology are presented in Table 2.1.

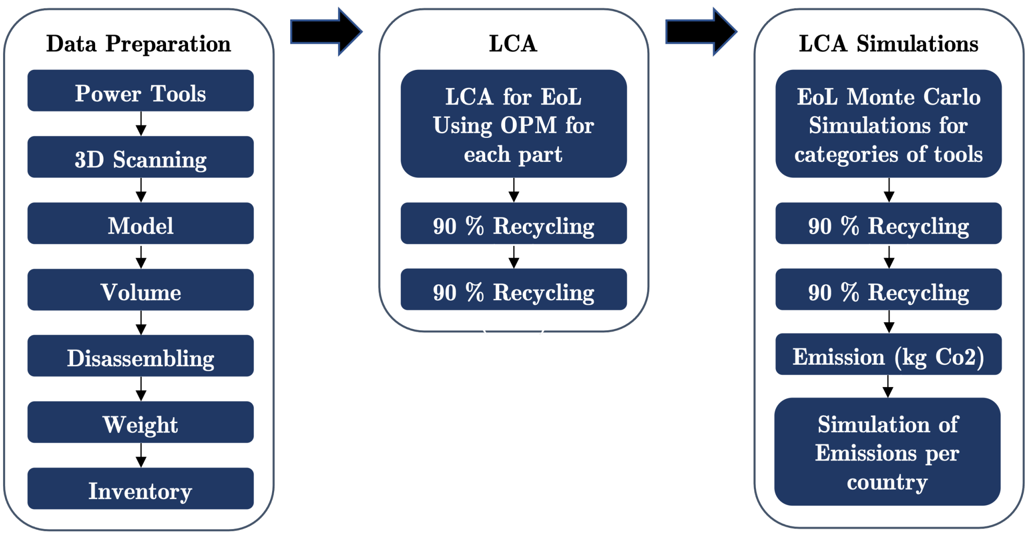
Table 2.1: Business Model LCA (Böckin et al., 2022)

Phase	**Description of each step**
Goal and Scope: Descriptive phase	Give a general description of the setup of each business model to be compared and of the related product(s) and state the relevant time period.
	Define system boundaries and environmental impact categories of the assessment. Map actors in the product chain.
	Find the connection of how the amount of production, q, depends on the number of transactions, t, for each business model.
Goal and Scope: Coupling phase	Step 1: Define the functional unit as the profit, π, that each business model must achieve.
	Step 2: Identify all of the business' costs and revenues associated with running of of the business models for the stated period. Find conversion factors, f, to couple costs and revenues to customer transactions, t. Set up an equation for the profit as revenues minus costs: $$\pi = f_{\text{revenue}} \times t - f_{\text{direct}} \times t - f_{\text{indirect}} \times t - f_{\text{contingent}} \times t \quad (2.1)$$
	Step 3: Solve the equations to find the transactions, t, required to reach the profit. Derive the required amount of production, q.
	Step 4: Repeat steps 2 and 3 for every business model to be compared.
Life Cycle Inventory	Construct a system model and quantify all environmentally relevant flows, scaled according to the functional unit.
Life Cycle Impact Assessment	Aggregate all the flows from LCI and quantify their effects on the chosen environmental impact categories.
Interpretation	Analyse of the results and scrutinize their robustness to identify the pros and cons of compared business models.

2.3 The volumetric method

The life cycle inventory (LCI) analysis presented in this study is derived from a prior LCA investigation, as reported by Sovják et al. (2022) in the article titled "Volumetric Method for Determining kg CO_2 eq- and Energy Requirements for the Production of Power Tools at an Early Stage of Product Design". The report evaluates the environmental impact of power tools by estimating energy consumption and emissions from material production to end-of-life disposal, utilizing volumetric product properties as the key metric. The volume was determined using 3D scanning and the LCA method is based on the Oil Point Method. An overview of the method can be seen in Figure 2.1. The method accounts for the environmental impact of the phases of the life cycle, including the production of materials, manufacturing, transportation, and end-of-life. The transportation phase of the transport was carried out at intervals by truck, van, and ship. In addition, the amount of packing material is estimated based on product volume and is expected to consist of cardboard and PE foil. The findings of the aforementioned LCA study served as a fundamental input to the LCI analysis conducted in this research.

Figure 2.1: The Volumetric LCA Method (Sovják et al., 2022).



2.4 Ethical considerations

In order to take ethics into account, an open discussion was continuously held with the company about the possibility to control what numbers that are included in the report. Moreover, the name of the company is excluded from the report in order to keep it anonymous. Beyond this, transparency was applied throughout the work process to achieve reliability and facilitate the reproduction of the results. The work process is represented trough out the different parts of the report and the methodological choices are well described. The results are presented in a clear and methodical manner to promote validity.

3

BM-LCA of a product sharing service

The case covers one product in a sharing locker depot; a percussion drill. The assessment is limited to looking at the scenario of an established box with a realistic number of users for a successful box.

3.1 Goal and scope: Descriptive phase

The descriptive phase includes defining the purpose, the business model, as well as the environmental impact category and system boundaries (Böckin et al., 2022). Some estimations are based on the assessment of the environmental performance of Husqvarna's rental lockers for renting tools, carried out by Martin et al. (2021).

3.1.1 Description of the business model and associated products

The case covers a use-oriented product service system, offering a sharing service for products. The products offered are typically considered to be under-used goods, including but not limited to gardening and power tools, as well as kitchen and household tools. The users get access to the service through a monthly subscription to a sharing locker depot, which is located in a public or private space geographically close to the users. The sharing point is strategically placed to ensure that walking is used as means of transportation. The subscription includes access to the products, as well as insurance and maintenance of products. As an alternative, the box can be provided by the landlord or the tenant owners' association ("bostadsrättsförening" in Swedish). In such cases, an upfront cost is paid along with an annual subscription fee, which is paid as an advance payment for each year. In contrast to a linear business model, the business model allows for products to be available to and used by multiple users. A simplified illustration of the business model can be seen in Figure 3.1.

Figure 3.1: The business model

The study will focus on a percussion drill, which is one of the products offered. The product is part of the product-sharing system with a profit-sharing agreement between the company and the manufacturer. The company in the study does thus not own the products but mediates these between the manufacturer and the users through the sharing model. New production is only required when the product needs to be replaced in the box.

3.1.2 System boundaries

The system boundaries for the business model are visualized in Figure 3.2 where all the stages of the product's life cycle are presented as well as the related sharing infrastructure consisting of the locker depot and mobile app. Figure 3.3 gives a more detailed view and indicates how the products are connected with the business models and where the transactions occur.

Figure 3.2: System boundaries

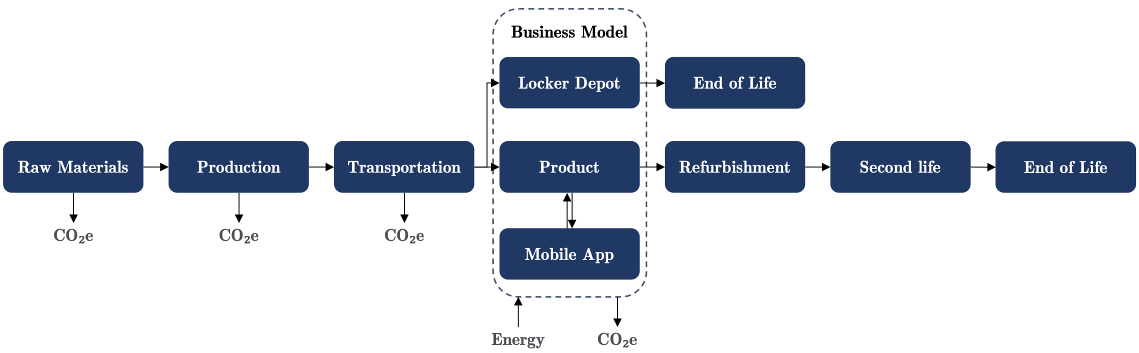
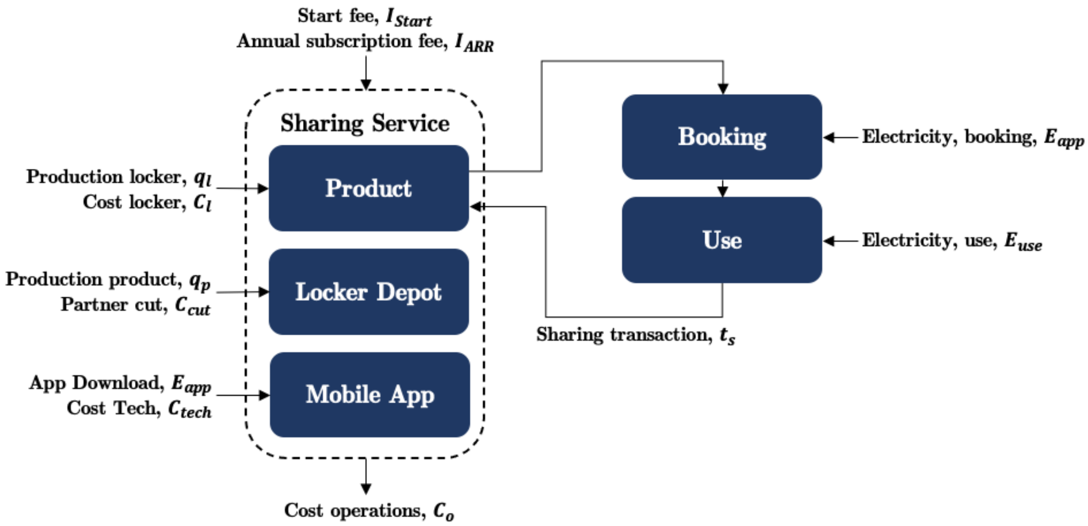


Figure 3.3: Overview of transactions



The environmental parameters encompass the entire life cycle of the product system from the extraction and refining of raw materials to the end-of-life management. The processes further include component manufacturing, assembly, packaging, and transportation to the box. The study is limited to the Swedish market where the company is operating.

3.1.3 Impact category

The study is limited to greenhouse gas emissions and will thus only look at the impact category climate change, by calculating the accumulated carbon dioxide equivalents (CO_2e). It is thus a green footprint study looking at the contribution to climate change. To calculate the CO_2e, the contribution from each phase of the product and the use is accumulated into a final value for the whole life cycle in the business model.

3.2 Goal and scope: coupling phase

To allow environmental comparison of business models, while taking the function of the business model into account, an economic basis of comparison is needed (Böckin et al., 2022). Coupling the profit-based functional unit with the product system allows for quantitative environmental assessment and comparison of business models (Böckin et al., 2022). To make business models comparable, while taking the function of the business model into account, an economic basis of comparison is needed. The functional unit for the study is the net profit allocated to the selected product in the locker depot during the business period corresponding to one year.

The company offers a wide range of products and financials are not necessarily allocated to individual products, but cover the entire collection of products offered in a locker depot. The study will focus on one specific product and the financials will be allocated to a common cost pool. The financials will be attributed to the specific product based on an allocation key. The allocation key is based on the company's cost of holding the specific product, known as the holding cost, which includes storage, insurance, and financing. The cost of holding the specific product covered in this study is given by the company that estimated to be 3.5% of the cost of holding all products in the locker depot.

3.2.1 Costs and revenues associated with running the business

Revenues

The company aims to have 140 subscribers per box, each paying a monthly subscription fee amounting to 120 000 per year in total. An upfront cost is paid along with the first annual subscription fee, which is paid as an advance payment. The customer is expected to keep the locker depot for five years and the upfront cost is allocated over this period of time. Although this may not be in accordance with accounting standards, it is being performed with the purpose of encompassing all revenues within a broader analysis. All revenues are indirect revenues, and can only be allocated to the specific product with the 3.5% allocation key. The revenues are summarised in Table 3.1.

Table 3.1: Revenues associated with running the business

	Entire box (SEK)	Allocated (SEK)
Revenues		
Start fee	4 000	140
Annual recurring revenue	120 000	4 200
Total	124 000	4 340

Costs

The direct cost connected to the product is the amount of the cut paid to the producer of the product, corresponding to 40% of the revenues allocated to the product. The indirect costs are the costs that will be allocated from the common cost pool. These costs include procurement of the box, maintenance of the products, and locker depot, as well as IT and overhead. The depreciation period for the box is five years, although the expected lifetime is ten years. The costs are summarised in Table 3.2.

Table 3.2: Costs associated with running the business

	Entire box (SEK)	Allocated (SEK)
Costs		
Partner cut	- 48 000	- 1 680
Box	- 6 000	- 210
Operations	- 18 000	- 630
Tech	- 12 000	- 420
Total	- 84 000	- 2 940

3.2.2 Definition of the functional unit

The functional unit for the study is the contribution margin of the selected product in the box during the selected business period, amounting to one year. The functional unit can be defined as the profit π that the product contributes to in the business model, and can reflect either historical numbers or the company's goals (Böckin et al., 2022). The company is an early-stage startup and the profit will be based on the company's goals for an established locker box with 140 active users. The revenues and costs indicate that the profit for the box amounts to 40 000 SEK. Allocating the profit to the product, implies a profit amounting to 1 400 SEK per product and year, as depicted in Table 3.3, and this is the functional unit.

Table 3.3: Income statement

	Entire box (SEK)	Allocated (SEK)
Revenues		
Start fee	4 000	140
Annual recurring revenue	120 000	4 200
Total revenues	124 000	4 340
Costs		
Partner cut	- 48 000	- 1 680
Box	- 6 000	- 210
Operations	- 18 000	- 630
Tech	- 12 000	- 420
Total costs	- 84 000	- 2 940
Net profit	**40 000**	**1 400**

Having identified all costs and revenues required to reach the determined profit or functional unit, allows for coupling the monetary flows with the environmental flows:

$$\pi = R_{start} + I_{ARR} * N_{sub} - C_{cut} - C_{box} - C_o - C_{tech} \tag{3.1}$$

Where:

π = Profit, functional unit
R_{start} = Start fee
I_{ARR} = Annual reoccurring revenues
N_{sub} = Number of subscribers
C_{cut} = Partner cut
C_{box} = Cost, box
C_o = Cost, operations
C_{tech} = Cost, tech

3.3 Life cycle inventory

The emissions related to the business model are grouped into three categories:

- *Product*: Including materials production, manufacturing process, transportation, and end-of-life
- *Sharing infrastructure*: Including the locker depot and data transfer required for downloading and booking the product through the app
- *Use*: Including electricity required to use the product

In order to match the environmental flows with the economic flows, according to the BM-LCA method, the values are presented for one percussion drill, and values that are not product-specific are allocated using the allocation key amounting to 3.5%. The allocation key corresponds to the share of the cost of holding the specific product. Just like the economic flows, the environmental flows are expressed as an average for the business period amounting to one year. Due to lack of data, some assumptions are based on the estimations made by Martin et al. (2021) in the report *Environmental Assessment of a product-service system for renting electric-powered tools*, which evaluates the environmental impact of Husqvarna's renting service.

The amount of production, q, needed for the business is determined by the lifetime of the products related to the business model. Setting the time, T, to one year allocates the total emissions, E, according to the time period of the economic flows. The components of the environmental flows related to the business model will be explained further in this section.

$$E_{tot} = \frac{q_p}{L_p} + \frac{q_l}{L_l} + E_{app} + (E_{use} + E_{app}) \times t \tag{3.2}$$

Where:
E_{tot} = Total emissions
q_p = Emissions, product
L_p = Lifetime, product
q_l = Emissions, locker depot
L_l = Lifetime, locker depot
E_{app} = Emissions, app
E_{use} = Emissions, product use
t = Transaction, the annual number of uses

Establishing a connection between the monetary flows, using the profit as a functional unit, FU, and environmental flows gives the following ratio:

$$\frac{E_{tot}}{FU} \tag{3.3}$$

3.3.1 Product

The present LCI calculations are based on a BOSCH percussion drill (model CSB 650-2 RE), visualized in 3.5. The product was deemed sufficient equivalent to the drills used in the sharing service. According to Bosch Support (personal communication, May 2, 2023), the product was launched 2005 and discontinued 2011. The drill's volume was determined to be 1254 ml, and the LCA report by Sovják et al. (2022) using the volumetric approach was applied to estimate energy requirements and CO_2 equivalents based on this volume. Material inputs, as well as packaging and transportation, are accounted for, as depicted in Figure 3.4. The emissions for the production in the report are based on the assumption that the end-of-life method is recycling (to a 90% level). Further, the emissions of this phase are determined by the energy requirements and values are specific to the energy mix of Sweden. The relevant flows for the environmental impact are in the production, manufacturing, end-of-life, and use-phase. These phases include energy [MJ] as inputs and emissions [CO_2e] as outputs. The end-of-life scenario is based on the energy outputs, which are converted to emissions [CO_2e]. The emissions are summarized and annually allocated in Table 3.4.

Maintenance and repair are carried out by the owner of the products, the manufacturer, and is not included as neither an economical nor environmental parameter due to the lack of data. The repair done by the company is included in the cost parameter Operations. The lifetime of the drill is estimated to be three years, and after that, the product will be refurbished and resold by the manufacturer.

Table 3.4: Emissions during the lifetime of the product

		Annual
	CO_2e (kg)	CO_2e (kg)
Production	21.6	7.2
Manufacturing	0.47	0.16
End-of-life	0.01	0.005
Total	22.08	7.36

Annual emissions allocated over the lifetime of ten years and corresponding to 3.5%.

Figure 3.4: Overview of the material composition of the product

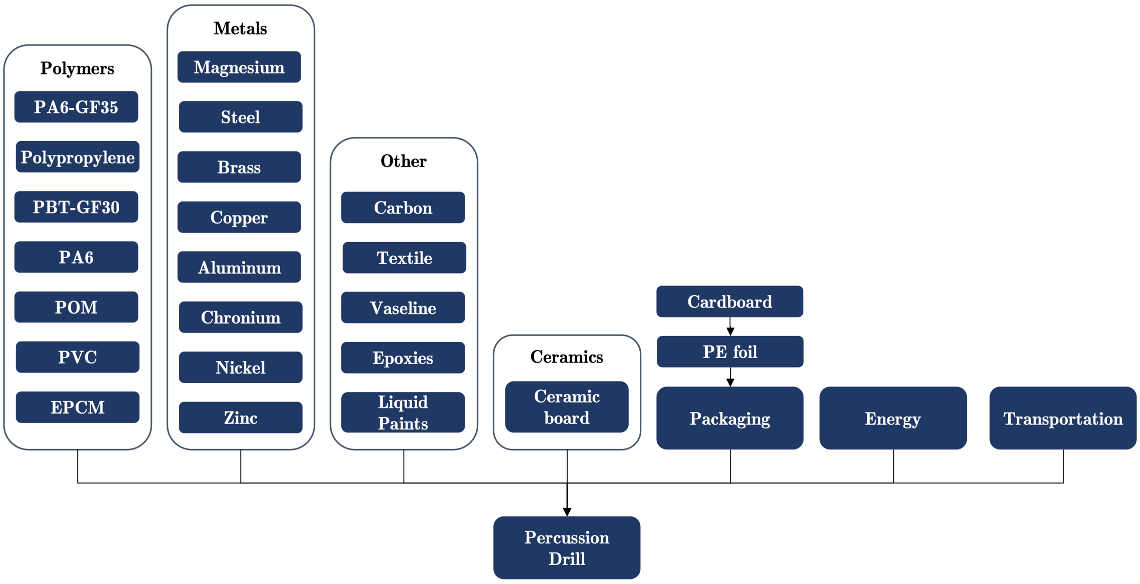
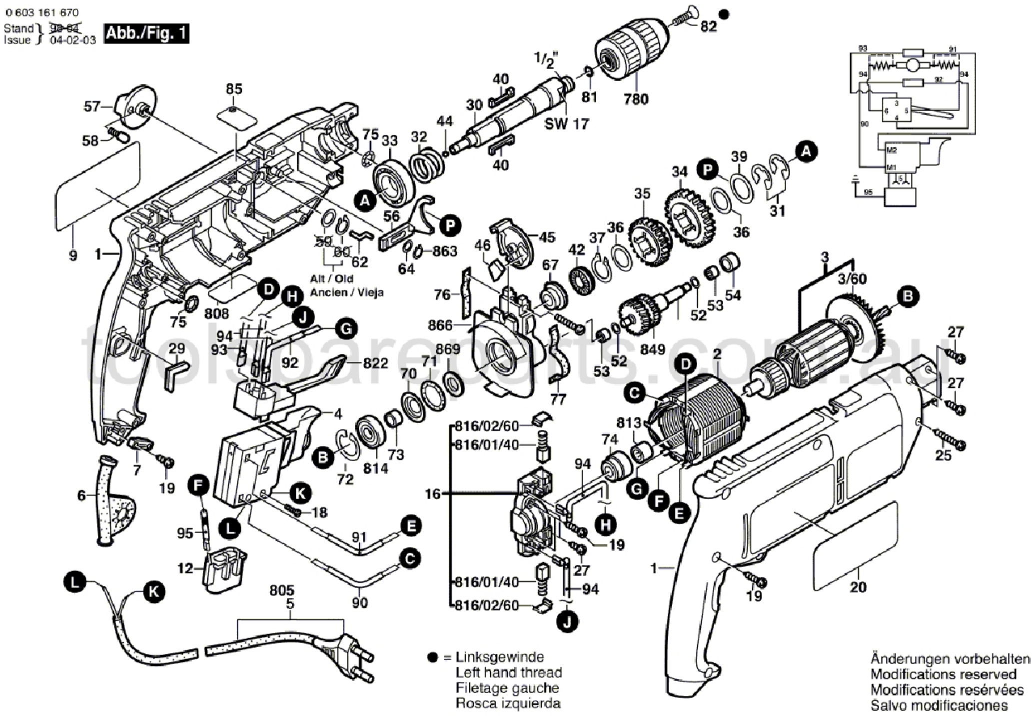


Figure 3.5: Bosch CSB 650-2 RE



3.3.2 Sharing infrastructure

Locker depot

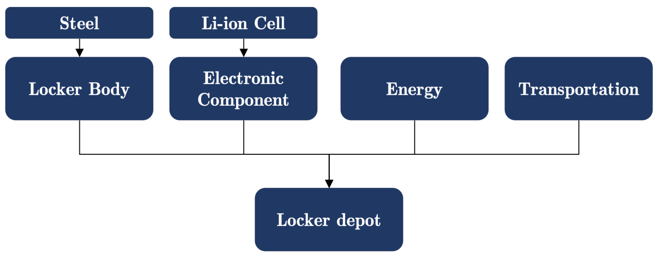
The locker depot consists of a frame and body made of steel and has a padlock and a battery. The carbon footprint accounts for the production of 300 kg of steel and is based on the global average (Worldsteel Association, 2022). Based on some assumptions (Transport Measures, nd), the battery is specified as an electronic component with a weight of one kg. The components are depicted in Figure 3.6. The lifetime is expected to be ten years for the locker depot as well as the electronic components and the padlock. For the initial five years, minimal maintenance, such as adding oil for lubrication, will suffice. Subsequently, further maintenance might be required, including the upgrading of electronic components or locks. When calculating the CO_2 emission for transportation of the locker, the distance was estimated to be 1000 km. The transportation type was set to a truck with a trailer for 34 tons (Transport Measures, nd). It was estimated that one truck could carry 30 lockers. The allocated flows from the locker depot that are attributed to the product by using the allocation key amounting to 3.5%, as seen in Table 3.5.

Table 3.5: Emissions during the production of the locker depot

				Annual [1]
Component	CO_2e (kg/kg)	Weight (kg)	CO_2e (kg)	CO_2e (kg)
Steel	1.91	300	573	2.01
Electronic component	24.90	1	24.90	0.09
Transportation[2]			20.3	0.07
Total			618.20	2.17

[1] Allocated to 3.5% over 10 years.
[2] Based on a distance of 1000 km using a 34-ton truck.

Figure 3.6: Overview of the locker depot



Mobile booking system

The booking system consists of a mobile app with a size of 11.7 MB. The time for downloading the app is estimated to be five minutes. The case is based on 140 subscribers and it is assumed that the app will be downloaded at least once per household. In addition, sixty additional downloads are added to account for potential reloading and additional family members. This adds up to a total of 200 downloads, which are allocated over five years of time and attributed to the product corresponding to 3.5%. The assumptions for booking a product are based on the estimations made by Martin et al. (2021), assuming that booking a product requires 2 MB of data use and takes 2 minutes. The impact is summarised in Table 3.6. The environmental footprint of booking is directly linked to the use of the specific product and is calculated for the individual product from the start.

Table 3.6: Environmental impact of the digital booking system.

			Annual	
	CO_2e (kg/kWh)	Data size (MB)	Quantity	CO_2e (kg)
App Download	0.093	11.7	250	0.11
Booking a Product	0.093	2	200	0.02
Total				0.12

3.3.3 Use

The user phase is assumed to account for an average of 15 minutes of use and environmental impact is related to the use of electricity, as shown in Table 3.7. Any further maintenance is carried out by selected users on locations, which minimizes the need for transportation. The manufacturer is responsible for additional product maintenance and repair.

Table 3.7: Environmental impact of the user phase.

			Annual	
Activity	CO_2e (kg/kWh)	Power (watt)	Hours	CO_2e (kg)
User phase	0.093	650	62.5	3.8
Total				3.8

The impact from the user phase is mainly electricity and depends on the energy mix. The carbon footprint depends on the energy mix and Sweden has the lowest emission values in Europe, amounting to 93 g CO_2 eq. per kWh (Sovják et al., 2022). The emissions for the use phase is highly dependent on the energy mix in the country. In this study, Sweden is the selected country. The energy production in Sweden is mainly hydroelectric and nuclear power which together corresponds to 75% of total production. Wind power accounts for another 15% (Ekonomifakta, 2021). The energy mix is thus mainly renewable without the use of fossil fuels. A change in the energy mix would have an impact on the emissions from the use phase.

3.4 Life cycle impact assessment

The inventory data is used to calculate the values for the impact categories, as seen in Table 3.8.

Table 3.8: Total impact of the product in the business model

	CO_2e (kg)	Lifetime (years)	Annually allocated CO_2e (kg)
Product impacts			
Product	22.08	3	7.36
Locker	618.20	10	2.16
Use impacts			
App [1]			0.13
Use [2]			3.8
Total	640.28		13.3

[1] Assuming 200 downloads and 250 bookings.
[2] Assuming 62.5 hours of use

The total energy for the percussion drill is 309.1 MJ and the emissions add up to 22.1 kg CO_2e. 98% of the emissions occur during the production phase and the user phase.

The environmental impact of the steel used for the locker depot contributes to a significant share of the total environmental impact of the business model. The locker contributes to a total of 575 kg CO_2e, which is 26 times higher than the product. However, with a lifetime of ten years and allocated to 3.5%, it will account for about 16% of the annual environmental impact of the business model. The environmental impact of the app is low, accounting for 0.03% of the annual impact of the business model. The product emissions can be seen in Figure 3.7 and the annually allocated emissions are depicted in Figure 3.8.

Figure 3.7: Total emissions for the business model for one percussion drill

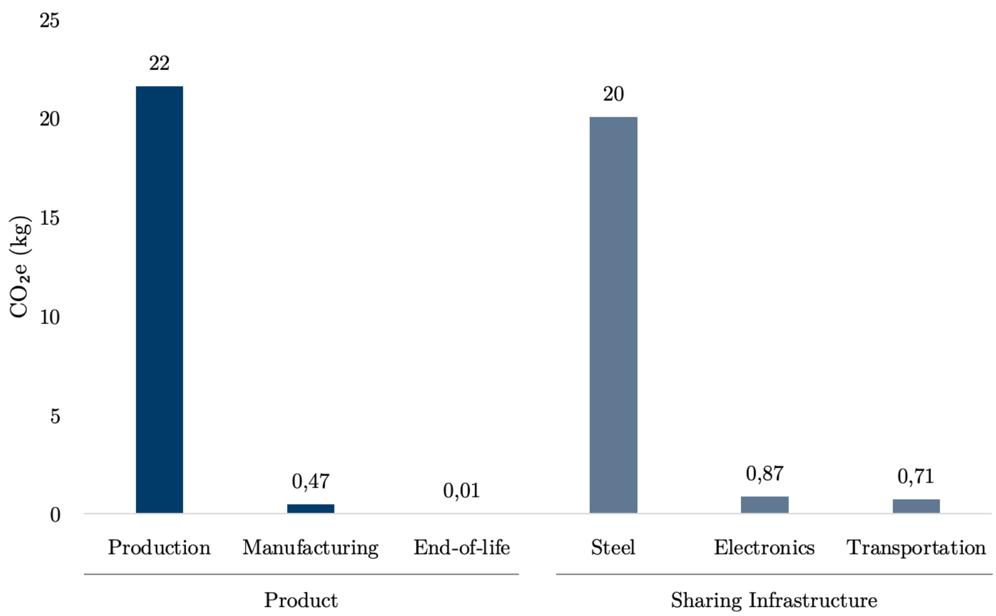
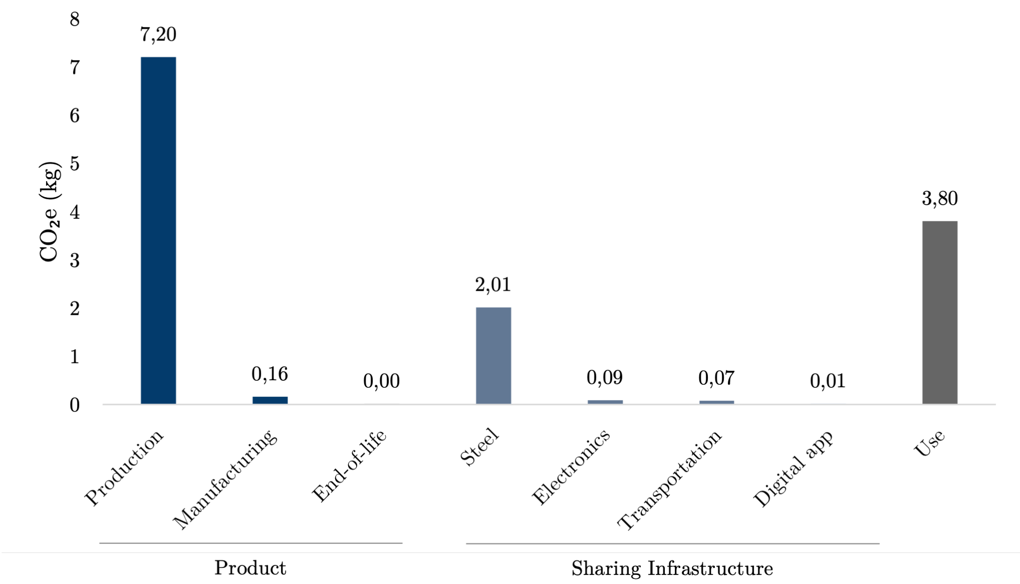
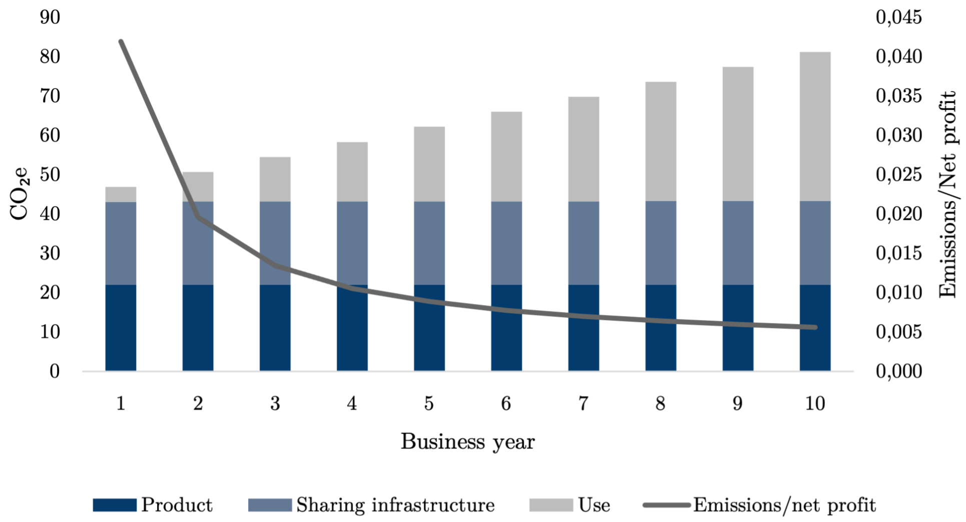


Figure 3.8: Annual emissions for the business model for one percussion drill



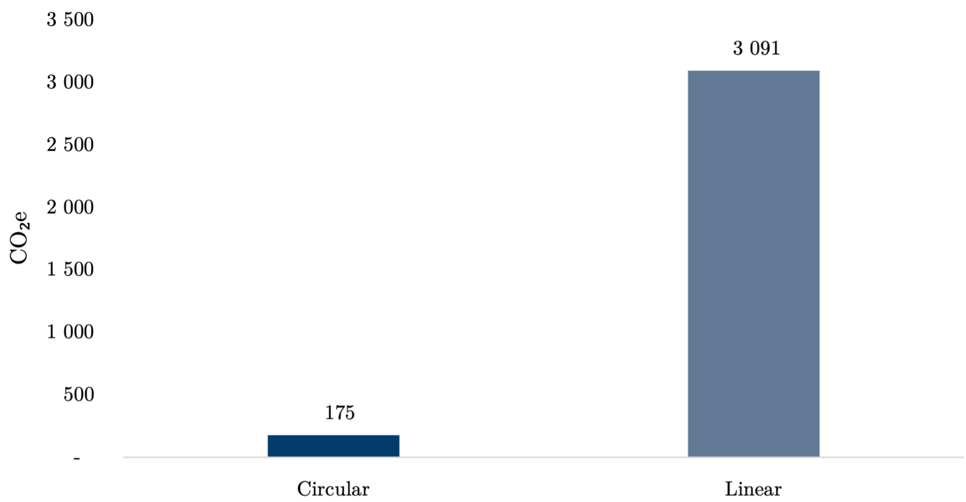
The accumulated emissions for a business period of 10 years are visualized in Figure 3.9 where it is clear that the emissions for use result in an increasing impact.

Figure 3.9: Accumulated emissions during a business period of ten years



It is difficult to predict the impact of implementing a PSS on conventional consumption, as it is unclear whether it would replace conventional consumption or create new demands. To put the impact of the product into perspective, it can be compared to the hypothetical scenario where all 140 users are to purchase their own percussion drills, as shown in Figure 3.10. However, it's worth noting that this scenario is unlikely to occur and is provided only as a reference point to understand the potential impact of the product. This comparison will be discussed later in the report.

Figure 3.10: A hypothetical scenario of a circular business model compared to a linear business model



4

Sensitivity Analysis

To analyze the results obtained from the BM-LCA, a sensitivity analysis was conducted. This involved altering the parameters to assess their impact on both the environmental and financial assessments. Using the profit which is the functional unit, amounting to SEK 1 400, as a basis of comparison allows for evaluating the emissions per functional unit.

Various parameters were assessed with differing values in the study, including environmental values such as the lifetime of the percussion drill and box, weight of the locker depot, number of users, and time spent using the drill. Additionally, financial values such as customer lifetime, number of households, monthly fee, and partner cut were also evaluated.

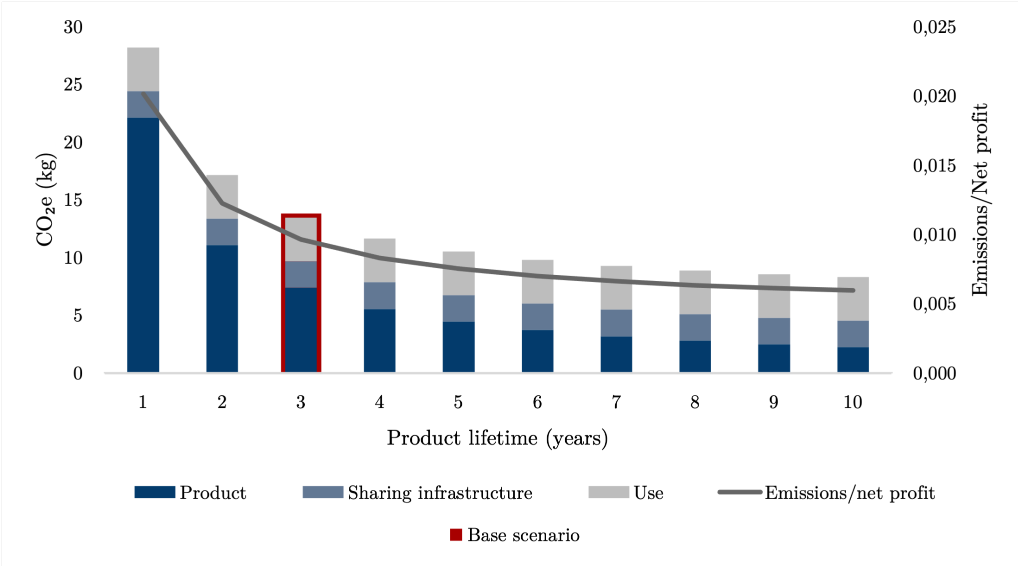
The parameters for the sensitivity analysis are categorized into:

- Product
- Sharing infrastructure
- Use
- Financials

4.1 Product

The factor that has the most dramatic effect on the environmental impact is the lifetime, extending the lifetime from three to five years would decrease the yearly environmental impact of the product from 7.36 kg CO_2e to 4.42 kg CO_2e. It is, however, important to note that the product is refurbished and sold and that extending the lifetime of the product in the business model would likely have financial implications since the value of the product would be lower once returned to the manufacturer. The environmental effect of changing the lifetime is shown in Figure 4.1. Looking at the graph, it is clear that the product should at least have a lifetime of three years since this is where the curve starts to flatten. However, since the product is assumed to have a second life outside of the business model, the time in the business model might not be that relevant when considering the environmental effects of the total lifetime of the product.

Figure 4.1: Product emissions based on different product lifetimes



4.2 Sharing infrastructure

The impact of the locker depot is mainly related to the production of steel. Although a lifetime of ten years is accounted for, it can likely be extended beyond that. The impact can be reduced by switching to steel produced using a method with a lower environmental impact. While the global average is used in the base scenario, steel produced using the Scrap-Electric Arc Furnance (Scrap-EAF) method will reduce the carbon footprint by 65% (Worldsteel Association, 2022).

Additional ways to reduce the impact include switching components to other materials. This may include aluminum, plastic or wood. It is important to account for differences in terms of durability, which may affect the total environmental impact over time. Further, whether the locker depot will be placed indoors or outside will be important to account for when determining a suitable material for the locker depot. However, this study focuses on changing the material to another type of steel.

In the figures below, the environmental impacts as well as the financial implications for four different steel types are presented. The different steel types that were investigated are the average steel that was used as the base case, as well as the recycled Scrap Electric Arc Furnance (Scrap-EAF), Basic Oxygen Furnance (BR-BOF), and Direct Reduced Iron (DRI). The environmental impact of reducing the weight of the locker depot is also investigated and presented for each of the steel types in Figure 4.2, Figure 4.3, Figure 4.4 and Figure 4.5.

Figure 4.2: Emissions with average steel

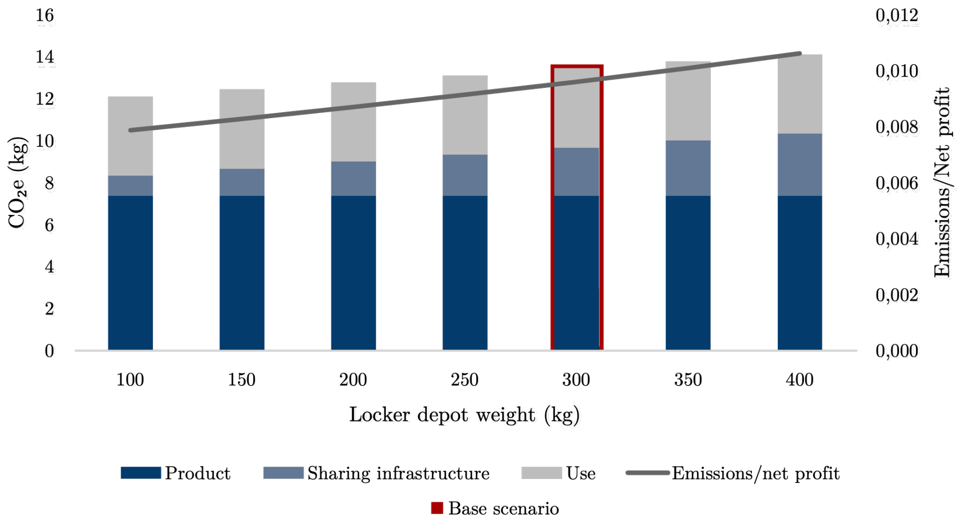


Figure 4.3: Emissions with Scrap-EAF

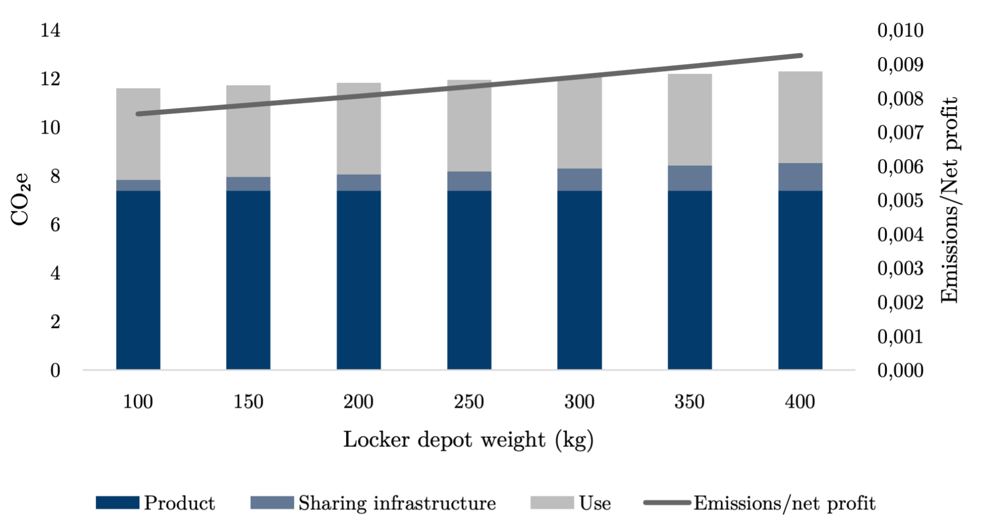


Figure 4.4: Emissions with BF-BOF

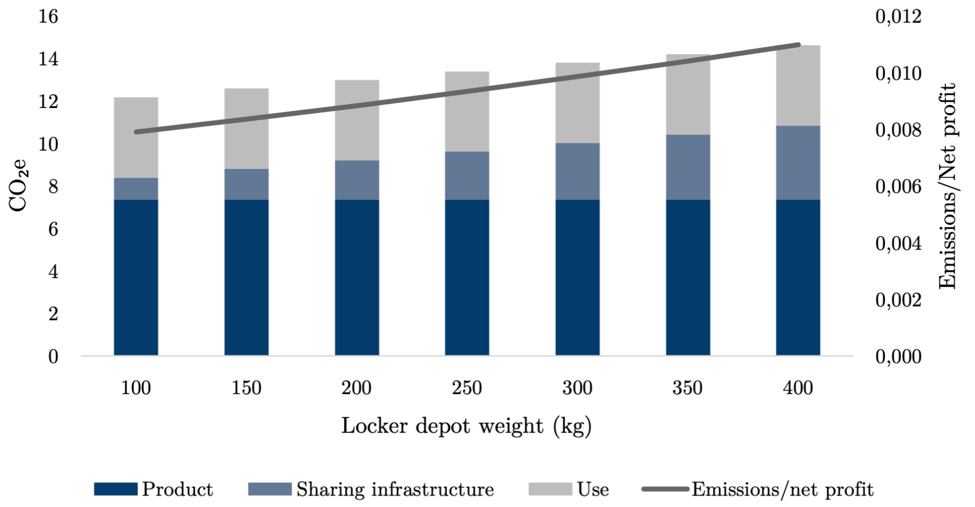
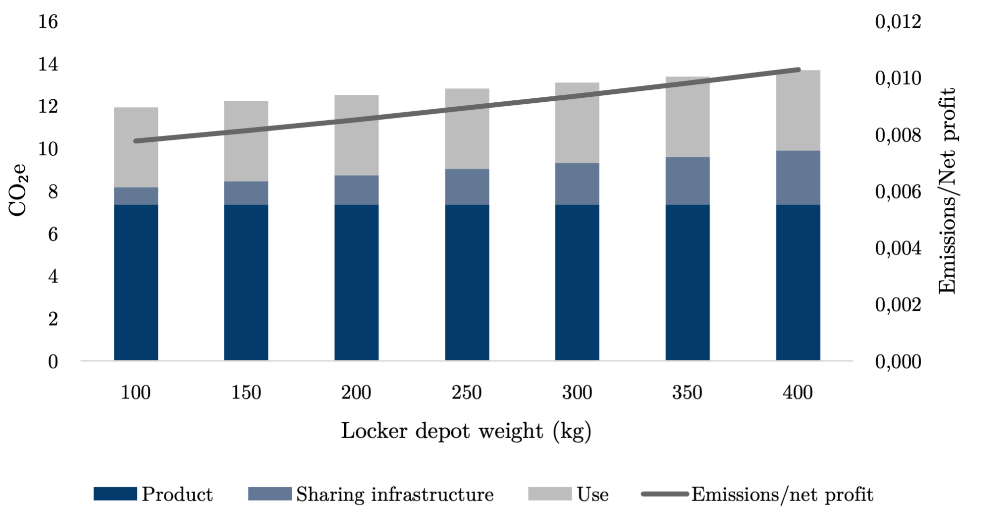


Figure 4.5: Emissions with DRI-EAF

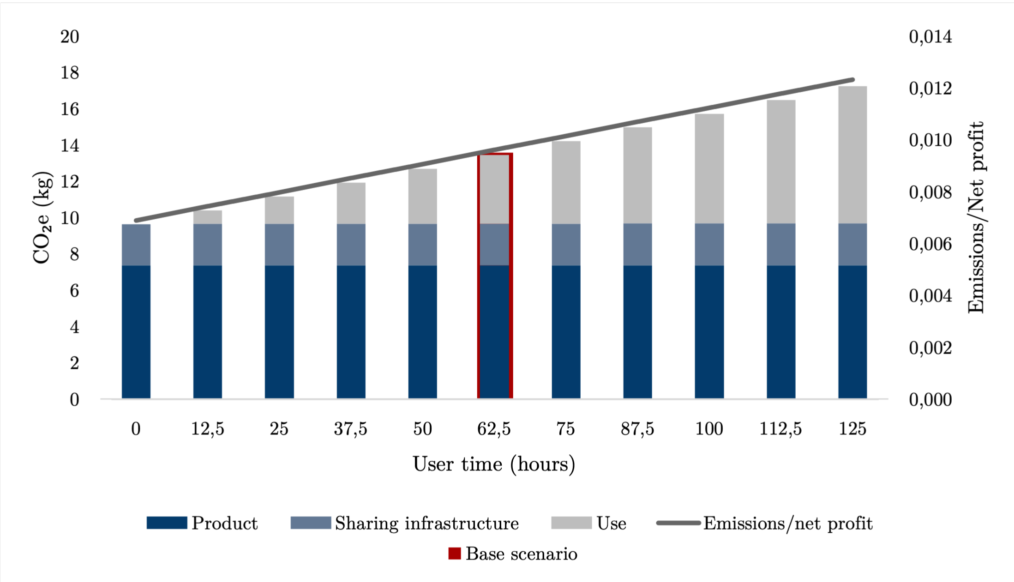


4.3 Use

The European average of renewable sources in the energy mix is 37.5% (Clean Energy Wire, 2021). This implies that the emissions from the use phase could be much higher if placed in another European country with an energy mix consisting of a lower share of renewable electricity. In order to reduce the impact of using the products, a renewable energy mix is required. This is an external factor that cannot be directly affected by the company, except from the decision of which countries to expand and implement their business model in.

Another parameter affecting the use phase is the behavior of the users. This is a difficult parameter to quantify with a lot of uncertainty. The data for how much the average person is using a drill have to be approximated. Beyond this fact, it is hard to estimate how the use is affected by having constant access to the drill. The effects of changing the number of uses and the length of the use are visualized in Figure 4.6.

Figure 4.6: Environmental impact based on the amount of usage



4.4 Financial parameters

In addition to the sensitivity analysis of the values from the BM-LCA above, a change in the financial values with a constant environmental load is also analyzed. Some of the financial parameters are changed in order to explore different values in relation to the environmental performance of the business model. The investigated parameters are the number of households that are signed up for the sharing box, the monthly subscription fee that they pay, and the cut of the allocated profit for a product that is paid to the partner with ownership of the product. These parameters are changed to values both higher and lower in order to investigate the financial effect of such a change and the results are presented in Figure 4.7, Figure 4.8 and Figure 4.9. The number of subscribing households is in the base scenario set to 140, according to the company's targets. For all the following scenarios it will be a change of the net profit but based on different parameters that affect the net profit in different ways. These scenarios are thereby not presented based on the previous set functional unit. The change in the emissions/net profit ratio is also included.

Figure 4.7: Net profit based on the number of subscribers

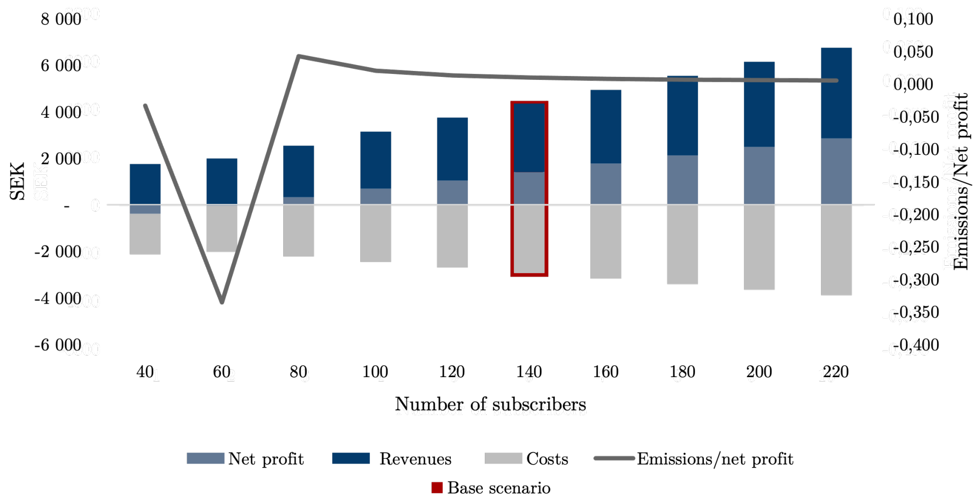


Figure 4.8: Net profit based on the subscription fee

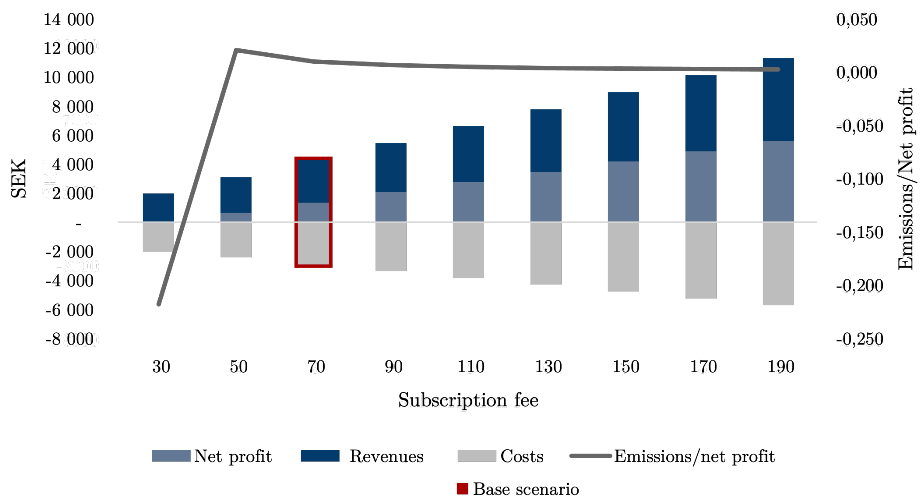
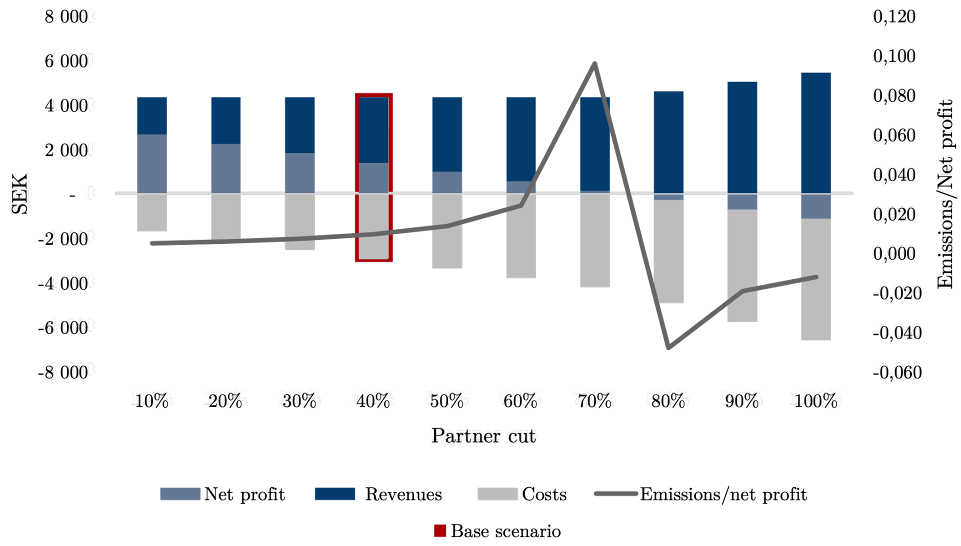


Figure 4.9: Net profit based on the partner cut



4.5 Integrated scenarios

A part of business model innovation for sustainability is to find an improved set up compared to the base case. In this section, the parameters that were changed above are thus investigated together in order to evaluate combined scenarios.

First of all, some of the successful changes of parameters in order to lower emissions per profit are tested together. The scenario is presented in the table below.

Table 4.1: Hypothetical optimal scenario

Parameter	Base	New
Percussion drill lifetime	3	5
Locker depot weight	300	100
Locker depot material	Average steel	Scrap EAF
User time	62.5	62.5
Number of subscribers	140	200
Monthly subscription fee	71	100
Partner cut	40	10

However, this scenario is not that realistic. After considering what values the parameters are more realistic inclined to take, the following scenario is investigated.

Table 4.2: Realistic optimal scenario

Parameter	Base	New
Percussion drill lifetime	3	4
Locker depot weight	300	200
Locker depot material	Average steel	Scrap EAF
Hours of use per year	62.5	62.5
Number of households	140	140
Monthly subscription fee	71	71
Partner cut	40	40

As a third scenario, the parameters are changed into a worse case. This is done in order to investigate what would happen if considerations for the environment are not taken.

Table 4.3: Worse scenario

Parameter	Base	New
Percussion drill lifetime	3	2
Locker depot weight	300	400
Locker depot material	Average steel	Average steel
Hours of use per year	62.5	100
Number of households	140	70
Monthly subscription fee	71	50
Partner cut	40	40

The changes in emissions per net profit are visualized in Figure 4.10 and Figure 4.11.

Figure 4.10: Environmental parameters for selected scenarios

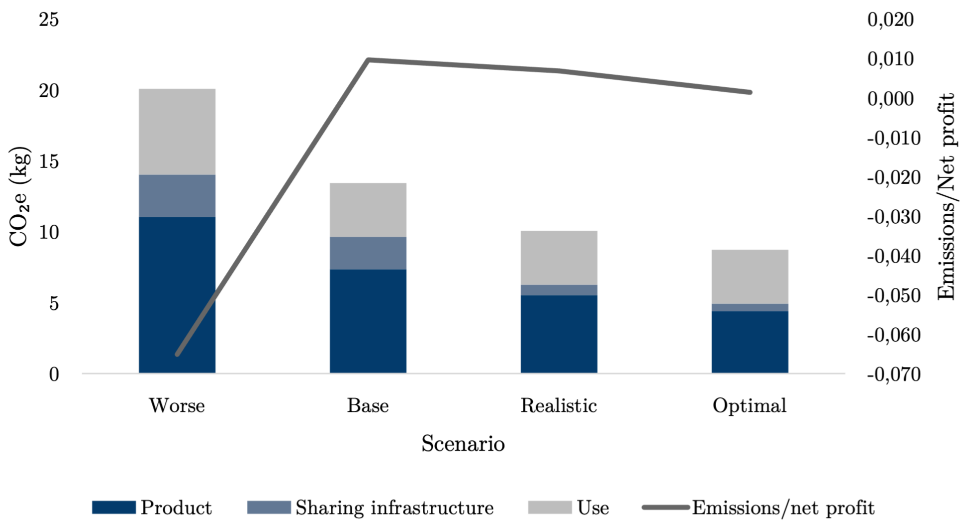
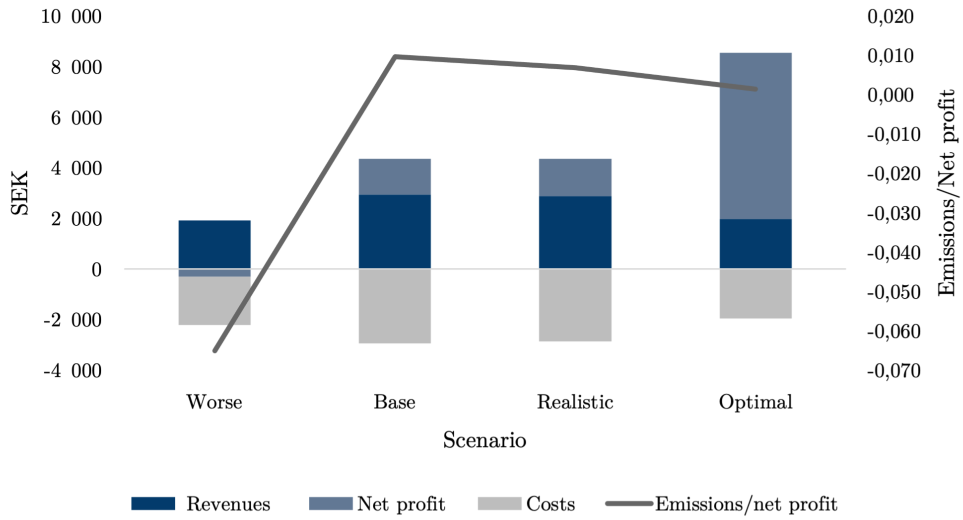


Figure 4.11: Financial parameters for selected scenarios



Based on the above-presented scenarios, it is clear that the most beneficial based on emissions per net profit would be the realistic scenario. This scenario would both decrease the environmental impact and lower the costs and is considered to be realistic and thus possible to implement for the company.

5 Discussion

After carrying out the above-presented BM-LCA, some key learnings and understandings are found. In this chapter, the results from the BM-LCA will be discussed together with the potential benefits of a transition from a linear to a circular business model. The discussion will also include reflections on potential weaknesses and areas of improvement for conducting a BM-LCA on a circular business model. Further on, the future benefits and potential applications for using BM-LCA will be discussed.

5.1 Discussing business model innovations

Looking at the findings from the completed study, some parameters and circumstances stand out with their clear impacts on the results. The source of revenue in the circular business model is the monthly subscription fee that customers pay for access to the shared product. It was found that adjusting income from the subscription fee and number of subscribers, as well as partner cut can have a significant impact on the emissions per profit ratio. However, it is important to note the importance of setting the subscription fee accordingly, as highlighted by Hunka and Habibi (2023), stressing that the subscription fee should account for inconveniences related to product sharing in relation to owning the product. According to the findings of Rexfelt and Hiort Af Ornäs (2009), the adoption of the investigated product service system can be considered a societal change that depends on the socio-cultural setting. This suggests that the increase in the number of users relies on how society at large accepts circular sharing solutions. Considering local variations within the country, it can be assumed that strategically selecting locations based on socio-cultural considerations plays a crucial role in increasing the number of subscribers.

For the product parameters which were presented in the sensitivity analysis, the lifetime of the drill and the weight of the locker depot, as well as the choice of locker material, are vital parameters when trying to lower the emissions per profit. These changes can be considered to be relatively easy to implement in the business model and thus a reasonable approach to improve and optimize the company's circular model with both reduced environmental impact and improved financial values.

Further, the sensitivity analysis also provided insight into scenarios in which there is a clear contradiction between the environmental benefits and the economic benefits. For instance, a higher level of use of the products contributes to increased emissions in the use phase. At the same time, a high user acceptance was found to be necessary for a successful implementation, aligning with the arguments of Kjaer et al. (2016). This implies that the service is appreciated by the subscribers and generating profit, while a lower use time results in lower emissions per net profit.

Beyond the hard values from the sensitivity analysis, other circumstances were found to have a considerable effect. First of all, the energy mix in the country controls how big the impact of the user phase will be. This study was set to the Swedish market where the energy mix is mostly renewable with low amounts of fossil fuels used for energy. Thus, the use phase accounts for a relatively small part of the emissions compared to production and sharing infrastructure. As stated by Tukker (2004), a product with a high share of emission in the product phase compared to the use phase allows for impact reductions which was further confirmed by this study. However, if the business model would be implemented in another country with an energy mix consisting of a higher level of fossil fuels, the use phase impact on the emissions would increase. This fact demonstrates the importance of a green energy mix and links the transition towards circularity to the national energy policy and thus the actions of politicians and authorities.

Second, the composition of the locker depot contributed to a significant part of the total emissions for the life cycle of the percussion drill even after being allocated. Both the kind of steel and the weight of it were shown to have a considerable effect. This finding is not entirely obvious as the locker is a secondary product used to provide the primary product. While the study was limited to investigating steel alternatives, other low-impact materials, such as wood, could be considered as well. The choice depends on aspects such as cost, durability, security, weather resistance, as well as maintenance requirements. The relative importance of these aspects will vary depending on the location and surrounding environment of the sharing point, which highlights an opportunity to lower the environmental impact by selecting secure locations indoors.

In addition, ensuring that the sharing point is located within walking distance from customers represents a crucial factor when it comes to limiting the environmental impact of the business model. This mitigates the need for user transportation, which could otherwise risk out-weighting the environmental benefits of product sharing (**?**). It can also be pointed out that the total climate impact from the locker depot is significantly higher since it is allocated to the specific product in the investigated case. A reduced climate impact from the locker depot would thus significantly reduce the emissions per profit of all products in the business model. It can thus be stated to be a very appropriate change to improve the company's overall business model and make it greener.

Another dilemma that arose was whether the partner cut should be lowered or not. Since the company needs to have a favorable agreement with the manufacturers in order to be able to compete with retailers and thereby continue to get manufacturers to want to place their products in the boxes, the partner cut needs to remain at a reasonable level, while a lower cut means lower costs for the company. It is therefore important to find the balance of how high the percentage should be, which could possibly mean that the partner percentage should be kept at the same level as today, but to finally determine the optimal level, the market would have needed to be examined more while a dialogue could have been held with the manufacturers. As previously outlined by Hunka and Habibi (2023), a close partnership with partners in the ecosystem has a positive effect on aspects such as financial risk and credibility. This implies that the partner cut should be set at a rate that makes a partnership an attractive option for all parties involved.

Lastly, by accumulating the emissions over the a longer period of time, it is clear that a substantial share of emissions are generated during the production phase of the product and associated sharing infrastructure. This implies that the annual emissions per profit reduces significantly when more business years are added. In addition, the majority of the costs occur during this early phase. Therefore, it is advisable to extend the lifetime of the product and the sharing infrastructure to improve the business model's financial and environmental performance.

5.2 General BM-LCA applications

By conducting the BM-LCA on the investigated business model, some insights about its future applications were found. The method takes both the purpose of creating value for the organization and its stakeholders as well as environmental performance into account which results in several areas of applications. A potential area of use is found to be communication with investors and the ability to show a measure of how green the business model is, which is important to attract investors looking for green investment opportunities. This might inhibit investments in businesses with high carbon dioxide emissions by providing clarity into the carbon dioxide intensity. Due to the difficulties of quantifying the actual environmental impact of a circular business model, this provides an opportunity for investors to make more informed decisions and hopefully choose to invest in greener businesses.

More apparent, BM-LCA provides the measure emissions per profit which can be useful for optimizing the business model based on both economic and environmental parameters, which is also concluded by Böckin et al. (2020). Traditional LCA only accounts for the environmental factors, but BM-LCA gives the company a tool to assess and evaluate its business from both perspectives and thus an opportunity to prepare for the future where it will be even more important to have a green business model that is also profitable. To attain this, the uncoupling of environmental and economic values needs to be achieved. This reports highlights that sharing business models can be a way for achieving this decoupling.

Overall, a major reason for using BM-LCA is the contribution to enabling the implementation of circular business models by providing a way to quantify and compare the total environmental impact compared to a linear correspondence. In the literature studied before conducting this study, for example Martin (2018), it was found that quantification and measurement of circularity are lacking. This study has further investigated how BM-LCA can be applied to circular business models and demonstrated that concrete results can be obtained for how the environmental impact can be reduced for the same profit.

5.3 Potential weaknesses of the study

While the results from the BM-LCA are promising and credible in most aspects, some limitations are acknowledged. The results only account for the behaviors inside the business model. When comparing to the corresponding linear business model it needs to be considered that even if all subscribers have access to the percussive drill via the sharing model, a certain part of them will probably still buy their own. In the linear business model, the difficulty lies in assessing how many of the users that would purchase their own percussive drill compared to how many that would choose to borrow or rent. It thus becomes difficult to estimate the actual difference between the business models and how much less the environmental impact will de facto be from the transition from a linear to circular. As previously highlighted, this remains a challenge in evaluating the environmental impact of a circular business model.

Another weakness of the study is the approximation of total usage time. As the business model is in an early stage, there is limited data on how much the products are used and the usage time is therefore an estimation. While the emissions from the use phase are based on how much the product is used, the profit is not affected since the price is for accessing the product instead of actually using it. A change in the using time would thus affect the emission per funcional unit ratio. In addition, another aspect of the use phase is the age of the investigated product. Since the specific product is not produced anymore, the actual product placed in the box is a newer version that might have a lower impact during the use phase and production. However, since the use phase does not correspond to a large part of the total impact from the life cycle, this is not that significant.

This study considers only a single product and its lifetime which is in contrast to previous studies where a BM-LCA is conducted. Previous studies e.g. Böckin et al. (2022) have investigated business models where transactions are linked to the emissions based on the number of sales while this study focuses on the sharing of one product, which results in the coupling equations being adjusted to this specific case. This approach deviates slightly from published research using BM-LCA. However, since it is a special case where the revenue streams are not directly linked to material flows of the product, it holds value for understanding the environmental characteristics of another type of business model.

These weaknesses should be taken into account when interpreting the results of the study.

6
Conclusion

This study shows that BM-LCA can be conducted on a sharing service and provide useful results. For the investigated business model, it can be concluded that it is a more sustainable model than a linear would be but that some changes can be done to improve it even more. However, in order to reach further success with implementing circular business models overall and the investigated model in particular, it is necessary to promote behavioral changes that result in users choosing to share products instead of owning them.

Also, the study indicates that BM-LCA provides a tool to quantify circular business models which can contribute to the transition towards a circular economy and green business models. Viewed from a global perspective it can be stated that the method might contribute to reaching the sustainable development goals by mitigating climate change.

6.1 Recommendations

After conducting the BM-LCA on the sharing service business model, some recommendations are formulated in order to improve based on the emissions per profit. The recommendations are:

1. Increase the lifetime for the products in the box
2. Reduce the weight of the locker depot and consider the choice of material
3. Increase the number of subscribing households per box
4. Consider partnerships with actors involved in the ecosystem, in order to increase credibility and reduce financial risk
5. Lobby for a change in consumer behavior throughout society
6. Consider how inconveniences related to sharing can be overcome, by e.g., ensuring a convenient placement of the sharing point and setting an acceptable subscription fee

6.2 Future research

For future research, it would be relevant to pursue BM-LCAs on other business models with different characteristics in order to evaluate the usefulness of the method.

Specific to the investigated company's business model it would be appropriate to conduct more studies on the other products that are provided in the box in order to evaluate which products that are most contributory to profit as well as environmentally friendly. Another option would be to investigate further impact categories. This could result in a more diversified and nuanced understanding of how the product is affecting the climate, environment, and animal life in different stages over its life cycle. In addition, further studies to understand customer behavior would be useful in order to fully understand the environmental impact of a subscription-based business model.

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