ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY SCIENCE

THE UTILIZATION OF LCA TO DETERMINE SIGNIFICANCE FOR HYDREMA'S ENVIRONMENTAL MANAGEMENT SYSTEM AND ESG REPORTING

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Abstract:

This Master's thesis investigates the utilization and implementation of LCA for determining significance for the Danish company Hydrema's environmental management system and ESG reporting. Hydrema is ISO 14001 certified, but got a deviation on missing life cycle perspective and product orientation in their determination of significant environmental aspects during their last audit. Therefore, LCA is chosen as a tool to help Hydrema identify which environmental aspects in a life cycle perspective might be relevant for them to work further with. The implementation of LCA is afterwards analyzed using theoretical terms, like institutional logics, relational data collection, etc., with data inputs from interviews with both employees at Hydrema and auditors from Bureau Veritas. Lastly, the usability of LCA for Hydrema, and the possibility of LCA aiding in significance determination will be discussed.

Preface

The following project is a Master's thesis conducted on the Master's degree 'Environmental Management and Sustainability Science' at Aalborg University. The thesis is produced from the 1st of February to the 28th of May 2025. The thesis is made in collaboration with the Danish company Hydrema, which produces construction machines. The thesis is about how Hydrema can utilize LCA to determine significance in their environmental management system and ESG reporting.

I would like to thank my supervisor, Søren Løkke, for the help and guidance throughout the project period. Other than my supervisor, I would like to thank all the nice people who have helped me at Hydrema. A special thank you is made to Morten Nielsen, Anders Bo Poulsen, Palle Kærgaard Larsen, and Jonas Sømod Laustsen, who have helped me gain knowledge and data essential for this thesis. I am grateful for the collaboration and the resources used to help me. Another thank you is made to the two interviewees from Bureau Veritas, Klaus Behrndt and Rikke Beider, whose insights were valuable for the analyses. A thank you is also made to the interviewee Stig Hirsbak, whose perspectives was taking account during the writing of the thesis.

The references made throughout the thesis are cited using the Harvard method, and therefore cited [Author last name, publication year]. In the end of the thesis can be found a thorough reference list, with all references used listed.

Summary

Dette kandidatspeciale er skrevet på kandidatuddannelsen 'Civilingeniør med speciale i miljøledelse og bæredygtighed', og er lavet i perioden fra 1. februar til 28. maj. Specialet er skrevet i samarbejde med den danske virksomhed Hydrema, som producere og sælger entreprenørmaskiner til hele verden. Problemet undersøgt i dette speciale er opfanget gennem et praktikophold og projekt på 9. semester, hvor der blev observeret at Hydrema oplevede problematikker i forhold til forskellige aspekter af deres miljøarbejde, herunder bestemmelse af væsentlighed til deres miljøledelsessystem og ESG rapportering. Hydrema er miljøledelsescertificeret i forhold til ISO 14001 standarden, samt står overfor krav om at rapportere på ESG i fremtiden. Til Hydremas sidste audit fik de en afvigelse på mangel på betragtning af livscyklusperspektiv i deres bestemmelse af væsentlige miljøforhold. I forbindelse med ESG rapportering har medarbejdere hos Hydrema udtrykt problematikker i forhold til bestemmelse af væsentlige scope 3 kategorier. Gennem en struktureret litteraturgennemgang kunne det konstateres at livscyklusvurderinger (LCA), kunne bruges som værktøj, både i forhold til bestemmelse af miljøforhold, som ecodesign værktøj og til miljødelen af ESG rapportering.

På baggrund af dette er følgende problemformulering valgt at arbejde videre med:

> *"Hvordan kan LCA hjælpe Hydrema med at vurdere væsentlighed i deres miljøledelsessystem og ESG rapportering?"*

Med dertilhørende underspørgsmål:

1. "Hvordan opfatter Hydrema LCA, og hvordan kan denne forståelse informere den praktiske implementering internt i virksomheden?"
2. "Hvad er mulighederne og begrænsningerne ved at implementere LCA hos Hydrema?"

For at svare på problemformuleringen, er der udført en LCA på alle Hydremas maskiner. Den er lavet ud fra en grundig analyse af en stykliste for en af Hydremas maskiner. Ud fra styklisten er maskinen blevet opdelt i moduler, som efterfølgende har fået hver deres skaleringsfaktor. På denne måde er maskinen blevet skaleret til alle Hydremas andre maskiner, så det på denne måde er muligt at få et indblik i hvordan de forskellige maskiner performer. Resultaterne fra

LCA analysen er blevet brugt til at kigge ind i hvordan Hydrema kan bruge disse resultater, samt hvordan en implementering af LCA i Hydremas miljøledelse kunne gavne dem, samt hvilke udfordringer der er. Analysen af implementering af LCA i Hydrema er bakket op af interviews med både medarbejdere fra Hydrema, samt auditører fra Bureau Veritas, og teoretiske termer identificeret i den fremstillede teori.

Ud fra analyserne kunne det ses at de maskiner med de største emissioner var de store dumpere, samt hjulgraverne. Det kunne også ses at brugsfasen er essentiel i forståelsen af påvirkningen fra Hydremas maskiner, fordi den forbrændte diesel udgør størstedelen af udledningerne gennem hele produktets levetid. I produktionen af maskinen er det primært materialerne stål, aluminium og gummi der bidrager mest til miljøpåvirkningen, som blandt andet er primære materialer i maskinernes motormoduler, chassismoduler og hjulmoduler.

LCA kunne være behjælpelig for Hydrema, ved at den kunne fungere som et identifikationsværktøj der kan være med til at påpege hvilke miljøforhold i produkternes livscyklus der vil give mening at arbejde videre med. LCA vil også kunne være behjælpelig med at identificere hvilke scope 3 kategorier, til ESG rapportering, der vil være relevante. Dog vil en implementering kræve at medarbejderne hos Hydrema forstår resultaterne fra LCA'en for aktivt at kunne anvende dem i fremtidigt miljøarbejde.

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Introduction 1

This Master's Thesis takes the point of departure in an internship and project carried out in the 9th semester at the company Hydrema. That project briefly touched upon the challenges Hydrema has met in its environmental work, regarding its environmental management certification and coming environment, social, and governance (ESG) reporting. This led to a solution with a simple life cycle assessment (LCA) model, to help them identify a baseline on their emissions, that they would be able to use in their environmental work. When finishing the project in the 9th semester, I thought that this project could be done more comprehensively, to be able to help Hydrema even more.

In recent years there has been a heightened focus on the environment, and global warming and climate change will need to be taken care of to keep the global temperature from rising above 1,5 degrees over the pre-industrial level [United Nations, 2025]. This is anchored in the Paris Agreement which was agreed on by 195 parties at the 2015 Climate Change Conference (COP21) [United Nations, 2025]. In Denmark, there has also been a heightened focus on the environment. A sector that has been subject to new requirements is the construction sector [Social- og Boligstyrelsen, 2025]. Here a new national strategy for sustainable construction was adopted in 2021, which amongst other things set requirements on documenting the climate footprint of buildings by phasing in LCA [Social- og Boligstyrelsen, 2025]. However, there can be detected a gap in the Danish building regulations according to Kim Haugbølle who is a senior researcher at Aalborg University [Dagens Byggeri, 2024]. He states that even though the construction machines are widespread across construction sites there are no climate calculations on them. He also states that even though the building regulations climate requirements are becoming tighter on the construction sites, there are no specific requirements on the machines, which makes them invisible in the total climate accounting [Dagens Byggeri, 2024]. Because of the heightened focus on LCA in the construction sector, and the lack of such requirements on the construction machines used in the construction sector this Master's thesis is focused on the construction machine company Hydrema, and their problems with their environmental work.

The problem that this Master's thesis will work with is primarily the determination of significance for Hydrema. This problem has occurred for Hydrema because they are environmental management certified in accordance with ISO 14001:2015 standard, and have previously gained deviations in their determination of significant environmental aspects. Another reason why this problem is relevant for Hydrema is because they are obliged to report on ESG, which is based upon a double materiality assessment, where they are only obliged to report on the aspects that they have assessed as being significant for them.

Problem Analysis 2

2.1 Hydrema

Hydrema is a large Danish family-owned company that produces mid-size earth-moving equipment, with around 600 employees and a yearly turnover of around EUR 175 million [Jensen, 2024]. Hydrema was founded in 1959 by Kjeld Werner Jensen in Aalborg, with a vision for innovative hydraulic construction equipment [Hydrema, 2024a]. Hydrema is a global company with many subsidiaries, which accounts for both sales/service centers in multiple countries, production in the military sector, and investments in renewable energy [Jensen, 2024]. Hydrema has production sites both in Støvring in Denmark and in Weimar in Germany [Hydrema, 2024a]. In 2000 the company changed leader and owner, to the founder's son, Jan Werner Jensen, who still owns the company today [Hydrema, 2024a]. Hydrema's sites have been expanded to ensure continuous development of product lines is possible because they want to make sure that they can meet future demands [Hydrema, 2024a]. Hydrema produces three types of machines, in multiple sizes. They produce dumpers, backhoe loaders, and excavators, which can be seen on Figure 2.1 [Hydrema, 2024c].

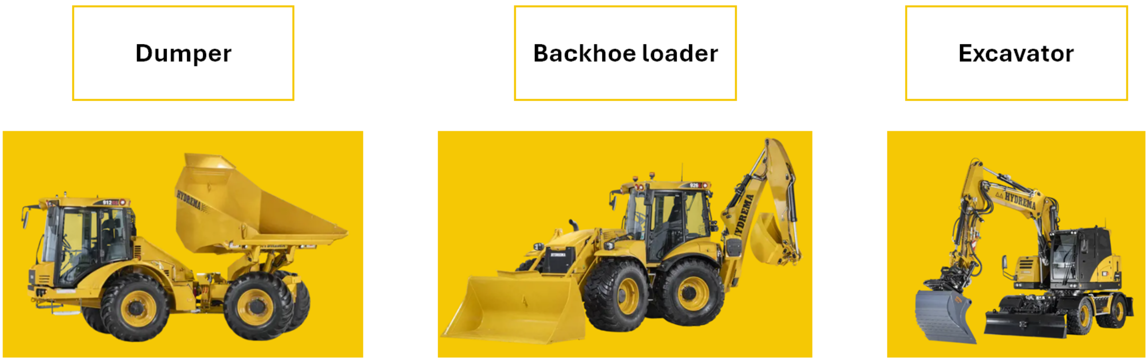


Figure 2.1. The three types of machines that Hydrema produces, dumpers, backhoe loaders, and excavators (Own production, based on [Hydrema, 2024c])

Hydrema has four core values: Flexibility, Drive, Engagement, and Energy [Hydrema, 2024d].

Hydrema aims to be able to adapt to changing markets, as well as customize its products to its customers [Hydrema, 2024d]. Hydrema's drive is anchored in its innovation culture, where they are constantly searching to optimize its work processes [Hydrema, 2024d]. Hydrema is dedicated to ensuring its finished products are of the highest quality [Hydrema, 2024d]. Hydrema's energy is channeled into making continuous improvements, and they are dedicated to making sustainable partnerships with its customers [Hydrema, 2024d].

Hydrema is certified by three International Organization for Standardization (ISO) standards, 9001:2015, 14001:2015, and 45001:2018 [Hydrema, 2024b]. ISO 9001:2015 is a quality management standard, which aims at getting companies to commit to quality by improving their performance and meeting their customer demands [International Organization for Standardization, 2015c]. An important aspect of the standard is that it sets requirements for the companies to define how they are establishing and continuously improving their management system [International Organization for Standardization, 2015c]. ISO 45001:2018 is an occupational health and safety management standard, which comes with a framework on how companies should manage risks and improve their health and safety [International Organization for Standardization, 2018]. ISO 14001:2015 is an environmental management standard, which sets requirements for companies to continuously improve their performance on the environment [International Organization for Standardization, 2015b]. The following section will go more into depth with the ISO 14001:2015 standard, as well as describing Hydremas environmental management system.

2.2 Environmental management system

Hydrema has been certified by the ISO 14001:2015 standard since 2022 [Hydrema, 2024b]. The ISO 14001 standard aims for companies to adopt a systematic approach to environmental management to be able to contribute to sustainable development [International Organization for Standardization, 2015a]. The standard provides a framework for protecting the environment and specifies requirements for the certified companies [International Organization for Standardization, 2015a]. The standard is based on the Plan-Do-Check-Act (PDCA) model, which is the basis for how companies can continuously improve their environmental performance [International Organization for Standardization, 2015a]. The management system has the aim of being able to provide information on for example protection of the environment by being able to prevent significant environmental impacts, increasing the environmental performance, and controlling the way the company's products are for example designed and manufactured using a life cycle perspective to minimize burden shifting [International Organization for Standardization, 2015a]. The standard is based on the environmental aspects of a company's products and activities that the company is able to influence or control in a life cycle perspective [International Organization for Standardization, 2015a]. An important aspect of an environmental management system is the determination of the environmental policy, which should suit the scope of the environmental management system, and contain a structure on setting the company's environmental objectives and a commitment to protecting the environment [International Organization for Standardization, 2015a].

A part of the standard that Hydrema clearly expressed challenges with, during the internship on the 9th semester, is the determination of significant environmental aspects, which is point 6.1.2 in the standard [Hydrema Employees, 2025]. This point specifies that *"the organization shall determine the environmental aspects of its activities, products, and services that it can control and those that it can influence, and their associated environmental impacts, considering a life cycle perspective"* [International Organization for Standardization, 2015a]. They will then have to determine those aspects that potentially have a significant impact on the environment, with established criteria for deciding the significance [International Organization for Standardization, 2015a]. When using a life cycle perspective, the company will have to take the different life cycle stages into account, which is defined by International Organization for Standardization [2015a] as: *"raw material acquisition, design, production, transportation/delivery, use, end-of-life treatment and final disposal"*. A challenge related to the determination of significant environmental aspects is the establishment of environmental objectives because they have to take the significant environmental aspects into account [International Organization for Standardization, 2015a]. In the spring of 2025, Hydrema has been undergoing a recertification of its management system. During the audits, Hydrema got a deviation on their determination of significant environmental aspects because they did not take the life cycle perspective into account in their mapping. Another thing related to this deviation is that their mapping of environmental aspects lacked some quantitative numbers and clear criteria for their determination of which environmental aspects were deemed significant.

Hydrema's environmental objective is to make sure that they are developing and producing machines with a long life cycle perspective and that the machines they are developing are impacting the environment less [Jensen, 2024]. This objective is anchored in Hydrema's environmental policy, which is as follows:

- *"Comply with existing legal requirements and relevant authority requirements*

- *Actively participate in sustainable development and cleaner technology under consideration of the economically responsible*
- *Ensure that we develop, produce, and service machines with a long life cycle perspective*
- *Aspire to develop and produce machines with lower consumption and thereby impact the environment less*
- *Register and list potential measures for environmental improvements that are prioritized and assessed based on determined technological, economic, and environmental aspects*
- *Actively reduce the number of suppliers and chemicals that are used in Hydrema Group*
- *Take an active and open attitude towards information, knowledge, and dialogue with relevant stakeholders*
- *Inform, educate, and motivate employees to ensure that we live up to the demands in the policy, objectives, and action plans"* [Jensen, 2024].

2.3 ESG reporting

The ISO 14001 standard is voluntarily adopted by Hydrema, however, they are also subject to environmental requirements from the authorities. A requirement that Hydrema is facing is that of a sustainability report, which is determined in the Corporate Sustainability Reporting Directive (CSRD) [European Commission, 2025a]. Hydrema is initially affected by this directive from 2025 and will have to publish its report in 2026 because they are a large company [Worldfavor, 2023]. This directive entered into force at the start of 2023 and is a part of the European Green Deal [European Commission, 2025a]. It aims at stakeholders being able to evaluate the companies' performance on sustainability parameters [European Commission, 2025a]. The companies that are affected by the directive will have to make their reports in accordance with the European Sustainability Reporting Standards (ESRS), which is developed by the European Financial Reporting Advisory Group (EFRAG) [European Commission, 2025a]. The ESRS specifies the information on sustainability that the affected companies of the CSRD will have to report in [European Union, 2023]. It specifies the information that the affected companies will have to report on their *"material impacts, risks and opportunities in relation to environmental, social, and governance sustainability matters"* [European Union, 2023]. Environmental, social, and governance reporting will henceforth be referred to as ESG reporting. In ESG terminology, the term "material" is essential and is, in this case, synonymous with the term "significance", which will be used henceforth in this project to streamline the language used. In February of 2025, the European Commission, however, released an omnibus proposal that aimed at reducing the requirements from the CSRD [European Commission, 2025b]. This proposal wants to reduce the requirements by making the only affected companies the ones with more than 1000 employees and postponing the time of the reporting requirements by two years [European Commission, 2025b]. This means that Hydrema would have to report from the financial year of 2027 instead of 2025, however, they might avoid the requirements totally if they agree on the part of only having the requirements for companies with more than 1000 employees. Even though Hydrema's requirements have been postponed with the possibility of being removed, they have decided to carry on the work with their ESG reporting, which they have already been started, and therefore they will release information on ESG in their annual report from 2025 [Hydrema Employees, 2025].

The companies affected by the CSRD will have to report on the ”minimum disclosure requirements” of the ESRS as well as the subjects that the company has assessed as being significant through their ”double materiality assessment” [European Union, 2023]. The double materiality assessment is used to identify the significant impacts, risks, and opportunities of the company, which they henceforth will need to report on in their ESG report [European Union, 2023]. The double materiality assessment contains impact significance and financial significance, and a sustainability subject can be assessed as significant if it meets the criteria for either of them or both [European Union, 2023]. This assessment is a starting point for a company's work with their ESG reporting because it identifies the things that the company will have to report on, based on what is deemed significant for the company [European Union, 2023]. The significant impacts, risks, and opportunities will have to be identified in the whole value chain of the company, meaning both upstream and downstream, which is affected by the direct and indirect business relationships of the company [European Union, 2023].

A part of the reporting requirements that Hydrema expressed as being a challenge was the calculation of their scope 3 emissions. The companies affected by the CSRD will have to report their scope 1, scope 2, and significant scope 3 emissions [European Union, 2023]. Scope 1 emissions are the direct emissions from the company, scope 2 emissions are the indirect emissions from the company that originate from the consumed energy, and scope 3 emissions are the indirect emissions that occur in the upstream or downstream value chain of the company [European Union, 2023]. The requirements on reporting on the company's scope 1 and 2 emissions are applicable from the first year of reporting, and the requirement on reporting on the significant scope 3 categories is applicable from the second year of reporting, for companies that are not exceeding 750 employees [European Union, 2023]. Because Hydrema has around 600 employees, they are affected by the requirement for their ESG report to be published in 2027. The significant scope 3 emissions are based on the scope 3 categories that are assessed as being significant for the company [European Union, 2023]. There are 15 categories of scope 3 emissions:

1. *"Purchased goods and services*
2. *Capital goods*
3. *Fuel- and energy-related activities*
4. *Upstream transportation and distribution*
5. *Waste generated in operation*
6. *Business travel*
7. *Employee commuting*
8. *Upstream leased assets*
9. *Downstream transportation and distribution*
10. *Processing of sold products*
11. *Use of sold products*
12. *End-of-life treatment of sold products*
13. *Downstream leased assets*
14. *Franchises*
15. *Investments"* [Greenhousegas protocol, 2011]

2.4 Incorporation of environmental aspects in product design

As stated in Section 2.2, Hydrema will need to look at the environmental aspects of their products using a life cycle perspective. A way that a company can consider its products' environmental aspects using a life cycle perspective is through the incorporation of the environmental aspects into the design or the redesign phase of their products, which can also be referred to as ecodesign [International Organization for Standardization, 2020]. Ecodesign is a systematic way of considering the environmental aspects in product development, aiming to reduce negative impacts [International Organization for Standardization, 2020]. Ecodesign can become an integrated part of a company's ISO 14001 environmental management system, which can create the advantage of identifying product-related environmental aspects and impacts in each life cycle stage and being able to use it in the development of the products [International Organization for Standardization, 2020]. The integration of ecodesign in a company's environmental management system is standardized in ISO 14006:2020, which describes guidelines for the implementation [International Organization for Standardization, 2020]. Ecodesign can be a method for identifying opportunities and risks in the design or redesign phase, which can be relevant when choosing to mitigate or reduce negative impacts [International Organization for Standardization, 2020].

On the 18th of July 2024 the 'Ecodesign for Sustainable Products Regulation' (ESPR) entered into force, which aims at improving the EU market's products' sustainability [European Commission, 2024]. This can be done by enhancing the products' energy performance, circularity, durability, and recyclability [European Commission, 2024]. It replaces the former Ecodesign directive, extends the scope to almost all physical products, and makes requirements on circularity, durability, and reduction of the environmental impacts from products on the EU market [European Commission, 2024]. The ESPR regulation is applicable to all products on the market, with a few exceptions [European Union, 2024b]. One of the things that is not regulated in the ESPR is vehicles that are regulated in other EU sector-specific regulations [European Union, 2024b].

Another part of the ESPR is the introduction of digital product passports (DPP), which aim to store relevant sustainability information for customers to make more sustainability-informed decisions [European Commission, 2024]. The aim of the DPP initiative is to enhance product value chain transparency, which is done by supplying information on the materials in the products, their environmental impacts, and recommendations for how to dispose of the products [European Union, 2024a].

Even though Hydrema is producing vehicles that are likely regulated by other EU sector-specific regulations, they are still certified by ISO 14001, which can benefit from adopting ecodesign as stated in International Organization for Standardization [2020]. This will enhance Hydrema's understanding of their environmental aspects and impacts in the different life cycle stages of their products, which can create the opportunity for them to make more sustainable design choices [International Organization for Standardization, 2015a, 2020]

2.5 State of the art

To uncover the state of the art of the current research in this field, a literature review was conducted. The method behind the literature review is described in Section 5.1. As mentioned in Chapter 1, an opportunity to make a more comprehensive LCA to help Hydrema with their environmental work occurred. Therefore, the use of LCA for compliance with environmental management and ESG reporting was uncovered in the literature review. These topics were chosen because they are some of the areas in Hydrema's environmental work that they are struggling with. Many linkages between these topics were found, as well as opportunities and limitations. The first topic that will be described is the linkages between LCA and environmental management systems, then the linkages between LCA and ecodesign, and then the linkages between LCA and ESG reporting. Next, the opportunities and limitations of LCA in a company's environmental work will be described, and lastly, simplified LCA will be touched upon.

2.5.1 LCA used for environmental management system

One of the challenges that were observed in Hydrema's environmental work during the internship was problems with determining the environmental aspects for their ISO 14001 certification. An important part of determining the environmental aspects is taking a life cycle perspective into account [International Organization for Standardization, 2015a]. This perspective promotes the use of LCA for environmental management systems, and to live up to these standards auditors have stated that the certified companies will have to conduct work that is likely to the work of a standardized LCA, even though a full LCA is not required, which means the life cycle approach can be much simpler [Lauesen, 2019]. LCA is a tool that can be used for assessing the potential environmental aspects of, for example, a company's products [Lin et al., 2018]. It can help with identifying opportunities for improvement of the environmental aspects, and from this be able to aid the decision-makers with making decisions in the strategic planning of the company's environmental management system [Rybaczewska-Błażejowska and Sulerz, 2017]. According to Cumming [2017], LCA is a critical part of the future approaches to environmental management systems for companies.

Another link identified while reading the articles from the literature review was the link between environmental management systems, ecodesign, and LCA. Here Lewandowska and Matuszak-Flejszman [2014] states that the updated ISO 14001:2015 standard might increase the interest for companies in ecodesign, where a tool for this is LCA. This is linked to integrating the environmental aspects into the design of a company's products [Lewandowska and Matuszak-Flejszman, 2014]. These calculated environmental impacts from the LCA could then be used when making the environmental policy and environmental objectives, where it would then be possible to make objectives to try to reduce the impacts [Lewandowska and Matuszak-Flejszman, 2014]. Lewandowska and Matuszak-Flejszman [2014] also states that LCA can have positive impacts on an environmental management system because it makes it possible to realize ecodesign processes.

LCA is not the only method that can be used to assess the environmental aspects and the significance of these for a company. Mahzun and Kalalo [2019] states that the environmental performance of a company can be assessed using different methods. When assessing the environmental aspects, the potential of environmental impacts, the frequency of these impacts, as well as the degree of the impacts are important factors [Mahzun and Kalalo, 2019]. Another important aspect of the determination of environmental aspects is that the certified companies will have to determine their significant environmental aspects [International Organization for Standardization, 2015a]. Mahzun and Kalalo [2019] sets seven criteria for determining significance:

1. *"Legal obligation*
2. *The risk of an environmental spill incident*
3. *Past environmental incidents*
4. *Nuisance to neighbors*
5. *International protocols or company policies/procedures*
6. *Lack of information available to decide on the impact*
7. *Operation control"* [Mahzun and Kalalo, 2019]

This approach of finding the significant environmental aspects does not explicitly take the life cycle perspective into account. The criteria look more into local environmental problems that can occur for a company, and therefore do not take global problems into account. From the life cycle perspective and global perspective, an LCA could help a company gain this knowledge.

LCA can therefore be a useful tool for assessing the environmental aspects of a company, which can be used in the environmental policy and environmental objectives in an environmental management system. The significance of the environmental aspects can be determined using the seven criteria mentioned above. In this part of the literature review, a connection between environmental management systems, ecodesign, and LCA was also identified. The linkage between LCA and ecodesign will be described further in the following section.

2.5.2 LCA used for ecodesign

Ecodesign has the aim of creating products that are both economically and technically good, with the lowest possible impact from a life cycle perspective [Campos-Carriedo et al., 2024].

As mentioned in Section 2.4 and 2.5.1, ecodesign can be a part of a company's environmental management system, which is also described in the ISO 14006 standard [International Organization for Standardization, 2020]. Therefore, the company's environmental management system can be a way for a company to incorporate ecodesign, which aims at minimizing the environmental impacts on products throughout their life cycle [Singhal et al., 2024]. Ecodesign is, however, difficult to implement because it is complex and requires consideration of both economic costs, social implications, and environmental impacts [Singhal et al., 2024].

Multiple of the read articles state that LCA can be used as a tool for ecodesign [Rybaczewska-Błażejowska and Sulerz, 2017; Cascini et al., 2016; Singhal et al., 2024; A. Maschio et al., 2024; Fang et al., 2024; Lee et al., 2024; de Lapuente Díaz de Otazu et al., 2022; McAloone and Pigosso, 2017; Suppipat et al., 2021]. LCA is a method for assessing the environmental impacts of a product in all its life cycle stages [Fang et al., 2024]. This is important in an ecodesign perspective because it can help with setting scenarios for minimizing the environmental impacts that are occurring in the production [A. Maschio et al., 2024]. Having an assessment of the environmental impacts can aid the decision-making processes for the ecodesign of products [A. Maschio et al., 2024]. LCA can be used in two ways in ecodesign, either by being used to evaluate the environmental sustainability of a product or for designers to identify where improvements on the environment can be made [Lee et al., 2024]. de Lapuente Díaz de Otazu et al. [2022] states that the incorporation of LCA in the ecodesign process can create the opportunity for the company to make informed decisions on the sustainability of products. As previously described, there is a link between LCA, ecodesign, and environmental management systems. LCA in ecodesign can aid the company in identifying its significant environmental aspects, and an evaluation of the environmental impacts can be useful in the design phase of products [Suppipat et al., 2021].

Even though LCA can act as a tool for the ecodesign process, there can also be challenges in this incorporation [McAloone and Pigosso, 2017]. One of the challenges is related to the dilemma between knowledge and opportunity, meaning when the knowledge about the product is high, the opportunity of changing the product is lower [McAloone and Pigosso, 2017]. Another challenge is related to the competencies and knowledge that are required to conduct the LCA in ecodesign [McAloone and Pigosso, 2017].

Another thing that Hydrema expressed challenges with, and there was also detected a link with LCA is the ESG reporting. The link between LCA and ESG reporting will be described in the following section.

2.5.3 LCA used for ESG reporting

As mentioned in Section 2.3, environmental accounting is a part of ESG reporting, which Hydrema initially faced in 2025. ESG has the aim of guiding companies in a more sustainable direction, and ESG can help transform and improve the decisions made in the company [Ngan et al., 2024]. Another aim of ESG reporting is for the obliged company to report on their emissions in their supply chain, which is to increase transparency [Emborg and Olsen, 2024]. However, there is a possibility of ESG reporting becoming subjective, where it is mostly used to attract customers, rather than becoming more sustainable [Ngan et al., 2024]. Therefore, there can be detected a lack of reliable ESG tools, where LCA is a tool that can be used for the environmental part of ESG reporting [Haque, 2024].

Multiple of the read articles state that LCA can be used to benefit the environmental part of ESG reporting [Shanker et al., 2025; Haque, 2024; Ngan et al., 2024; Del Borghi et al., 2024; Molnár et al., 2024; Emborg and Olsen, 2024]. One of the specific challenges Hydrema perceived was the calculation of scope 3 emissions for their ESG reporting. Here Molnár et al. [2024] states that LCA is an important tool for calculating the scope 3 emissions from a company. This observation is also made by Shanker et al. [2025] and Emborg and Olsen [2024], who also state that LCA can help with calculating the environmental impacts of a company, which includes their scope 3 emissions.

The field of ESG reporting is rather new, and therefore, there is not much literature on the use of LCA in ESG reporting. In the following section, some general opportunities and limitations of the use of LCA in a company's environmental work will be described.

2.5.4 Opportunities and limitations of LCA in environmental work

Incorporation of LCA in a company's environmental work can create both opportunities, but it also has certain limitations. LCA can give a company information about their products' environmental consequences [Di Bari et al., 2022], which can be used to identify the largest impacts and why they are occurring [Rybaczewska-Błażejowska and Sulerz, 2017]. LCA can also aid as a decision-making tool for the company to make informed decisions, which can be used to achieve sustainable goals and be used to compare alternatives [Tascione et al., 2024; Eleftheriou et al., 2022]. It can also be considered as a useful tool for designers, where LCA can be used with the aim of mitigating the environmental impacts from the products they are designing [Suppipat et al., 2021]. Other than being used as a decision-making tool, an LCA also has the ability to be used as a branding tool, because it can increase the trustworthiness of the impacts on a company's products [Lauesen, 2019].

Even though a company can benefit from incorporating LCA in their environmental work as described above, however also has some limitations. Although LCA can aid the design process, Cicconi et al. [2018] states that it is more useful in a redesign phase and therefore not appropriate for the early design phases, because it is both time-consuming, and the data that are needed to conduct the LCA is not yet available. Another challenge in incorporating LCA in the design phase is linked to the requirement of expert knowledge to carry out the LCA because LCA is mostly perceived as time-consuming, complex, and costly [Prideaux et al., 2024]. Multiple of the read articles explain the challenge in LCA being time-consuming and resource-intensive [Cicconi et al., 2018; Lauesen, 2019; Fang et al., 2024; Dekker et al., 2024; Prideaux et al., 2024]. This can be explained by an LCA being very comprehensive [Ng, 2018], and because the data needed are complex [Eleftheriou et al., 2022]. Because of the complexity of data, Shanker et al. [2025] states that reliable databases are important because some LCAs are based on generic background data from databases, as comprehensive data collection might not have been possible. The data used for the LCA is affecting the results, and another thing that is affecting the results of the LCA is the modeling approaches. Therefore, the knowledge about the data and modeling approach is important [Mendecka and Lombardi, 2019]. The different modeling approaches of LCA will be described in Section 5.2.

Because there are certain challenges with incorporating traditional, detailed LCA in a company's environmental work, simplified methods have been researched. The use of simplified LCA methods will be described in the following section.

2.5.5 Simplified LCA

As stated above, an LCA is a detailed analysis tool that is both comprehensive, time-consuming, and resource-intensive. Therefore, simplified LCA methods were looked into through the literature review. The simplified LCA methods have the aim of making the use of LCA more practical, accessible, and less data-intensive, and several methods can be used to simplify the LCA [Prideaux et al., 2024]. These simplifications can be done, for example, by adopting estimates or harmonizing LCA results [Mendecka and Lombardi, 2019]. The aim of the simplified LCA methods is therefore to provide the same information as a detailed LCA, but more superficially, which can be used to both identify environmental hotspots and highlight the improvement opportunities [McAloone and Pigosso, 2017]. Another way of simplifying the LCA is by limiting the data requirement and the impact categories that are calculated [Dekker et al., 2024].

These simplified LCA methods are recognized as useful in the design phase of a product [McAloone and Pigosso, 2017; Prideaux et al., 2024; Pollini and Rognoli, 2021]. This is both because the simplified models make it more accessible and less difficult for designers to conduct [Prideaux et al., 2024], and it can aid the designers in choosing materials for a product [Pollini and Rognoli, 2021].

Research Question and research design 3

Through the internship, 9th semester project, and the problem analysis, it became clear that Hydrema has some challenges in their work with their environmental management system and their ESG reporting. It was found in the state of the art of how LCA is used in this problem field, that LCA can aid in a company's determination of their significant environmental aspects for their environmental management system, and that it can aid the environmental part of ESG. During the internship, problem analysis, and audit observations, a gap was, however, detected in how Hydrema takes the life cycle perspective of their environmental aspects into account, which is a part of point 6.1.2 in the ISO 14001 standard [International Organization for Standardization, 2015a]. This problem analysis and gap then led to the following research question:

> *"How can LCA aid Hydrema with assessing significance in their environmental management system and ESG reporting?"*

With related sub-questions:

> *"How does Hydrema perceive LCA, and how can this understanding inform its practical implementation within the company?"*

> *"What are the benefits and barriers of implementing the LCA system in Hydrema?"*

3.1 Research design

To map out the logical path of how to answer the research question and related sub-questions, a research design was made. The research design can be seen in Figure 3.1.

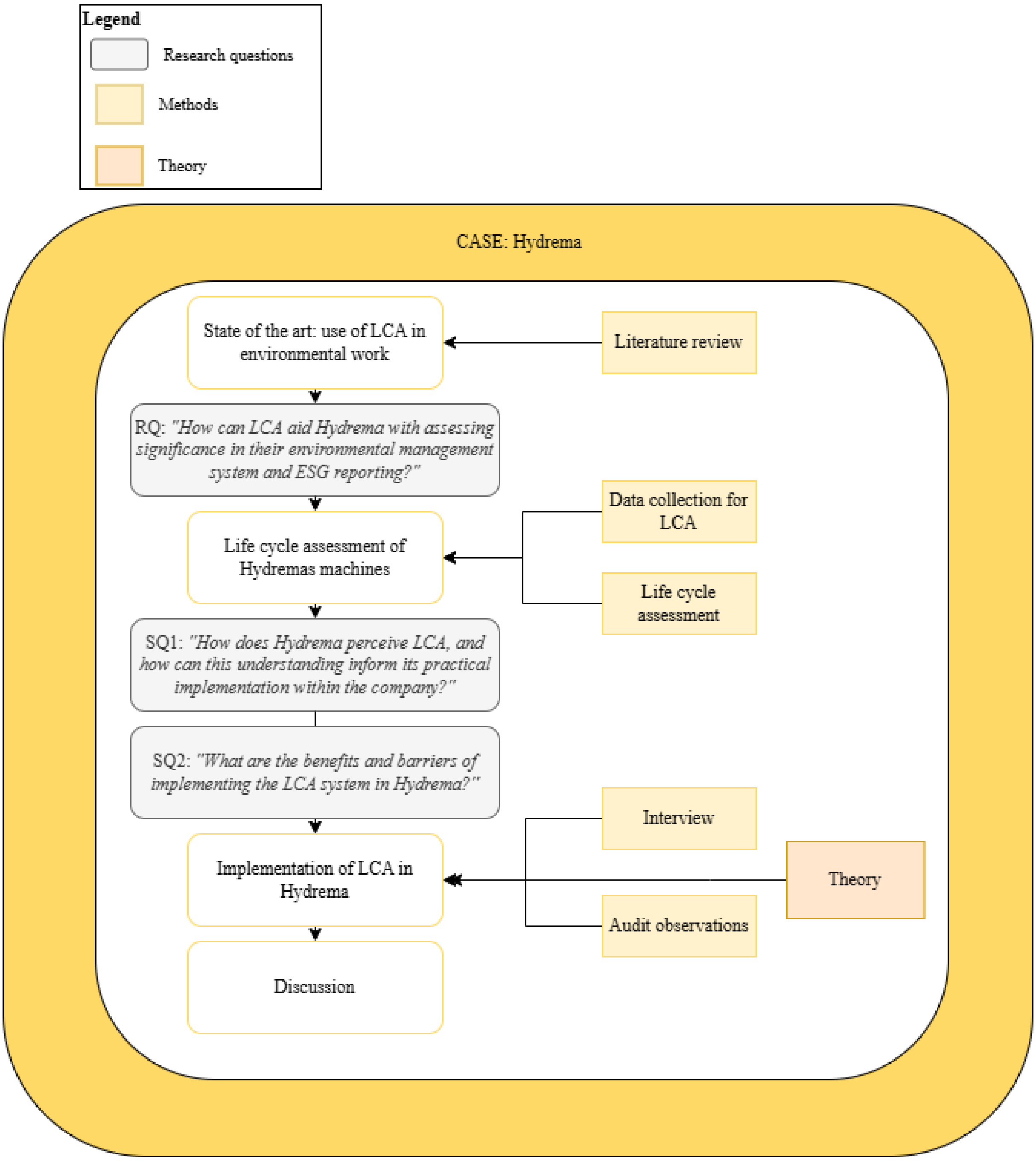


Figure 3.1. Research design of Master's thesis (Own production)

The research design is pictured as a case design, with Hydrema as a case. The case is pictured as a frame for the whole research because aspects of the case are present in the research questions and related analyses. In the research design, the grey boxes contain the research questions and sub-questions, the full yellow boxes contain the methods used and which analyses they are used in, and the orange box is the theory.

Theory 4

4.1 Theoretical framework

In this section, the theoretical framework will be presented. The theoretical framework is chosen to create a language in which it would be possible to describe an eventual implementation of sustainable initiatives in environmental management systems and other general corporate environmental work. This master's thesis specifically aims to describe how the implementation of LCA in Hydrema's environmental management system and ESG reporting can take place and what the benefits and barriers are. The theory takes the point of departure in multiple scientific articles, and is therefore not an established theory, but a composition of anecdotes connected, from which the implementation can be described on behalf of. The theory will be used explicitly in the implementation analysis in Chapter 7.

In recent years, there has been a higher focus on companies' environmental performance. The environmental performance of a company depends on the management in a company, and therefore, the organization and management are important when talking about environmental performance [Baumann, 2004]. A common way of dealing with environmental performance for companies is through the adoption of an environmental management system [Baumann, 2004]. An example of an environmental management certification is the ISO 14001:2015 standard, which is described further in Section 2.2. These systems are, although often limited to production site-specific operational issues, and therefore often do not take issues 'around' the operation of the company into account [Baumann, 2004]. According to Baumann [2004], the environmental effectiveness of implementing an environmental management system is, however, not known. This is because the environmental performance is often first evaluated after the environmental management system is implemented, and therefore it is not transparent whether improvements on the environmental performance of a company originate from the environmental management system or other initiatives, such as, for example, a changed production [Baumann, 2004]. In the literature examined by Baumann [2004], there is a larger focus on the operation of environmental institutions, but less focus on their actual ability to deliver environmental protection.

Baumann [2004] identifies two approaches for linking the organizational processes with the environmental performance. These are the correlational and the relational approaches [Baumann, 2004]. When the organizational processes are linked with the environmental performance on the correlational approach, their environmental data collection is done independently from their other organizational data collection [Baumann, 2004]. If they, on the other hand, are using the relational approach, they are looking at the technology for handling their data collection, and the activities that are related to the data collection and the performance thereof [Baumann, 2004].

Environmental parameters that will be used in environmental management can be based on LCA or other similar methods [Baumann, 2004]. A way of incorporating the life cycle perspective in environmental management is by utilizing LCA, and although many attempts have been made to facilitate it, the industry has been slow to adopt it [Rex and Baumann, 2008]. The primary driver for a company's adoption of LCA is through regulatory and market demands, however, LCA is an ambitious tool, because the adopting companies will have to look into their activities outside traditional responsibilities [Rex and Baumann, 2008].

The management of the life cycle for a company requires the employees to manage a lot of knowledge, because it exceeds the traditional environmental issues inside of the company's boundaries [Nilsson-Lindén et al., 2014]. As stated in Section 2.2, a part of the ISO 14001 standard is that certified companies should consider their environmental aspects in a life cycle perspective. This perspective creates attention on all life cycle stages, and results in certified companies having to broaden their scope of their environmental management system [Kristensen et al., 2021]. This perspective thus creates an incentive for companies to look at impacts in their product life cycle, rather than only in the production, which is the more traditional way of handling the environmental management systems [Kristensen et al., 2021]. According to Kristensen et al. [2021], the environmental management systems are an embedded part of Danish companies, which focus mainly on production processes, with a smaller focus on the development of products, ecodesign, and circular economy.

A part of the environmental management system is also the determination of environmental objectives, where the most common ones are on energy, waste, and water consumption, and the least common ones are for LCA, biodiversity, and design [Mosgaard et al., 2021]. A way of including the life cycle perspective in an environmental management system, according to Mosgaard et al. [2021], is by broadening the scope of the system, by including more product-oriented and strategic initiatives when determining the environmental objectives, which can create strategic drivers that go beyond traditional operational measures. In recent years, the understanding of environmental aspects has broadened from end-of-pipe solutions to a more sustainable development, but although this development, the Danish environmental management systems seem to fall behind in this regard [Mosgaard et al., 2021]. The development of environmental aspects can be reflected in an environmental management system by implementing LCA, because this technology has joined the environmental understanding [Mosgaard et al., 2021]. According to Mosgaard et al. [2021], a company's environmental management system should be able to aid the development of environmental aspects, to minimize the consequences of a company implementing environmental objectives that might not be strategically most relevant for them.

Heiskanen [2002] states that the company life cycle approach is not widespread. A way to explain why is by the utilization of institutional logics, where the different logics represent beliefs, which establish the appropriate behaviors [Heiskanen, 2002]. When talking about institutional logics, LCA can be seen as an institutional logic that is emerging, because the context of companies' use of LCA is expanding [Heiskanen, 2002]. According to Heiskanen [2002], LCA has in some cases been used tactically and instrumentally to protect the adopting companies from approaching legislation. The utilization of LCA has also expanded from being used only to compare products, to now being used to identify where environmental initiatives might be most effective [Heiskanen, 2002]. Even though LCA can benefit companies, some sectors still struggle to acknowledge the benefits of implementing LCA [Heiskanen, 2002]. If a company then implements the life cycle thinking into their management, it will direct their attention towards some of the indirect environmental impacts of their organizational activities, that might happen outside the company boundary [Heiskanen, 2002]. When a company chooses to adopt a life cycle approach to its management system, it can become a structural process where already established institutional practices are changed because of the adoption of a new technique, in this case LCA [Heiskanen, 2002]. According to the analysis made by Heiskanen [2002], the employees at the analyzed companies became more interested in collecting environmental data after their introduction to LCA.

LCA can therefore be described as an emerging institutional logic that can be used both instrumentally and tactically by companies with an environmental management system. It thus has the potential to broaden a company's scope of its environmental management system to take more untraditional aspects into account. For implementing LCA in an environmental management system, more data is needed, and this link between a calculation of product environmental performance and established organizational processes can be done with either a correlational or a relational approach. To sum up the theoretical terms presented in the theoretical framework, Figure 4.1 is presented below.

Theoretical term	Description
Institutional logic	Different institutional logics represent different beliefs that affect behavior. Different companies can therefore have different institutional logics, in which the employees' perceptions come into play, in this case on how companies understand and act on environmental aspects and impacts.
Correlational approach	The first approach for linking organizational processes with environmental performance, the correlational approach, the company's environmental data collection are done independently from other organizational data collection.
Relational approach	The second approach for linking organizational processes with environmental performance, the relational approach, the companies are looking into finding technologies for a more connected data collection, containing both environmental data and organizational data

Figure 4.1. Table of description of theoretical terms essential for the theory (Own production, based on [Baumann, 2004; Heiskanen, 2002])

These terms will be used to describe the benefits and barriers of the implementation of LCA in Hydrema's environmental management system, which can be found in Chapter 7.

4.2 Reflections on the chosen theories

This theoretical framework is relevant for the research of this Master's thesis, because it creates a basis for explaining the implementation benefits and barriers of LCA in environmental management. The theoretical framework is based upon multiple different scientific articles, and therefore it is not as a whole, tested as a theory, but the anecdotes from the literature will be used for the analysis. The theoretical framework is based on an initial hypothesis that LCA can aid companies' environmental management systems, and therefore, the findings in the articles reflect this. This creates limitations on other perspectives of this field because it focuses solely on LCA, environmental management, and organizational processes. This theoretical framework thus leaves out other opportunities of utilizing LCA for a company, which could be, for example, as a decision-making tool, which is described further in Section 2.5.

Method 5

In this chapter, the methods used in this Master's thesis will be described. The first method that will be described is the method behind the literature review, described in Section 2.5. The second method that will be described is the method behind an LCA, which will be used in Chapter 6. The last method that will be described is the collection of empirical data for this thesis. This section is divided into three sub-sections, where the first section describes the method behind the conducted interviews, the second describes the method behind the audit observation, and the last describes the data collection for the LCA i Chapter 6.

5.1 Literature review

A literature review was conducted to describe the state of the art of the current research in the problem field. The literature review was carried out using multiple searches in the Scopus and Aalborg University Library databases. The search words used were mainly about LCA, environmental management systems, ESG, ecodesign, compliance, and significance, as well as a search about simplified LCA. The searches can be seen in Figure 5.1.

Figure 5.1. The searches carried out in the literature review (Own production (See Appendix A))

The searches were carried out in a way where the search words were searched for in the title and the abstract of the articles. When the searches were carried out, the titles and abstracts of the resulting articles were read through, and the articles that seemed relevant to cover the state of the art were chosen. The article names, year of publication, and a link were then put into an Excel spreadsheet, this Excel spreadsheet can be seen in Appendix A. In this spreadsheet, the articles each got a number. The numbers were given, so it was easier to see if some of the articles were repeated in the different searches; if that was the case, the articles would gain the same number. Initially, the time frame of how old articles were researched was down to 2010, however, through some reading of some of the older articles about environmental management it became clear that they were referring to the older ISO 14001 standard, and therefore the time frame was adjusted to not further down than 2015, where the new standard entered into force.

When all of the articles were chosen by reading through their abstracts, they were read more in-depth, where the key information from the articles was highlighted. The key findings were then noted in the Excel spreadsheet again (See Appendix A).

5.2 Life cycle assessment

To answer the research question and the following sub-questions, a life cycle assessment (LCA) will be conducted. LCA, as well as two methods and two modeling approaches, will be explained in the following sections. As stated in Section 2.5, LCA can be used for both environmental management systems, ESG reporting, and ecodesign. Therefore, LCA can be beneficial for a company's environmental work, even though it also has some limitations because it is comprehensive and time-consuming. LCA is standardized in two ISO standards: ISO 14040 and ISO 14044. The 14040 standard describes the principles and frameworks of LCA [International Organization for Standardization, 2008a], and the 14044 standard describes the requirements and guidelines of LCA [International Organization for Standardization, 2008b]. LCA is a method that can be used to understand the environmental impacts of products, which can then aid with identifying improvements for the product's environmental performance, as well as other things [International Organization for Standardization, 2008a]. LCA, therefore, can aid a practitioner in addressing the environmental aspects in the whole life cycle of a product [International Organization for Standardization, 2008a]. An LCA study is divided into four phases:

1. *Goal and scope*
2. *Life cycle inventory (LCI)*

3. *Life cycle impact assessment (LCIA)*
4. *Interpretation* [International Organization for Standardization, 2008a]

The first phase of an LCA is the goal and scope phase, where the goal of the LCA study is determined as well as the system boundary and functional unit of the product system that will be analyzed [International Organization for Standardization, 2008a]. The second phase of an LCA is the LCI phase, where all the inputs and outputs needed to fulfill the functional unit are described, as well as collecting the data on these inputs and outputs [International Organization for Standardization, 2008a]. The third phase of an LCA is the LCIA phase, which provides information on the environmental significance of the processes defined in the LCI phase [International Organization for Standardization, 2008a]. The fourth and last phase of an LCA is the interpretation phase, where the results of the LCI and LCIA are discussed to make conclusions and recommendations in relation to the determined goal and scope from the first phase of the LCA [International Organization for Standardization, 2008a].

5.2.1 Process and Input-output LCA

There are two methods for conducting an LCA, being a process LCA or an input-output LCA (IO-LCA), which lead to two different results from the LCA study [Säynäjoki et al., 2017]. Even though these two methods are different from each other, they can still follow the requirements of the two ISO standards [Säynäjoki et al., 2017].

The process LCA method is the traditional way of making an LCA and can be claimed to be more accurate than IO-LCA, even though the IO-LCA is less resource intensive [Säynäjoki et al., 2017]. The way a process LCA is modeled is by each process being modeled process by process and connected within a flow diagram to include all the relevant materials and energy within the system [Säynäjoki et al., 2017]. For this method, a lot of data and workload are needed, and therefore, it is rare that a process LCA study contains all the processes in the product [Säynäjoki et al., 2017].

The IO-LCA method builds upon economic transaction matrices based on sectors [Säynäjoki et al., 2017]. These matrices can, when environmental burden data is added, be able to assess the environmental consequence of making a transaction in the specific sector [Säynäjoki et al., 2017]. Even though the IO-LCA is less comprehensive than the process LCA method, it has the downside of not taking the gate-to-grave perspective of the life cycle into account, which means it only accounts for the extraction of raw materials to the company has sold the product into account [Säynäjoki et al., 2017]. It is important to distinguish between these two methods because they are affecting the results of the respective LCAs, and therefore they are making differing results [Säynäjoki et al., 2017].

5.2.2 Attributional and consequential LCA

As described in the section above, LCA can be made using two different methods, which affect the results of the LCA study. Another thing that can affect the results of the LCA study is the modeling approach used. There are two different modeling approaches for an LCA: attributional and consequential modeling [Hauschild et al., 2018]. The first modeling approach that will be explained is attributional modeling. An attributional LCA aims at representing a product system and does not take the rest of the technosphere and ecosphere into account [Hauschild et al., 2018]. It answers the question of which environmental impacts a product can be responsible for [Hauschild et al., 2018]. The attributional modeling uses average processes from the background system, and therefore, it highly reflects a modeling of an average supply chain [Hauschild et al., 2018].

The next modeling approach that will be explained is consequential modeling. This is a newer modeling approach compared to the attributional modeling, and it was made to remove some of the weaknesses from the attributional modeling [Hauschild et al., 2018]. It aims at describing the changes in the economy that are caused by the studied product entering the market, meaning the consequence of producing the product [Hauschild et al., 2018]. This means that a consequential LCA aims at answering the question: *"What are the environmental consequences of consuming X?"* [Hauschild et al., 2018]. This approach is different from the attributional approach because it takes the changes in the economy into account, and this can make differing results compared to a study that looks at a product isolated from the economy [Hauschild et al., 2018]. Instead of using average processes as the attributional approach does, the consequential modeling approach uses marginal processes, which can be explained as the processes that are taken in or out of use as a reaction to a decrease or increase in the product demand [Hauschild et al., 2018].

The foreground systems of both attributional and consequential modeling are mostly modeled the same way, however, the background systems are modeled differently [Hauschild et al., 2018].

The LCA carried out in Chapter 6 is made using the consequential modeling approach. Therefore, the analysis aims to find the environmental consequences of buying a Hydrema machine. The machines produced at Hydrema are only produced on demand, and therefore, the production is highly dependent on the sales of machines. The consequential modeling approach is relevant because it is forward-looking at consequences, taking into account the market changes that will happen in accordance with the demand for the Hydrema machines. The consequential modeling approach, therefore, does not use average processes like the attributional modeling approach [Hauschild et al., 2018]. Another relevant aspect of choosing the consequential modeling approach is that it aims at being used as decision support [Consequential-LCA, 2021]. Therefore, the consequential system can be used to compare the different machines, or look into a specific machine and look at the internal hotspots [Consequential-LCA, 2021]. This can then hopefully aid Hydrema in assessing where in the life cycle of their products are hotspots that are relevant for them to work with in their environmental management system, when setting environmental objectives.

5.3 Collection of empiricism

Some empirical data was gathered to answer the research question and the related sub-questions. This collection of empiricism consisted of both qualitative methods as well as quantitative methods. One of the qualitative methods used to gather data was 4 interviews with different professionals in the field. Another qualitative method used to gather data was observations made at both internal and external audits at Hydrema. A quantitative method for data collection was also used to gather weights and other data on the different materials in the machines Hydrema is producing, which are used in the LCA. The methods for gathering empiricism will be described further in the following sections.

5.3.1 Interview

As stated above, one of the qualitative methods used to gather data was interviews. In the interviews, a semi-structured approach was used, based on an interview guide. The aim of the semi-structured interview is that the interviewer, prior to the interview, has determined some questions they want answered during the interview in an interview guide, however, it is possible to go beyond the questions [Aarhus Universitet, 2025]. This is an advantage because it is then possible for the interviewer to ask questions that they might have along the way, and therefore be able to twist the interview in a more desired way [Aarhus Universitet, 2025]. The interviews were recorded, so it was possible to go back into the recording and get direct quotes from the interviewees. After each interview, the recordings were heard again and transcribed, which can be seen in Appendix G-I.

For this Master's thesis, 4 interviews were held. The first interview took place on the 20th of March 2025, and the interviewee was Stig Hirsbak. Stig Hirsbak is an Associate Professor at Aalborg University's department of planning and sustainability. This interview gained insights into the thought behind incorporating the life cycle perspective in the ISO 14001 standard. This interview became more of a conversation, where he came up with ideas for things to incorporate into the thesis and people that might be relevant to contact. This interview, therefore, benefited from the semi-structured approach because it allowed both the interviewer and interviewee to take the conversation in directions that they found beneficial. The interview answers were not actively used in the thesis, but his perspective was used throughout the project period.

The second interview took place on the 12th of May 2025, and the interviewees were Morten Nielsen (MN) and Anders Bo Poulsen (ABP). Morten Nielsen is the HSEQ manager, and Anders Bo Poulsen is a HSEQ coordinator in Hydrema's Health, Safety, Environment, and Quality (HSEQ) department. This interview gained insights into employees at Hydrema's perception of the utilization of LCA, their perspective on the implementation of LCA in their environmental management system and ESG reporting, and which benefits and barriers thereof they identify. The transcript of the interview with MN and ABP can be seen in Appendix G.

The third interview took place on the 12th of May 2025, and the interviewee was Klaus Behrndt (KB). Klaus Behrndt is a lead auditor at Bureau Veritas. This interview gained insights into an auditor's perspective on the implementation of LCA in environmental management systems, and which benefits and barriers there can arise when doing this. The transcript from the interview with KB can be seen in Appendix H.

The fourth interview took place on the 15th of May 2025, and the interviewee was Rikke Beider (RB), who is the product owner for the ISO 14001 standard in Bureau Veritas. This interview gave additional insights into an auditor's perspective on LCA in environmental management systems. The transcript from the interview with RB can be seen in Appendix I.

The last three interviews will be used for the analysis of the implementation of LCA at Hydrema in Chapter 7. The purpose of these three interviews was to gain insights from both sides, from the auditor who is reviewing the environmental management systems at companies, and from inside Hydrema, who have to live up to the requirements set by the standard and the deviations the auditors are finding.

5.3.2 Audit observation

During the project period, the author of this Master's thesis participated in two audits at Hydrema. The first audit was an internal audit on the 10th of March 2025, and the second audit was an external audit to recertify Hydrema in their three certifications on the 24th-26th of March 2025. To explain the observations that were made, the method 'Participant Observation' can be used. With this method, it distinguishes between active or passive observation as well as overt or covert observation [Dawn Brancati, 2018]. In passive participation, the researcher only observes the studied people without interacting [Dawn Brancati, 2018]. In active participation, the researcher interacts with the studied people, which can be both during interviews, but can also be where the researchers engage in the studied people's everyday lives [Dawn Brancati, 2018]. When the participant is covert, it means that the researcher does not reveal that they are researchers, however, they reveal this when being an overt participant [Dawn Brancati, 2018].

The participation observation method used when participating in Hydrema's audits was a passive, overt participation observation. This was because it was made clear to the auditors that a Master's thesis student was present, however, very little interaction from the student was made. The primary goal of attending the audits was to gain insights into which aspects of the certifications the auditors were particularly attentive over. Another reason was to make observations on how the auditors talk about the aspect of the life cycle perspective in the ISO 14001 standard.

5.3.3 Data collection for LCA

To conduct the LCA in Chapter 6, some data were needed. To gain the data, a meeting was held with Hydrema's research and development manager and one of the engineers employed in the research and development department. In this meeting, the modular setup of the machines was determined, and a part list of their bestseller machine, the 912G dumper, was gained [Hydrema Employees, 2025]. This parts list is made on the BOM level and contains qualitative descriptions of the components, however, it does not contain much quantitative data that could be brought directly into an LCA model. The structure of the BOM parts list can be seen in Figure 5.2.

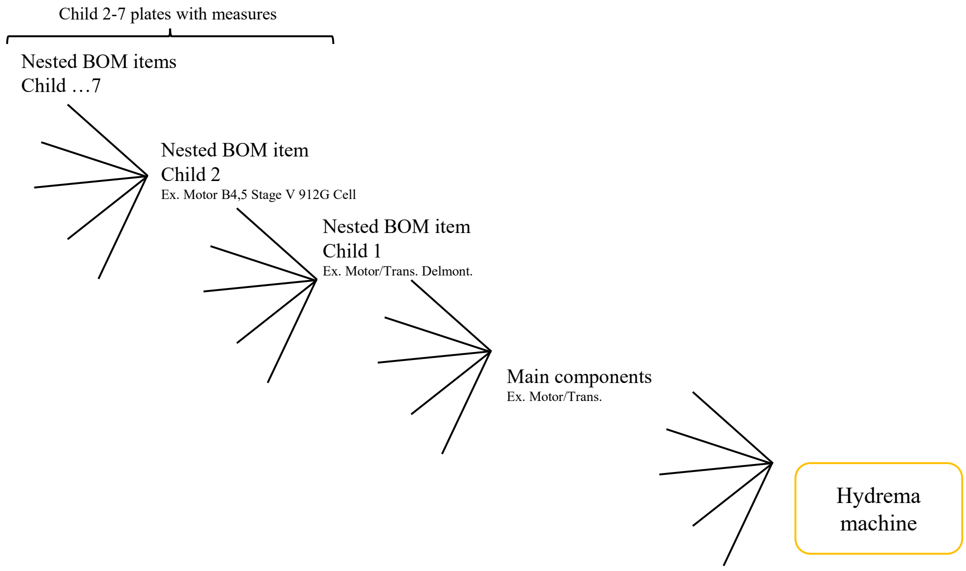


Figure 5.2. Construction of the BOM parts list with main components, that lead to different levels of sub-components (Own production, based on Hydrema BOM parts list 912G dumper)

The BOM structure starts with what the visualization refers to as the main components. These main components link further down to what the visualization refers to as "nested BOM items." These nested BOM items are modeled in the parts list like a Chinese box system, where each level, also referred to as a child, of the nested BOM items contains some 'empty' references to further childs and also some materials and components. This means that for most childs is both materials and further links to a lower child.

The modular setup that was agreed on consisted of 8 modules, which are:

- Motormodule
- Tyremodule
- Hydraulicmodule
- Cabinmodule
- Wirenetmodule
- Batterymodule
- Functionsmodule
- Chassismodule

By reading the parts list, it became clear that the 912G dumper consisted of multiple main components with multiple sub-components, and many of these sub-components could also be divided into multiple sub-sub-components. Some of these sub-components eventually led to the steel plates that were used to make the components, as visualized in Figure 5.2. The parts list, however, was not explicit about other materials that were used, and did not contain quantitative measures of the materials. This knowledge from the BOM part list then had to be translated into data that could be used in the LCA. The path of the translation can be seen in Figure 5.3.

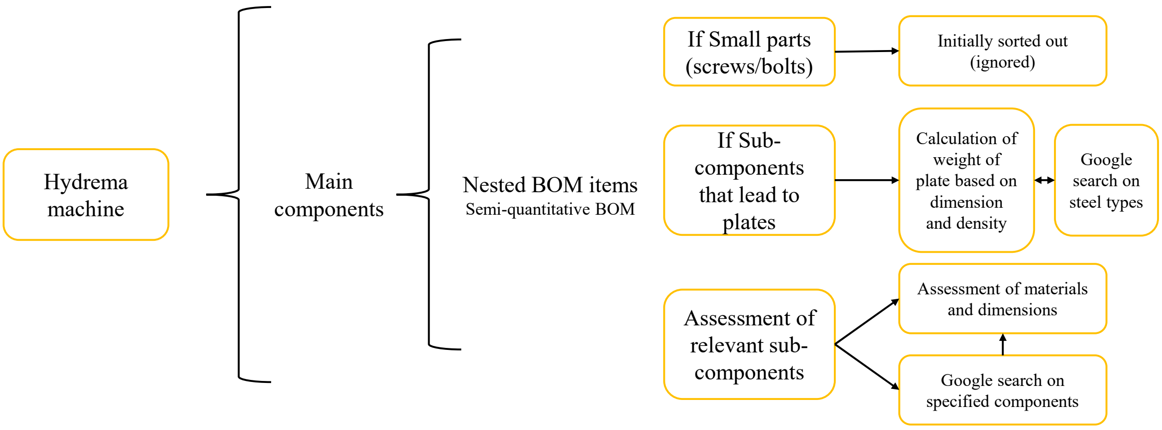


Figure 5.3. Visualization of how the BOM data has been translated to LCA data (Own production)

To model the machine in the 8 determined modules, the main components were looked at and classified into the different modules. This was done by looking at the machine and the technical drawings of the components. This was done in a separate Excel spreadsheet, which can be seen in Appendix B. In this Excel spreadsheet, the first sheet consists of the 912G dumper divided into the different modules, with the different relevant main components listed under the modules. Each module then got its own sheet in the spreadsheet, and in each sheet, the different components with their appurtenant sub-components and sub-sub-components were inserted. Many of the components did not explicitly state which materials they were made of and the dimensions thereof; however, the steel components led back to the steel plates, dimensions thereof, and alloys that were used, as well as how much of the plate was used for the component. All of these plates were then put into a separate sheet divided into the different modules they belonged. Then, the weight in kilos of the amount used of the plates was calculated by using the density of steel, using this equation:

$$(Density_{steel} * (volume_{plate} * amount_{used}))/1000 \tag{5.1}$$

When the weight of the plates was calculated, they were summarized so it was possible to see how much steel went into the different components, modules, and in total of the whole machine. Because it was mostly not explicit in the parts list which other materials were a part of the machine, another trip to Hydrema was made. This time, the visit took place in the production area to see the production of the components, the assembly of the machine, and the finished machine. This helped with determining some other materials that were visible on the machine but not described in the parts list. On this trip, a lot of pictures were taken both of the production and of the finished machine to remember the observations. With this knowledge, the parts list was looked at again, and this time, some important components that were not described further in the parts list were put into a separate sheet. Some of the materials and weights of components were found using a Google search. This was done, for example, for the motor, the transmission, the battery, the tyres, and other components where a name for the specific component could be found. Some of the other components were dimensioned based on the observations of the machines and the materials, and from this, a weight could be estimated using the density.

In the first sheet, where the 912G dumper has been modeled with the different modules and related components, the different components were divided into the head materials that they consist of. Based on this, the estimated weight of the different materials was put into the components that they belonged to, and then the materials gained estimated weights, to create a mass balance with the total weight of the machine. Based on these general materials, EcoInvent background data processes were chosen, which will be described further in Section 6.2. The link between the finished machine, the chosen modules, the determined general materials, and the EcoInvent background processes can be seen in Figure 5.4.

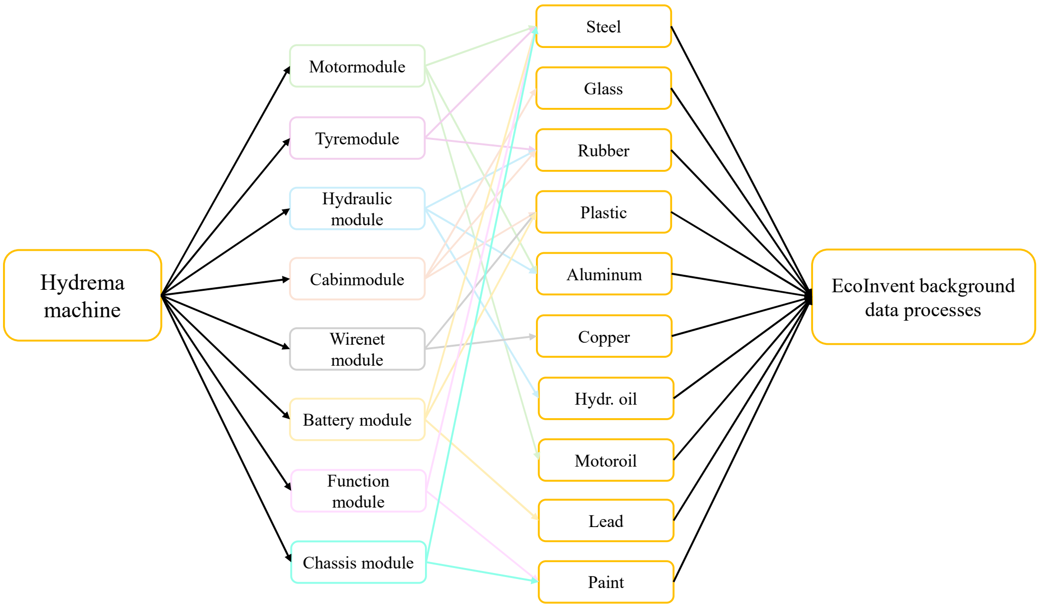


Figure 5.4. Construction of the LCA system (Own production)

When modeling the other machines in the LCA system, scaling factors have been used. The different modules each have individual scaling factors, based on which variables make sense in the individual modules. The scaling factors can be seen in Figure 5.5.

	Scalingfactor
Motormodule	Horsepower (hp)
Tyremodule	Diameter (mm)
Hydraulicmodule	Volume flow rate (l/min)
Cabinmodule	Volume (m3)
Wirenetmodule	Length (m)
Batterymodule	Voltage (V)
Functionmodule 1	Volume (m3)
Functionmodule 2	Length (m)
Functionmodule 3	Volume (m3)
Chassismodule	Mass (kg)

Figure 5.5. Scaling factors of the different modules (Own production)

This means that each module from each machine gains an individual scaling factor. These scaling factors have then been used to multiply the materials used in the different modules to estimate the impacts from the other machines. The way the scaling factors have been calculated is by using this equation:

$$n_{machine}/n_{912Gdumper} = Scalingfactor \tag{5.2}$$

The machine's foreground and background systems have been modeled using an Excel CSV file. The Excel spreadsheet that can be converted to a CSV file can be seen in Appendix C.

The foreground system is square, meaning that all of the processes modeled in the first row are the same as the processes in the first column. Under the foreground system is the background system, modeled with the processes from the background database. In this project, the EcoInvent consequential database is used as background data to model the different main materials as inputs to the different modules. This is explained further in Section 6.2. When the Excel CSV product system was finished, it was imported into the LCA software SimaPro, and from this, the LCIA results were calculated.

To be able to model the whole product system from cradle-to-grave, calculations on the use phase were necessary. The results of the calculations can be seen in Section 6.2.5. The variables that had to be calculated were the time spent idling full life, the fuel consumption when active full life, and the fuel consumption when idling full life. For the dumpers, the total tipping count and amount of earth moved in their full life were also calculated. These variables were calculated based on actual use data from Hydrema's machines from Hydrema's online portal 'Telematics', where owners can gain insights into their machines' performance (See Appendix D). The calculations are based on an average of the data from the Telematics portal on each specific machine, and scaled up to the full life of a machine, which for all machine types is determined as 15000 hrs.

Time spent idling

To calculate how many hours the machine spent idling when active for 15000 hrs, this equation was used:

$$(Idledhrs_{average}/Activehrs_{average}) * 15000hrs \tag{5.3}$$

This scales the amount of average idling hours down to how many idling hours there are for one average active hour, and then this number is scaled up to fit the full life by multiplying it by 15000 hours.

Fuel consumption working and idling

To calculate the total fuel consumption for when the machine is active and when it idles, the following equations were used:

$$(Fuelusedactive_{average}/Workedhrs_{average}) * 15000hrs \tag{5.4}$$

And:

$$(Fuelusedidling_{average}/Idledhrs_{average}) * Totalidledhrs \tag{5.5}$$

These equations are made with the same purpose as the equations in the previous section, to scale the average fuel consumption down to one hour, and then scale it up to the full life.

Tipping count and earth moved

The dumpers deliver information on their tipping count. This average tipping count is also scaled up to the full life by using this equation:

$$(Tippingcount_{average}/Activehrs_{average}) * 15000hrs \tag{5.6}$$

This is to find how many tipping counts are in one active hour, and then scale it up to fit the full life. To calculate how much earth each dumper has moved, it was essential to know how much the troughs can contain. This knowledge is found in Hydrema [2024c], and based on this, it was chosen to use a ton less than the full weight to multiply the tipping count with. This means that for the 707G series, the tipping count was multiplied with 6 tons, for the 912G series, the tipping count was multiplied with 9 tons, for the 922G series, the tipping count was multiplied with 19 tons, and for the 920G the tipping count was multiplied with 17 tons. The reason for not using a full load when multiplying is that it was assessed that the dumpers would not be full for all tippings.

These methodological choices for the LCA create the basis for the conducted LCA, which will be described further in Chapter 6.

Life cycle assessment of Hydrema's machines 6

The first analysis of this Master's thesis will be a process consequential LCA on Hydrema's machines. The definition of process LCA and consequential LCA is described in Section 5.2. The LCA will be divided into four sections in accordance with the ISO 14040/14044 standards: A goal and scope section, a life cycle inventory section, a life cycle impact assessment section, and lastly, an interpretation section.

6.1 Goal and scope

The first phase of the LCA is, as stated in the ISO 14040/14044 standards, the goal and scope phase. The goal of this LCA study is to quantify significant environmental aspects of Hydrema's environmental management system and to cover the life cycle perspective that they are lacking in their system. The LCA can also highlight hotspots in Hydrema's products, which can give them a more product-oriented view of their management system. This LCA will, however, only take estimated versions of Hydrema's products into account, and therefore, other activities made by Hydrema will not be visible in this LCA. A limitation of the goal of modeling all of Hydrema's machines in this simplified LCA model is that Hydrema's machines are complex machinery with many components, and therefore, estimates and scaling factors have been used, which will be described further in the LCI phase in Section 6.2. The target audience of this LCA is the employees at Hydrema. It aims to be useful for multiple departments at Hydrema, but the quality department that works with the management systems will mainly have a quantitative tool for quantifying and choosing their significant environmental aspects, considering the life cycle perspective. Another department that could gain usage of the LCA system is the research and development department, which will have the opportunity to see how new designs or technologies perform from an environmental perspective.

As stated in Section 2.1, Hydrema produces three machine types in multiple sizes. Even though it is three different machines, dumpers, backhoes, and excavators, they have the same function, which is: ”moving earth”. They, however, have different ways of doing their function. Therefore, a generic functional unit that will fit all three machine types has been made, which makes them comparable. This functional unit is also chosen on behalf of the parameters Hydrema normally works with, for them to be able to use the LCA results. The functional unit is presented hereafter.

Functional Unit

1 operational hr of moved earth

For this functional unit, there are some important factors to know, which are:

- Total amount of operational hours in the whole lifetime
- Time spent working
- Time spent idling

This simplified LCA model aims to model all of Hydrema's machines based on a more thorough examination of a specific machine and then scale the other machines based on this examination. The LCA model is divided into modules, as described in Section 5.3.3, and the examination of the specific machines led to an identification of the main materials in these modules. The machines have different types of use phases, which are visualized in Figure 6.1.

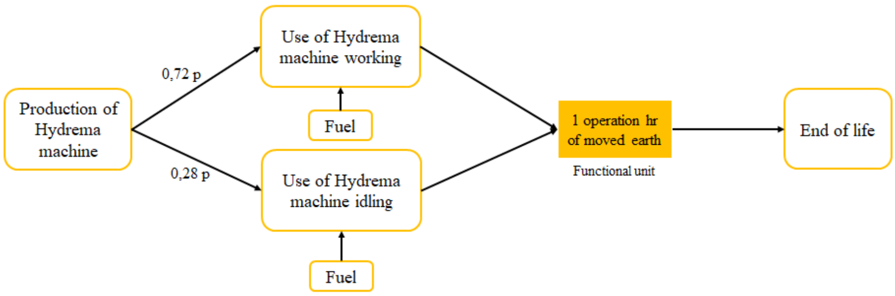


Figure 6.1. The different use phases of a Hydrema machine (Own production)

This is because the machine uses both time spent working and time spent idling. The average amount of time spent working and time spent idling is the basis for the 0,6 p of the Hydrema machine used when working and the 0,4 p of the Hydrema machine used when idling. This is based on actual use phase data from Hydrema, which will be explained further in Section 6.2.5. The product system of a Hydrema machine can be seen in Figure 6.2, where the materials are linked to the modules, which are linked to the finished machine, which are linked to the use phases, which has an input of fuel, which leads to the functional unit and further to the end of life stage of the life cycle.

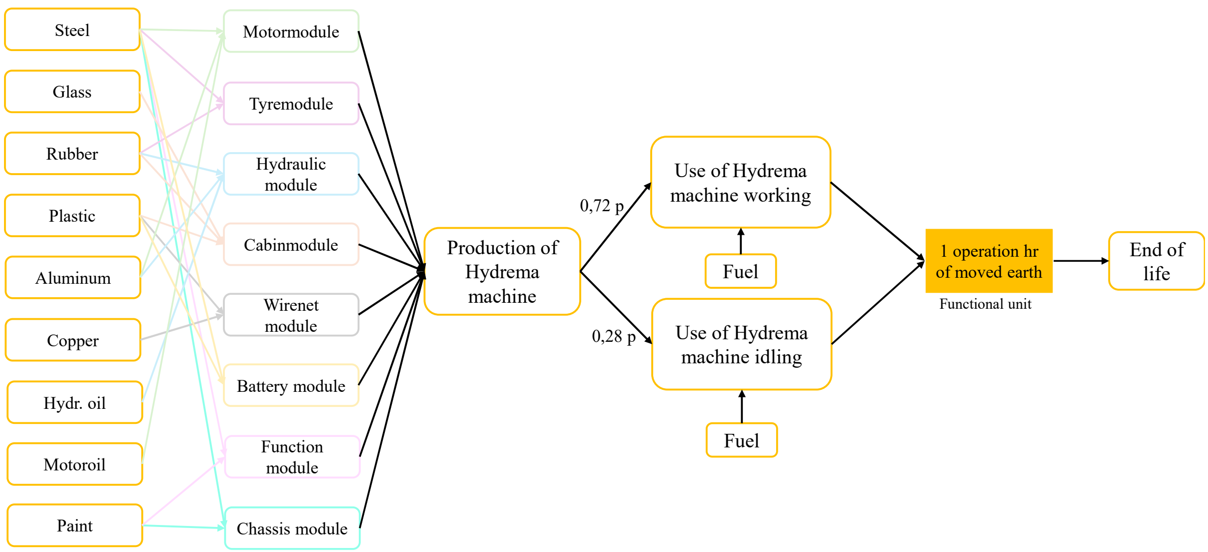


Figure 6.2. Product system of a Hydrema machine (Own production)

The LCA will be modeled using a consequential framework, which has been described in Section 5.2. The foreground system is based on the modules that have been chosen in collaboration with the research and development manager [Hydrema Employees, 2025], and the background processes needed are the inputs of materials into the modules, as well as the fuel for the use phase of the machines. As stated in Section 5.3.3, the data gained from Hydrema was not always explicit in the materials and dimensions used for the machines, and therefore, some of the materials and their weights are based on assumptions based on observations and Google searches. The database that will be used for the background data is the EcoInvent 3.9.1 consequential database. EcoInvent is a comprehensive LCI database that aids in giving companies information on the environmental impacts of their operations [Ecoinvent, 2025]. For the LCIA phase of the LCA, an impact assessment method will be used. The method that will be used is the Stepwise2006 method made by 2.0 LCA consultants [2.0 LCA consultants, 2025]. This method takes all impact categories to a single score that can be either "Quality Adjusted Life Years" (QALYs) or monetary units [2.0 LCA consultants, 2025]. However, it also still gives the opportunity to get midpoint results [2.0 LCA consultants, 2025]. The definition of a QALY is a *"Life-year lived at* *full well-being"* [2.0 LCA consultants, 2025]. The Stepwise method has four different weighting methods, where the weighting method *"Europe95 person/ EUR excl. biogenic C."* has been chosen for this LCA.

6.2 Life cycle inventory

The second phase of the LCA is the LCI phase, which maps the product inventory. This means the reference flows needed as inputs to the product system. The aim of the LCA is, as stated in Section 6.1, to make a simplified model to calculate the impacts from all of Hydrema's machines. However, as stated in Section 5.3.3, the initial data collection was made on a specific machine from Hydrema, which was their 912G dumper. The reason for choosing this machine specifically is that it is their bestseller model, and it is one of their simpler machines. The Hydrema 912G dumper can be seen in Figure 6.3 and 6.4, which are pictures taken from the side and from the front of the machine. The data that are based on the 912G dumper is then divided into modules as stated in Section 5.3.3, and the LCI data of these modules will be described further in Section 6.2.1. The main materials will be described further respectively in Section 6.2.2 and 6.2.3, with the first section describing the steel inputs and the other section describing the other material inputs in the machine. These reference flows will be scaled to fit other Hydrema machines in Section 6.2.4 using the scaling factors described in Figure 5.5. Then the use phase of the Hydrema machines will be described in Section 6.2.5, and the end-of-life phase will be described in Section 6.2.6.

Figure 6.3. Hydrema 912G dumper from a side perspective (Own photo)

Figure 6.4. Hydrema 912G dumper from a front perspective (Own photo)

6.2.1 Modules

In this section, the machine modules and their respective inputs will be described. For each module is a corresponding table, and the components in these are named as in the original parts list to minimize confusion, and therefore they are in either Danish or German. The modules will be described in the sequence that is stated in Section 5.3.3. The first module that will be described is the motormodule, and the components with their respective materials and estimated weights can be seen in Figure 6.5.

Component	ID number	Material	Weight [kg]
Motormodule			
Brændstofanlæg	2165700	Plastic	-
		Steel	-
Sprinklervæske anlæg	2142000	Plastic	-
Køleranlæg	2165000	Steel	26,72
		Aluminium	15
		Rubber	5
Motor/Trans.	2187470	Steel	876,54
		Rubber	5
		Motoroil	10
		Aluminium	78
Udstødningssystem	2164900	Steel	75,67
		Rubber	5
		Plastic	-
AC maschine	2165310	Steel	7,82
		Rubber	5
		Plastic	-
Motorhjelm	2187290	Steel	67,56
		Rubber	5
Ansauganlage	2164800	Steel	5,82
Vorder	2141900	Steel	30,28

Figure 6.5. Components in motormodule with main materials and weights for each. When the weight is marked with an "-" it means that the value is estimated of being unsignificantly small (Own production, with weights on motor and transmission from [Lectura, 2025] and [Aftermarked, 2025] (See Appendix B))

In the analysis of the parts list, 9 components were assessed as fitting under the motormodule category. These 9 components are:

- Fuel plant
- Washer fluid system
- Cooling system
- Motor/transmission
- Exhaust system
- Air conditioning machine
- Bonnet

- Extraction system
- Front

These components have been analyzed in the parts list, and based on this analysis, a determination of the main materials in the components has been made. The motormodule contains most of the main materials chosen, however, the main material in the motormodule is the steel inputs. This is mainly due to the motor and transmission being assessed as made mostly of steel, and these are the biggest components in the motormodule. The second module that will be described is the tyremodule, and the components with their respective materials and estimated weights can be seen in Figure 6.6.

Component	ID number	Material	Weight [kg]
Tyremodule			
Hjul H	7100563	Rubber	464,6
		Steel	100
Hjul V	7100564	Rubber	464,6
		Steel	100

Figure 6.6. Components in tyremodule with main materials and weights for each (Own production, with weights on tyres from [Heuver, 2025c] (See Appendix B))

The tyremodule contains two components from the parts list, being the wheels on the right and the wheels on the left. This module contains two materials: rubber for the tyres and steel for the rims. The third module that will be described is the hydraulicmodule, and the components with their respective materials and estimated weights can be seen in Figure 6.7.

Component	ID number	Material	Weight [kg]
Hydraulicmodule			
Verbindungsblock	2168980	Aluminium	10
		Rubber	20
Verrohrung hinten	2143010	Aluminium	10
		Rubber	10
		Steel	0,2
Schläuchen	2188090	Steel	1,05
		Rubber	10
Rørf. vange forrest	2187780	Steel	1,19
		Rubber	20
		Aluminium	-
Hydraulicpump	2187470	Hydraulic oil	50

Figure 6.7. Components in hydraulicmodule with main materials and weights for each. When the weight is marked with an "-" it means that the value is estimated of being unsignificantly small (Own production (See Appendix B))

In the analysis of the parts list, 5 components were assessed as fitting under the hydraulicmodule.

These 5 components are:

- Connection block
- Piping at the rear
- Hoses
- Piping at the front
- Hydraulic pump

These components mainly consist of rubber and steel for the pipes, and the hydraulic oil that is used through the pipes. Most of these weights are estimated, to what was assessed as a reasonable weight, and what was fitting with the mass balance. The fourth module that will be described is the cabinmodule, and the components with their respective materials and estimated weights can be seen in Figure 6.8.

Component	ID number	Material	Weight [kg]
Cabinmodule			
Scheibenwaschanlage	2142030	Plastic	-
Kabineaufhängung	2141700	Steel	2,45
Bodenmatte	2141711	Steel	1,47
Trin	2167350	Steel	13,12
Kabine 912	2187430	Steel	429,3
		Plastic	15
		Glass	108,1
		Rubber	5

Figure 6.8. Components in cabinmodule with main materials and weights for each. When the weight is marked with an "-" it means that the value is estimated of being unsignificantly small (Own production (See Appendix B))

In the analysis of the parts list, 5 components were assessed as fitting under the cabinmodule. These 5 components are:

- Windshield washer system
- Cabin suspension
- Floor mat
- Step
- Cabin

The main materials in the cabinmodule are steel, glass, which is used as the windows in the cabin, and plastic, which is used both in the interior of the cabin and in the roof of the cabin, which can also be seen in Figure 6.4. The fifth module that will be described is the wirenetmodule, and the components with their respective materials and estimated weights can be seen in Figure 6.9.

Component	ID number	Material	Weight [kg]
Wirenetmodule			
Ledn.net	2187640	Steel	1,3
		Plastic	1
		Copper	3

Figure 6.9. Components in wirenetmodule with main materials and weights for each (Own production (See Appendix B))

The wirenetmodule only consists of one component, which is the wirenet of the machine. For this module, three materials are determined: steel, plastic, and copper for the wires and the holders for the wires. The sixth module that will be described is the batterymodule, and the components with their respective materials and estimated weights can be seen in Figure 6.10.

Component	ID number	Material	Weight [kg]
Batterymodule			
Dæksel batteri	2167510	Steel	22.36
Batteri arr.	2165890	Steel	4.03
		Plastic	-
		Lead	49
		Copper	-

Figure 6.10. Components in batterymodule with main materials and weights for each. When the weight is marked with an "-" it means that the value is estimated of being unsignificantly small (Own production, with weight on battery from [Batterilageret.dk, 2025] (See Appendix B))

In the batterymodule there were assessed two component: the cover of the battery and the battery. The main material in this module is the two batteries in the machine. The seventh module that will be described is the functionmodule, and the components with their respective materials and estimated weigths can be seen in Figure 6.11.

Component	ID number	Material	Weight [kg]
Functionmodule 1			
Knækledslås	2188030	Steel	3.39
Mulde	2147960	Steel	907.64

Figure 6.11. Components in functionsmodule 1 of a dumper trough with main materials and weights for each (Own production (See Appendix B))

This functionmodule models the trough of the dumper. The three machine types at Hydrema will each have their own functionmodule, because their work tool differs. The functionmodule of the trough mainly consists of steel, and it is a large component in the total machine. The functionmodules for the two other functions can be seen in Figure 6.15 and 6.14. The eighth module that will be described is the chassismodule, and the components with their respective materials and estimated weights can be seen in Figure 6.12.

Component	ID number	Material	Weight [kg]
Chassismodule			
Vorderrahmen	2187330	Steel	1527,2
Hinterrahm	2149040	Steel	1031,34
Bauchschutzplatte	2143500	Steel	79,04
Hinterachsen	2141800	Steel	475,27
Abdeckung, vorne	2143300	Steel	12,1
Lygter forrest	2140860	Steel	18,95
		Plastic	-
Kotfluegel	2140451	Plastic	40
		Rubber	10
		Steel	9,47
Rückleuchte	2168660	Plastic	-
		Steel	1,79
Seitenmark.leuchten	2169540	Steel	0,56
		Plastic	-

Figure 6.12. Components in chassismodule with main materials and weights for each. When the weight is marked with an "-" it means that the value is estimated of being unsignificantly small (Own production (See Appendix B))

In the analysis of the parts list, 9 components were assessed as fitting under the chassismodule. These 9 components are:

- Frontframe
- Rearframe
- Bottomplate
- Rear axle
- Frontcover
- Lights front
- Screens
- Rear lights
- Side lights

The main materials in this module are steel and plastic, which are used for the chassis of the machine and the screens that cover the tyres of the machine. Lastly, there can be detected two components that repeats throughout the whole machine, which is paint and screws, and the materials and estimated weights can be seen in Figure 6.13.

Component	ID number	Material	Weight [kg]
Other			
Paint		Paint	10
Screws/bolts		Steel	8,07

Figure 6.13. Components that it used in multiple modules are added in the category "other", with the estimated materials and weights of each (Own production (See Appendix B))

These weights are estimated to fit the mass balance, and are therefore only a rough estimate, because these components were initially sorted out in the analysis of the parts list, however, they are important because they are repeated throughout the whole machine.

Backhoe and excavators

Because the functions differ in Hydrema's three machine types, two other functionmodules are modeled. These are for the digging arms of both the backhoe and the excavators, as well as the shovels on the backhoe. These modules are made based on an analysis of four BOM parts lists, one for the digging arm of an excavator, one for the digging arm of a backhoe, one for the front shovel of a backhoe, and one for the back shovel of a backhoe. Therefore, there are three functionmodules in this LCA system, the first is for the dumper trough, as presented in Figure 6.11, the second is for the digging arms, which can be seen in Figure 6.14.

Component	ID number	Material	Weight [kg]
Functionmodule 2			
Gravearm L2,5 MX14-17 Gul	5059400	Steel	200
Gravearm backhoe	2040100	Steel	340

Figure 6.14. Components in the functionmodule 2 of the excavation arms with main materials and weights for each (Own production (See Appendix B))

In this module, two digging arms are modeled, because the weight of the materials differs when it is a digging arm for an excavator and when it is for a backhoe. The only visible material in the digging arms in the analysis of the BOM parts list was steel. In this analysis, it also became clear that more steel was needed for the backhoe digging arm than for the excavator digging arm, and therefore, two different reference variables will be chosen when making scaling factors for functionmodule 2. The third functionmodule is for the shovels on a backhoe, and is presented in Figure 6.15.

Component	ID number	Material	Weight [kg]
Functionmodule 3			
Dybdeske A8Hh 60Cm U/Tænder	2041035	Steel	130
Skovl L10EHHF 2550 Forstærket	2106600	Steel	900

Figure 6.15. Components in the functionmodule 3 of the backhoe shovels with main materials and weights for each (Own production (See Appendix B))

In this module, there are two components because a backhoe consists of a shovel in both the front and the back. During the analysis of the BOM parts lists, it became clear that these two components mainly were made of steel, and that the shovel in the front contained the most steel, compared to the shovel in the back.

6.2.2 Steel

The main material in Hydrema's machines is steel. In the analysis of the parts list, it became clear that multiple steel-type plates are used in the production of the machine. Firstly, it was defined how much of each steel-type was used in each component in kilos. This overview can be seen in Figure 6.16.

Module	S650Mc Dek	Fe Po1 Am	S420 Mc Dek	S355Mc Dek	S355ML Dek	S690Q Dek	S355J2G3	Hardox 450	Hardox 500	Sum
Motor	86.27	39.61	117.43	8.42	0.702	0	0	0	0	252.432
Tyre	-	-	-	-	-	-	-	0	0	0
Hydraulic	1.09	0.14	1.02	0	0	0	0	0	0	2.25
Cabin	72.34	53.09	317.46	1.89	0	1.58	0	0	0	446.36
Wirenet	0.35	0	0.98	0	0	0	0	0	0	1.33
Battery	5.38	0.42	20.59	0	0	0	0	0	0	26.39
Function 1	810.21	2.5	16.26	7.37	74.69	0	0	0	0	911.03
Function 2	0.28	0	398.1042	5.27	0.44	42.12	84.24	0	0	530.4542
Function 3	573.09	0	24.39	0.53	0	50.54	0	18.72	349.45	1016.72
Chassis	1152.92	0.68	526.81	3.84	201.23	244.69	125.58	0	0	2255.75

Figure 6.16. Table of the different steel types used in the different modules with indicated weights (Own production)

Then, the percentage share of the total amount of steel plates in each module was found. This can be seen in Figure 6.17.

Module	S650Mc Dek	Fe Po1 Am	S420 Mc Dek	S355Mc Dek	S355ML Dek	S690Q Dek	S355J2G3	Hardox 450	Hardox 500	Sum	Sum low-alloyed	Sum unalloyed	Sum alloyed
Motor	34.18%	15.69%	46.52%	3.34%	0.28%	0.00%	0.00%	0.00%	0.00%	100.00%	80.69%	15.69%	3.61%
Tyre											0.00%	0.00%	0.00%
Hydraulic	48.44%	6.22%	45.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	93.78%	6.22%	0.00%
Cabin	16.21%	11.89%	71.12%	0.42%	0.00%	0.35%	0.00%	0.00%	0.00%	100.00%	87.68%	11.89%	0.42%
Wirenet	26.32%	0.00%	73.68%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	100.00%	0.00%	0.00%
Battery	20.39%	1.59%	78.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	98.41%	1.59%	0.00%
Function 1	88.93%	0.27%	1.78%	0.81%	8.20%	0.00%	0.00%	0.00%	0.00%	100.00%	90.72%	0.27%	9.01%
Function 2	0.05%	0.00%	75.05%	0.99%	0.08%	7.94%	15.88%	0.00%	0.00%	100.00%	83.04%	15.88%	1.08%
Function 3	56.37%	0.00%	2.40%	0.05%	0.00%	4.97%	0.00%	1.84%	34.37%	100.00%	99.95%	0.00%	0.05%
Chassis	51.11%	0.03%	23.35%	0.17%	8.92%	10.85%	5.57%	0.00%	0.00%	100.00%	85.31%	5.60%	9.09%

Figure 6.17. Table of percentage of the different steel types used in the different modules. On the right side of the figure is indicated whether the steel type is low-alloyed, alloyed, or unalloyed (Own production, with alloys based on [SSAB, 2025; Steelnumbers, 2025b; YJ, 2025; SIDASTICO, 2025; Steelnumbers, 2025a; GNEE STEEL, 2025; Fuhong, 2025])

This table also shows how much of the steel is low-alloyed, unalloyed, or alloyed. This was found by googling the steel-types, and was needed to choose the relevant EcoInvent processes for the LCA. Based on this table, it can be seen that the majority of steel going into the machines is low-alloyed steel, and a smaller amount of unalloyed and alloyed steel. The unalloyed steel is mostly present in the motormodule and the cabinmodule, whereas the alloyed steel is mostly present in the functionmodule 1 and the chassismodule. The description of the steel-types and the chosen EcoInvent processes can be seen in Figure 6.18.

Steel used	Description	EcoInvent process
S650Mc Dek	High strength low alloy	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Conseq, U
Fe Po1 Am	Non-alloy quality steel	Steel, unalloyed {GLO}| market for steel, unalloyed | Conseq, U
S420 Mc Dek	Low alloyed steel	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Conseq, U
S355Mc Dek	Alloyed steel	Steel, chromium steel 18/8, hot rolled {GLO}| market for steel, chromium steel 18/8, hot rolled | Conseq, U
S355ML Dek	Alloy special structural steel	Steel, chromium steel 18/8, hot rolled {GLO}| market for steel, chromium steel 18/8, hot rolled | Conseq, U
S690Q Dek	Low alloyed steel	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Conseq, U
S355J2G3	Non-alloyed steel	Steel, unalloyed {GLO}| market for steel, unalloyed | Conseq, U
Hardox 450	Low alloyed steel	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Conseq, U
Hardox 500	Low alloyed steel	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Conseq, U

Figure 6.18. Table of the steel used in the machine, with the steel used as described in the parts list is listed in the column to the left, the description of the steel type in the column in the middle, and the chosen EcoInvent process in the column to the right (Own production, with alloys based on [SSAB, 2025; Steelnumbers, 2025b; YJ, 2025; SIDASTICO, 2025; Steelnumbers, 2025a; GNEE STEEL, 2025; Fuhong, 2025])

The EcoInvent processes are chosen based on the alloys of the steel-types. Three different processes have been chosen to make the LCA as close to the truth as possible. The EcoInvent processes chosen are all under the market category. This means that they have included inputs from specific regions and inputs of transport [SimaPro, 2025]. The reason for choosing the market processes is that it is not known from which suppliers the materials come, and therefore it is recommended to use the market processes to take transportation and the market into account [SimaPro, 2025].

6.2.3 Other materials

Apart from steel, the Hydrema machines consist of multiple other main materials. These are: Glass, rubber, plastic, aluminum, copper, lead, paint, hydraulic oil, motor oil, and fuel. These materials and the chosen corresponding EcoInvent processes can be seen in Figure 6.19.

Material	EcoInvent process
Glass	Flat glass, coated {RER}| market for flat glass, coated | Conseq, U
Rubber	Synthetic rubber {GLO}| market for synthetic rubber | Conseq, U
Plastic	Polyethylene, high density, granulate {GLO}| market for polyethylene, high density, granulate | Conseq, U
Aluminum	Aluminium, cast alloy {GLO}| market for aluminium, cast alloy | Conseq, U
Copper	Wire drawing, copper {GLO}| market for wire drawing, copper | Conseq, U
Lead	Battery, lead acid, rechargeable, stationary {GLO}| market for battery, lead acid, rechargeable, stationary | Conseq, U
Paint	Alkyd paint, white, without solvent, in 60% solution state {GLO}| market for | Conseq, U
Hydraulic oil	Lubricating oil {RER}| market for lubricating oil | Conseq, U
Motor oil	Lubricating oil {RER}| market for lubricating oil | Conseq, U
Fuel	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Conseq, U

Figure 6.19. Table of other main materials used in the machine other than steel, with the materials listed in the column to the left and the EcoInvent process chosen described in the column to the right (Own production)

The EcoInvent processes are chosen based on an assessment of which materials they have to cover and the purpose of the material. The plastic process is chosen based on communication with a Hydrema employee [Hydrema Employees, 2025]. The material copper was chosen because it is a part of the wires that go into the wirenet, and therefore, the EcoInvent process for wire drawing, copper, was chosen. The purpose of the lead material was to cover the battery of the machine, and therefore, the EcoInvent process for a lead-acid battery was chosen. Both the hydraulic oil and the motor oil were assessed as fitting under the EcoInvent process for lubricating oil, and therefore, this process is used for both of these materials. To cover the fuel that the machines will be using during their use stage, to make sure that the LCA is not only modeled as a cradle-to-gate LCA, the EcoInvent process for diesel burned in a building machine was chosen as the most fitting. As was the case in the EcoInvent processes chosen for the steel-types in Section 6.2.2, the EcoInvent processes chosen for the other materials are also market processes.

6.2.4 Scaling to other machines

As stated in the goal and scope phase in Section 6.1, the aim of this LCA is to make a simplified model that is able to model all of Hydrema's machines ideally. The LCA is based on an analysis of the parts list of one of Hydrema's machines: the 912G dumper. Based on the modules, scaling factors were chosen, which were described in Section 5.3.3, in Figure 5.5. The variables needed to calculate the scaling factors for each specific machine can be seen in Figure 6.20.

		Motormodule (hp)	Tyremodule (mm)	Hydraulicmodule (l/min)	Cabinmodule (m^3)	Wirenetmodule (m)	Batterymodule (V)	Functionmodule 1 (m^3)	Functionmodule 2 (m)	Functionmodule 3 (m^3)	Chassismodule (kg)
7 ton dumpers	707G	75	1170	59			24	3,5			5350
	707G power+	122	1172	59			24	3,5			5400
10 ton dumpers	912G	147	1333	84			24	5,6			7270
	912GS	147	1350	84			24	5,6			7540
	912HM	147	1500	84			24	5,6			8260
20 ton dumper	922G	314	1500	195			24	9,2			15900
	922HM	314	1500	195			24	9,2			16350
	922G 2.55	314	1487	195			24	9,2			16600
18 ton dumper	920G	314		195			24	9,2			16500
Electric dumper	DT6	69 kW					96/24	3,5			5200
Excavator	MX14G	175	1120	319			24		9,045		16000
	MX16G	175	1120	319			24		9,32		17300
	MX17G	175	1120	319			24		9,32		18300
	MX18G	175	1120	319			24		9,72		18700
	MX20G	175	1120	319			24		9,72		20100
Backhoe	906G	122		165			24		6,13	1,4	9200
	908G	122		165			24		6,5	1,4	9100
	926G	147		220			24		6,25	1,7	9500
	928G	147		220			24		6,5	1,7	9400

Figure 6.20. Table of variables used to make scaling factors for each machine. In this table are listed three functionmodules, because the components in the functionmodule will differ according to which machine type it is. The DT6 machine has different variables in the motor and battery columns, because it is an electric machine (Own production, with numbers from [Hydrema, 2024c; Brixius Trading, 2025; Bohnenkamp, 2025a; Heuver, 2025a,b; Holland Tyre, 2025; Jydekrog.dk, 2025; Bohnenkamp, 2025b](See Appendix B))

The line with the green color is the 912G dumper, and therefore, the reference factor for calculating the factors. The orange color highlights the variables that were not found and would therefore need further research. The cells with a cross in them are where the column is not relevant for the specific machine type. This is in relation to that the three machine types: dumpers, backhoes, and excavators, each have different functionmodules, because this differs the most among the three machine types. Because these modules are different, they also have different scaling factors according to what is fitting for each function. Therefore, functionmodule 1 is only used for the dumpers, functionmodule 2 is used for both the backhoes and excavators, and functionmodule 3 is used only for the backhoes. The scaling factors are then calculated using Equation 5.2. The calculated scaling factors can be seen in Figure 6.21.

		Motormodule (hp)	Tyremodule (mm)	Hydraulicmodule (l/min)	Cabinmodule (m^3)	Wirenetmodule (m)	Batterymodule (V)	Functionmodule 1 (m^3)	Functionmodule 2 (m)	Functionmodule 3 (m^3)	Chassismodule (kg)
7 ton dumpers	707G	0,51	0,88	0,70			1	0,63			0,74
	707G power+	0,83	0,88	0,70			1	0,63			0,74
10 ton dumpers	912G	1	1	1			1	1			1
	912GS	1	1,01	1			1	1			1,04
	912HM	1	1,13	1			1	1			1,14
20 ton dumper	922G	2,14	1,69	2,32			1	1,64			2,19
	922HM	2,14	1,69	2,32			1	1,64			2,25
	922G 2.55	2,14	1,67	2,32			1	1,64			2,28
18 ton dumper	920G	2,14		2,32			1	1,64			2,27
Electric dumper	DT6	-					-	0,63			0,72
Excavator	MX14G	1,19	0,84	3,80			1		1		2,20
	MX16G	1,19	0,84	3,80			1		1,03		2,38
	MX17G	1,19	0,84	3,80			1		1,03		2,52
	MX18G	1,19	0,84	3,80			1		1,07		2,57
	MX20G	1,19	0,84	3,80			1		1,07		2,76
Backhoe	906G	0,83		1,96			1		1	1	1,27
	908G	0,83		1,96			1		1,06	1	1,25
	926G	1		2,62			1		1,02	1,21	1,31
	928G	1		2,62			1		1,06	1,21	1,29

Figure 6.21. Table of calculated scaling factors for each machine (Own production (See Appendix B))

The cells highlighted in green are the reference variables. This means that for all modules except functionmodule 2 and 3, the reference variables are from the 912G dumper, where the BOM parts list has been analyzed, as described in Section 5.3.3. For functionmodule 2 and 3, the reference variables come from the smallest excavator and the smallest backhoe. These scaling factors are then used to calculate how much of each module is needed for each machine. The scaling factors are added to the product system, and from this, the other machines can be calculated in a simplified way. For the cabinmodule and the wirenetmodule it was not possible to find data for scaling, and therefore, these will be equal to the reference module. For the tyres for which no data on, it will also be equal to the reference module. However, for the 920G machine specifically, it will be scaled up, because this machine has six tyres, whereas the reference machine only has four tyres.

Creating mass balance for all machines

To make sure that the scaling was truthful for all of the machines, their mass balance was checked after the modules had been scaled with their respective calculated scaling factors. The scaled weight and the actual weight of the machines can be seen in Figure 6.22.

		Scaled weight	Actual weight	Scalingfactor for massbalance
7 ton dumper	707G	5327.18	5350	1.004
	707G power+	5717.07	5400	0.94
10 ton dumpe	912G	7270	7270	1
	912GS	7409.52	7540	1.02
	912HM	7865.6	8260	1.05
20 ton dumper	922G	14010.82	15900	1.13
	922HM	14203.17	16350	1.15
	922G 2.55	14276.75	16600	1.16
18 ton dumper	920G	14052.73	16500	1.17
Excavator	MX14G	10837.49	16000	1.48
	MX16G	11410.52	17300	1.52
	MX17G	11859.32	18300	1.54
	MX18G	12027.61	18700	1.55
	MX20G	12636.7	20100	1.59
Backhoe	906G	8514.52	9200	1.08
	908G	8470.81	9100	1.07
	926G	9128.34	9500	1.04
	928G	9109.88	9400	1.03

Figure 6.22. Scaling factors to create mass balance for all of Hydrema's machines (Own production (See Appendix B))

The scaled weight is calculated using this equation:

$$SUM(Totalmoduleweight_{scaledmodules}) \tag{6.1}$$

The scaling factors from Figure 6.21 did not create mass balance for all of the Hydrema machines, and therefore, an additional scaling factor was calculated for each machine. This scaling factor was multiplied by the scaling factors in Figure 6.21. By doing this, it scales all of the modules up proportionately, and by this creates mass balance for all of the machines. The mass balance scaling factor is calculated using this equation:

$$Actualweight/scaledweight = massbalancescalingfactor \tag{6.2}$$

6.2.5 Use phase of Hydrema's machines

To model the LCA from cradle-to-grave, the use phase of the machines is essential to gain knowledge on. On this basis, the amount of time spent working and the amount of time spent idling, and their respective fuel consumptions, are relevant to know. These amounts for all of Hydrema's machines can be seen in Figure 6.23.

		Estimated operational hours full life	Estimated time spent active	Estimated time spent idling	Estimated percentage of time spent idling	Estimated fuel consumption working	Estimated fuel consumption idling	Estimated tipping count full life	Estimated moved earth full life [t]
7 ton dumpers	707G	20175	15000	5175	26%	65311	10460	60343	362060
	707G power+	19439	15000	4439	23%	61857	9356	57139	342832
10 ton dumpers	912G	24810	15000	9810	40%	62093	17821	56533	508793
	912GS	25229	15000	10229	41%	69653	18266	57605	518445
	912HM	23892	15000	8892	37%	78658	17567	72604	653436
20 ton dumper	922G	23290	15000	8290	36%	141932	28765	64083	1217583
	922HM	23053	15000	8053	35%	158789	30171	64336	1222378
	922G 2.55	23352	15000	8352	36%	138141	30511	50396	957519
18 ton dumper	920G	22717	15000	7717	34%	164104	27303	72195	1227314
Electric dumper	DT6		15000						
Excavator	MX14G	18095	15000	3095	17%	115707	6561		
	MX16G	18223	15000	3223	18%	127612	7161		
	MX17G	18259	15000	3259	18%	125939	6921		
	MX18G	18116	15000	3116	17%	122637	6241		
	MX20G	18634	15000	3634	20%	118588	6922		
Backhoe	906G	20512	15000	5512	27%	97043	10757		
	908G	19037	15000	4037	21%	92112	6783		
	926G	20303	15000	5303	26%	92162	12894		
	928G	20167	15000	5167	26%	98128	11276		

Figure 6.23. Visualization of estimated active hours, idling hours, fuel consumption, tipping count, and amount of moved earth for all of Hydrema's machines (Own production, based on IoT data from all of Hydrema's machines from the first end-user (See Appendix D))

The cells highlighted with the light orange color represent the amounts that were not possible to calculate. These variables are for the DT6 machine, which is Hydrema's electric dumper, and the variables for tipping count for the excavators and backhoes, which is because their function can not be measured in this way. The data used to calculate these numbers is from Hydrema Telematics, which is an online portal for Hydrema and its customers to be able to follow the performance of their machines (See Appendix D). Therefore, these numbers are scaled up to the determined total lifetime of a Hydrema machine based on actual empirical data on real machines. In Figure 6.23, it can be seen that the dumpers are the machines that spend the most time idling, and the excavators are the machines that spend less time idling. This can potentially be explained by the dumpers spending more time waiting while their troughs are being filled, and to keep their motors warm, they are likely to be idling. This could also indicate that the use of the backhoes and excavators is more effective, because they are not dependent on waiting for other machines to be able to do their job.

As shown in Figure 6.1, there is a part of the machine that goes into working and a part of the machine that goes into idling. As shown in Figure 6.23, these two use phases have different fuel consumption. Therefore, the use phase of the machines is modeled for three different types for one hour.

- 1 active hour
- 1 idling hour
- 1 total hour

For the calculation on 1 operation hour, the percentage of the time the machine is active is used as the amount of machine needed for being active, and then this amount of machine is divided by 15000 hrs, to get the amount of machine needed for one operational hour. The fuel needed for one operation hour is calculated by taking the amount of fuel used for the total lifetime and dividing it by 15000, to get the fuel consumption for one operation hour. This fuel consumption is then multiplied by 38 to get the fuel consumption in MJ rather than liters, because it is the unit used in the background data. The background data that will be used for the fuel is: ”Diesel, burned in building machine GLO| market for diesel, burned in building machine | Conseq, U”. For the calculation on 1 idling hour, the percentage of time the machine spends idling is used as the amount of machine needed for idling, and then this amount is divided by the number of idling hours the respective machines have in their full lifetime, to get the amount of machine needed for one idling hour. The fuel needed for one idling hour is calculated by taking the amount of fuel used for idling in the full lifetime of the machine and dividing it by the number of idling hours the respective machines have. This fuel consumption is also multiplied by 38 to get it in MJ rather than liters. In the 1 total hour calculation, it aims to give a picture of how much of an hour is spent working and idling, and what impact this has. For calculating this, the percentage of time spent active and time spent idling is used to determine how much of the machine is used for being active and how much is used for idling. An example of how it is modeled can be shown for the 912G dumper. This machine spends 40% of the time idling and 60% of the time being active. For the process of one total use hour of the 912G dumper, it then has an input of 0,40 from the idling use hour and 0,60 from the active use hour. This in total creates one hour of use, which takes both the amount of time spent working and the amount of time spent idling into account.

Another important part of the machine's use phase is the maintenance of the machine. The way this has been taken into account in this LCA model is by adding 1% of the machine to the amount of machine needed in the use phase. This means that the amount of machines needed for being active and for idling is calculated off 1,01 machines. This is because it is unlikely that the machine will not undergo repairing, where parts of the machine will be changed, and therefore, by using 1,01 machine for the calculations, it takes some new parts into account. This way of modeling it, however, does not take into account which parts of the machine will break.

6.2.6 End of life of Hydrema's machines

After the machine is done being used, it enters the end-of-life phase. For this LCA, two different end-of-life scenarios will be modeled. One where the recyclable materials of the machine will be recycled, and one where the machine is left alone in a field.

The last scenario is a possibility because during the use phase of the machine, it is likely that when the machine gets older and more worn down, it will be sold to a small entrepreneur or a farmer, who will use the machine now and then [Hydrema Employees, 2025]. The end-of-life phase of a Hydrema machine is therefore likely to be way out in the future. This is visualized in Figure 6.24, with the time on the x-axis and the impacts on the y-axis.

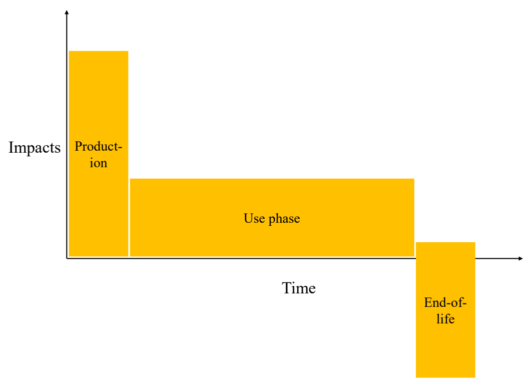


Figure 6.24. Visualization of the impacts over time, with a short amount of time and a large amount of emissions in the production, a long amount of time and a less concentrated amount of emissions in the use phase, and short amount of time and a large amount of positive emissions for the end-of-life stage (Own production)

The end-of-life modeling for this LCA will take the point of departure in two scenarios, based on what is likely to happen to the machine. In the first scenario, the machine is discarded and sent to a waste facility that has the opportunity to demolish the machine and recycle the materials that are recyclable. In the second scenario, the machine crashes in a field and is left there to rust. In this scenario, nothing is done to the machine, and the materials of the machine will not be recycled. The second scenario will then not create an avoided impact from the production, because the materials in the machine will likely go to waste. To model the first scenario, multiple EcoInvent processes will be needed, which can be seen in Figure 6.25.

Material recycled	EcoInvent process
Steel	Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Conseq, U
Rubber	Waste rubber, unspecified {RoW}| treatment of waste rubber, unspecified, municipal incineration | Conseq, U
Aluminum	Aluminium scrap, new {RER}| treatment of aluminium scrap, new, at remelter | Conseq, U
Copper	Electronics scrap {RoW}| treatment of electronics scrap, metals recovery in copper smelter | Conseq, U
Glass	Waste glass sheet {RoW}| treatment of waste glass sheet, sorting plant | Conseq, U
Plastic	Waste polyethylene, for recycling, unsorted {Europe without Switzerland}| treatment of waste polyethylene, for recycling, unsorted, sorting | Conseq, U
Lead	Scrap lead acid battery {RER}| treatment of scrap lead acid battery, remelting | Conseq, U
Paint	Waste paint {Europe without Switzerland}| treatment of waste paint, hazardous waste incineration, with energy recovery | Conseq, U
Hydraulic/motoroil	Waste mineral oil {RoW}| treatment of waste mineral oil, hazardous waste incineration, with energy recovery | Conseq, U

Figure 6.25. Choice of EcoInvent processes for the first end-of-life scenario (Own production)

In the choice of the EcoInvent processes, it was chosen to use the recycling processes for the materials that had recycling, and for the other waste management processes were chosen.

The amounts used for the first scenario are the same as the inputs, which reflects a scenario where all the materials in the machine will be managed, either through recycling or other waste processes.

6.3 Life cycle impact assessment

For the LCIA phase of the LCA, the impacts of producing the machines at Hydrema, the use phase, and the end-of-life phase will be described. Firstly, the LCIA will look into the production of the machines, with an insight into impacts from the reference modules. Then the LCIA will look into the impacts from the use phase of the machines, which is divided into three parts: one active hour, one idling hour, and one total hour. Lastly, the avoided burdens from the end-of-life stage will be described.

6.3.1 Production of Hydrema machines

The first phase that will be described in this LCIA is the impacts from the production phase of all the scaled Hydrema machines.

Weighted impacts

To choose which impact categories are most relevant to report on in this LCIA phase, the weighting from the Stepwise method is used. Firstly, the weighted impacts are calculated for all the scaled machines, and afterwards the modules and materials will be dived into. Based on these weighted impacts, the relevant impact categories will be found, and then the characterized amounts of the chosen impacts will be described. In Figure 6.26, the weighted impacts from all of the scaled Hydrema machines can be seen.

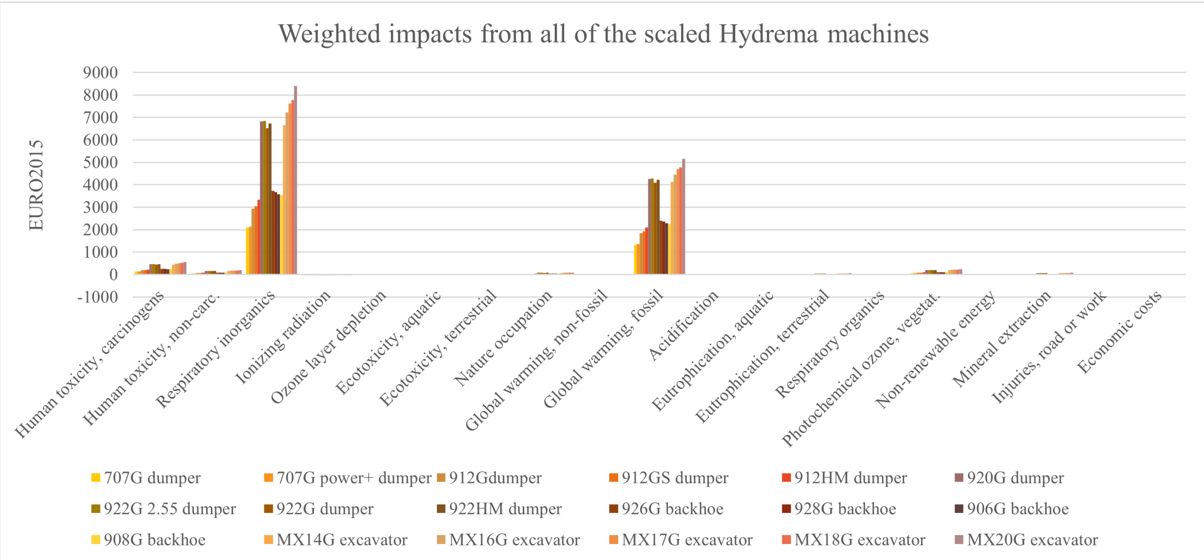


Figure 6.26. Weighted impacts from all of the scaled Hydrema machines (Own production (See Appendix E))

On the figure, it is evident that the most significant impact categories are 'respiratory inorganics' and 'global warming'. Therefore, these two impact categories will be described in more depth with their characterization factors. The LCA on the machines is built using a modular setup as described in Section 6.2, therefore, it is also relevant to see which impact categories are weighted as the most significant in the individual modules, which can be seen in Figure 6.27.

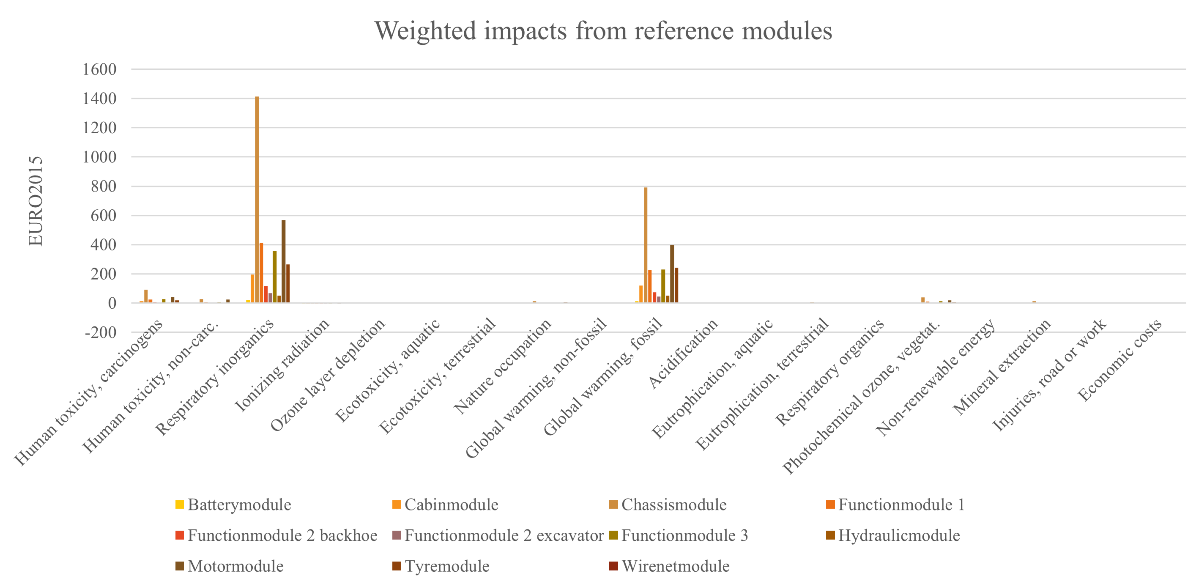
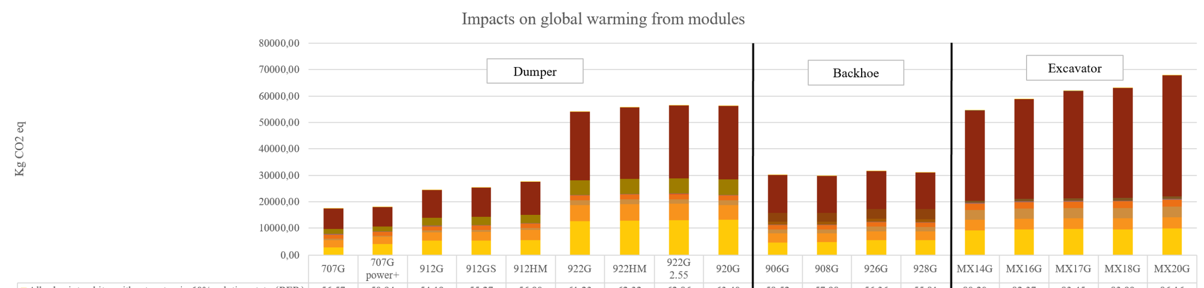


Figure 6.27. Weighted impacts from reference modules (Own production (See Appendix E))

For the modules, the same impact categories are deemed significant as was the case for the full scaled machines, being 'respiratory inorganics' and 'global warming'. In the following section, the characterization factors for 'respiratory inorganics' and 'global warming' will be described on machine, module, and material levels.

Characterized impacts

To dive more into the two significant impact categories, the characterized impacts are looked into. In the characterized impacts, the impact categories have individual units for impacts, whereas the weighted Stepwise impacts are described in monetary EURO2003 or EURO2015 values. Even though the impact category with the highest weighted impacts is the 'respiratory inorganics', the first impact category that will be described is 'global warming'. This is due to this impact category being the most well-known at Hydrema, and it is therefore more likely that they will be able to understand and use the global warming impacts in their environmental management system and ESG reporting. The characterized impacts on global warming from the different scaled modules in all of the scaled Hydrema machines can be seen in Figure 6.28.



	707G	707G power+	912G	912GS	912HM	922G	922HM	922G 2.55	920G	906G	908G	926G	928G	MX14G	MX16G	MX17G	MX18G	MX20G
Alkyd paint, white, without water, in 60% solution state {RER}	56,57	50,94	54,19	55,27	56,90	61,23	62,32	62,86	63,40	58,52	57,98	56,36	55,81	80,20	82,37	83,45	83,99	86,16
Steel, low-alloyed {GLO}	24,10	22,56	24,00	24,48	25,20	27,12	27,60	27,84	28,08	25,92	25,68	24,96	24,72	35,52	36,48	36,96	37,20	38,16
Chassismodule	7763,58	7268,69	10449,52	11084,85	12508,08	25859,43	27038,14	27636,89	27752,88	14332,56	13976,23	14236,43	13884,28	34023,64	37802,19	40552,50	41625,67	45856,68
Functionmodule 3										3278,84	3248,48	3820,45	3783,72					
Functionmodule 2 excavator														871,24	921,63	933,75	976,31	1001,51
Functionmodule 2 backhoe										1080,80	1135,04	1061,59	1092,61					
Functionmodule 1	1907,55	1785,95	3015,79	3076,11	3166,58	5588,86	5687,78	5737,24	5786,70									
Batterymodule	192,75	180,46	191,98	195,82	201,58	216,93	220,77	222,69	224,61	207,34	205,42	199,66	197,74	284,13	291,81	295,65	297,57	305,24
Wirenetmodule	8,64	8,09	8,60	8,77	9,03	9,72	9,89	9,98	10,06	9,29	9,20	8,95	8,86	12,73	13,07	13,25	13,33	13,68
Cabinmodule	1600,76	1498,72	1594,38	1626,27	1674,10	1801,65	1833,54	1849,48	1865,42	1721,93	1705,99	1658,15	1642,21	2359,68	2423,46	2455,34	2471,29	2535,06
Hydraulicmodule	462,85	433,34	658,58	671,75	691,50	1726,52	1757,08	1772,36	1787,64	1394,07	1381,16	1794,49	1777,23	3703,83	3803,93	3853,98	3879,01	3979,11
Tyremodule	2830,52	2650,09	3203,69	3300,44	3801,17	6118,08	6226,36	6206,18	5622,47	3459,98	3427,94	3331,83	3299,80	3982,82	4090,47	4144,29	4171,20	4278,84
Motormodule	2687,64	4095,18	5248,88	5353,86	5511,33	12692,85	12917,50	13029,83	13142,15	4617,97	4661,53	5458,84	5406,35	9244,33	9494,18	9619,10	9600,21	9931,41

Figure 6.28. Visualization of impacts from the scaled modules in all of Hydrema's machines on global warming (Own production (See Appendix E))

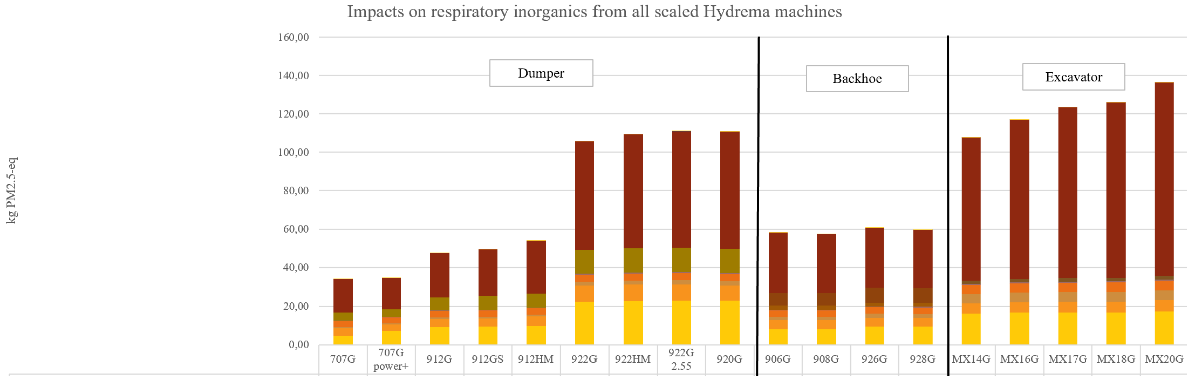
This impact category operates with the unit kg CO2 equivalents (eq), which is a collected term of how much greenhouse gases contribute to global warming [Eurostat, 2025]. In the figure, it is clear that the large dumpers, 922G, 922HM, 922G 2.55, and 920G, and the excavators, MX14G, MX16G, MX17G, MX18G, and MX20G have the largest impact on global warming, with emissions on between 50.000-70.000 kg CO2 eq. It is also evident that the largest contributors are the chassismodule, the tyremodule, and the motormodule. The large dumpers and excavators emit the most because these machines have the largest scaling factors, which can be seen in Figure 6.21 and 6.22. For the excavators, the hydraulicmodule also accounts for a fair amount, which can be explained by them having a big hydraulic system, and therefore the hydraulicmodule is scaled the most for these machines. This impact category can also be dived further into, by looking at the SimaPro calculation for the process contribution, to see which background processes are the biggest contributors to global warming. The process contribution from SimaPro can be seen in Appendix F. For the reference machine 912G dumper, the following processes are contributing the most to the impact on global warming:

1. Pig iron ROW
2. Iron sinter ROW
3. Hard coal CN
4. Heat, district or industrial, other than natural gas ROW
5. Pig iron RER
6. Coke ROW
7. Heat, district or industrial, natural gas ROW
8. Natural gas, vented GLO

9. Carbon black GLO
10. Clinker ROW

These processes mainly go into the steel production processes, which indicates that the highest contributor to the global warming impact on the production of the scaled Hydrema machines comes from the steel inputs. This would also make sense, because steel is by far the main material in the Hydrema machines. The contribution from carbon black originates from the production of rubber needed for the tyres and hydraulic pipes. The rubber also accounts for a fair amount of the machines' total weight, and therefore, the production of the rubber needed also has a high contribution to the total impact on global warming from the production of the machines.

The second significant impact category that will be presented for all of the scales Hydrema machines is 'respiratory inorganics', which can be seen in Figure 6.29.



	707G	707G power+	912G	912GS	912HM	922G	922HM	922G 2.55	920G	906G	908G	926G	928G	MX14G	MX16G	MX17G	MX18G	MX20G
Alkyd paint, white, without water, in 60% solution state {RER}	0,05	0,04	0,04	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,07	0,07	0,07
Steel, low-alloyed {GLO}	0,05	0,04	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,07	0,07	0,07
Chassismodule	17,04	15,95	22,93	24,33	27,45	56,75	59,34	60,65	60,91	31,45	30,67	31,24	30,47	74,67	82,96	89,00	91,35	100,64
Functionmodule 3										6,28	6,23	7,32	7,25					
Functionmodule 2 excavator														1,66	1,76	1,78	1,86	1,91
Functic Datatabel ackhoe										2,06	2,17	2,03	2,09					
Functionmodule 1	4,23	3,96	6,70	6,83	7,03	12,41	12,63	12,74	12,85									
Batterymodule	0,38	0,35	0,37	0,38	0,39	0,42	0,43	0,43	0,44	0,40	0,40	0,39	0,39	0,55	0,57	0,58	0,58	0,60
Wirenetmodule	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,03	0,03	0,03
Cabinmodule	3,21	3,00	3,20	3,26	3,36	3,61	3,68	3,71	3,74	3,45	3,42	3,32	3,29	4,73	4,86	4,92	4,95	5,08
Hydraulicmodule	0,57	0,53	0,81	0,82	0,85	2,12	2,16	2,17	2,19	1,71	1,69	2,20	2,18	4,54	4,67	4,73	4,76	4,88
Tyremodule	3,78	3,54	4,28	4,41	5,08	8,18	8,32	8,29	7,51	4,62	4,58	4,45	4,41	5,32	5,47	5,54	5,57	5,72
Motormodule	4,72	7,20	9,22	9,41	9,69	22,31	22,70	22,90	23,10	8,12	8,19	9,59	9,50	16,25	16,69	16,90	16,87	17,45

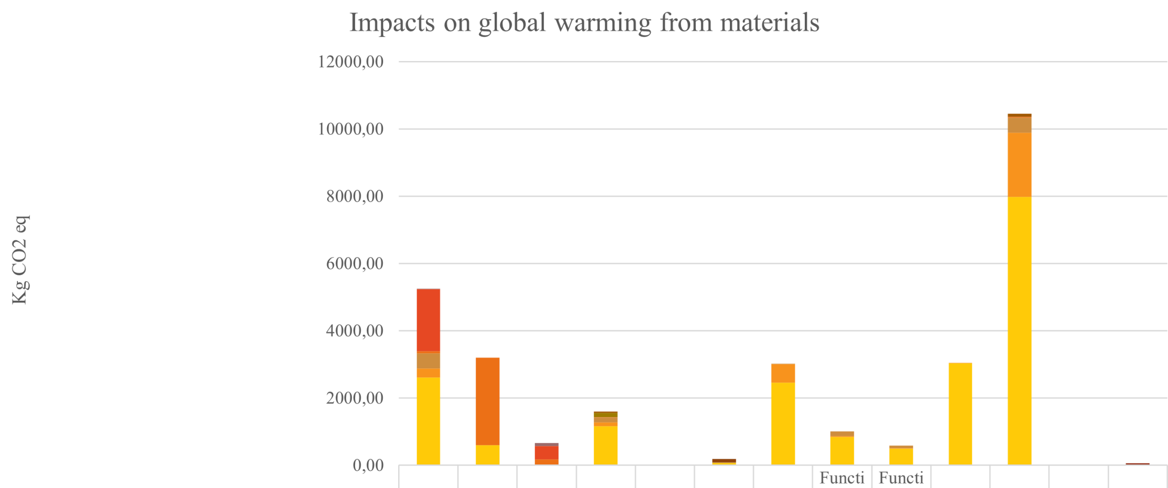
Figure 6.29. Characterized impacts on respiratory inorganics from all scaled Hydrema machines (Own production (See Appendix E))

The respiratory inorganics impact category in the Stepwise method originates from the IMPACT2002+ LCIA method. The unit for respiratory inorganics is kg PM2.5-eq, which describes the human intake fraction of particulate matter (PM), which are fine particles [European Commission, 2011]. As with global warming, the largest impact on respiratory inorganics originates from the large dumpers, 922G, 922HM, 922G 2.55, and 920G, and the excavators, MX14G, MX16G, MX17G, MX18G, and MX20G. For the large dumpers, the largest impacts originate from the chassismodule, motormodule, functionmodule, and tyremodule. For the excavators, the largest impacts originate from the chassismodule, motormodule, tyremodule and cabinmodule. As was done for the global warming impact category, this impact category can also be dived further into by looking at SimaPro's process contributions, to see which background processes contribute the most to the total impact of respiratory inorganics, see Appendix F. For the reference machine 912G dumper, the following processes are contributing the most to the impact on respiratory inorganics:

1. Coke ROW
2. Heat, district or industrial other than natural gas ROW
3. Molybdenite GLO
4. Electricity, high voltage, for internal use in coal mining CN
5. Ferrochromium, high-carbon , 68% Cr ROW
6. Ferronickel GLO
7. Heat, district or industrial, other than natural gas RU
8. Electricity, high voltage ROW
9. Iron ore, crude ore, 63% Fe IN
10. Transport, freight, sea, bulk carrier for dry goods GLO

As well as for the global warming impact categories, these processes go into the production of the steel used for the production of the scaled Hydrema machines. As previously mentioned, this is logical because the largest amount of material in the scaled Hydrema machines is steel. This means that the largest impact on respiratory inorganics, being the fraction of particulate matter a human inhales, originates from the production of steel that is used to produce the scaled Hydrema machines.

To dive further into where the impacts originate, the materials that go into the reference modules will be described. The reference modules are the modules made based on the analysis of the BOM parts list of the 912G dumper, the digging arms from the 906G backhoe and the MX14G excavator, and the shovel from the 906G backhoe. For the materials, the same impact categories are described, being 'respiratory inorganics' and 'global warming', and here the characterized values are used again. Again, the first impact category that will be described is impacts from the materials on global warming, which can be seen in Figure 6.30.



	Motor module	Tyremodule	Hydraulicmodule	Cabin module	Wirenetmodule	Batterymodule	Functionmodule 1	Functionmodule 2 backhoe	Functionmodule 2 excavator	Functionmodule 3	Chassismodule	Screws	Paint
Alkyd paint, white, without water, in 60% solution state {RER}													54,19
Battery, lead acid, rechargeable, stationary {GLO}						114,06							
Wire drawing, copper {GLO}					2,69								
Polyethylene, high density, granulate {GLO}				30,64	2,04						81,71		
Flat glass, coated {RER}				133,40									
Lubricating oil {RER}	17,49		87,44										
Aluminium, cast alloy {GLO}	1838,95		395,47										
Synthetic rubber {GLO}	70,19	2608,91	168,46	14,04							28,08		
Steel, unalloyed {GLO}	444,21		0,39	135,24		1,01	6,26	136,78	80,46		449,95		
Steel, chromium steel 18/8, hot rolled {GLO}	264,36			126,25			552,18	24,73	14,55	3,47	1912,68		
Steel, low-alloyed {GLO}	2613,68	594,78	6,82	1154,81	3,87	76,91	2457,35	839,24	493,67	3032,49	7977,09	24,00	

Figure 6.30. Visualization of characterized impacts from the different materials in the different modules on global warming (Own production (See Appendix E))

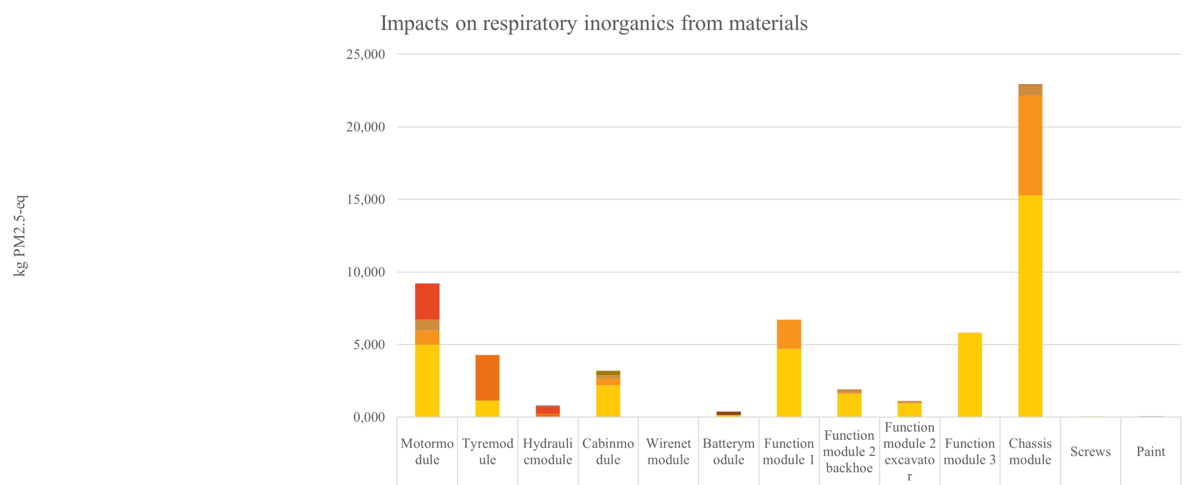
On this figure, it is possible to see which materials emit the most in each module. It is clear from the figure that the reference modules with the highest impacts on global warming are the chassismodule, motormodule, and tyremodule. In these modules, respectively, it is the steel, rubber, and aluminum that have the largest CO2 eq emissions. The rubber has an impact of 2,81 kg. CO2 eq pr. kg., the low-alloyed steel has an impact of 4,15 kg. CO2 eq pr. kg. and the aluminum has an impact of 19,77 kg. CO2 pr. kg. It is, however, evident that the steel that is used in the machines has the largest impact, which can be explained by this material being the main material of the machine, with around 80% of the reference machine's weight coming from the steel. These three modules can be analyzed further by looking into SimaPro's process contribution, which can be seen in Figure 6.31.

Chassismodule	Motormodule	Tyremodule
Pig iron {ROW}	Pig iron {ROW}	Carbon black {GLO}
Iron sinter {ROW}	Hard coal {CN}	Ethylene {ROW}
Heat, district or industrial, other than natural gas {ROW	Iron sinter {ROW}	Natural gas, vented {GLO}
Hard coal {CN}	Heat, district or industrial, other than natural gas {ROW	Pig iron {ROW}
Pig iron {RER}	Pig iron {RER}	Sweet gas, burned in gas turbine {GLO}
Coke {ROW}	Coke {ROW}	Propylene {ROW}
Heat, district or industrial, natural gas {ROW}	Heat, district or industrial, other than natural gas {ROW	Ethylene {RER}
Clinker {ROW}	Aluminium, primary, liquid {CN}	Hard coal {CN}
Quicklime, in pieces, loose {ROW}	Heat, district or industrial, natural gas {ROW}	Heat, district or industrial, other than natural gas {ROW}
Heat, district or industrial, other than natural gas {RU}	Clinker {ROW}	Heat, district or industrial, natural gas {ROW}

Figure 6.31. Process contribution to the three largest emitting modules on global warming (Own production (See Appendix F))

Here, the processes that are contributing the most are the processes needed for the production of the main materials in the respective modules. This means that for the chassismodule, the processes that are contributing the most are the processes needed to produce the steel needed to produce the chassismodule. For the motormodule, the processes that are contributing the most are the processes needed to produce the steel and aluminum needed to produce the motormodule. Lastly, for the tyremodule the processes that are contributing the most are the processes needed to produce the rubber and steel needed to produce the tyremodule.

The impact category 'respiratory inorganics' will also be described on behalf of the materials going into the reference modules, which can be seen in Figure 6.32.



	Motormodule	Tyremodule	Hydraulicmodule	Cabinmodule	Wirenet module	Batterymodule	Function module 1	Function module 2 backhoe	Function module 2 excavator	Function module 3	Chassis module	Screws	Paint
Alkyd paint, white, without water, in 60% solution state {RER}													0,044
Battery, lead acid, rechargeable, stationary {GLO}						0,226							
Wire drawing, copper {GLO}					0,009								
Polyethylene, high density, granulate {GLO}				0,022	0,001						0,059		
Flat glass, coated {RER}				0,281									
Lubricating oil {RER}	0,012		0,058										
Aluminium, cast alloy {GLO}	2,479		0,533										
Synthetic rubber {GLO}	0,085	3,143	0,203	0,017							0,034		
Steel, unalloyed {GLO}	0,697		0,001	0,212		0,002	0,010	0,215	0,126		0,706		
Steel, chromium steel 18/8, hot rolled {GLO}	0,948			0,453			1,981	0,089	0,052	0,012	6,861		
Steel, low-alloyed {GLO}	5,004	1,139	0,013	2,211	0,007	0,147	4,705	1,607	0,945	5,806	15,273	0,046	

Figure 6.32. Characterized impacts from the different materials in the different modules on respiratory inorganics (Own production (See Appendix E))

On this figure, it is clear that the modules that contribute the most to impact on respiratory inorganics are the chassismodule, the motormodule, and the functionmodule 1, which is the dumper trough. In these modules, it is steel and aluminum that are the biggest contributors. Another material that is contributing a fair amount is the rubber in the tyremodule. As well as the previous impact category, the largest impacts come from the steel, because this is the primary material in the scaled machines. The process contribution to the four relevant modules can be seen in Figure 6.33.

Chassismodule	Motormodule	Functionmodule 1	Tyremodule
Coke {ROW}	Coke {ROW}	Coke {ROW}	Carbon black {GLO}
Heat, district or industrial, natural gas {ROW}	Heat, district or industrial, other than natural gas {ROW}	Heat, district or industrial, natural gas {ROW}	Electricity, high voltage {ROW}
Molybdenite {GLO}	Electricity, high voltage, for internal use in coal mining {CN	Molybdenite {GLO}	Heat, district or industrial, other than natural gas {ROW}
Ferrochromium, high-carbon, 68% Cr {ROW}	Molybdenite {GLO}	Ferrochromium, high-carbon, 68% Cr {ROW}	Coke {ROW}
Ferronickel {GLO}	Ferronickel {GLO}	Ferronickel {GLO}	Electricity, high voltage, for internal use in coal mining {CN
Heat, district or industrial, other than natural gas {RU}	Electricity, high voltage {ID}	Heat, district or industrial, other than natural gas {RU}	Heat, district or industrial, other than natural gas {RU}
Electricity, high voltage, for internal use in coal mining {CN}	Transport, freight, sea, bulk carrier for dry goods {GLO}	Electricity, high voltage, for internal use in coal mining {CN	Ethylene {ROW}
Iron ore, crude ore, 63% Fe {IN}	Heat, district or industrial, other than natural gas {RU}	Iron ore, crude ore, 63% Fe {IN}	Transport, freight, sea, tanker for petroleum {GLO}
Transport, freight, sea, bulk carrier for dry goods {GLO}	Iron ore, crude ore, 63% Fe {IN}	Transport, freight, sea, bulk carrier for dry goods {GLO}	Electricity, high voltage {UA}
Iron sinter {ROW}	Iron sinter {ROW}	Iron sinter {ROW}	Molybdenite {GLO}

Figure 6.33. Process contribution to the four largest emitting modules on respiratory inorganics (Own production (See Appendix F))

As well as in the previous process contribution table in Figure 6.31, the processes that are contributing the most are the processes needed to produce the main materials. The processes contributing the most to respiratory inorganics from the four most emitting modules are much alike the processes contributing to respiratory inorganics on the machine level. This means that it is mostly processes related to the production of steel and the production of rubber that are contributing the most to the impacts on respiratory inorganics.

As mentioned in Section 6.2.5, the Hydrema machines use fuel in their use phase, and therefore, the impacts from the use phase are relevant because there are also impacts related to the machine's post-production. The impacts from the machine's use phase will be described in the following section.

6.3.2 Use phase of Hydrema machines

The use phase is, as described in Section 6.2.5, modeled on three different 'use phases'. It is also modeled following the functional unit being: *1 operational hr of moved earth*. Therefore, this section is divided into three sections, the first describing the impacts from one active hour of the machine, which do not take idling into account, the second describing the impacts from one idling hour of the machine, which do not take being active into account, and the last combining the amount of time spent active and idling into one operational hour. In the three following sections, for the three use phases, the impact categories will be chosen based on the weighted impacts from the Stepwise method, and based on this, the most significant impacts will be described based on their characterization factors.

Active

The first use phase that will be described is for one hour of the machine being active. This takes into account the amount of machine and fuel needed to carry out one hour of being active, for all of Hydrema's machines. In Figure 6.34, the weighted impacts from 1 active hour of all of the scaled Hydrema machines can be seen.

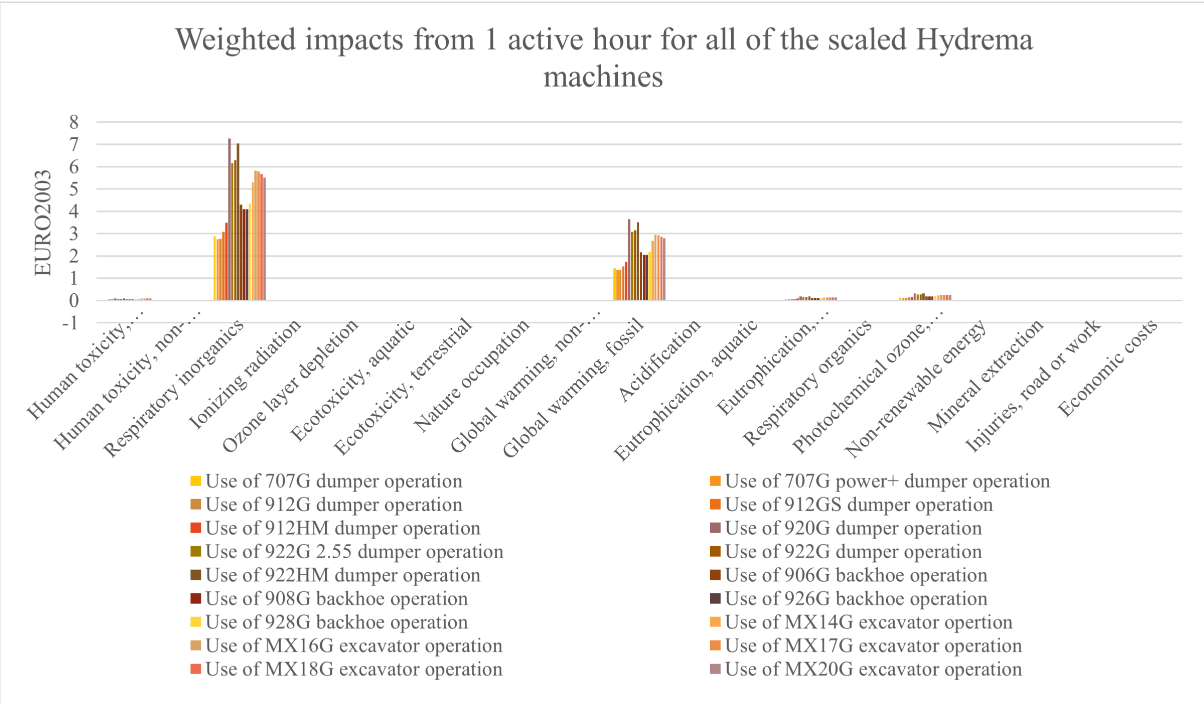
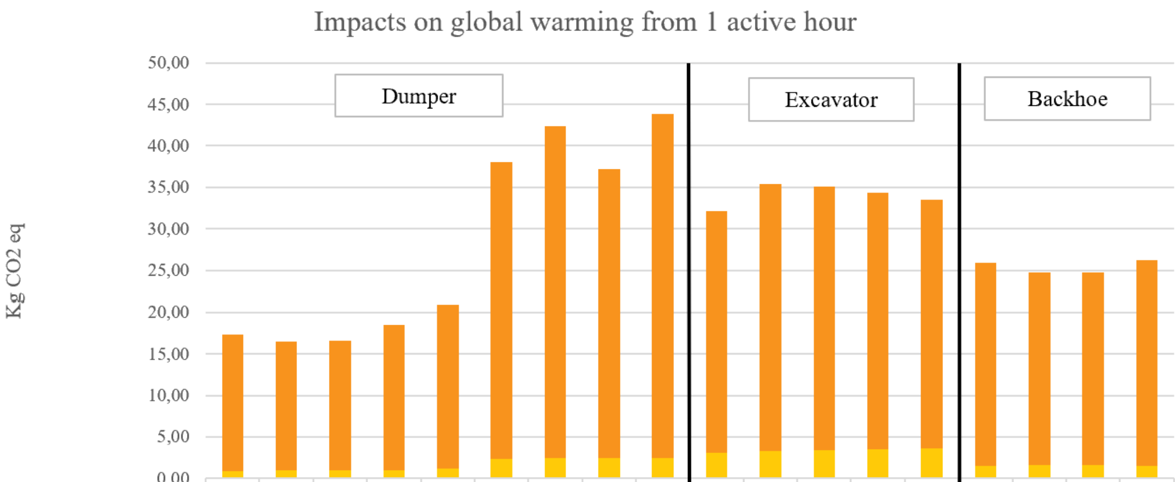


Figure 6.34. Weighted impacts on 1 hour of operation (Own production (See Appendix E))

On this figure, it is clear that the most significant impact categories for one working hour of the scaled Hydrema machines are 'respiratory inorganics' and 'global warming'. Therefore, these two impact categories will be described in the following, based on their characterization values.

The first impact category that will be described is 'global warming', which can be seen in Figure 6.35. The reason for this impact category being the first one to be described, despite the other chosen impact category being larger, is, as previously mentioned, because this is the most well-known impact category for Hydrema, and therefore likely to be the most useful one for them.



	707G	707G power +	912G	912G S	912H M	922G	922H M	922G 2.55	920G	MX1 4G	MX1 6G	MX1 7G	MX1 8G	MX2 0G	906G	908G	926G	928G
Diesel burned	16,44	15,57	15,63	17,53	19,80	35,73	39,97	34,77	41,31	29,13	32,12	31,70	30,87	29,85	24,43	23,19	23,20	24,70
Production of machine	0,87	0,93	1,00	1,01	1,17	2,33	2,44	2,44	2,50	3,05	3,26	3,42	3,53	3,66	1,48	1,59	1,58	1,55

Figure 6.35. Visualization of impacts from 1 active hour, with the amount of produced machine and diesel needed for 1 hour of being active on global warming (Own production (See Appendix E))

In the figure, it is evident that the diesel used during 1 hour of being active accounts for the largest emissions compared to the production of the fraction of the machine needed for 1 hour of being active. The biggest contributors to this impact category are the large dumpers, 922G, 922HM, 922G 2.55, and 920G, because these machines have the largest fuel consumption of all of the machines. Another machine type that creates large emissions to global warming are the excavators. For the large dumpers, they emit between 35-41 kg CO2 eq from their diesel burned, and only around 2,5 kg CO2 eq for the production of the fraction of machine needed for 1 hour of being active. The excavators emit between 29-33 kg CO2 eq from their burned diesel, and around 3,5 kg CO2 eq from the production of the fraction of machine needed for 1 hour of being active. The larger emissions from the amount of machine needed for the excavator compared to the dumpers can be explained by the excavators having a higher percentage of active time, and therefore, need a larger fraction of machine for working compared to idling. To look further into what makes the biggest contribution to the global warming impacts from one working hour, the SimaPro process contribution is used, which can also be seen in Appendix F. The biggest contributors to 1 active hour are as stated below.

1. Diesel, burned in building machine GLO
2. Natural gas, vented GLO
3. Diesel ROW
4. Sweet gas, burned in gas turbine GLO

5. Pig iron ROW
6. Waste natural gas, sweet GLO
7. Transport, freight, sea, tanker for petroleum GLO
8. Heat, district or industrial, natural gas ROW
9. Diesel Europe without Switzerland
10. Iron sinter ROW

By this, it is clear that the largest contributors are processes needed for producing the diesel needed for the use phase of the machines. This fits well with the trend shown in Figure 6.35, with the fuel contributing most to the emissions from 1 active hour.

The second impact category that will be looked into is the impacts on respiratory inorganics from 1 active hour, which can be seen in Figure 6.36.

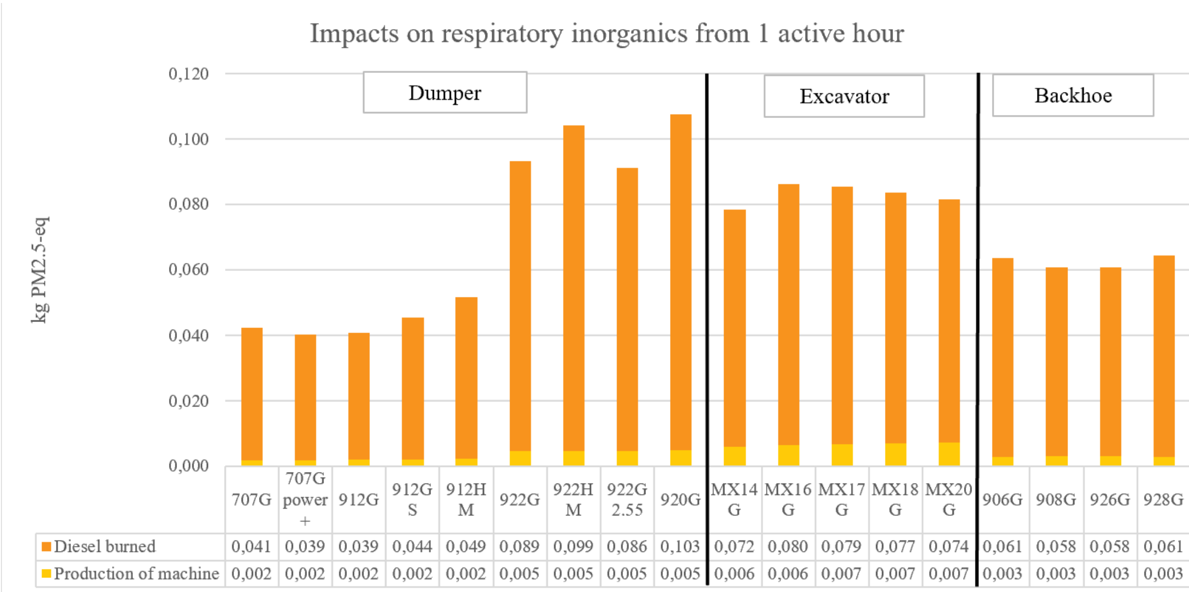


Figure 6.36. Visualization of impacts from 1 active hour, with the amount of produced machine and diesel needed for 1 hour working on respiratory inorganics (Own production (See Appendix E))

The impacts on respiratory inorganics follow the same trend as the impacts on global warming, where the largest emitters are the large dumpers and the excavators. For this impact category, the process contribution is also looked further into, where the largest contributors are presented below, see Appendix F.

1. Diesel burned in building machine GLO
2. Coke ROW
3. Transport, freight, sea, tanker for petroleum GLO
4. Diesel ROW

5. Electricity, high voltage ROW
6. Molybdenite GLO
7. Electricity, high voltage, for internal use in coal mining CN
8. Ferronickel GLO
9. Iron ore, crude ore, 93% Fe IN
10. Transport, freight, sea, bulk carrier for dry goods GLO

For this impact category, both the processes needed to produce the diesel needed for the use phase, as well as the production of steel needed for producing the machines, are large contributors to the impact on respiratory inorganics.

The next use phase that will be described is idling of the machines, which will be described in the following section.

Idling

In this section, the impacts of 1 hour of idling for all of Hydrema's machines will be described. This takes into account the amount of machine and fuel needed to carry out one hour of idling for Hydrema's machines. In Figure 6.37, the weighted impacts from 1 idling hour of all of the scaled Hydrema machines can be seen.

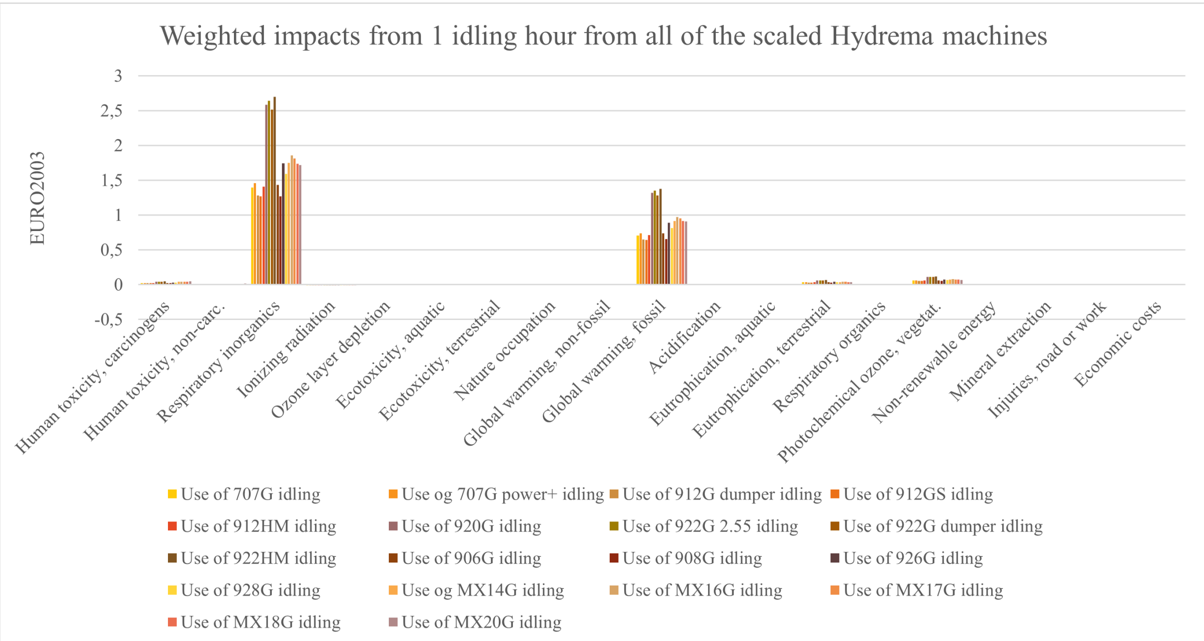


Figure 6.37. Weighted impacts from one idling hour (Own production (See Appendix E))

On this figure, it is clear that the most significant impact categories for one idling hour of the scaled Hydrema machines are 'respiratory inorganics' and 'global warming'. Therefore, these two impact categories will be described in the following, based on their characterization values.

The first impact category that will be described is 'global warming', which can be seen in Figure 6.38.

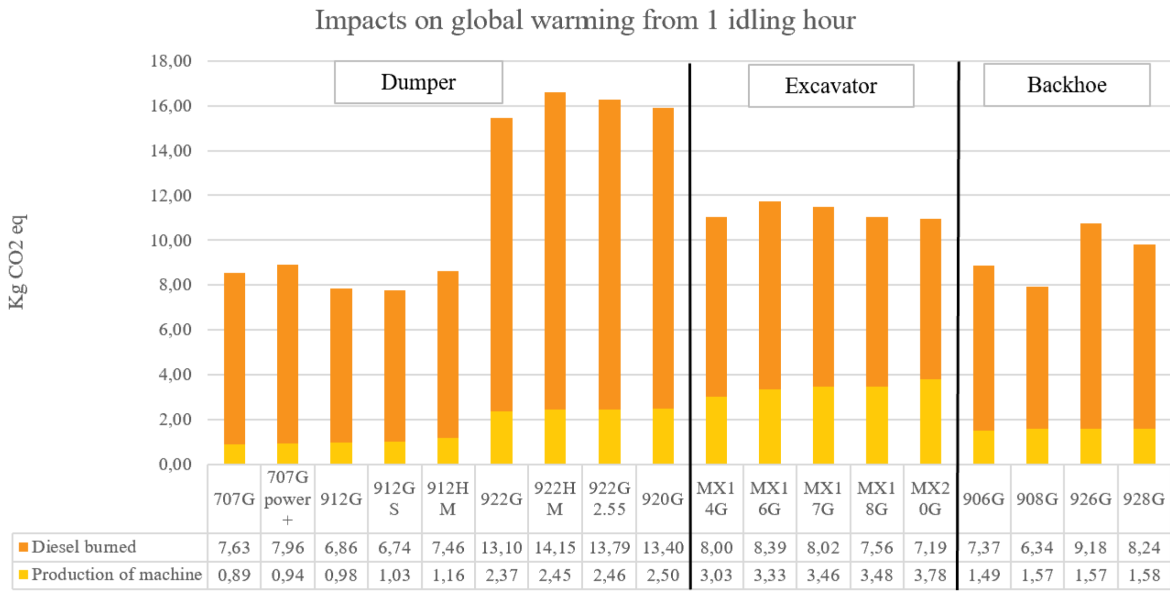


Figure 6.38. Visualization of impacts from 1 idling hour, with the amount of produced machine and diesel needed on global warming (Own production (See Appendix E))

The largest emissions of global warming come from the diesel burned during idling. The large dumpers are again, as well as in the active hour, the biggest contributors, where the diesel burned for one hour of idling lies around 13 kg CO2 eq, and the production of the fraction of the machine lies around 2,5 kg CO2 eq. The emissions from the diesel burned are, however, smaller than for the one active hour, because the machines spend less time idling than being active, and they have a lower fuel consumption. The emissions from the production of the fraction of the machine needed for one idling hour are not very different than those for one active hour. This is because even though a larger part of the machine goes to being active, the machine is also active for longer, so when the smaller piece for idling is divided by the shorter amount of time to get one hour, they do not differ that much, and therefore their emissions are quite alike. Another difference in the global warming impact from the active hours and the idling hours is connected to the percentage share of emissions from diesel burned and the production of machines needed. For the active hour, the diesel burned accounts for between 89-95% of the total emissions, whereas the span for the idling hour lies between 66-90%. The production of the fraction of machines needed is therefore larger for the idling hour. This applies in particular for the excavators, which can be explained by them spending less time idling than the other machine types, but because the fraction of machine needed for 1 active hour and one idling hour are much alike, the production of the fraction of machine needed will constitute more to the total emissions for the idling hour than for the working hour. The process contribution from 1 idling hour is similar to the process contribution for 1 active hour, where the processes for producing the diesel needed for 1 idling hour contribute the most (See Appendix F).

The next impact category that will be described is for the respiratory inorganics, for 1 idling hour, which can be seen in Figure 6.39.

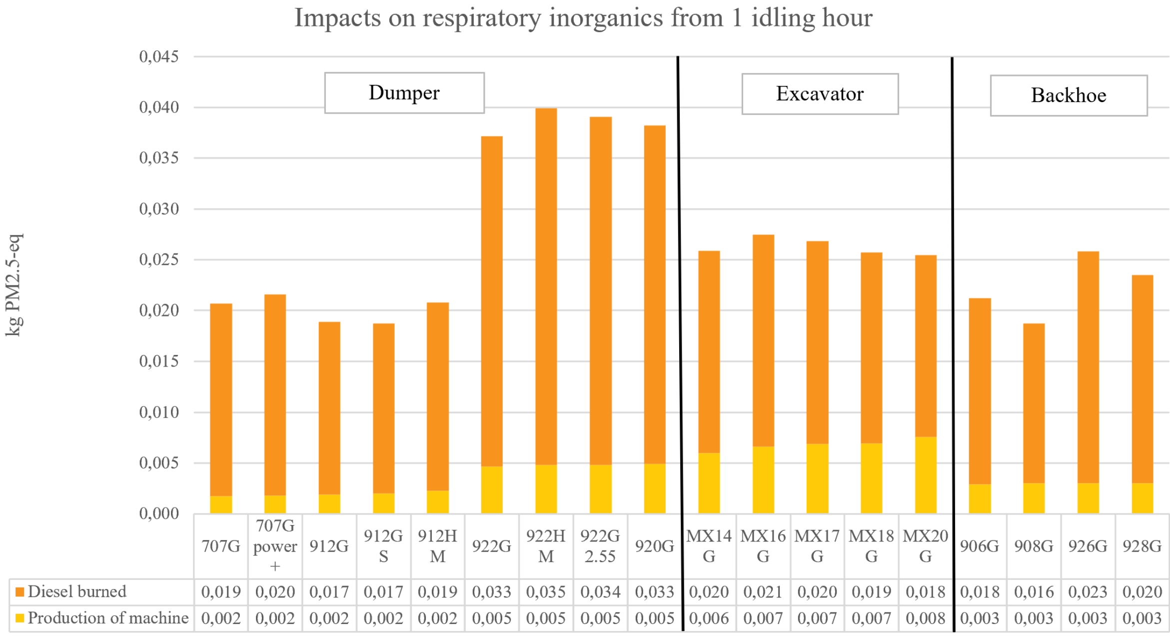


Figure 6.39. Visualization of impacts from 1 idling hour, with the amount of produced machine and diesel needed for 1 hour idling on respiratory inorganics (Own production (See Appendix E))

The impacts on respiratory inorganics for 1 idling hour follow the same trend as the impacts on respiratory inorganics for 1 active hour, where the diesel burned during the idling hour accounts for the largest impact in comparison with the impact from the production of the fraction of the machine needed. The process contribution from 1 idling hour on respiratory inorganics is also similar to the one for the 1 active hour, where the processes needed to produce the diesel and the steel needed are contributing the most (See Appendix F).

Lastly, in this LCIA of the use phase of all of Hydrema's machines, emissions from the total operation hour will be presented.

Total

By a total operation hour, it takes into account the percentage of time the machine spends active as well as the time the machine spends idling in one connected hour, which can be seen in Figure 6.23. In Figure 6.40, the weighted impacts from 1 total operation hour of all of the scaled Hydrema machines can be seen.

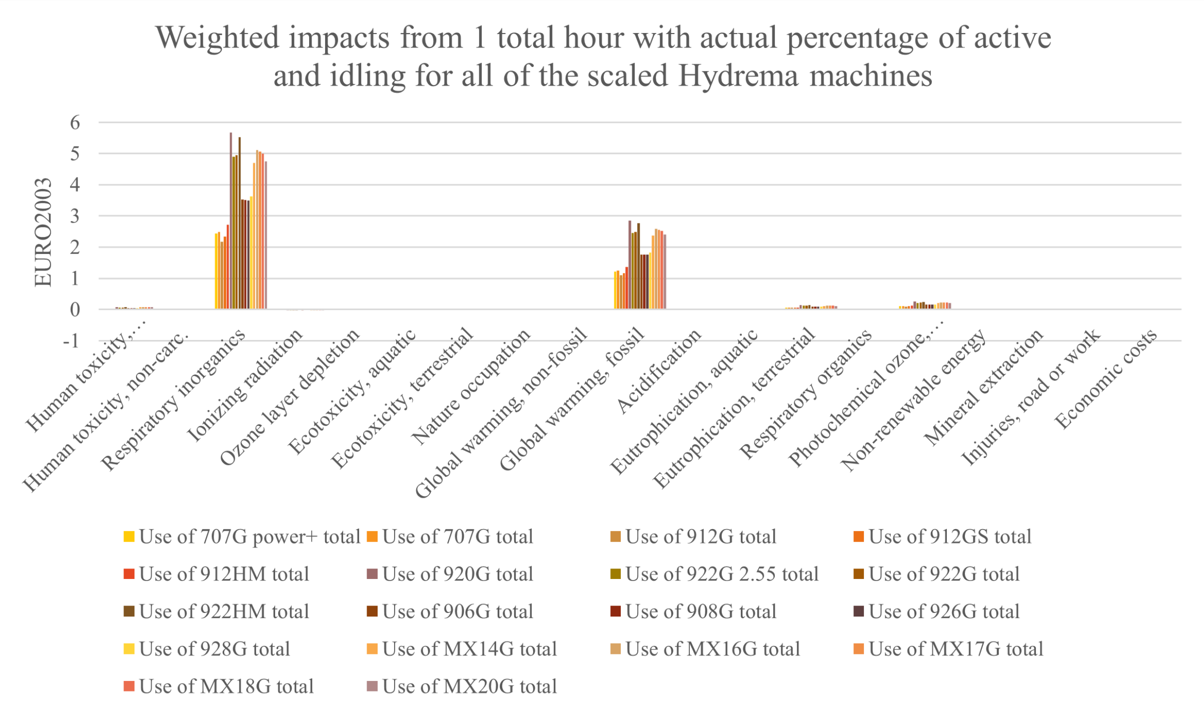


Figure 6.40. Weighted impacts on 1 hr with the actual percentage share of being active and idling (Own production (See Appendix E))

On this figure, it is clear that the most significant impact categories for one total operation hour of the scaled Hydrema machines are 'respiratory inorganics' and 'global warming'. Therefore, these two impact categories will be described in the following, based on their characterization values.

The first impact category that will be described is 'global warming', which can be seen in Figure 6.41.

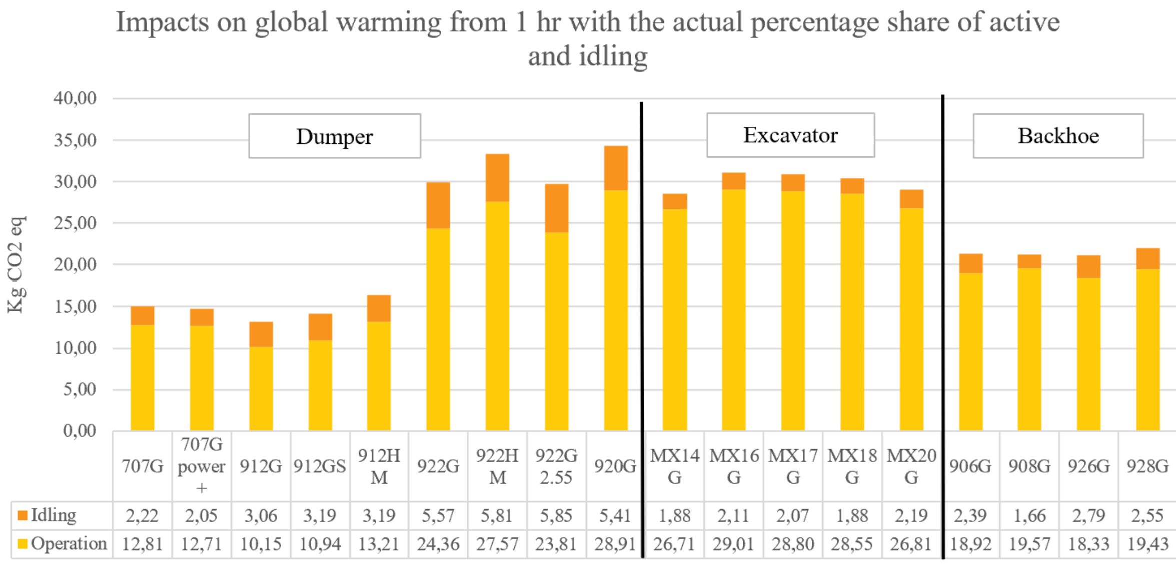


Figure 6.41. Visualization of impacts from 1 total hour, with the actual percentage share of time spent working and time spent idling on global warming (Own production (See Appendix E))

In the figure, it can be seen that the largest emissions in the total hour come from the percentage of time the machine is active. The emissions are largest for the large dumpers and excavators, which can be connected with these machines having the largest emissions when they are active. However, it is also evident from the figure that the large dumpers have the largest emissions on the percentage of time spent idling compared to the other machines, which is because these are the machines that spend the most time idling. Here, the emissions from the dumpers working part are between 77-86%, whereas the emissions from the excavators working part are between 92-94%, and the emissions from the backhoes working part are between 87-92%. This translates to the dumpers working part of an hour, emitting between 10-28 kg CO2 eq, the excavators working part of an hour, emitting between 26-28 kg CO2 eq, and the backhoes working part of an hour, emitting around 19 kg CO2 eq. On the contrary, the dumpers are emitting between 2-6 kg CO2 eq in the idling part of an hour, the excavators emitting around 2 kg CO2 eq in the idling part of an hour, and the backhoes emitting between 1,5-3 kg CO2 eq in the idling part of an hour. The process contributions are, like for the idling hour, are similar to the process contribution from one active hour, which makes sense because the same inputs go into the total operational hours. Therefore, the largest contributor to the total operational hour is the processes needed to produce the diesel needed for the usage of the scaled Hydrema machines (See Appendix F).

The next impact category that will be described is 'respiratory inorganics', which can be seen in Figure 6.42.

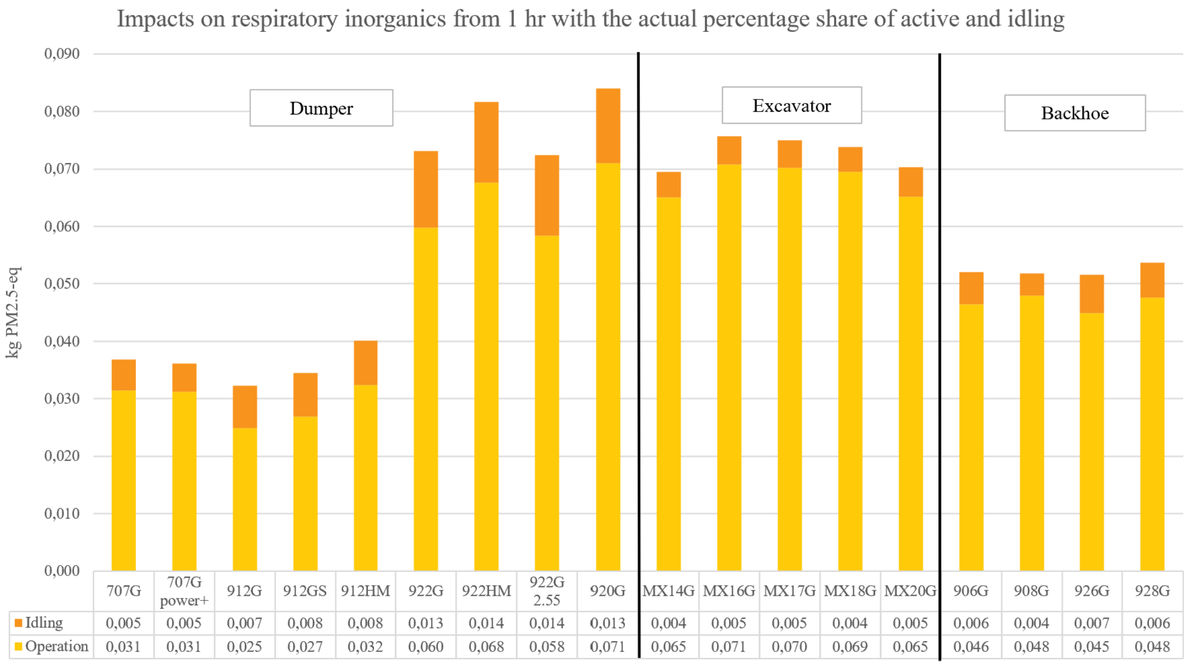


Figure 6.42. Visualization of impacts from 1 total hour, with the actual percentage share of time spent working and time spent idling on respiratory inorganics (Own production (See Appendix E))

The impact category for respiratory inorganics for 1 total operational hour follows the same trend as the global warming impact category, where the working part of an hour emits the most. Again, the large dumpers and excavators are the machines emitting the most.

To model the whole product system from cradle-to-grave, the end-of-life of all of Hydrema's machines will also be modeled, and the impacts thereof will be presented in the following section.

6.3.3 End-of-life scenarios

In this section, the LCIA for the end-of-life phase of the Hydrema machines will be described. The end-of-life phase will be modeled on the reference machine, the 912G, to give an insight into how the impacts are from the waste management. If it were to be scaled to the other machines, it would follow the same trend as the impacts from the production of the scaled machines. To find which impact categories are most relevant to look further into, the weighted impacts from the Stepwise method are looked into, which can be seen in Figure 6.43.

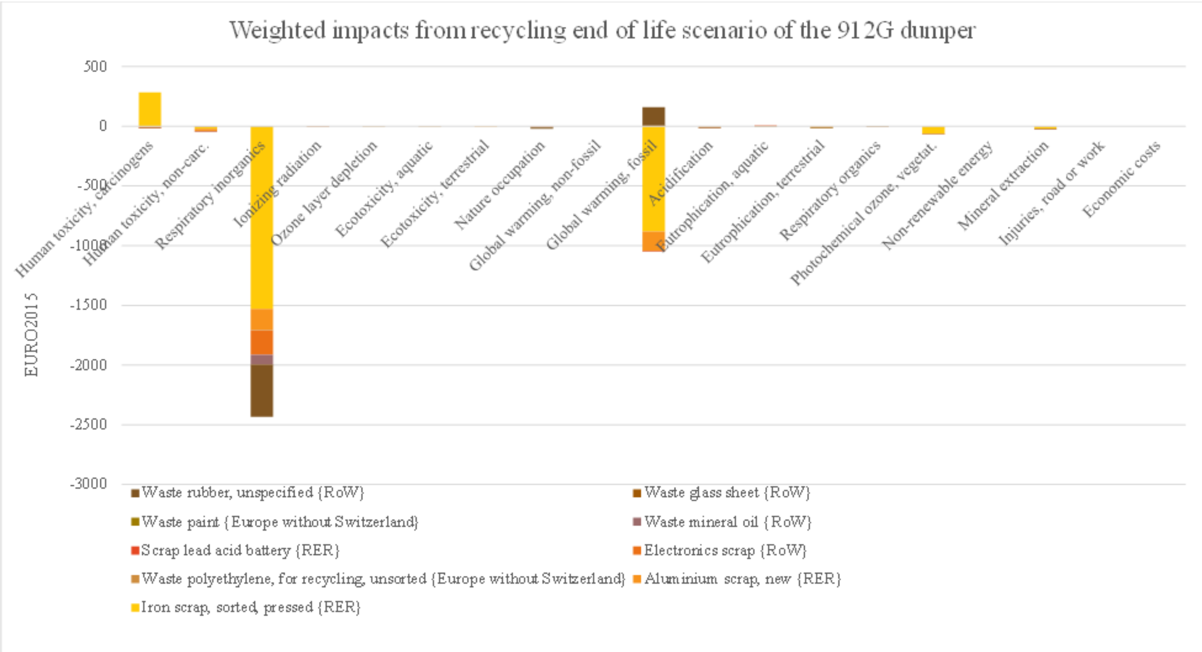


Figure 6.43. Weighted impacts on the first end-of-life scenario (Own production (See Appendix E))

Based on the figure, it can be seen that the most significant impact categories are 'global warming' and 'respiratory inorganics', as was the case for both the production and use phases of the scaled Hydrema machines. The first impact category that will be described is 'global warming', which can be seen in Figure 6.44.

Figure 6.44. Impacts on global warming from the first end-of-life scenario (Own production (See Appendix E))

This figure looks into the waste management processes of all materials going into the reference machine, the 912G dumper. In the figure, it is evident that the largest positive impact comes from the avoided process of iron scrap. This means that the steel in the machine will be recycled, and by, avoid the production of iron scrap, which is why the impacts are positive because it prevents new virgin steel from being made. Another positive emission from the waste management of the machine is from the recycling of aluminum, where a large amount of aluminum is also able to be used in other products. A waste process that produces negative emissions is the management of rubber, which can indicate that the rubber is undergoing an incineration process rather than a recycling process.

The next impact category that will be described is 'respiratory inorganics', which can be seen in Figure 6.45.

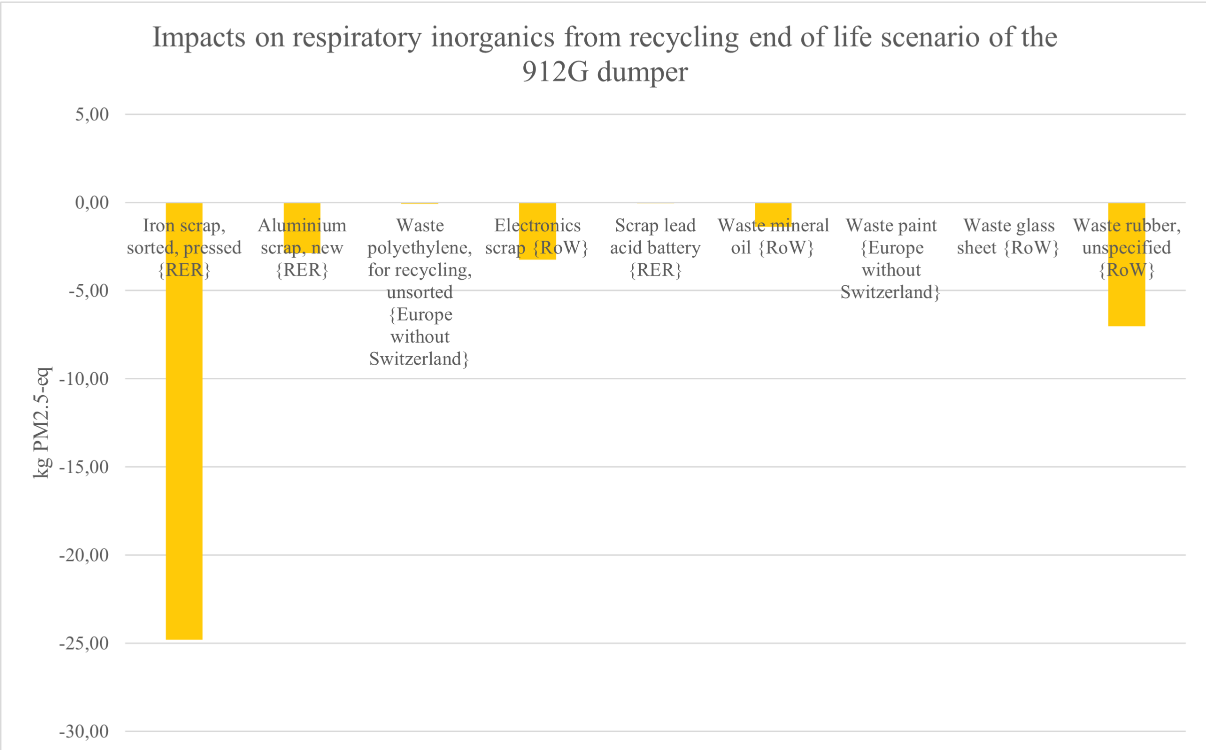


Figure 6.45. Impacts on respiratory inorganics from the first end-of-life scenario (Own production (See Appendix E))

The impacts from the first end-of-life scenario on respiratory inorganics are much alike the impacts on global warming; thus are the impacts from the waste management of rubber making a positive emission of respiratory inorganics compared to global warming.

The second end-of-life scenario is a scenario where the machine is left in the field, where it has potentially broken down. In this scenario, the machine will not undergo any waste management, which means that the emissions from the production will not be avoided by recycling the recyclable materials in the machine. This means that the avoided burdens, as visualized in Figure 6.44 and 6.45, will not happen. Other than this, the machines undergoing this end-of-life scenario are expected to be old and unmaintained, which can also cause leakages to the ground and water, which can cause other environmental problems for the local environment around the leaking machine.

6.4 Interpretation

The last phase of the LCA is the interpretation phase, where results from the LCI and LCIA phases will be discussed, and recommendations and conclusions will be made on behalf of the functional unit stated in the goal and scope. In this interpretation, five aspects will be discussed: firstly, the conclusions on the LCI and LCIA phase will be discussed, secondly, the use phases of the machines will be discussed, thirdly, the data will be discussed, fourthly, the opt-out of Hydrema's electrical machine DT6 will be discussed, and lastly, the potential of other overlooked emissions will be discussed.

6.4.1 Conclusions

The first thing that will be described in this interpretation is the conclusions that can be made on behalf of the LCI and LCIA made in this chapter. Based on the functional unit set in the goal and scope phase, it can be concluded that for 1 operational hour, the largest emissions come from the part of the hour the machine is active. Looking further into the use phases for being active and idling, it is clear that the largest emissions come from the diesel burned during activity or idling; thus does the production of the fraction of machine needed for 1 operational hour also plays a role. The role of the production of machines is, however, small for 1 operational hour, because the machines are operating for many hours, and therefore only a small fraction of the machine is needed for one operational hour. The relationship between how much the diesel accounts for and how much the production accounts for can be scaled up to, for the working part of the machine, to 15000 hours. This is looked further into for the 912G dumper, which uses 60% of the machine for the working part of its use phase. The working part scaled to 15000 hours, for the 912G dumper can be seen in figure 6.46.

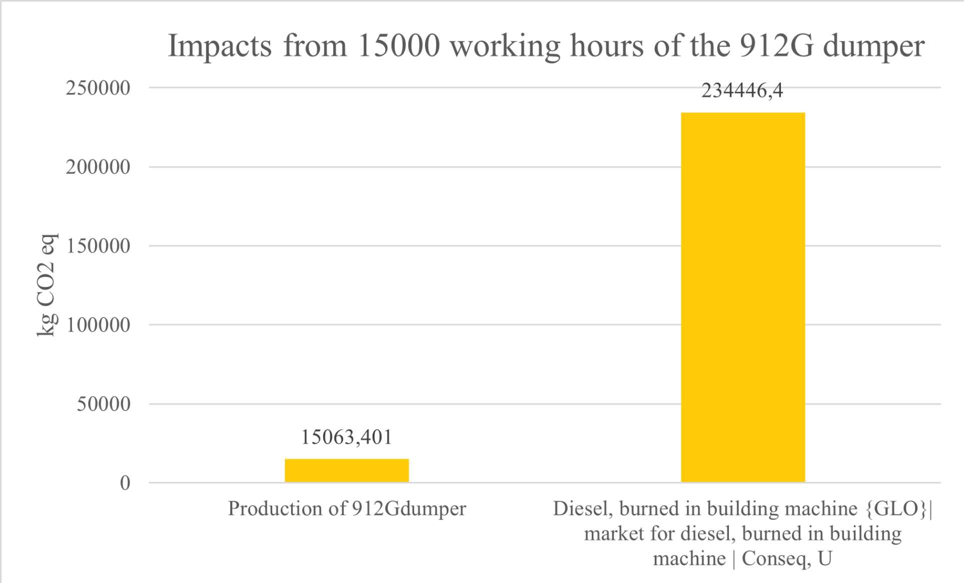


Figure 6.46. Characterized impacts from 15000 working hours for the 912G dumper (Own production)

Based on the figure, it can be seen that only 6% of the emissions from 15000 working hours originate from the emissions from producing the fraction of the machine needed for the working part of the use phase. This means that the diesel burned during working for the dumper accounts for 94% of the total emissions. Therefore, the use phase of the Hydrema machines is relevant for Hydrema to look into when setting objectives for their environmental management system and ESG reporting, because these emissions are deemed a large contributor to their total scope 3 emissions.

Based on the LCIA phase, it can also be concluded that the modules contributing most to the emissions of producing the machines are the chassismodule, the motormodule, and the tyremodule, which leads to steel, aluminum, and rubber being the largest contributing materials of producing the machines at Hydrema. It was also clear that the machines with the highest emissions were the large dumpers and the excavators, which is because these are the machines scaled with the largest scaling factors, as seen in Figure 6.21 and 6.22.

6.4.2 Discussion of use phase

In this section, it will be discussed whether the use phase of the machines could have been modeled in a more accurate way. This is in relation to the amount of machine used for the idling part of the full life. A part of this discussion will contain whether or not the machine will be worn during idling. The second thing that will be discussed is the answers this way of modeling will give, in relation to idling causing smaller emissions of CO2, and therefore, if the machine is idling more, it will create a smaller footprint, even though it is not as effective. In relation to this, the last thing that will be touched upon in this section is how the emissions from the dumpers would have looked if the functional unit had been 1 ton of earth moved instead of one operational hour.

Wear of machine during active or idling

For the use phase of the LCA model, as described in Section 6.2, different amounts of machine are required for the active part and the idling part of the use phase. The amount of machine used for being active is equivalent to the amount of time the machine spends being active. The same goes for the idling part of the machine. By this way of modeling, it indicates that the active part and the idling part of the use, wear evenly on the machine. This is likely not the case because more parts of the machine are actively used during working, and not during idling. It is likely that the only part of the machine used during idling is the motor, and therefore other parts, like for example the tyres and the functionmodules will not be worn on. Therefore, it would have been more accurate to assume that the produced machine only goes into the active part of the use phase, which results in the idling only emitting from the fuel burned. This is because the wear of the machine during idling is assessed to be much smaller than during being active, and therefore, the distribution of the machine should not be distributed evenly in accordance with the percentage of time spent active and idling.

This would make the results differ slightly in Section 6.3.2, where the emissions from the production of the machine will be larger in the active hour, because it would now contain all of the machine. This would result in a larger total emission from the one active hour. The idling hour would also be affected, and by this become smaller, because the production of the machine would be removed, and therefore the emissions would only come from the diesel burned. For the total hour, that takes both the active and idling parts into account, the active hour would account for an even larger impact than what has now been modeled in Section 6.3.2, because the active hour would gain a larger fraction of the machine needed for being active.

This perspective was gained after the modeling of the use phase had been done, and because it was assessed that it would not change the results largely, it was chosen to discuss here in the interpretation instead. This is also mainly because the largest impacts arise from the diesel burned, and therefore the emissions from the fraction of the machine needed are small in comparison, as seen in Figure 6.35 and 6.38.

In the following section, the emissions in relation to the effectiveness of the dumpers will be discussed.

Emissions according to effectiveness

This discussion is based on the results from Figure 6.41, on the dumpers. In that figure, it can be seen that the 7-ton dumpers, 707G and 707G power+, emit more than the 10-ton dumpers, 912G and 912GS. The reason for this might be that the 10-ton dumpers spent more time idling than the 7-ton dumpers. The 7-ton dumpers spent between 22-26% of the time idling, whereas the 10-ton dumpers spent around 40% of the time idling. Because the 7-ton spent more of the time active than the 10-ton dumpers, they therefore have a larger fuel consumption, which results in larger emissions. This then creates the image that the machines that spend more time idling are better because they have a smaller footprint. This, however, makes the machines less effective, and therefore, another functional unit can be tested on the dumpers, being '1 ton of moved earth'. This can be tested, because the amount of moved earth in the total lifetime of the dumpers can be seen in Figure 6.23. If this were the functional unit, the 10-ton dumpers would likely have higher emissions, because they mostly have a larger fuel consumption when working. Because both the 7-ton and the 10-ton dumpers are estimated to be able to work the same number of hours, the 10-ton dumpers can be assessed as being less effective, because they spend more time idling. Therefore, the 10-ton dumpers use more fuel in their total life than the 7-ton dumpers. However, the 10-ton dumpers are also capable of moving more earth during their lifetime, and therefore, the effectiveness of these two can not be based only on the number of hours idling.

The following example only describes the 707G dumper as the 7-ton dumper and the 912G dumper as the 10-ton dumper. Here, the 707G dumper has a total fuel consumption in its full lifetime of 75771.14 liters, and the 912G dumper has a total fuel consumption in its full lifetime of 79913.92 liters. This total fuel consumption takes both active and idle fuel consumption into account. Because it is estimated that both of these machines are able to be active for the same number of hours, the 912G dumper uses more fuel than the 707G dumper. However, this amount of fuel can be scaled down to the amount of earth the machines are likely to move during their lifetime. Here, the 707G dumper is capable of moving around 362060.28 tons of earth, whereas the 912G dumper is capable of moving around 508793.04 tons of earth. This means that the 912G dumper is able to move more earth during its life, because it has a larger trough. The fuel consumption can then be scaled down to how much fuel is needed to move 1 ton of earth. Here, the 707G dumper would need 0.21 liters of diesel to move 1 ton of earth, and the 912G dumper would need 0,16 liters of diesel to move 1 ton of earth. This indicates that the 912G dumper uses less fuel in relation to capacity than the 707G dumper. Even though the 912G dumper can be calculated as being more effective than the 707G dumper, it uses more time idling, which can be described as ineffective time, where the machine is emitting, without being useful. Therefore, if the idling time or the fuel consumption during idling could be lowered, the machine would need less fuel, which would bring down economic costs for the user, as well as bring down the emissions.

To see how the idling affects the effectiveness of the machines, an example is made, where the idling time and consumption are scaled down to 20% of the total time, meaning that all the dumpers spent 80% of the time active and 20% of the time idling. This is to make the fuel consumption pr. ton moved earth comparable. The amount of fuel needed pr. ton moved earth for the two examples can be seen in Figure 6.47.

	Moved earth full life	Total fuel (active+idle)	Fuel pr. ton earth	Total fuel (80% active 20% idle)	Fuel pr. ton earth (80% active 20% idle)
707G	362060.28	75771.14	0.21	71375.28	0.20
707G power+	342832.14	71212.34	0.21	68180.02	0.20
912G	508793.04	79913.92	0.16	67542.71	0.13
912GS	518445.45	87919.17	0.17	75010.14	0.14
912HM	653435.82	96225.76	0.15	84585.60	0.13
922G	1217582.51	170696.74	0.14	152341.92	0.13
922HM	1222377.73	188959.57	0.15	170027.72	0.14
922G 2.55	957519.06	168652.36	0.18	149100.52	0.16
920G	1227314.15	191406.93	0.16	174718.95	0.14

Figure 6.47. Visualization of amount of fuel pr. moved earth, with both the actual fuel consumption with actual percentage share of active and idling, and the example with 80% active and 20% idling (Own production, based on Appendix D)

In this figure, it is clear that the same amount of idling does not change the picture that much. The 912 dumpers are still using less fuel than the 707 dumpers for moving 1 ton of earth, meaning that the 912 dumpers can be deemed more effective than the smaller dumpers. This calculation, however, does not take the amount of machine needed to move 1 ton of earth into account. The larger machines have more emissions in production than the smaller machines, but they are also able to move more earth, and therefore, it is likely that these emissions will not affect the results highly.

6.4.3 Data

In this section, the data used for the LCA will be discussed. This means that the data collection and database will be discussed, based on how they have affected the results. The first thing that will be discussed is the data collection, which was made based on the BOM parts list that was gained from Hydrema's research and development department. As stated in Section 5.3.3, the BOM parts list did not contain much quantitative information that was useful for the LCA calculation. Therefore, the BOM parts list was reviewed to find the main materials for the determined modules. Based on this review, rough estimates of weights were either calculated based on the dimensions of steel plates or assessed based on real-life observations of materials and sizes. Therefore, the data used in the LCA of the reference machine is not truthful, but it gives a good estimate of the materials and their weights in relation to creating a mass balance with the total weight of the reference machine. Based on this, it is not possible to tell whether certain materials have been overlooked. A more correct data collection could have been made on the reference machine if more time were available. This could be done by following the production of the reference machine, weighing the different components, and gathering thorough knowledge of the specific materials for the different components. This method, however, would be even more comprehensive, and still have the opportunity of creating biases, and because of the amount of time needed for this data collection, this method was opted out. Therefore, based on the data basis gained and the time available, the estimated data collection was chosen. Furthermore, it is not certain that the results would have differed much from a more comprehensive data collection, because the estimates are based on calculations of the amount of steel, and always made sure that the inputs were fitting with the total weight of the machine. Therefore, based on the time versus outcome, the used method can still give relevant knowledge on the machines, which can be used in Hydrema's environmental management system, where limited resources are available, which will be described further in Chapter 7.

The next thing that will be discussed in relation to data is the background database used, which is the EcoInvent consequential database. The background database affects the results of the LCA, and therefore, it is relevant to discuss. For the LCA, other background data could also have been used, where other approaches could have been made. For example, could the attributional EcoInvent database have been used, which would have created differing results because the attributional approach uses average processes, and therefore models an average supply chain. Here, the consequential approach can be deemed more relevant because it takes the changes in the economy into account when buying the Hydrema machines. Another approach that could have been used was to model the LCA like an input-output LCA rather than a process LCA, like this one is. The input-output LCA could then have used the database EXIOBASE, which is a global input-output database that contains data on sector-specific processes, where the emissions can be seen [EXIOBASE, 2025]. A benefit of having chosen to model the LCA using the EXIOBASE database is that EXIOBASE is an open source database, and therefore Hydrema would be able to access the data and results for free [EXIOBASE, 2025]. The EcoInvent database is not an open source database, and therefore Hydrema would have to pay to use their data [Ecoinvent, 2025]. The EcoInvent consequential database is, however, better for modeling the Hydrema machines more specifically, where the processes in EXIOBASE are more coarse.

6.4.4 Opt-out of DT6

The next thing that will be discussed is the opt-out of Hydrema's electrical machine DT6. The LCA aims at modeling all of Hydrema's machines using a modular setup and individual scaling factors. However, the electrical machine DT6 was not chosen to be included in the model. This was because it was assessed that some of the modules were of a different nature than the reference modules, so scaling factors could not be used in the same way for all of the modules in the DT6 as was the case for the traditional diesel-driven machines. The modules that were assessed as too different were the motormodule and the batterymodule. The reason behind, was that it was not possible for the motormodule to find a scaling factor like the ones used for the other machines, that would be right for the DT6. The analysis of Hydrema's diesel-driven machines versus their electrical machine could, however, have been interesting, because the large emissions from the diesel burned during the use phase would be shifted to most likely smaller emissions from the electricity needed. The tyremodule, hydraulicmodule, cabinmodule, wirenetmodule, functionmodule, and chassismodule for the DT6 would most likely be around the same scaling as for the small 707G-707G power+ dumpers, because they are more or less the same size, which can be seen in Figure 6.20. To model the DT6 machine in this LCA system, it would require a separate motormodule and batterymodule specific for electrical machines, like the backhoes and excavators have gained separate functionmodules. The motormodule and batterymodule of the DT6 machine would probably make the emissions from the production of the DT6 higher compared to the diesel-driven machines, but it will emit less during the use phase [European Environment Agency, 2024]. Therefore, it is assessed that the biggest difference between the modeled diesel-driven machines and the electrical DT6 machine is that the emissions from 1 hour of use would be smaller, especially if the electricity used to power the machine is of renewable nature.

6.4.5 Potential of other emissions

As briefly mentioned in the LCIA end-of-life, in Section 6.3.3, there might be other emissions that have not been modeled in the LCA. One of these can be the risk of leakages in the use phase of the Hydrema machines. This can be both leakages of diesel, hydraulic oil, and motor oil. These substances then have the potential of seeping into the ground or nearby waters, and by this affect the local environment around the leakage. If this leakage is not discovered, the machine can potentially drive around with the leakage, causing a broader area for the impacts. Another bias with the modeling of the use phase is that the maintenance is modeled by using 1,01 machine in the use phase, which can make up for the repairing with spare parts. This way of modeling, however, does not take into account which modules are most likely to need maintenance during the use phase. It is assessed that the wear parts, like the tyres of the machine, will need to be changed more frequently than other parts of the machine will, because they are burdened when the machine is working. The modeling, therefore, takes 1% extra of each material, even though it is more likely that some materials will need more repairing than others.

7 Implementation of LCA at Hydrema

The second analysis of this Master's thesis aims at analyzing the implementation of LCA in the case company Hydrema. This analysis will analyze the regulatory incentives for implementing LCA in environmental management systems and ESG reporting, an auditor's perspective on LCA in environmental management systems, as well as employees at the HSEQ department's perspective on this, with their perceptions. This will lead to a number of benefits and barriers to the implementation of LCA in Hydrema's environmental management system and ESG reporting. For this analysis, three interviews were carried out, which are explained further in Section 5.3.1. These were held with two auditors from Bureau Veritas and two employees at Hydrema's HSEQ department to analyze the perspective of LCA implementation from both sides.

As mentioned in Section 2.2, Hydrema is certified in accordance with the ISO 14001:2015 standard, and has been since 2022, with a recertification in 2025. An important part of an environmental management system is the identification of significant environmental aspects [International Organization for Standardization, 2015a]. This is point 6.1.2 in the standard and specifically states:

> *"The organization shall determine the environmental aspects of its activities, products, and services that it can control and those that it can influence, and their associated environmental impacts, considering a life cycle perspective"* [International Organization for Standardization, 2015a]

This means that when Hydrema assesses which aspects of their activities and products have the potential to significantly impact the environment, they will have to consider the life cycle of their products and other activities. As described in both Section 2.5 and 4.1, LCA is a method for making sure that the life cycle perspective is considered. Hydrema has not yet implemented LCA in its environmental management system; therefore, it assesses its significant environmental aspects based on internal knowledge and what is deemed significant based on legislative requirements. Their environmental aspect thus does not contain quantitative measures on the chosen significant environmental aspects. Furthermore, the environmental aspects only take traditional on-site aspects into account. In Hydrema's last audit of their environmental management system, which was also a recertification, where a participant observation was made, as described in Section 5.3.2, Hydrema got a deviation on their assessment of their significant environmental aspects, with the justification that they do not consider the life cycle of their activities, lack environmental aspects specifically for their products, and quantitative measures.

This could indicate, according to the theory presented in Chapter 4.1, that Hydrema is stuck in an institutional logic that has not followed the recent trends in environmental technologies for environmental management systems. This can be supported by an observation made at the audit, where some employees at Hydrema seemed surprised at this deviation, and a statement from the interview with two employees at Hydrema, where MN stated that they probably have not understood the point about environmental aspects correctly in their system (See Appendix G). Both the interviewed employees at Hydrema also stated that they do not experience customer requirements on environmental parameters yet, and this therefore does not create further incentive for them to do a more thorough analysis of their environmental aspects (See Appendix G). RB states that they often see this trend, of companies not thoroughly knowing what environmental aspects and environmental impacts are, if they have not attended a course about it (See Appendix I). Another statement that could indicate that Hydrema is a more old-school institutional logic is also made by an employee at Hydrema, who stated that for now, they only have focus on smoke, noise, and dirt when working with the environment (See Appendix G). This view of environmental problems is of old origin, and the view of the environmental problems has developed a lot over the past decades [Miljøministeriet, 2012]. In relation to this, the auditor RB stated that she thought a great effect of implementing the life cycle perspective in the ISO 14001 standard was that it forces companies away from the old smoke, noise, and dirt approach (See Appendix I). The auditor, KB, also stated that the requirement set in the standard is non-negotiable, and therefore, the auditors have a large focus on this point in the standard (See Appendix H). KB, however, also stated that the different auditors have different focus areas, because they have different competencies, but because it is a non-negotiable requirement that many companies seem to have difficulties with, they all focus on this point of the standard (See Appendix H). Both KB and RB stated that the life cycle perspective is an integrated part in the courses of becoming an auditor, and that it is always a point on the agendas (See Appendix H and I). An explanation for Hydrema's missing consideration of the life cycle perspective is because they as stated previously, do not see it as a customer requirement as well as they do not see it as a legislative requirement, but because they are certified according to the ISO 14001 standard, there is a clear requirement that they have to consider it according to KB (See Appendix G and H). MN, however, also states that the company has an old-school attitude towards their environmental aspects, and therefore, has not had a focus on the life cycle of their products previously (See Appendix G). In this year's audit, it was the first time Hydrema gained a deviation for missing consideration of the life cycle perspective, which is also an indicator that the auditors have gained a higher focus on this point, specifically in the standard.

This more old-school institutional logic might limit Hydrema in seeing newer technologies in the environmental field, and they, because of this, according to the theory, might have difficulties in seeing how they can utilize more modern technologies strategically in their environmental management system. As mentioned in the theory in Chapter 4.1, LCA can be seen as an emerging institutional logic that can aid a company in determining its environmental aspects, and pinpointing which areas are relevant to set further environmental objectives on. Both MN, ABP, and KB mentioned this opportunity of LCA being used as an identification tool for finding relevant hotspots to improve on (See Appendix G and H). By being stuck in an older institutional logic, Hydrema misses the opportunity of seeing how LCA can be used strategically, to see where initiatives for the environment would be most effective, and to see which indirect impacts would be relevant for them to consider in their environmental management system.

According to the theory described in Chapter 4.1, the knowledge on the effectiveness of implementing an environmental management system is not widespread, and therefore, it can be hard to tell whether an improvement of the environmental performance is caused by the environmental management system, or other organizational changes that affect the environment positively. Again, LCA can be utilized as an identification tool to gain baseline knowledge, which has the potential of being updated over the years, to see the development of the environmental performance over time. An evident problem in Hydrema's environmental management system is its lack of consideration of the life cycle perspective and its products. The most effective incentive for implementing LCA for a company is by it becoming a requirement from their customers or becoming a legal obligation, according to the theory. This is also backed up by a statement from MN, who states that Hydrema, as well as most other companies, are customer-driven, and if new technologies should be adopted, the requirement would have to come from their customer (See Appendix G). In the interview with the two employees from Hydrema, they also stated that a customer requirement for them to focus more on the environment could come from, if the customers became subject to requirements from, for example, authorities (See Appendix G). As mentioned in Chapter 1, there have become tighter requirements on the construction sector, but not yet specifically on the construction machines. Because of these tighter requirements on the construction sector, one might presume that this has the potential to affect the requirements for construction machines eventually. Even though there is no legal obligation for Hydrema to implement LCAs in their environmental management system, it is a technology for identifying relevant environmental parameters, and an implementation of LCA could, according to the theory in Chapter 4.1, help broaden the scope of Hydrema's environmental management system, to take more untraditional and indirect impacts into account. KB also states that the use of an LCA creates more scientific knowledge for the choice of relevant environmental aspects, but adds that for a company to make the largest improvement on their environmental performance, they should focus on fewer environmental aspects at a time, to make the improvements manageable (See Appendix H). In relation to this, RB states that she thinks companies should make a gross list of environmental aspects and, based on the consequences and probability, the companies should prioritize the significant ones to work with (See Appendix I). To this, she adds that in the determination of a company's environmental aspects, it is important to both take local environmental problems as well as global environmental problems occurring in the life cycle and value chain into account (See Appendix I). Both KB and RB state that the leadership and strategies of the companies are important to assess relevant environmental aspects to get some environmental measures completed (See Appendix H and I).

According to the theory in Chapter 4.1, the traditional way of handling an environmental management system is by having the largest focus on the production, and on-site activities in general, and less focus on the development and design of products. A way of implementing LCA at Hydrema to serve multiple purposes was an implementation in Hydrema's research and development department. Here, LCA could aid as an ecodesign tool, which was also described in Section 2.5, and therefore, become an integrated part of the development process of new machines. By integrating LCA in the development process, it would have a larger focus on the life cycle perspective from the start, which potentially can affect the choice of materials and therefore, the choice of suppliers from the purchasing department. According to KB, he distributes the most deviations on the lack of a life cycle perspective on companies' development and purchasing departments (See Appendix H). MN also states the possibility of LCA becoming an integrated part of the development process, if requirements come from their customers, but that at right now they do not have the resources internally to do such an implementation (See Appendix G). MN also could see the benefit in implementing LCA if it could serve as a sales parameter and create a competitive advantage (See Appendix G). If the LCA were incorporated in the development phase of the machines, and a higher focus on ecodesign were made in Hydrema, this could give Hydrema's customers further knowledge on the impacts of the different machines, and help them make more sustainable decisions, as the aim of the ESPR are, as mentioned in Section 2.4. By using LCA to identify environmental aspects in Hydrema's products, this could be used conversely to improve the products, based on as previously mentioned choice of materials or processes. If LCA were to become a part of the development process, Hydrema could benefit from a relational approach to their data collection, as described in the theory in Chapter 4.1. Here, data needed to carry out LCA, for example, materials and weights of components, could be gathered in the BOM parts list, and from this have all data collected in the same place. This then has the potential of making the data intensity of carrying out an LCA more manageable.

As mentioned in the LCA in Chapter 6, the machines produced at Hydrema have high emissions in their use phase. Therefore, they would benefit from implementing the knowledge on their impacts both upstream and downstream in their value chain, because their environmental impacts are not solely from their upstream and production activities. On this basis, ABP stated in the interview that it is the users of the machines who account for their products' impact in the use phase, but that they see it as the user of the machines' burden (See Appendix G). This could indicate that they are not aware that these emissions are a part of Hydrema's scope 3 emissions. As stated in Section 2.3, scope 3 includes all emissions happening in the upstream or downstream value chain, divided into 15 categories. By the LCA showing large emissions from the fuel used during the use phase, it will fit into the scope 3 category 'use of sold products', and therefore, it is an indirect emission from Hydrema happening in their downstream value chain. This knowledge, gained from the LCA, can then also aid Hydrema in their ESG reporting, by having quantitative measures of their scope 3 categories, and from this, be able to identify which scope 3 categories are the most significant for them to report on. In accordance with the calculation of scope 3 emissions, ABP also sees potential in LCA becoming a valuable tool for Hydrema (See Appendix G).

Even though an implementation of LCA seems to have many benefits, such as aiding Hydrema to develop a method for determining their environmental aspects, which can be used in the design stage, and determining their scope 3 emissions, there can, however, also be certain barriers to an implementation. KB states that he often has experiences with LCAs being too quantitative, and therefore, they are missing some qualitative elements that will help with the change management of an environmental management system (See Appendix H). He also states that it is often used just to identify where the hotspots are, which he also points out that it is an excellent tool for, but afterwards the companies just carry on their work as before, which leads to no changes, and therefore no improvements being made (See Appendix H). He then adds that the hotspots that are identified through an LCA should then be risk assessed thoroughly, and then the company should choose fewer aspects to focus on improving, to make the most improvements (See Appendix H). To this, he adds that an LCA can not stand alone as a method for creating environmental improvements, and that it might be too comprehensive and difficult for some companies (See Appendix H). Another challenge to LCA, KB addresses, is that one should be cautious of comparing LCA results (See Appendix H). This can be explained by the different LCA methods and approaches delivering different results, as described in Section 5.2. RB states in relation to this that LCA is not a requirement in the ISO 14001 standard, but that she thinks that the assessment can create a better basis for decision making (See Appendix I).

Discussion 8

In this chapter, the discussion of this Master's thesis will take place. Different aspects of the thesis will be discussed. Firstly, the usability of LCA for Hydrema will be discussed, and which aspects of their work it will benefit from. And secondly, it will be discussed whether or not LCA can aid Hydrema when assessing significance for their environmental management system and ESG reporting.

8.1 Usability of LCA for Hydrema

In this section, the usability of the LCA system made in Chapter 6, for Hydrema, will be discussed. This means that how Hydrema can use the LCA system, and what opportunities and limitations it will create, will be discussed. The discussion will be based on the simplified LCA model made in Chapter 6, and how Hydrema can use this, taking into account the results gained from the implementation analysis in Chapter 7. The LCA model is made like a simplified LCA, where it is based on a more thorough analysis of one of Hydrema's machines, which is divided into modules. These modules are made to be fitting to all of Hydrema's three machine types. Afterwards, these modules are scaled to fit the mass balance of Hydrema's other machines, using scaling factors individual for each module (See Figure 6.21 and 6.22). This then gives an idea of the emissions coming from all of Hydrema's machines, and minimizes the comprehensive data collection that would have been needed to conduct thorough LCAs for all 19 machines that Hydrema produces. The LCA, therefore, becomes less resource-intensive by conducting it using this simplified method, rather than a comprehensive and specific LCA for all machines individually.

As mentioned in the analysis in Chapter 7, the LCA can be used as an identification tool for Hydrema when assessing where their large impacts originate from. Therefore, Hydrema would be able to use the results from the simplified LCA in Chapter 6, when identifying which environmental aspects make sense for them to go more into depth with in their environmental management system. As mentioned in Section 2.5, LCA can aid with adding the life cycle perspective to the determination of a company's environmental aspects. Even though a full LCA is not required when considering the life cycle perspective of a company's environmental aspects, the simplified LCA gives an overview of which aspects could potentially be assessed as significant for Hydrema, without being as resource-intensive as a full LCA of all machines. This would be important for the practical implementation of LCA at Hydrema, because they state that they do not have the resources internally to conduct full LCAs as of right now (See Appendix G). Therefore, to implement LCA as an integrated part of Hydrema's environmental management system, it is deemed necessary for it to be of a simplified nature. Another obstacle to the implementation of LCA at Hydrema is whether or not the employees are able to understand and actively use the results from the LCA model. This is due to Hydrema not having any employees with an environmental educational background, and therefore, LCA, as well as the life cycle perspective, is a new discipline for them (See Appendix G). Therefore, this simplified LCA model with a few chosen impact categories might be the way forward for implementing LCA at Hydrema. On the contrary, as mentioned in Chapter 7, it seems like Hydrema is stuck in an older-school institutional logic, where it seems like they do not see the benefit of implementing LCA as of right now. This is despite the employees from Hydrema stating that they have not fully understood point 6.1.2 in the ISO 14001 standard, but because they do not experience requirements from their customer on behalf of environmental performance, yet, they do not see the point in implementing LCA right now (See Appendix G).

Another place where the LCA could be useful in Hydrema was in their research and development department, where it can be utilized as an ecodesign tool. As mentioned in Section 2.5, ecodesign aims at minimizing the environmental impacts of products in their life cycle, where LCA can aid as a tool for assessing the development of impacts of said products. Ecodesign can then become an integrated part of Hydrema's environmental management system, and from this, LCA can play a role in the environmental management system as well, which was also mentioned in Section 2.5. This implementation would thus also need employees in the research and development department capable of understanding, using, and updating the LCA when making alterations to their products from an ecodesign perspective. An implementation of LCA in the research and development department could result in LCA becoming an integrated part of the development process of developing new machines, and from this, a relational approach to the data collection could make the basis of data easier when conducting the LCAs, as mentioned in Chapter 7.

As stated in this section, LCA can aid both the HSEQ department with their environmental management system and the determination of environmental aspects, and it can aid in the research and development department as an ecodesign tool. A third aspect that the LCA could help Hydrema with is in relation to its ESG reporting. Even though the requirements for Hydrema's ESG reporting have been postponed, they have chosen to carry on the work that they had already started. An aspect wherein the LCA model could aid the ESG work is the determination of significant scope 3 categories for Hydrema. The LCA model looks into the value chain of their products, and is therefore able to pinpoint which scope 3 categories might be of most relevance for Hydrema. Based on the LCA made in Chapter 6, two scope 3 categories that could be deemed relevant are: 'Purchased goods and services', and 'use of sold products'. The 'purchased goods and services' category is deemed relevant because some of the materials are large contributors to the impacts of producing the machines, for example, the steel that goes into the machine. As mentioned in Section 6.3, the largest contributor to the production of the machines was the processes needed to produce the steel needed to produce the machines, and therefore, this scope 3 category can be deemed relevant. The 'use of sold products' category is deemed relevant because the diesel burned during the use phase, both when working and idling, of the machine, is a large contributor to the total impacts of the machine. As seen in Figure 6.46, the diesel accounted for 94% of the total impacts of 15000 working hours, and therefore, this scope 3 category can be deemed relevant. Again, to be able to utilize the LCA for this purpose, the employees at Hydrema would need some training to be able to understand and use the results. Another challenge in relation to this is that for this purpose to be relevant, the employees will need to update the system year after year, to be able to track the performance, and therefore, Hydrema would need further knowledge on LCA. As stated in Appendix G, Hydrema does not have the resources internally, as of right now, to conduct this work, and therefore, the system will not be able to be updated in the coming years, if the employees do not receive training.

An important thing to remember for Hydrema, if they were to use the LCA results, is to be careful with comparing their results with other companies' LCA results. This is due to different methods and approaches giving differing results. Therefore, it is important for Hydrema to be aware of how other companies' LCAs have been conducted, because the different approaches are not comparable, as they answer two different questions, as described in Section 5.2. Therefore, the LCA system is better to use internally to identify optimization areas than to compare Hydrema's products with other competing products.

In the following section, the possibility of the LCA model aiding the determination of the significance of Hydrema will be discussed in more depth.

8.2 Possibility of LCA aiding in assessment of significance

In this section, the possibility of the LCA model, made in Chapter 6, aiding Hydrema's assessment of significance, both in relation to their environmental aspects in their environmental management system, and their scope 3 categories for their ESG reporting will be discussed.

As mentioned in Section 8.1 about the usability of the LCA model for Hydrema, it was described that the LCA system can help Hydrema pinpoint where in their product value chain hotspots can be detected. These impacts can then be used as an active part of Hydrema's assessment of significance. When assessing which environmental aspects are significant, Hydrema has only looked into local environmental aspects and assessed significance based on legislative requirements and other focus points. They therefore have assessed significance based on criteria, like the ones presented in Section 2.5.1, which mostly take local problems into account. As mentioned in Chapter 7, the LCA system can help Hydrema with broadening their scope of their environmental management system, and by this, take more global environmental aspects into account in their assessment of significant environmental aspects. The LCA system, therefore, makes it clear to Hydrema how their products are emitting to the environment, and which parts of the product value chain might be most relevant for them to work further with.

A way of implementing the LCA results in the assessment of whether or not environmental aspects can be deemed significant is by choosing limit values, wherein if the emissions exceed this limit, it will create an incentive for assessing the environmental aspect as significant. KB stated in the interview that he thought the most effective way of handling a company's environmental aspects was to choose a few aspects to work with, and then set objectives on these specifically to improve on them (See Appendix H). He then adds that the company working with their environmental aspects should make a prioritization list, which should also be a part of the determination of significance (See Appendix H). In relation to this, RB states that the company should consider both local and global environmental aspects in determining their significant environmental aspects, to make sure that everything is considered (See Appendix I).

A challenge of using LCA for determining significant environmental aspects is that, according to KB, it can not stand alone in the assessment (See Appendix H). This is due to the LCA not taking changes into account traditionally, and therefore is not useful alone for change management in a company's environmental management system (See Appendix H). Therefore, LCA can be utilized as an identification tool, and the results as a part of the significance determination, but it can not stand alone, and therefore, other tools will need to be taken into account when assessing significance. This is, for example, more qualitative assessments, to, for example, determine more local environmental aspects, as well as risk assessments, to see which environmental aspects constitute the largest risks for the company. LCA can thus help with quantifying more global environmental aspects considering a life cycle perspective, which is what Hydrema got a deviation on during their last audit, and therefore, Hydrema could benefit from this more quantitative approach, as part of their significance determination.

Another place where LCA could aid in the determination of significance is, as previously mentioned, in their ESG reporting. The significance part of a company's ESG reporting is related to which impacts, risks, and opportunities are significant for the company, because this is what is necessary for them to report on, as further described in Section 2.3. Here, the LCA can help highlight the largest impacts of Hydrema's machines' value chains, which can come into play when deciding which impacts are significant. Another part of the ESG reporting, where LCA can become a helpful tool for Hydrema, is when they are facing the requirement of reporting their significant scope 3 categories. As stated in Section 2.3, this requirement is postponed so therefore, it is not necessary as of right now, but for the future, it might be relevant. The assessment of the significant scope 3 categories can be aided from the LCA, because it shows emissions from different parts of the value chain, and from this, it is possible to detect, wherein the value chain the largest contributors are, which can be divided into the scope 3 categories, as listed in Section 2.3.

Therefore, the LCA system can give a more quantitative basis for the different aspects of significance determination at Hydrema; however, as stated in Section 8.1, the users of the LCA system would have to understand and actively use the results for the LCA system to actually benefit the significance determination. If the LCA system is not understood, it will likely just become more paperwork, which does not improve Hydrema's environmental performance, which KB also pointed out (See Appendix H).

Conclusion 9

This project is based on an internship and a project made in the 9th semester of the Master's degree, and aims at researching LCA and how the company Hydrema can utilize it as an integrated part of their environmental work. This Master's thesis hence aims at answering the following research question:

> *"How can LCA aid Hydrema with assessing significance in their environmental management system and ESG reporting?"*

With related sub-questions:

> *"How does Hydrema perceive LCA, and how can this understanding inform its practical implementation within the company?"*

> *"What are the benefits and barriers of implementing the LCA system in Hydrema?"*

To answer this research question and related sub-questions, an LCA of all of Hydrema's machines was made. This LCA was based on an analysis of one of Hydrema's machines, which is divided into modules, which are then scaled to fit Hydrema's other machines, and by this, all of the machines are a part of the LCA model. This LCA model was then used to see where in the machines' life cycle hotspots could be detected. This was deemed relevant because Hydrema got a deviation of missing consideration of the life cycle perspective and product orientation during their last audit, as described in Section 2.2. LCA was chosen because it was identified in Section 2.5 that LCA could aid in determining environmental aspects in a life cycle perspective for companies. From the LCA in Chapter 6, it can be concluded that the two largest impact categories, from both the production, the use phase, and the end-of-life phase, were 'global warming' and 'respiratory inorganics'. In the production of the machines, the largest contributors were the modules with a large content of steel, aluminum, and rubber, which can be explained by the processes needed to produce steel, aluminum, and rubber, being large contributors to the total emissions from producing the machines. However, looking at the results of the functional unit, it is clear that the largest contributor to 1 hr use of the machines comes from the diesel burned, both during the working and idling part of the 1 hr use.

It can be concluded, based on the analysis in Chapter 7, and discussion in Chapter 8, that Hydrema does not have the resources internally, as of right now, to be able to conduct the LCAs, but that they see opportunities, in that it can act as an identification tool for assessing their environmental aspects for their environmental management system and calculating scope 3 emissions for their ESG reporting. Because of this, it can be concluded that Hydrema is stuck in an older-school institutional logic, which makes it difficult to implement more proactive tools. It was detected that LCA can aid Hydrema and make sure that they take global life cycle environmental aspects into account, but that LCA will not be able to stand alone in the detection of environmental aspects, because it does not take local environmental aspects into account. It can thus be concluded that for Hydrema to be able to use the LCA results, their employees would need training in this regard.

It can therefore be concluded that LCA could aid as an integrated part of the determination of significance for Hydrema, by highlighting where the large emissions occur in their products' value chains, and that this, together with some qualitative assessments, could create a more knowledge based determination of significance at Hydrema, if the employees utilizing the LCA understands the results fully.

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Literature review A

The Excel spreadsheet used for the literature review is attached as an external appendix.

Life cycle inventory B

The Excel spreadsheet used to calculate the LCI variables is attached as an external appendix.

C CSV

The Excel spreadsheet used for import in SimaPro is attached as an external appendix, with a guide for import into SimaPro.

D IoT data

The Excel spreadsheet used to calculate the operation data based on IoT data is attached as an external appendix.

E Life cycle impact assessment

The Excel spreadsheet used to calculate LCIA results is attached as an external appendix.

Process contribution F

The Excel spreadsheet containing the process contributions from SimaPro is attached as an external appendix.

Interview with Hydrema employees G

Participants: Morten Nielsen (MN), Anders Bo Poulsen (ABP), and Tanja Kristensen (TK)

TK: Hej og velkommen til det her interview, som skal bruges til min analyse omkring implementering af LCA i miljøledelse, og hvilke fordele og ulemper det har. Så først vil jeg spørge jer om i vil fortælle lidt om jer selv, og jeres baggrund

ABP: Jeg kan godt starte, jeg hedder Anders og er HSEQ koordinator, og ved Hydrema sidder jeg med vores certificeringer indenfor miljø og arbejdsmiljø, 14001 og 45001. Jeg har en bred baggrund bag mig, fra forsvaret, transportbranchen, sundhedsvæsenet, og er nu havnet her hos Hydrema som HSE. Inden jeg kom her sad jeg i PTA i en mindre virksomhed, hvor jeg også havde en del med arbejdsmiljøet at gøre, men miljø er først kommet til ved Hydrema.

MN: Jeg hedder Morten, jeg er HSEQ manager her på Hydrema, og min baggrund er at jeg har en håndværksmæssig baggrund som finmekaniker, meget langt tilbage, og derefter har jeg en uddannelse som maskinkonstruktør, og har aldrig arbejdet med noget der minder om konstruktion. Jeg har arbejdet i mange år som produktionsansvarlig, på forskellige niveauer, fra værkfører, afdelingsleder, site manager, produktionsdirektør. Jeg har været projektleder for store kundeprojekter, og så på mine senere år er jeg begyndt at arbejde med systemer, begyndt at arbejde med kultur i virksomhederne. Noget som jeg aldrig troede jeg skulle for 30 år siden, men ting ændre sig og man finder lige pludselig ud af at der er nogle ting man kan gå ind og påvirke, og der er nogle mekanismer i virksomhederne der gør at systemerne er meget vigtige, i forhold til performance.

TK: Nu har i jo den her 14001 standard, som er den jeg kommer til at dykke ned i, så mit første spørgsmål går på hvordan forstår i den del af standarden der snakker om de her miljøforhold, altså hvordan forstår i den?

MN: Jamen det har vi jo nok heller ikke rigtig forstået helt ordentligt, for den har ikke været helt rigtig implementeret her. Den har også ændret sig meget under de sidste opdateringer. Jeg vil sige, det er ved at være nogle år siden jeg har arbejdet med 14001 sidst, og der var den meget baseret på miljødelen, hvor i dag bliver den også lidt bredere vil jeg sige, og det tror jeg det er kommet lidt bag på os. Men det giver rigtig god mening hvis man ser på vores omgivelser, og vores globale udfordringer, så skal vi selvfølgelig også gå ind og tage vores del af ansvaret.

ABP: Det er jo selvfølgelig, det der ligger i den det er jo at vi skal kunne påvise hvor vi påvirker miljøet mest og hvad sandsynligheden er for at vi påvirker, det er de to parametre der er alfa omega i den.

TK: Hvis vi nu går lidt videre på den, for til jeres audit fik i jo en afvigelse på lige præcis det her punkt, i forhold til mangel af det her livscyklusperspektiv, hvordan ser i den afvigelse, hvad er jeres syn på den?

ABP: Sådan lidt lala, det er jo selvfølgelig en alvorlig afvigelse, eller den var bare minor, men vi har jo fået flere afvigelser på netop det punkt 6.1.2 i standarden før. Men lige livscyklusperspektivet er jo ikke noget vi har arbejdet med, og det har ikke været kundekrav, og det er ikke et lovgivningskrav endnu, og derfor er det sådan lidt.

MN: Ja og det rigtig som Anders siger at det ikke er et kundekrav, og vi er jo kundedrevet. For at det er noget der skal gå igennem hele vores virksomhed, så er det noget der skal komme fra vores kunder, fordi hvis vi i HSEQ mener at det her det er vigtigt, så kører vi i utakt i forhold til resten af virksomheden, fordi virksomheden er så kundedrevet som den er, og det er generelt alle virksomheder. Der er de helt store virksomheder hvor de har en stor afdeling til at sidde og håndtere alt det her, og det er jo fordi de måler på alt mulig andet end vi andre vi gør. Vi ser jo egentlig bare meget basic på om vi har til dagen og vejen i morgen.

TK: Så lidt i flæng af det her, hvordan forstår i så begrebet miljøpåvirkninger?

ABP: Direkte forurenings ricisi, det er sådan det ligger i mine øre.

MN: Ja, og jeg ved godt set i forhold til standarder og så videre så er det måske lidt gammeldags, jamen hvor meget udleder vi her og kan vi gøre noget for at udlede mindre, men jeg ved udemærket godt at vi også har nogle produkter der også udleder et eller andet. Vi har dog ikke direkte fokus på det, indirekte har vi fordi vi bruger store leverandører indenfor branchen. Nu er vi en lille spiller i det her, så vi bruger de store leverandører, og de store leverandører de har fokus på det her, og derigennem har vi de bedste motorer der har den bedste performance der findes på markedet. Så derigennem gør vi noget, men det er ikke noget vi går ud og flager med desværre. Og det har vi også fået afvide så mange gange, at vi greenwasher i hvert fald ikke.

ABP: Altså når vi udvikler maskinerne så er det jo med fokus på at kunde får den bedst mulige maskine for pengene, og det er både indenfor arbejdsmiljø og drifstomkostninger. Det har jo også en afsmitning på den miljømæssige påvirkning, men det er ikke det der er hovedfokuset.

MN: Og igen fordi det ikke er efterspurgt, var det nu efterspurgt, så ville det helt sikkert blive en mere integreret del af udviklingsprocessen.

TK: Nu går vi lidt tilbage til livscyklusperspektivet, hvad er jeres perspektiv på at det ligesom er en del af den her standard?

ABP: På en eller anden måde giver det jo god mening at man kigger på hvordan vi påvirker miljøet i hele vores produkters levetid fra vugge til grav. Man kan jo gå ind og arbejde med hvad for noget stål man køber, skal det være genanvendt stål. Nu begynder de jo i Sverige at producere fossilfrit produceret stål, så der kan man jo gå ind og påvirke miljøet mindre på den måde. Men jeg tænker ikke at vi ser længere frem, vi producere nogle maskiner som er forholdsvis miljørigtige, uden at komme til at greenwashe det alt for meget, de har selvfølgelig en påvirkning, men det er jo egentlig brugeren af maskinen der står for udledningen, det er sådan min holdning til det.

MN: Man må også sige at hvis vi går ind og kigger på vores maskiner, så har de en forholdsvist lang levetid, det er ikke køb og smid væk. Og igen, vores kunder er jeg 100 på vil ikke betale for at de får grøn stål, det nægter jeg at tro på. Der er vi overhovedet ikke endnu indenfor den her branche. Det vores kunder fokusere på det er driftomkostninger, det er at de får noget udstyr der holder og at de kan holde en forholdsvist lav driftomkostning på det, alt andet har på nuværende tidspunkt ikke noget interesse for dem. Og igen så smitter det selvfølgelig også af på os som virksomhed. Men vi har jo haft en studerende der har stillet nogle rigtig gode spørgsmål som vi har inkorporeret i vores væsentlighedsanalyse. Så vi har nogle af de her ting med så vi stiller os selv, men det er på det niveau vi er på for nuværende.

TK: Mit hovedfokus er jo LCA, efterhånden har jeg vel forklaret hvad det går ud på, så jeg vil gerne høre hvad jeres perspektiv er på at implementere LCA i Hydremas miljøledelse?

MN: Perspektivet er vel at vi bliver tvunget til det. Kunne vi blive fri så ville vi jo nok gerne det et eller andet sted, men det kommer på et tidspunkt, men før vi får vreden armen om på ryggen så tror jeg ikke vi har fokus på det. For igen hvor mange ressourcer vil vi sætte af til det, vi har ingen ressourcer inhouse nu til at håndtere det, og går jeg ind og spørger om jeg kan få en ressoruce til det her, så kender jeg godt svaret.

ABP: Det er en omkostning vi på ingen måder får dækket nogle steder.

TK: Lidt i flæng, hvilke fordele kunne i så se ved at implementere det?

MN: Jamen jeg kunne se fordelen i at vi nok vi ville være foran vores konkurrenter på det område her. Og igen kunne vi gøre det til et salgsparameter, så ville det stå stærkt. Men jeg tror bare ikke på at vi kan gå ud med det her som et salgsparameter, ikke på nuværende i hver fald. Måske om tre år, who knows.

TK: Tænker i sådan i jeres miljøldelsessystem, hvilken værdi tror i det kan skabe der?

ABP: Jamen det ville vel give mulighed for at man kunne kigge på nogle udlednigner i forbindelse med greenhouse gas protokollen (GHG), vi skal til at lave noget CO2 regnskab, men det er jo når vi snakker scope 3, og det er også flere år ud i tiden. For scope 1 og 2 der kan vi ikke bruge det til så meget.

TK: Også lidt i flæng, tror i at LCA kan skabe værdi for jer som virksomhed når i skal ind og afdække jeres miljøforhold?

ABP: Ja når vi ser det i produktets levetid fra vugge til grav så kan det jo, hvor vi kan pinpointe nogle steder hvor der er større udledninger, men som det er nu så er det røg, støj og møg, det er det vi har fokus på.

MN: Også stadigvæk kun i forhold til hvis det kan skabe noget værdi for vores kunder. Kan det skabe værdi for vores kunder, så kan det også skabe værdi for Hydrema. Jeg må bare sige hvis ikke det skaber værdi for vores kunder så skaber det i bund og grund heller ikke nogen værdi for Hydrema. Det er sådan lidt en gammeldags holdning til tingene, men det er jo det der driver virksomheden, og det skal vi jo huske på. Og igen har vi ikke en strategi hvor vi siger at vi er proaktive på det område her. Havde vi nu det og vi ville gå ud og flashe det så kunne vi gå ud og skabe en anden profil, men jeg tror igen ikke vores kunder ville betale for det for nuværende. Det er igen kun hvis vores kunder bliver pålagt et eller andet, en afgift eller et eller andet krav fra myndighedernes side, jamen så vil det skabe værdi.

TK: Så du mener ikke det kan skabe værdi internt?

MN: Jeg har svært ved at se det for nuværende i hvert fald.

ABP: Altså det ville kunne pinpointe nogle steder hvor vi har nogle udfordringer internt med nogle udledninger hvor vi kan se hvor vi har de store hurdles henne. Så for at kortlægge vores miljøpåvirkning der ville man godt kunne bruge det, men igen, skabe værdi, det kommer også an på hvad man ligger i ordet værdi.

MN: Men omvendt så har vi jo også rigtig meget i forhold til vores eksterne miljø, det er jo ikke sådan at vi bare lukker op for sluserne og så lukker alverdens ting og sager ud, vi har rimelig styr på det, det er ikke noget der kan få mig til at ligge vågen. Jeg synes vi opfører os ordenligt, men det kan altid blive bedre, det er helt sikkert. Men skal vi gøre mere så skal det være kundedrevet.

TK: Hvilke ulemper kunne i så se ved at LCA skulle være en del af jeres miljøledelse?

MN: Jeg tror såmænd ikke der er nogle ulemper ved det, det kræver ressourcer, men det er jo ikke en ulempe. Vi kunne blive klogere på mange områder også, det kunne helt sikkert skabe værdi internt, også i forhold til det arbejde vi laver. Men igen kommer vi i karambolage med at det ikke rigtig giver noget kundeværdi på nuværende tidspunkt. Men vi kunne blive dygtigere internt, det er helt sikkert, og få mere viden.

ABP: Jeg tænker også kun administrativ udgift, bureaukrati.

TK: Tror i det kunne gavne, sådan i forhold til audit, hvis man kom og sagde til audit, vi har implementeret det her, for at kunne afdække det her og for at kunne lave nogle mål ud fra noget kvantificerbart?

MN: Det tror jeg godt det kunne, det kommer også lidt an på hvilket fokus auditor har, hvis auditor er en med en miljøbaggrund, så helt sikkert at det kunne. Det sjove ved auditorer er jo at de også har deres key områder. Men hvis det var en der var meget miljøorienteret, så kunne det helt sikkert skabe noget værdi der.

TK: Har i erfaringer med at det svinger meget i forhold til hvilken auditor der kommer?

MN: Ja det gør det. De har deres, man kan ikke sige fokusområder, for de har jo fokus på det hele, men der er områder de er skarpere på end andre.

TK: Nu har jeg jo læst jeres auditrapporter igennem også fra førhen, og jeg synes det her punkt står meget ud hver gang, om det er normalt eller om det er auditorspecifikt

ABP: Det er simpelthen vores process for lige det her væsentlige miljøforhold har været for svag, og vi har ikke forståelse for punktet. Det er ikke fordi vi ikke gør noget, for vi ved godt, hvor skoen trykker, vi har bare ikke været gode nok til at beskrive og dokumentere og fortælle hvordan vi har fundet ud af det, det er bare noget vi ved. Og det er ikke helt godt nok når vi snakker et styret system.

TK: Hvis i nu skal beskrive hvordan i har fundet ud af hvor skoen den trykker, hvordan ville i så beskrive det?

MN: Det har vi jo nok vidst hele tiden, fordi det omkring væsentlighedsvurderingen, det har været sådan en gråzone vil jeg sige, der er lagt noget ind, og så er der egentlig ikke lagt noget ind alligevel. Det har været sådan lidt en sludder for en sladder vil jeg sige. Jeg synes at det vi har stillet op i dag gør er vi er blevet mere specifikke, og vi har lært meget her de sidste måneder i forhold til at lave væsentlighedsvurderingen, også at komme bredere ud. Den del vi har mindst af er sådan set kvalitet, vi har rigtig meget arbejdsmiljø, og vi har også en del miljø på nu, så det synes jeg egentlig gør at vi bliver stærkere, og det gør også at vi bliver tvunget til at gå ind og tage stilling til nogle ting, det har vi ikke gjort førhen. Det har været noget ligegyldigt venstrehåndsarbejde.

TK: Hvordan vil i så sige i vurdere hvad der er væsentligt for jer?

MN: Vi har fået hjælp udefra med andre øjne for at kigge ind på os selv som virksomhed, det gør jo også at det ikke bliver så meget ananas i egen juice, men egentlig at vi bliver udfordret på nogle parametre vi nok ikke havde med før. For et eller andet sted skal vi nok også blive bedre til at bruge lidt ekstern hjælp frem for at køre meget internt, for vi bliver lidt farvede, og det påvirker den måde vi ligesom arbejder på. Kan vi blive udfordret udefra så er jeg også sikker på vi kommer længere rundt, og får stillet nogle spørgsmål som vi måske ikke har fået stillet før, det var du jo selv en del af kan man sige, så det var jo super fedt.

TK: Så har jeg ikke flere spørgsmål, tak for jeres tid

Interview with Klaus Berhndt H

Participants: Klaus Berhndt (KB) and Tanja Kristensen (TK)

TK: Jeg vil lige starte med at formålet med det her interview er at få indblik i hvad en auditors perspektiv er på implementering af LCA i miljøledelse, samt fordele og ulemper

KB: Er det livscyklusanalyser i miljøledelse?

TK: Ja men også generelt hvordan det her livscyklusperspektiv bliver håndteret. Mit første spørgsmål går på om du vil fortælle lidt om dig selv og din baggrund?

KB: Jeg hedder Klaus Behrndt, og har været auditor siden 1996, og har også sammen med Aalborg og DTU lavet noget omkring miljøledelse i nogle af deres projekter i Thailand. Jeg var ansat på det tidspunkt som policy advisor for deres miljøtilsyn der, hvor vi lavede nogle ting, og hvor vi talte sammen om hvordan vi skulle bruge miljøledelse i nogle af de projekter som DTU og AAU havde der. Der mener jeg også Søren var med, men der var også andre. Og så kender jeg jo stort set dem der arbejder med nogle af de her ting både på aalborg og københavn. Jeg har været med i gamet, også i dansk standard hvor vi også er de samme folk stort set indenfor miljøledelse. Jeg har også været med til at lave ISO 14001 standarden på internationalt plan, først i baggrunden i dansk standard men også været med internationalt. Jeg kan vel sige jeg er en af dem der har en meget stærk holdning til hvordan ISO 14001 kan bruges og skal håndteres.

TK: Vil du uddybe det, hvad du tænker med det?

KB: Altså jeg mener at jeg har holdninger om der hvor jeg føler at den godt kunne blive stærkere, og der hvor jeg føler at brugen af den i dag ikke yder alle krav.

TK: Mit fokus handler meget om det her livscyklusperspektiv og det er nok det jeg har kigget mest ind i, hvad er dit perspektiv på at livscyklusperspektivet er en integreret del af ISO 14001 standarden? Hvad synes du om det?

KB: Jamen det er det, det er der ikke nogen diskutioner om, det er en del, og det var en del af ideen da vi lavede det. Der var dengang vi sad i den internationale gruppe, der var der en hel undergruppe om hvordan man skal håndtere livscyklusperspektivet, og det er helt klart at hele den metodik var at det skulle have meget større fremtrædende plads end det havde haft hidtil. Det er der overhovedet ikke nogen diskussion om at det har været hensigten. Om det så bliver gjort det er jo så noget helt andet. Hensigten med det og kravelementerne er bygget op til at livscyklusperspektivet er meget mere fremme end det har været før. Jeg vil også godt sige at der hvor jeg giver flest afvigelser i dag er på henholdsvist udvikling eller indkøb.

TK: Hvordan bliver det her livscyklusperspektiv generelt håndteret?

KB: Det jo meget svært at sige generelt, Jeg har jo været den der har, nu har jeg lige trådt tilbage og en ny har trådt ind, men jeg har været enormt meget fortaler for at lige præcis livscyklusperspektivet skal bankes mere op end det har været, og det har jo også noget at gøre med hvad det er for nogle virksomheder. Det er jo ikke nødvendigvis i alle virksomheder hvor det er det mest afgørende, men der vil være mange hvor det man gør i indkøb og udvikling er det der har betydning, og ikke indenfor selve produktionen.

TK: Har i som auditør særligt fokus på det her livscyklusperspektiv når i auditere en virksomheds miljøforhold?

KB: Ja, vi har jo haft sådan nogle lister hvor vi har prøvet at sige hvad det er for nogle ting vi skal have fokus på, der har vi blandt andet haft nogle oplæg, blandt andet af Arne Remmen, om både det der med at gå udover virksomheden, og se på den i sin, nu kalder du det livscyklus, men måske nærmere i hele sin værdikæde, og se på hvad der egentlig miljømæssigt kunne give størst mulig værdi af det her. Så det har vi meget kørt op, vi har nogle tjeklister på det, vi har en masse interne træningsdokumenter hvor vi arbejder med det perspektiv, så det har vi gjort. Jeg tror også at vi er nok dem der primært arbejder bedst med at prøve at få de her ting kørt ind. Jeg har i hvert fald siddet meget markant både i dansk standard, og jeg har været med til at sige at de her ting var vigtige, og det er også mig der har kørt alt træningen for miljøauditorerne her i Bureau Veritas, jeg har i hvert fald forsøgt at få det pisket op til at det her det er bare monster vigtigt for at få det her kørt ind. Men jeg vil godt sige at hos os er det måske ligeså vigtigt med de her ledelsesbeslutninger, og hvordan de ser det. Jeg tror vi ligeså meget har haft oplevelsen af at det er vigtigt miljø skal være som en del af strategisk ledelse, at miljø ikke bare bliver en del af et eller andet omkring produktionen, men miljø bliver en del af den strategiske ledelse. Så derfor har hele kravelementerne i 4, altså rammer og vilkår, har det været enormt vigtigt for os at få kørt op og arbejde med at ledelsen går ind i det, så man ligesom kommer skridtet højere op, at ledelsen bliver opmærksom på det her, så det ikke er en miljøkoordinator vi sidder med alene på det område. Men hvis man skal det så er der nogle ting i hele værdikæden som virksomhedslederne typisk kan se giver god mening for dem, eller ligeså meget overfor kunderne, ikke kun opstrøms men også nedstrøms altså overfor kunderne, kan det være enormt vigtigt at ligge vægt på de her ting, og komme ud med de udtalelser om hvad det er der skal ske og hvordan fungere det i praksis, hvordan er det værdikæden er når det kommer ud på markedet.

TK: Når i så kommer ud til de her virksomheder, hvordan beskriver i så som auditør hvordan de her virksomheder skal håndtere det her punkt i standarden, med at de skal afdække deres væsentlige miljøforhold i et livscyklusperspektiv?

KB: Ja det er jo en del af det. Vi er jo alligevel over 30 miljøfolk, og vi er jo lidt forskellige. Nogle er stærkere på det og andre er ikke så stærke på det, men generelt er det et fuldstændigt klokkeklart krav, og i hvert fald har jeg da set rigtig mange afvigelser på at væsentlige miljøforhold i værdikæden ikke er identificeret i tilstrækkeligt omfang, det har i hvert fald været en hel del afvigelser vi har haft på det.

TK: Så det kan godt være svært at få virksomheder til at arbejde med det?

KB: Ja, det er et skifte for mange af virksomhederne, og kunne se at det der er ligeså vigtigt som det der er internt. Nu har vi jo en del af de helt store virksomheder og de kan godt se at sådan er det jo, men derfra og så gøre det operationelt, der synes jeg der er lidt forskel, og jeg tror ikke bare det er at sige at der bare skal være væsentlige miljøforhold i miljøkæden, og så sender de et kæmpe langt spørgeskema ud, men det er nogle helt andre ting der skal til for at det giver mening.

TK: Hvordan vil du så sige at den mest optimale metode er til at afdække virksomhedens miljøforhold?

KB: Det vi typisk ser, det er at man afdækker, når man laver sine væsentlige miljøforhold identifikation i 6.1.2 der, så vil de også sige, så bliver det sådan nogle lidt overordnede ting, som ikke er tilstrækkeligt definerede. Det kunne for eksempel være energi, affald, eller kemiske stoffer eller sådan noget lignene, uden og have præciseret det i tilstrækkeligt omfang til at man kan operationalisere det. Det betyder så at man bliver på det der plan, og når man så kommer til indkøb, så bliver det sådan noget at typisk så indkøbsfolkene de sender en skrivelse ud hvor de siger at de gerne vil se at man overholder ROHS og WEEE direktivet, det er sådan nogle lovkrav, og ikke mere. Og det er her hvor jeg oplever at der kunne standarden efter min mening, og jeg er også fortaler for at man gjorde noget mere ved det punkt. Nu har jeg jo været i en revision, typisk bliver nummer to revision bare sådan en form for at man ligesom gør den mere præcis, og jeg har ikke været med i det arbejde der har været nu, men jeg var med i 2015 udgaven. Men det jeg vil sige omkring det det er at for mig at se så bør man kunne, når man snakker om væsentlige miljøforhold, så er folk jo rimelig gode til at udpege dem indenfor deres egne grænser, det er ikke det store problem. Men når man går over til indkøb så går det meget efter leverandøren, og det burde jo efter min mening være i standardkravene, at man burde indele sine indkøb alt efter hvad det er for nogle varegrupper eller tjenesteydelser man indkøber. Man kan for eksempel sige at man har kemiske stoffer som en gruppe, så havde du transport som en anden gruppe, og en tredje gruppe kunne være nogle bestemte typer af råmaterialer. For hver af dem skulle du så prøve at satse på nogle, og der synes jeg man skal passe på med ikke bare at tage hele paletten og ser om man kan finde alt hvad der hedder væsentlige miljøforhold, men man skal finde de såkaldte strategisk væsentlige miljøforhold i hver af disse grupper, og der ud fra, er jeg interesseret i ikke at skabe en masse støj, med en masse papire der bliver smækket i hovedet på hinanden, jeg synes man burde gøre meget for at stoppe det. Man skulle være efter at der sker forandringer på det der, at man virkelig gjorde det der var interessant. Mit motto har været, hellere to væsentlige ting indenfor en bestemt ting end 10 hvor man ikke gør noget som helst, men bare sender noget papir ud, altså to der gør en forskel i stedet for 10 hvor man ikke gør en skid. Forstået på den måde, at hvis det er kemiske stoffer, så skal jeg virkelig se at man gør noget præcist på det der for eksempel er nogel stoffer som man simpelthen ikke vil have eller deres hazard er for høj. Hvis det er for transport kan man sige, der kan man stille sådan en fire fem krav som ville være de mest interessante krav at stille til sine leverandører. Hvis vi har nogle forskellige råmaterialer, f.eks. plast, så er der nogle forskellige fire, fem krav der er de væsentligeste man skal stille, og det samme indenfor metaller. Så du får hver gruppe havde sådan en to-tre-fire stykker som er de vigtigste lige præcis for den type virksomhed som indkøbte. Det vil jeg mene man burde gøre meget mere, og det var jeg fortaler for da vi lavede standarden, men det kom ikke igennem. Men det gør jo efter min mening at det bliver for løst det der sker på det, og hvor det andet ville være relativt meget konkret at man var nødt til at sikre at der var de her miljøkrav, som man egentlig havde identificeret. Og det betyder nemlig at selvom standarden er bygget op sådan, så er det de færreste virksomheder, når de så laver deres miljøindkøb, viser tilbage til de væsentlige miljøforhold. De tror at miljøkrav så skal indkøbsafdelingen lave det, nej, men de kommer jo fra de væsentlige miljøforhold, og de skulle være identificeret der i 6.1.2, men det er de typisk ikke ordentligt. Det jeg mener var at hvis man havde gjort det nede på sådan nogle lidt større indkøbskategorier, så kunne man komme meget videre i at få det gjort ordenligt. For mange virksomhederne er typisk ikke af ond vilje, men de har bare ikke forstået det der ordentligt. De roder rundt og kan ikke rigtig se hvad de kan bruge det il, de kan ikke se at det giver nogen værdi. Så hvis du spørger mig så mener jeg at vi har, med noget af det der er sket, så synes jeg jeg ser for meget at vi har skabt et uhyrre at papir, hvor vi smider papir i hovedet på hinanden, at man ikke skal sige at man vil alt mulig fnidder fnadder som ikke rykker en dyt ved det reelle miljøproblemstillinger der kan være, og der ikke er nogen kontinuert forbedring i det. Jeg vil jo sige at hvis man havde haft som krav at man skulle identificere indenfor sine indirekte miljøforhold skulle identificere et antal indenfor hver, skulle man definere nogle grupper, defineret nogle strategiske eller væsentlige miljøforhold indenfor hver gruppe, ville man komme rigtig meget videre indenfor den der, det kom jeg desværre ikke igennem med.

TK: Så går vi lidt videre til, mit fokus er ligesom på de her LCA'er, de her livscyklusvurderinger, hvad er dit perspektiv på at implementere LCA i en virksomheds miljøledelse?

KB: Jamen det synes jeg da selvfølgelig er en god ting, men jeg vil bare sige at jeg oplever nogle gange at livscyklusanalyserne har så meget fokus på det kvantitative, at de mister simpelthen forandringen, det bliver bare sådan en øvelse i at man har fundet alle de der ting og så gør folk ellers bare hvad de plejer, den bliver ikke noget brugt til forandringsledelse, til at gøre det bedre. Jeg synes det bliver en øvelse i at se på hvad der er vigtigt, og selvfølgelig er det jo interessant, men for langt de fleste ting som jeg er involveret i, mener jeg at det jeg kunne sige om alle de her grupper det kunne jeg have sagt uden at skulle lave en livscyklusanalyse over hvad der er vigtigt, det behøver ikke en kvantitativ livscyklusanalyse til. Så på den måde mener jeg at man skal passe på at det ikke bliver sådan en skrivebordsøvelser, som kun kan laves af akademikere, med en lang uddannelse indenfor det der, og så bliver det ikke brugt i tilstrækkeligt omfang til at skabe miljøforbedringer. Når det så er sagt, så er det jo ikke fordi jeg ikke tror på livscyklusanalyser, jeg bruger dem jo selv, jeg laver også selv EPD'er og verificere EPD'er, så det er jo ikke sådan jeg ikke gør det, og jeg mener bestemt at det kan bruges til rigtig meget, og til et identifikationsværktøj synes jeg det er rigtig godt. Men det er som om at bare fordi man har lavet identifikationen så tror man at det er rigtig fedt, og mange af dem efter min mening, kan jeg bare sige industrien og så kan jeg udvalgt de her tre eller fire væsentligste ting ved det uden at bruge en livscyklusanalyse, det er ikke svært. Der mener jeg bare man får for meget fokus på en beregning ned i detaljer som egentlig bekræfter det man allerede ved. Og så til hvad jeg så mener, at hvis man vil noget med det indirekte, så er du nødt til at risikovurdere meget kraftigt således at du kun tager en to tre stykker og så arbejder med dem. For ellers så sender man bare papirer til hinanden og så sker der ikke en skid. Du skal tage tre og sige at nu vil jeg have forbedringer på det her, og så arbejder du benhårdt på det, og når det så er færdigt så kan man tage de tre næste. For det jeg bare ser det er at man har identificeret hvad der egentlig er og så sker der ikke en skid. Der mener jeg at livscyklusanalyserne er lidt med til den der for de identificere jo fint alt muligt, og så kan man jo vælge hvad som helst i en rækkefølge, og det mener jeg ikke er okay. Hermed meget klart at det er jo ikke fordi jeg ikke synes livscyklusanalyserne er gode, man skal passe på hvad de bliver brugt til, og det kan efter min mening ikke stå alene hvis man gerne vil opnå noget mere miljøforbedringer. I den her sammenhæng, men der er jo mange der bruger det i forhold til produkter, og der ville det jo give god mening hvis man skal sammenligne. Men igen vil jeg bare sige at jeg synes de fleste af de steder, PEF'erne er et bedre sammenligningsværktøj, men man skal være påpasselig med at sammenligne. Jeg oplever ikke rigtig, den ide om og den måde at kategorisere produkterne efter deres miljømæssige problemstillinger, jeg ved ikke, jeg er lidt bange for at den er svær at få til at virke i praksis, og det er som om at det bliver meget ofte til at folk får lavet en, og så kan de være lidt bedre end den anden, og så bruger de en anden metode og så bliver det underligt svært at se den fælles vurdering af det. Der forsøger man så at gøre det endnu bedre og sådan nogle ting. I den sidste ende så tror jeg bare ikke det er det som kommer til at afgøre hvad der bliver brugt, så kan man bare sige at man har valgt det næst bedste eller det tredje bedste. Min pointe er at jeg er sådan lidt luren ved hvor meget det kommer til at ændre den her ide om at PEF'erne kan være med til at man vælger det bedste, den er lidt svær. Derimod mener jeg at den er enormt velegnet til at skære det dårligste fra som jo også er EU kommissionens ide. Hvis man kan se at det går helt ad helvedes til så vil man nok ikke tage den, så der tror jeg at man får skåret de værste eksempler fra, men jeg ved ikke om det er den bedste måde at gøre det på.

TK: Hvilke fordele ser du så ved at kunne implementere de her LCA'er i miljøledelse?

KB: Jeg mener det er et videnskabeligt grundlag for at kunne tage et ordenligt stillingstagning til det, så der synes jeg stadig det er en god ting. Jeg er bestemt ikke imod det, arbejder med dem, har siddet i udvalget til at lave dem, så det er jo ikke derfor, men jeg vil bare sige at hvis man gerne vil gå efter miljøforbedringer, som jo er miljøledelsens ide, så synes jeg ikke altid, mener jeg den har begrænset værdi fordi typisk er den over kvantitativ og egentlig hvis man som mig mener at vi ikke er nået videre indtil at kunne udtrykke at man tager de første 3-4 ting. Jeg vil næsten sige at i 90% af tilfældene der kan jeg vælge uden at lave en analyse af det, der kan jeg got pege på de 4-5 ting. Det er jo et udsagn fra min side, men jeg tror ikke det er meget galt at når man har arbejdet meget med det så kan man godt næsten se det på forhånd uden at skulle gøre det. Der kommer jo nogle aha oplevelser ind imellem, men langt de fleste vil jeg sige er ret evident.

TK: Hvad tror du der kommer til at ske på det her område, både i forhold til med livscyklus i miljøledelse og LCA?

KB: Jeg laver jo greenhousegas verifikationer og der tror jeg at den kvantificering godt kan være ganske interessant, og der er nogle interne principper og der er kun et man taler om. Så der kan jeg godt se det for mig at den er med til at få fokus på det, på livscyklusanalysen er jeg lidt bange for at den er for vanskelig for for mange, og jeg har svært ved lige at finde ud af hvordan den egentlig kommer til at spille ind, på en fornuftig måde til at gøre forbedringer. Jeg tror hvis du spurgte Arne, det gør du ikke du spørger mig, så ville han sige at for eksempel har dem der har lavet forbedringer på køleskabe og sådan noget, fra A-A++, de har opnået meget mere miljøforbedringer end livscyklusanalyser nogensinde har kunne få gjort. Jeg synes at det er en måde at få overblik, det synes jeg er vigtigt, men de konkrete miljøforbedringer de kommer typisk nogle andre steder fra. Når vi går nogle år tilbage så har jeg altid været fortaler for at man laver en kvalitativ miljævurdering, men ikke en kvantitativ for at kunne se på de miljøforhold der er i kæden, og det tror jeg stadigvæk, at det skulle være et krav at der er en form for kvalitativ vurdering af de der miljøting uden nødvendigvis at kvantificere. Der bliver for meget beregning og sådan noget som jeg ikk mener rykker så meget og et bliver meget akademisk diciplin i stedet for at man med en eller anden livscyklusvurdering af hvad er det for nogle ting man går op i, så kan man gøre rigtig mange ting. Men som sagt, jeg laver dem, jeg er med til det og jeg kan se hos nogle af de store virksomheder at når de skal lave sådan en livscyklusvurdering så rykker det måske nogle enkelte ting. Så på den måde kan det også godt have en betydning, men jeg oplever bare at det ofte er noget der er ret evident hvis man bare har forstand på tingene. Aalborg Portland det jo ret evident at de skal af med noget CO2, det behøver jeg ikke en livscyklusanalyse for at finde ud af og kvantificere det, det kan jeg sagtens med en god vurdering finde ud af, altså der er nogle ting, der bruges rigtig meget krudt på det og det ser fint og videnskabeligt ud og så værdien af det bagefter tvivlsom.

TK: Jeg har ikke super meget mere, så medmindre du har noget du vil tilføje

KB: Så det er hvordan livscyklusvurdering kommer ind i miljøledelse?

TK: Ja altså jeg har lavet en simplificeret LCA model, ud fra en af Hydrema's maskiner og så skaleret den til de andre, så det er sådan et rough estimate af hvor

meget hver maskinetype ligesom påvirker, og så vil jeg ind og analysere på hvordan de ligesom kan bruge de resultater i deres miljøledelse, og hvordan det kan blive implementeret

KB: Men der har du jo også noget der som jeg måske ikke har været inde på, og det er jo de miljøting der hedder hele risikovurderingen, den er lidt sværere at få med i livscyklusanalyserne og hele styringen på virksomheden, styringen af de ting de allerede har, måde de øger det på og måden de vedligeholder er rigtig vigtig og det kommer ikke rigtig frem i sådan nogle livscyklusvurderinger hvad betydningen af de her ting er. Som identifikationskrav fra starten synes jeg det ville være rigtig fedt at gøre det der, men for mig hvis den skal bruges så skal man bruge det til kvalitativt inddele dem i grupper som for eksempel plast eller metal, fordi der hvor du har en fælles mængde af væsentlige miljøforhold som giver mening. Det der med at tro at man kan lave væsentlige miljøforhold for transport, plast og det hele, og sige at det gælder for alle produkter, så misser man det vigtige, min pointe er mere at hellere nogle gode og få punkter indenfor hver gruppe som du så arbejder med og gør noget ved i stedet for 10-12-20 punkter hvor man bare sender papir ud og siger at vi vil gerne have du beskriver lidt om hvad du gør ved dem og dem, det rykker ikke en dyt. Som værktøj til identifikation, og dernæst mener jeg at der burde være noget i standarden der gjorde det mere præcist om hvordan man skal gøre det der, det har jeg i hvert fald været fortaler for. Det ville nok være min holdning, men når det så er sagt så det her med at kende sine, jeg mener at de her GHG vurderinger vi laver i øjeblikket giver god mening, det får folk til at ændre karakter, fordi der er så meget fokus på det, men det er også lidt lettere fordi det er en, så det er kun en miljøproblemstilling. Det giver alt for mange handlemuligheder for virksomheden hvis man skal have det hele med, og der synes jeg sådan en GHG verifikation virkelig får dem til at tænke over hvad de gør og hvad vil de.

Interview with Rikke Beider I

Participants: Rikke Beider (RB) and Tanja Kristensen (TK)

TK: Mit første spørgsmål det går på om du vil fortælle lidt om dig selv og din baggrund?

RB: Jeg er oprindeligt uddannet kemiingeniør og så har har jeg arbejdet med miljø siden, men primært miljø. Jeg kom ud og var i sådan et kommunalt miljøfællesskab hvor jeg var miljøsagsbehandler på Fyn. Efter det kom jeg ud i en produktionsvirksomhed hvor jeg var afdelingsleder, fordi det var egentlig det jeg troede jeg skulle lave da jeg læste til ingeniør, det var det så ikke. Så søgte jeg tilbage til at blive miljøsagsbehandler men denne gang ved miljøstyrelsen i deres virksomhedsafdeling, så jeg har været rundt og lavet massere af miljøtilsyn og miljøgodkendelser og VVM-redegørelser til alle mulige forskellige virksomheder, og siden jeg var ved miljøstyrelsen har jeg været ved en anden privat virksomhed hvor jeg sad i deres miljøafdeling, der var det primært REACH og kemi og den slags ting jeg sad med, og så også med ansøgelser om godkendelser, vi skulle have lavet en ny VVM for hele sitet på det tidspunkt, som jeg så var projektleder på. Så jeg har sådan en bred baggrund indenfor miljø, så jeg har erfaring med mange forskellige virksomheder og miljøforhold og alt muligt andet. Nu er jeg jo så ved Bureau Veritas, og der er jeg auditor i kvalitet og miljø, og derudover er jeg produktejer på ISO 14001, så det er mig der er sådan lidt den ansvarlige for hvad retning auditore skal træning, og hvad der er vigtigt at have fokus på og hvad retning miljøområdet bevæger sig lidt i. Der er jo altid noget der er mere oppe i tiden end andet.

TK: Det jeg vil starte lidt ud med at spørge ind til, det er omkring det her livscyklusperspektiv der er en del af ISO 14001 standarden, hvad er dit perspektiv på at den er en integreret del, hvad tænker du om det?

RB: Jeg synes det er super fedt at virksomhederne skal bevæge sig væk fra den gammeldags røg støj og møg tilgang til at man nu skal se på hele livscyklus, og der er jo rigtig mange af de virksomheder som vi kommer på som auditor, hvor deres lokale miljøforhold, eller nogen er også begyndt at kalde dem scope 1 miljøforhold at de jo ikke er særlige, når de så får lavet den her vurdering af deres miljøforhold i hele livscyklus, så finder de jo ud af at det udgør jo, altså hvis de laver beregninger og alt muligt så finder de jo også ud af at det udgør en meget lille del af deres samlede miljøbelastning, hvert fald CO2 belastning. Så det kan jo aldrig stå alene, man skal jo have begge dele med. Det er også det vi tit ser på audit synes jeg at virksomhederne er udfordret på, mange er tilbøjelige til at have fokus på enten det ene eller det andet, typisk fordi medarbejderne enten er skolede eller trænede eller uddannede i det ene eller det andet. Altså enten røg støj og møg eller sådan mere det brede perspektiv.

TK: Hvordan ser du så det her livscyklusperspektiv bliver håndteret ved virksomhederne sådan helt generelt?

RB: Det er meget forskelligt. De fleste kan godt finde ud af at definere at deres råvare har en eller anden impact og de skal være opmærksomme på det. Men hvordan man så håndtere det, det er der kæmpe stor forskel på. Nogle har jo store bæredygtighedsafdelinger, hvor de håndtere det, men så kan det jo tit blive lidt afkoblet fra deres miljøledelse. Vi ser hele spændet fra at det overhovedet ikke er noget de forholder sig til, og så ser vi det andet hvor det er sådan helt afkoblet, men de har et mega flot bæredygtighedsregnskab, og alt muligt andet. Vi ser hele spektret vil jeg sige.

TK: Har i som auditører særligt fokus på det her livscyklusperspektiv når i auditere en virksomheds miljøforhold?

RB: Det skal vi jo have, og det er noget af det som, når man kommer på kursus som lead auditor i ISO 14001, så fylder det meget, det her med at man skal kortlægge miljøforhold i hele livscyklus. Så derfor er det noget vi ved der er fokus på, og jeg er en af dem som, ja nu har jeg jo også en rimelig bred baggrund, hvor jeg også har arbejdet politisk med miljø, så jeg kender alt muligt om bæredygtighedsfagsnakken om livscyklus og hvad ved jeg, men jeg kan godt se at selvom man har været auditor i mange år, så kan det være svært. Så det er noget vi er meget opmærksomme på i vores træning af auditorer, at vi skal blive ved med at have det op. Nu har jeg været ved Bureau Veritas i knap tre år, og siden jeg startede der har det her med livscyklus koblet sammen med hele den her bæredygtighedsdagsorden der har været politisk, det har været på vores træningsagendaer hver eneste gang, og det bliver det ved med at være, for det er noget vi har meget fokus på, og det er noget der faktisk kan være meget svært at auditere. Og bare det med at få de rette mennesker i tale når man laver et program, hvis dem man er vandt til at snakke med ikke, altså dem der er ansvarlige for miljøledelsessystemet, hvis de ikke er en del af det her med livscyklus, det ligger typisk i en eller anden sustainability afdeling, det kan det jo gøre, og hvis de så ikke har noget med det at gøre, og de ikke i virksomheden ikke har koblet det sammen, så kan de have meget svært ved at forstå at man også skal tale med de der sustainability folk, fordi det er jo ikke en del af miljøledelse. På den måde er det en udfordring, ikke at få auditeret selve det med om de har fået kortlagt deres miljøforhold i hele livscyklus, det kan man jo godt se om man har dem alle sammen med, men at det kan være svært at få auditeret ned i hvordan de så har forholdt sig til de her miljøforhold, det er mere det jeg tænker der er en udfordring.

TK: Hvordan beskriver i så når i skal ud og auditere de her virksomheder, hvordan beskriver i så til dem hvordan de skal håndtere det her punkt?

RB: Som udgangspunkt har vi jo en forventning om at virksomheder der har miljøledelse skal have kompetente folk siddende, så de skal som udgangspunkt selv kende standarden og vide at det er noget der er vigtigt, så på den måde vil vi jo ikke skrive ud og rådgive dem om et eller andet, for det skal de jo selv vide. Men det er faktisk noget vi har fokus på, og vi er i gang med at lave, eller jeg er i gang med sammen med Klaus Berhndt der var den tidligere produktejer, vi er i gang med at lave sådan lidt en tjekliste og et udkast eller forslag til agendaer til miljøaudits, om hvordan man husker som auditor at få det her punkt addresseret, det her med sustainability eller bæredygtighed eller hvor det nu ligger henne. Så det er faktisk noget vi er i process med hvordan vi får det bredt ud til alle andre auditorer. Jeg gør jo selv det at jeg typisk inden jeg planlægger en audit så snakker jeg tit med virksomhederne hvis ikke jeg har været der før, og så tager jeg en snak med dem og siger, jamen hvordan har i organiseret det her, og så får jeg lige lagt et punkt ind, for så skal jeg også lige tale med dem og dem. Der er det jo bare lavpraktisk jo.

TK: Er det sådan branchespecifikt om det er svært at få med eller?

RB: Jeg har lyst til at sige at det måske har noget med størrelsen af virksomheden at gøre, for de små virksomheder har jo ikke en bæredygtighedsafdeling, der er det jo typisk den samme person, så det kan jo gøre det nemmere faktisk. Det er lidt svært at sige, det kan man faktisk ikke sige. Det skal jeg i hvert fald lige tænke over om jeg mener der er en forskel, det har jeg i hvert fald ikke sådan lige tænkt over at der er en forskel på.

TK: Hvordan ser du så den mest optimale metode er for at afdække en virksomheds miljøforhold?

RB: Det er et vidt begreb. Nu skal jeg jo lige op på audit i dag, der har jeg et punkt på der hedder noget med deres miljøkortlægning og så se på deres strategi og ned på deres miljø, hvordan de så har defineret deres miljøforhold, og så skal jeg jo ned igennem om det de ligesom har defineret som væsentligt. Det der er vigtigt, det er jo op til virksomheden hvordan de prioritere deres væsentligste miljøforhold, eller vurdere hvad der er væsentligst. Hvad der er miljøforhold, altså nu har jeg jo et ret stort bagkatalag i forhold til alle de virksomheder jeg har været på, så jeg ved godt hvad der er af miljøforhold i de forskellige virksomheder, så hvis der er nogen jeg ikke føler de har med, så spørger jeg jo ind til det, og så kan det jo være at de redegøre for hvorfor de ikke har det med, men selve den der bruttoliste over hvad der er af miljøforhold, der er det jo ret svært hvis det er et eller andet miljøforhold, så er det jo svært at sige at det ikke skal være på bruttolisten så det er diskussionen om hvorfor de ikke vurdere det væsentligt man kan tage. For den der med, hvis de har noget, i går havde jeg en i telefonen hvor vi havde givet en afvigelse på at de ikke havde lavet den her kortlægning af væsentlige miljøforhold godt nok, og det kunne han jo ikke forstå fordi de havde jo en miljøgodkendelse, og deri stod der hvad der var af miljøforhold, og så havde de jo også deres bæredygtighedsrapportering som lå ved deres hovedkontor, som de tog sig af, og så havde de også deres energigennemgang. Så sagde jeg at det jo ikke er det samme som at i ligesom har kortlagt hvad der er. Jeg er godt med på at det der lokalt er, fordi det er sådan en virksomhed der har godt styr på deres lokale miljøforhold, så de lokale miljøforhold dem har i jo inde i jeres miljøgodkendelse, og det er fair nok, men i skal stadig have på en bruttoliste, i skal have en liste over alle de miljøforhold i har og som i har indflydelse på. De havde lavet sådan en liste over ricisi og muligheder men det var jo også sådan noget med at naboerne kunne blive sure, så ham fik jeg også spurgt undervejs i samtalen om han havde været på kursus, det havde han så ikke, så han havde jo ikke styr på hvad miljøforhold og miljøpåvirkninger er, og det ser vi jo ret tit. Vi har jo ikke tid til på en audit at sidde og undervise dem i alle mulige ting. Jeg sagde til ham at han var jo nødt til på den her virksomhed var de nødt til at få det samlet på en bruttoliste, de var nødt til, at det med at de havde sagt at det lå over ved hovedkontoret alt det med deres, det er en virksomhed der køber jern, både råjern og genbrugsjern, og jeg sagde at det er et ret væsentligt miljøforhold, men det havde de jo ikke noget at gøre med, for de købte det jo bare og så var det jo nogle andre, det dur ikke, for de her havde deres eget certifikat, de hørte ikke under hovedkontoret, det er jo jer der er ansvaligte for det, for det er jo jeres certifikat. At i så har et hovedkontor der laver noget arbejde for jer, det er jo ikke det samme som at sige at i ikke skal vurdere hvad der er væsentligt. Jeg synes jo personligt noget af det der fungere godt er i forhold til væsentlige miljøforhold er at lave en bruttoliste, gå ind og få prioriteret dem i forhold til hvad er konsekvensen og hvad er sandsynligheden, så er der mange der gør det, og når de så har vurderet dem der, så skriver de op hvordan de kontrollere de her miljøforhold, og så kan det være de laver en ny score, jamen med den her kontrol så vurdere vi, og så får den en eller anden anden score og så er det jo dem der får den højeste score som de går ind og vurdere på. Nogle de siger at alt hvad der er lovkrav til, hvis de har en godkendelse til så er det væsentligt det hele, men så kan det jo være temmelig meget, og så får man ikke prioriteret hvad man vil arbejde med, men det kan man kan så gøre i sin risikovurdering. Der er ikke noget entydigt svar på hvordan man gør.

TK: Så går vi lidt videre, mit fokus er ligesom på de her livscyklusvurderinger, de her LCA'er, hvad er dit perspektiv på at implementere LCA i en virksomheds miljøledelse?

RB: Det er jo ikke nødvendigt i forhold til miljøledelse, det er jo ikke et krav. Når vi er på audit hvis jeg skal tage det perspektiv, så har vi jo ikke tid til at dykke ned i om tallene er rigtige. Men nu er jeg personligt en type der elsker data, og jeg synes jo mere viden man har, og jo mere data man har, og hvis man formår at bruge det rigtigt så kan man også tage nogle bedre beslutninger tit og ofte. Det er meget sjældent vi oplever at en virksomhed har en LCA beregning som ligger til grund for deres miljøledelse, altså som de bruger i deres miljøledelsessystem, det er meget sjældent.

TK: Hvilke fordele kunne du så se ved at have en LCA i miljøledelse?

RB: Jeg kan se det især, jeg kommer jo også på nogle virksomheder som er handelsvirksomheder, altså de køber nogle vare som de så sælger videre til nogle andre, der synes jeg det giver super god mening for det kan være enormt svært for sådan nogle virksomheder at se hvilke produkter, der har jeg oplevet nogen der er blevet bevidste om at nogle produkter, altså de har selvfølgelig haft en ide om hvilke produkter der har været mere miljørigtige mere grønne, uden at sige noget om greenwashing men de har haft en ide om hvad for nogle produkter der har været mest miljørigtige og så kan det jo så give dem noget dokumentation for det, altså bekræfte dem i det eller også kan de blive klogere på noget andet, og ved sådan nogle virksomheder hvor det i bund og grund er deres vare, det er jo en eller anden handelsvare, det er jo det som er deres miljøbelastning det er jo ikke deres kontorfaciliteter, som er miljøbelastningen, der synes jeg det giver super god mening, fordi for det første så har de også noget argumentation overfor kunderne. Noget af det nogle af de her virksomheder arbejder med, jamen det er jo den vare de sælger der er deres miljøforhold, så hvis de skal arbejde med det. Nogle af dem jeg har set lykkedes rigtig godt det er at de så har fundet ud af at de kan lave nogle interne træninger i forhold til salg og hvordan får vi solgt nogle flere af de her produkter, fordi det jo er den måde vi kan påvirke, og have god indflydelse på miljøet ved at kunderne så vælger de mest grønne produkter frem for nogle andre hvis det er to forskellige produkter som stort set kan det samme. I sådan en virksomhed synes jeg det giver super god mening. I en produktionsvirksomhed, mega tung, altså miljøtung produktion hvor der selvfølgelig er nogle råvare der også har en belasting, der har jeg ikke oplevet man har brugt det, og jeg har heller ikk siddet og tænkt at det kunne give en stor gevinst, så det er mest når det er produkterne det handler om synes jeg.

TK: så lige et tænkt eksempel, hvis så man har et produkt hvor man siger, jeg ved det udleder meget i brugsfasen, men jeg ved ikke hvor meget kontra produktionen det udleder, kunne du så se en gavn af at have lavet den beregning?

RB: Ja, det har jeg faktisk også oplevet en virksomhed. Det var en virksomhed der laver ventilationsanlæg, sådan nogle store der hænger nede i parkeringskældre og sådan noget, og de bruger jo en masse aluminium, så selve deres produkt er ret belastende kan man sige. Men de har så lavet, en livscyklusanalyse er det jo ikke som sådan, fordi de har lavet det i forhold til CO2, og ikke en fuld LCA hvor de har alle mulige andre aspekter med. Men der har de så lavet det for så brugte de det i deres business case i forhold til, at det kan godt være i køber den her ventilation og vi bruger noget aluminium, og den er så og så belastende, men hvis du skifter den ud så kan den holde i så lang tid, og hvis du laver service, og så til gengæld så laver de nogle af de mest energieffektive ventilationsløsninger i verden, og ventilation er virkelig en energisluger så så lavede de sådan en hel business case på at hvis den holder i så og så lang tid og du bruger den til det og det behov, så kommer du så til gengæld over, inklusiv produktionen og så i brugsfasen, så kommer du til at bruge så meget mindre, og så havde de nogle forskellige scenarier. Men det synes jeg også gav super god mening for der var nogle kunder der blev ved, for det kan være svært at sælge et produkt der har et virkelig dårligt aftryk selve produktionen, men hvis man så tager den anden del med så synes jeg det giver super god mening.

TK: Hvilke ulemper ser du så ved en eventuel implementering af LCA i miljøledelse?

RB: Umiddelbart kan jeg jo kun tale ud fra hvad jeg ser hvis det er lagt meget over på nogen som er meget, altså nogen som sidder og laver LCA de kan godt være meget nørdede, det er også positivt, men de kan være nørdede i den forstand at de kender måske ikke så meget til det der foregår ude i selve produktionen, og man bliver meget blind på brugsfasen på ens produkt eller råvarene, og så kan man glemme det som også er helt lokalt miljø, det kan godt blive meget stort. Og i det hele taget er CO2 og energi helt vildt meget oppe i tiden og alle er meget opmærksomme på CO2 og så kan det komme til at handle om det, og så kan man komme til at glemme noget helt elementært, som spildevand eller overfladevand eller støj helt lokalt miljøforhold, det kan man jo komme til at overse fordi det andet kommer til at få så meget fokus.

TK: Hvordan tror du udviklingen kommer til at være på det her område?

RB: Det er svært at spå om, altså vi har jo arbejdet med i Bureau Veritas at det ville, alt den her CSRD og alt den rapportering der har været krav til, ville drive meget af det, men nu bliver noget af det jo rullet lidt tilbage og bliver sat på standby så det er lidt svært at sige. Men jeg tænker da opmærksomheden på produkter og råvare er jo nok kommet for at blive, så det har jeg svært ved at sige. Men jeg håber da at man kommer til at blive ved med at have det her fokus på hele paletten, så man får hele livscyklus med og også det lokale og det brede perspektiv, men det tror jeg også er det der er vejen frem.

TK: Så har jeg ikke flere spørgsmål