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A FRAMEWORK FOR SUSTAINABILITY DATA COLLECTION AND PERFORMANCE ASSESSMENT OF PAPERS FOR CORRUGATED BOXES

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TIIVISTELMÄ

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Diplomityössä käsitellään paperin, jota käytetään aaltopahvin valmistukseen, ympäristöllisen suorituskyvyn arviointia ja siihen liittyvää tiedonkeruuta. Tässä työssä on hyödynnetty kirjallisuutta, standardeja, haastattelututkimusta ja verkkosivuja. Työssä on huomioitu kestävän kehityksen strategian luomisen ajureita, toteutusta ja seurantaa ja sidosryhmien merkitystä kestävässä kehityksessä. Tämän diplomityö empiirinen osa keskittyy Stora Enso Packaging Solutions divisioonaan. Stora Enso aloittaa ympäristönsuojelutason arvioinnin paperista josta tehdään aaltopahvipakkauksia, parantaakseen tuotteen ympäristönsuojelutasoa. Tämä opinnäytetyö arvioi eri ympäristönsuojelukyvyn arviointimenetelmien vastaavuuden Stora Enson kestävän kehityksen strategiassa mainittuihin päämääriin ja yleisiin kriteereihin. Tulokset osoittaa että, on useampia arviointimenetelmiä jota on mahdollista käyttää, niistä erottuva on Product Environmental Footprint-elinkaariarviointistandardi. Product Environmental Footprint menetelmä mahdollistaa Stora Enson kestävän kehityksen tavoitteiden seurannan ja tämän vuoksi se vaikuttaa pitkällä tähtäimellä parhaalta mallilta Stora Ensolle. Sidosryhmien valmius ottaa käyttöön erilaisia arviointimenetelmiä arvioitiin lähettämällä kysymyssarjan kestävän kehityksen viitekehysten käytöstä nyt ja tulevaisuudessa heidän yrityksessään. Kyselyn tulokset osoittavat, että Product Environmental Footprint-tutkimukseen liittyvä tiedonkeruu ei ole tällä hetkellä realistinen. Tiedonkeruu pitäisi aloittaa yksinkertaisemmasta viitekehyksestä kuten hiilijalanjäljen tai -kädenjäljen laskemisesta. Kun yksinkertaisempi tiedonkeruu ja arviointi on toteutettu, tiedonsiirrosta saatua kokemusta voidaan laajentaa ja hyödyntää edelleen Product Environmental Footprint-tutkimukseen.

ABSTRACT

Lappeenranta-Lahti University of Technology LUT
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A Framework for Sustainability Data Collection and Performance Assessment of Papers for Corrugated Boxes

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Keywords: Life Cycle Assessment, intermediate paper, impact assessment, impact categories, sustainability strategy, life cycle assessment standards

This thesis studies the environmental assessment of paper used for corrugated boxes and the data collection associated with it. The references used in this thesis are literature, questionnaire, webpages, standards and guidelines. This thesis takes into consideration the sustainability strategy creation drivers, implementation and monitoring and the importance of stakeholders in sustainability strategies. This thesis will focus on the case study of Stora Enso Packaging Solutions. Stora Enso is initiating an environmental performance study on paper used for corrugated boxes, to improve their product’s environmental performance. This thesis evaluates the different standards and guidelines against general criteria and Stora Enso’s environmental agenda. According to the results of the study, multiple assessment methodology can be used, however the Product Environmental Footprint stands out more than others. The Product Environmental Footprint life cycle assessment category rules satisfies the environmental agenda of Stora Enso in the long run and would therefore be ideal to use. The status of suppliers must not be overlooked and therefore a questionnaire was sent to the suppliers to inquire their opinions on environmental assessment. The current supplier development status shows that the completion of the data collection that a comprehensive Product Environmental Footprint study requires will not be realistic. A more suppressed study that considers the whole life cycle of a product like the carbon footprint and handprint should be initiated first. The suppressed study can then work as a stepping-stone towards the Product Environmental Footprint study.

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LIST OF SYMBOLS

AOX	Absorbable Organic Halides
BAT	Best Available Technology
CEPI	Confederation of European Paper Industries
COD	Chemical Oxygen Demand
CYP	Check Your Paper
EMS	Environmental Management System
EPD	Environmental Product Declaration
FEFCO	The European Federation of Corrugated Board Manufacturers
FSC	Forest Stewardship Council
GHG	Greenhouse Gas Emissions
GRI	Global Reporting Initiative
GWP	Global Warming Potential
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
PCR	Product Category Rules
PI	Performance Indicator
PM	Particulate Matter
POCP	Photochemical Ozone Creation Potential
PAS	Publicly Available Specification
PEFC	Programme for the Endorsement of Forest Certification
SFS	Standards Association of Finland
SWOT	Strengths, Weaknesses, Opportunities and Threats
VOC	Volatile Organic Compound

1 INTRODUCTION

The term sustainability has different definitions such as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* defined in the UN World Commission on Environment and Development (UCLA 2018) or "*the ability to continue a defined behavior indefinitely"* (Thwink 2018). Despite having different definitions, in general it is accepted that there are three pillars of sustainability or also called the triple-bottom-line, which takes into consideration the environmental, economic and social aspects of sustainability (University of Alberta 2013). To achieve sustainability in business operation, all the three different aspects are taken into consideration and a common balance between them must be found (ISO 14001 2015, 5). To counteract the growing pressures on the environment and increasingly strict regulations, many companies have decided to adopt an environmental management system that aims to contribute to the environmental aspect of sustainability (ISO 14001 2015, 5). This thesis will focus on the environmental sustainability aspect, as currently the tools for sustainability assessment lean towards environmental sustainability. To properly focus on the environmental aspect of sustainability, an environmental sustainability strategy must be implemented.

A sustainability strategy can be implemented with the help of environmental management systems like the ISO 14001. Different sustainability assessment tools can be used to make the implementation easier. The assessment tool must support the goals and values set in the sustainability strategy of the company. This thesis will inquire into not only the implementation of a sustainability strategy, but also the engagement of stakeholders and choosing valid frameworks for performance assessment.

Stakeholder management is important in the success of projects. Often project managers can make decisions about their project themselves, however in the case that key stakeholder opinions are not taken into consideration, the chances of success are slim (UKEssays 2013). This applies to the implementation and creation of a sustainability strategy. As environmental assessment becomes more common, assessing your processes environmental performance is a good start, however assessing the product life cycle, including all the involved stakeholders, is becoming more important. The engaging of suppliers may not be as easy as it sounds and must be well thought out. An environmental assessment of a product is a great way to get stakeholders involved in the sustainability strategy of your company, however, does require effort from these stakeholders and the motivation to give this effort may vary depending on the relationship of the stakeholder and the company. In the case of

Stora Enso Packaging Solutions, it is extremely important that the suppliers of paper used for corrugated boxes are involved in the environmental performance assessment.

The renewable raw material for paper is wood or plant fibers. Paper production has been around for thousands of years, but the manufacturing method has developed (Paper Trading International, Inc, 1998). The type of paper, which this thesis will concentrate on, is the paper used in corrugated boxes. The problem in the environmental assessment of paper used for corrugated boxes, is that there is no universally accepted standard. The goal of the assessment framework is to allow the increase of environmental performance by analyzing current processes. The main competing products, and therefore the comparison target, for corrugated boxes are the boxes made from plastics. To gain an upper hand in the competition against these products, the environmental performance of the product needs to be clearly shown. Currently, there is not one specific tool, which has been adopted by the industry to provide a comprehensive environmental assessment of intermediate paper. A sustainability assessment framework and good performance according to it would provide a significant advantage to corrugated boxes in the packaging markets.

Different sustainability assessment tools of products were assessed and weighted for their advantages and disadvantages. In the case study, the assessment cannot be completed without the cooperation of stakeholders since manufacturing of the product is a step by step process, that may involve multiple companies as suppliers of raw materials. Therefore, the methods of engaging stakeholders and possible challenges it provides are addressed. Sustainability evaluation of papers can be completed with the help of various standards or guidelines. These standards and guidelines have their own characteristics and therefore also their advantages and disadvantages. Some standards or guidelines can be based on a similar baseline process; therefore, the baseline process advantages and disadvantages must be mentioned along with the current developments and limitations of it.

Stora Enso would like to choose a tool for the environmental assessment of papers used for corrugated boxes that suits their environmental agenda to prove the environmental performance of their final products. The aim of this thesis, is to identify and suggest a feasible sustainability assessment framework for paper used in corrugated boxes that reflects the sustainability strategy of the company and allows the development of the products life cycle. The framework must satisfy the company's sustainability targets and policies, but at the same time be simplistic enough to make it feasible for implementation with relevant stakeholders. The aim of the company is to improve the environmental performance of the product and choose the suppliers that help the company achieve its sustainability goals. The short-term reduction goals, set with the help of Science Based Targets, must be considered throughout the study, therefore the assessment framework chosen must provide information relatively fast. An indicator that is used for the environmental assessment should be relevant, measurable, easy to communicate and access, limited outcome focused and methodologically sound (Hák et al. 2015). The suggested sustainability evaluation must be comprehensive but not too complex so it requires too much unobtainable or confidential information. A questionnaire for the relevant stakeholders was created to identify the correct environmental assessment framework to compare, show license to operate, create trust, show the benefit to the customer and communicate environmental performance. The information acquired by conducting the questionnaire will direct the environmental assessment of products in a direction that is beneficial for most and hopefully all stakeholders.

The main research questions in this thesis are:

1. How can environmental assessment tools be used as a part of sustainability strategy implementation?
2. What are the different environmental assessment tools and what are the advantages and disadvantages of them?
3. How do the involved stakeholders see the feasibility of different environmental assessment tools?
4. What environmental assessment tool should Stora Enso use for the environmental performance assessment of paper used for corrugated boxes?

The thesis will begin with explaining the creation, implementation and monitoring of a sustainability strategy, then move further towards the engagement of stakeholders and what their role is within the sustainability strategy. Then the thesis will focus on the methods of monitoring environmental performance through indicators provided by frameworks. The limitations of life cycle assessment and the current development of impact categories in life cycle assessment is explained. Once life cycle assessment as a tool has been explained, the standards or guidelines that either implement it or don’t will be introduced. Many of these frameworks include the assessing of impact categories and therefore general development points of impact category assessments were pointed out. Then the case study was introduced, which is the process of creating corrugated board. After this, the thesis will explain the environmental agenda of Stora Enso and why suppliers as stakeholders play an important role. A questionnaire was sent out to inquire about the views of environmental performance assessment of the suppliers. After this, one environmental performance assessment framework was suggested by combining the results of both the empirical and theoretical sections of the thesis. The structure of the thesis is shown in figure 1. The aim is to start with a broad overview of the larger strategy, then go down to the individual indicators of sustainability and then expand the thesis back to decision-making to define and advance the strategy further. At the narrowest point in the diagram, the assessment methodology that suits both the stakeholders and Stora Enso, is chosen.

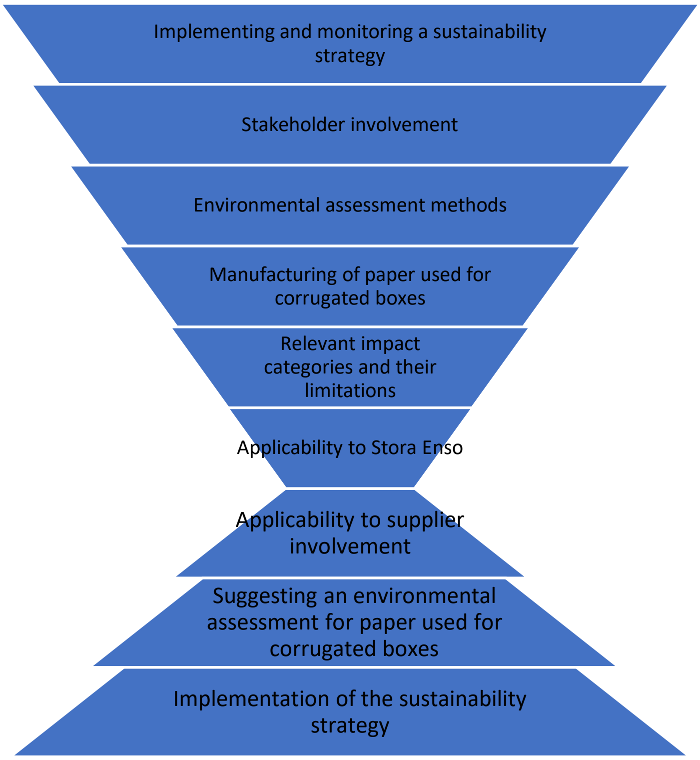

Figure 1: This figure shows the structure of the thesis.

The scope of the thesis is the environmental pillar of sustainability and more specifically the internal development of the life cycle of corrugated boxes. The social and economic aspects of sustainability are not included, and this thesis does not differentiate the environmental performance assessment between different types of corrugated offering. The thesis does not focus on a single unit of Stora Enso or a single supplier, but rather the life cycle of one product type and the way the environmental performance can be assessed.

2 COMPANY SUSTAINABILITY STRATEGY AND THE ROLE OF ENVIRONMENTAL ASSESSMENT OF PRODUCTS IN THEM

Companies are putting more resources to ensure future needs of their own company, and hence are encouraged to create a transparent, easy to communicate and strong sustainability strategy. The company's proactive sustainability strategy reflects on the actions of each individual within the company and even external stakeholders' actions. An adequate sustainability assessment tool has to be in place in order to follow sustainability targets set in the strategy of the company. This chapter will focus on the drivers, creation and communication of a sustainability strategy.

2.1 Drivers behind a sustainability strategy

When developing a sustainability strategy for a company, there are several factors that need to be taken into consideration and drivers that either force or encourage the process. The drivers all relate to the stakeholders of the company. Profitability is one big driver, and it tends to relate to the actions of a company in one way or another. Over the past 20 observation years, investors have had an increased interest in environmental sustainability, as it has evidently had positive direct and indirect effects on the economic performance and overall sustainability of a company (Kyungho 2017). A lot of green engineering solutions include the reduced usage of resources and is aimed to create value for a company while reducing the expenses. Profitability is linked to increase of market share through achieving competitive advantage, attracting employees and entering international markets. Costs can be reduced in four different categories related to sustainability: risk management, relations with external stakeholders, cost of material, energy and services and cost of capital and labor. (Naidoo 2018, 128.)

The continuous development of environmental policies encourages companies to either be a forerunner in environmental development, abide by the rules or not abide with them at all. Forerunners in environmental sustainability have the chance of steering the future of environmental policy development by offering resources to the development process. As environmental policies are being developed constantly, the forerunners have the chance to commit to the development and foresee the legislation changes, therefore avoiding the catch-up costs in the future. The companies that barely abide by the rules have a tendency of hiring a third party for the actions required by the applicable environmental policy, possibly due to the lack of knowledge within the company. Some companies do not abide by the environmental rules at all, as the investment required to abide by the rules outweighs the fines of not abiding by the rules. Therefore, when creating a sustainability strategy, the company must choose whether they want to be a forerunner in sustainability or focus more on compliance. (Naidoo 2018, 129.)

The pressure provided by stakeholders is the main reason companies are encouraged to develop their sustainability policies. The image and social perception of a company is a key instrument in the developing and upholding of customer relations. Good reputation encourages trustworthiness, which can then lead to a competitive advantage (Turnkey Group, 2018). Stakeholder knowledge of environmental issues is increasing due to adequate frameworks (in comparison with older sustainability frameworks), which in turn means the demand of environmental performance and its communication increases. The increased role of stakeholders within large companies encourage the transparency in the decision-making process of a company, and this is not to be underestimated. (Naidoo 2018, 129.)

Currently there is no straightforward, easy to interpret and comprehensive way communicate the environmental performance of products. The constant development of sustainability tools and the increased stakeholder knowledge provides the demand to green the life cycle of a company's product. Some of the current ways that environmental performance is advertised predisposes greenwashing. The continuous misuse of the environment will decrease the brand value, customer loyalty and maybe even affect the legal and social licenses to operate. Therefore, firms that create a long-term strategy and work towards that strategy in decision-making are usually the firms that survive longer. In short, some of the main reasons a company would improve their sustainability would be: to meet public concerns, improve reputation and create an image, gain a competitive advantage, increase knowledge of their own products, ensure the future of the company, compare products to alternatives and reduce effects on impact categories (CEPI, 2007). (Naidoo 2018, 129.)

2.2 Implementation of a sustainability strategy

At first, the sustainability strategy must be created into the context that applies to the company and then implemented with the help of sustainability assessment tools. Sustainability strategy implementations differ from company to company, with it being more complex in some companies when compared to others. The implementation depends on the culture of the company and what is being implemented, however the management of the company needs to be engaged and motivated for the implementation to follow through to each individual employee. There is no universal implementation method and therefore, what works for one company may not work for another company (Radomska 2015). There are different levels of managements: normative, strategic and operational. Normative asks the question of who we are and who do we want to be. This usually depends on the organizational culture consisting of values, attitudes, beliefs and judgements. The strategic level are goals that have PIs and can therefore be followed and monitored. An example of a PI could be the energy consumption per employee per year for short term. Long term goals could be constant reduction of energy consumption and increase use of renewable energy. The last level is the operational level, which requires a goal that is not based on increase of economic value. Learning loops need to be established in the management through constant reciprocation between the operational and normative level. (Baumgartner 2016, 18-19.)

Operational level focuses on increasing the capabilities of all employees. To increase the capabilities of employees, the transfer of information and knowledge to the management level needs to be as convenient as possible. For the strategy to properly operate, all levels of the organization need to enforce it. The goal of the operation level is to execute strategic guidelines and provide feedback for the development of the strategic goal. In an ideal situation, the sustainability strategy will influence the daily operations of all employees. Decisionmakers need to balance between tradeoffs with the different pillars of sustainability, for which they need to be familiar with the current and potential future benefits of environmental, societal and economical improvements. For example, investing into Best Available Technology (BAT) will increase investment costs, however, may increase the duration of the life cycle, and decrease the environmental impacts due to emissions, maintenance and disposal. It could even have a good social effect where the operation of machinery is enjoyable for employees, gaining social value to the company through employee satisfaction. Sustainability strategy comes down to the ability of decisionmakers to make decision that are directed towards the future of the company, instead of short-term wins. (Baumgartner 2016, 19.)

2.2.1 ISO 14001

There are many ways to implement sustainability strategies and the implementation is different within all companies, however there are guidelines and standards on how it can be done, one of which is the

ISO 14001. The aim of the ISO 14001 is to "*provide organizations with a framework to protect the environment and respond to changing environmental conditions in balance with socio-economic needs."* The ISO 14001 can provide the management team with important information, which helps them protect the environment by the mitigation of impacts or potential impacts, complying with regulations, controlling the life cycle of a product and enhancing overall environmental performance. The ISO 14001 can also be a communication tool of environmental practices. The ISO 14001 follows the Plan-Do-Check-Act model, which is an iterative process to ensure continual development or processes. (ISO 14001 2015, 5)

The ISO 14001 helps achieve the wanted outcomes of environmental performance goals by using an environmental management system. The aim is to provide value for the environment, the organization and the interested stakeholders. The intended outcomes consist of the fulfillment of environmental regulations, enhancement of environmental performance and the achievement of environmental objectives. The standard is applicable to the products and services that an organization has control or influence over regardless of the company's size and type. The international standard approaches environmental sustainability through a life cycle perspective, however does not state specific environmental performance criteria. The standard can be used partially, however in the case that a company claims compliance with the ISO 14001, all the different criteria provided by the document must be met. (ISO 14001 2015, 8)

2.3 Performance indicators

Environmental sustainability assessment tools and Performance Indicators (PI) are a part of the monitoring of a sustainability strategy. As mentioned above performance indicators are quantitative data that is relevant, measurable, easy to communicate and access, outcome focused and methodologically sound (Hák 2015). There are ways to counteract this, for example with the help of Science Based Targets, which is a collaboration that helps companies find out what to measure, when to measure it and how fast the reduction of the key values must be done (Science Based Targets 2019a). Science based targets offers workshops, resources and guidance, and showcases companies that have taken a step towards making science based targets through case studies, media and events (Science Based Targets 2019b).

PIs that are chosen must be relevant to the impact category that it is meant to measure. This supports that the quantitative data must have a clear link to the sustainability targets set by the company. It also must be relevant and provide enough information so that they can be used for company policy formation and assessment. A relevant indicator must represent the location and scale of what is being measured. For example, in a multinational company, indicators should be relevant to all countries. For national monitoring, the indicator should be specified to that location and its priorities according to the environment that it is in. The scope of each target must be clearly defined so that it stays consistent and the background information on the targets doesn't change. The PIs must be clearly operationalized so that they change from just theoretical frameworks to tools that end up changing everyday actions of stakeholders. Companies must use extreme caution in the creation of PIs, as a target can be relevant, measurable, and applicable without contributing to the designing of right concepts beyond set targets. Operationalization of the targets using indicators potentially causes false interpretation that only the effects that can be measured are important to the company. It is possible that some goals cannot be measured and therefore provides the need for further research in the subject. (Hák 2015.)

Many different indicators have been suggested and developed, however despite the efforts of many international corporations and governments, the indicators still face challenges that usually stems to the lack of theoretical framework in the subject. It has been a trend that the number of indicators without proper theoretical background has increased instead of good quality indicators. There are multiple organizations that have developed environmental assessment frameworks with similar requirements regarding data and its use. The criteria are well defined and decent in theory; however, the operationalization of the framework seems extremely complex. It is known that indicators should be easy to understand, however we do not know how it can be done. Often this leads to companies measuring what can be measured rather than measuring what is relevant for the phenomenon. The relevance of indicators is a field that is actively studied and the range goes from an indicator not being verified at all, that is believed to show indication of the phenomenon at hand, or being "indicator-indicated fact", which in turn is verified by theory or empirical tests. Indicators have a direct effect on linking data collected into environmental impact categories, which many of the assessment frameworks require. (Hák 2015.)

When developing indicators, the company must acknowledge that not only is the indicator a science based quantitative representation of progress or current condition, but it is also the setting of a political norm. An indicator can be directed towards the non-expert audience or a more technical audience, and therefore should be chosen accordingly. The non-expert audience requires an easily understood indicator, where as an indicator directed at experts usually has a technical nature to it and is highly relevant to the phenomenon at hand. Unfortunately, currently choosing an indicator is often based on data availability. Therefore, there is often a tendency to use already available indicators to assess a phenomenon, which the indicator was not first created for. The vague description of targets, strategies and impact categories naturally tempt to use the cost-effective approach, which is using the already available indicators. The main problem with indicators is that they are more designed towards the gathering of statistical data rather than designing methodologically sound and more conceptual frameworks that assist performance assessment. With correct PIs, sustainability strategy monitoring will become easier and allow better approaches of environmental sustainability. (Hák 2015.)

2.4 Approaches of environmental sustainability

The content of a company’s sustainability strategy can fall into a scale of proactive and reactive approaches. The reactive approach puts emphasis on compliance with environmental regulations and applying environmental activities such as end-of-pipe solutions at a minimal level. As mentioned above, sometimes companies do not even comply with laws due to lack of punishment. By contrast, a proactive approach puts emphasis on pollution preventing technologies, high order learning and redesign of current processes. Proactive approaches pay close attention to the development of organizational capabilities and resources that may or may not be economically beneficial. In the proactive approach, actions can be divided into first and second orders of sustainability actions, where first order is the development of products (such as increasing the fuel efficiency of cars, decreasing the energy consumption of machinery or increasing the recycling rate of products), and second order is the introduction of new technologies, products and services, which focus on reuse, refurbishment and remanufacturing (Baumgartner, 2016, 12). However, interpretation of proactive approaches must be approached with caution, as companies often present their proactive environmental performance while suppressing negative reactions, which is also called green washing. Using standardized environmental assessments that are mentioned in section 4 could cancel out this issue. The tendency to do this stems from environmental disclosures being directly linked to stakeholder relations. (Kyungho 2017.)

The difference between a proactive and a reactive company has become a popular issue in literature. Environmental practices are likely to depend on the company management's response to environmental risks and opportunities, and a company's buffer zone to react to environmental risks and pressures. The main advantages of the reactive approach to sustainability, is that it does not require company-wide training. Reactive approaches take risks by limiting investment in environmental performance and therefore risks environmental failure, while assuming, that limited investments will pay off. The most common practices of reactive strategy are changing physical equipment or changing the company's waste removal facilities. Companies with a reactive strategy may spend the investment into improving communication of environmental aspects instead of actual change. Improving a narrow sector of processes might improve the short-term competitiveness of a process or product but may have a hindering effect on the overall sustainability of a company, as development in already existing projects take away from research and development of new sustainable technology (Baumgartner 2016, 16). (Kyungho 2017.)

Proactive approaches in contrast often require company-wide environmental training, since environmental development starts from every individual. Proactive companies put serious efforts on resource productivity, material substitutions, innovative manufacturing processes and products and substitutions. Firms adopting a proactive strategy expect significant improvement in environmental performance and a long-term economic benefit through sustainability and yield. In simple terms, a proactive strategy is the prevention of environmental problems instead of cleaning up already made messes. The ideal cycle is that proactive strategy leads to economic benefits through increased sales, lower footprint and process and product offsets, which in turn allows further investment into proactive environmental development. The industries that tend to focus more on proactive approaches are the industries, which emit a lot, for example the metal industry or the forest industry, as they are more likely to be under environmental regulation control. Studies have shown that bigger firms release less toxic waste, as they are more susceptible to public scrutiny. An indication of a proactive approach to sustainability is the willingness to question current processes (Baumgartner, 2016, 16). The short-term business value gains are the reduction of costs and increase of profits, however in the long-term way of thinking, it is to improve innovation, introducing new business models and improve competitiveness (Baumgartner, 2016, 16). (Kyungho 2017.)

Studies have shown that environmental practices are time-lagged when compared to environmental performance. Partial evidence is provided that proactive environmental actions reduce toxic waste releases, and reactive actions increase them. Time-lagged models show a slight improvement in correlation, which implies that environmental performance is a long-term process, that shows improvements in the future. Therefore, it is safe to say that there is a weak casual relationship between environmental performance and environmental practices, when environmental performance is defined as "*the ability of a firm to reduce its environmental impact by committing to optimal environmental practices*". (Kyungho 2017.)

Assessment frameworks can help the companies identify their points of improvement and find ways to transfer their strategy from reactive to proactive. Regardless of the framework for environmental assessment that it chosen, in the end the main goal is to increase the productivity and efficiency of a process, support the development of more sustainable products, reduce social and environmental risks and improve company credentials.

2.5 Stakeholder involvement in a sustainability strategy

As the topic of sustainability is under development by both companies and higher learning institutions, companies are encouraged or even forced to examine their processes and determine social and environmental impacts caused by them. Companies are also encouraged to innovate products, services or business models to substitute or reduce these environmental and social impacts through tools like the carbon handprint. Stakeholder involvement in sustainability development has moved past only recognizing the stakeholder expectations and goals and further towards the involvement of stakeholders in stimulating activities, which lead to decision-making (Trapp 2013, 43). Complex industries such as the forest industry are often forced to involve stakeholders for their sustainability strategy to be successful. An example of this is the paper making process, where sometimes the processes of manufacturing pulp, paper, corrugated paper or even corrugated boxes can be in different locations and companies. (Brandli, Filho 2016.)

The engagement process however is more complex than it initially sounds. To do a comprehensive environmental performance assessment of a product, engaging relevant stakeholders cannot be avoided. Stakeholder involvement provides many benefits for operational excellence and steering the strategic development, and many experts mention the following benefits. It increases the quality of decisions made by the decision makers and steers to more effective work and production. It also increases the chances of decision equity and prevents or finds solutions to possible conflicts. Finally, it also allows the possible implementations to be tested and refined before adoption. Stakeholder engagement can also be seen as social interaction, building of relationships and getting to know cooperation partners. In the best-case scenario, stakeholder engagement can lead to sharing the same values and create a shared vision of the future. For stakeholder cooperation to be successful, it requires the following: dialogue, listening, resources, integration and collaboration, leadership commitment, systemic thinking, capability to deal with environment and market volatility, ambiguity and openness along with many more. Along with the positives in stakeholder involvement, it faces many obstacles, which are shown in table 1. (Brandli, Filho 2016.)

Table 1: Hindrances in Stakeholder Involvement. (Brandli, Filho, 2016)

Hindrance	**Explanation**
Lack of a standard	There is no single correct way of engaging stakeholders, however they go from passive interaction to self-mobilization.
Conflict of interests	Positive stakeholder behavior is hard to achieve; however, it is possible if the benefit of the stakeholder is properly taken into consideration. The process should be designed to encourage cooperation and decrease competition.
Insufficient capabilities	Shifting from traditional stakeholder management to proactive management requires resources, from both sides. The process requires communication, negotiations, contracts and relationship management to encourage beneficial performance.
Excessive number of stakeholders	Prioritization and involvement of all stakeholders can be extremely difficult when there are excess amounts of focuses.
Later involvement of stakeholders	Stakeholders should be involved at the very beginning of the strategy development, as problems tend to occur when stakeholders are being implemented into an already existing strategy.
Stakeholder fatigue	The increase of projects involving stakeholders is increasing and often left unfinished due to different reasons and can make stakeholders see the projects as useless and not rewarding for them.
Responsibility shifting	Environmental performance is highly politicized and under permanent public disclosure, therefore engaging stakeholders in studies can be seen as shifting responsibility to the stakeholder instead of the company conducting the study.
Engaging specific stakeholders	Environmental impacts are long-term and therefore stakeholders such as future generations should be taken into consideration. However, companies cannot engage future generations for processes that are happening now, and will affect them in the future.

Stakeholders can be engaged in different ways, with the least engagement being information sharing and most significant is involving them in decision making, which follow one of five levels of engagement: inform, consult, involve, collaborate and empower. Another way to distinguish between the methods are: informational, persuasive, and dialogue strategy (Trapp 2013, 43). The informational strategy is simply informing the stakeholder about something (Trapp 2013, 43). The persuasive strategy is the attempt to change the views of the stakeholder to fit the initiating company's values and views and receive feedback from the stakeholder for strategy modifications (Trapp 2013, 43). The dialogue strategy is the proactive engagement of stakeholders in organizational decision-making (Trapp 2013, 43). To successfully engage stakeholders, companies could assign stakeholders to different company targets, prioritize them, measure the performance and put targets into actions. The measuring and monitoring can be done with the tools mentioned in section 3. In the engagement process, it is important to clearly state the following to avoid ambiguity. (Brandli, Filho 2016.)

1. Clarify the context, scope and goal transparently
2. Clarify the roles, responsibilities and capabilities.
3. Clarify the timeline.
4. Clarify the rules of cooperation to avoid conflicts through misunderstandings.

In addition to the four above clarifications, each stakeholder must know that their opinions and interests were considered and discussed thoroughly. Stakeholder engagement should be taken into sustainable development as partnerships are seen as solutions to many global level multi-stakeholder challenges. As it is more complex to involve stakeholders into an already polished strategy, therefore they should be engaged already during the creation process. (Brandli, Filho 2016.)

There are different ways of engaging stakeholders, depending on the strategy that is being pursued, for example informative approach will only require reports and announcements such as GRI reports, the persuasive method may include meetings and discussions and the most complex method, dialogue strategy, may involve workshops and cross company work teams. The main difference between the informative and persuasive methods are that one requires two-way communication, and the other in only one-way and therefore doesn't require action from the stakeholder. The main difference between dialogue and persuasive methods is that in persuasive, the idea is not to change the way the company is working, but instead change the stakeholder's strategy. In the dialogue strategy, the idea is to include the stakeholder in decision-making and therefore change the way the company operates. Out of all the three ways of engagement, involving the stakeholders in decision-making has proven to be the most beneficial in regard to providing company benefits through win-win situations. (Trapp 2013, 43-45.)

According to a study done by Trapp (2013), the nature of the discussion between stakeholders rarely get into concrete examples of doing, but rather stay at a conceptualizing level. Even when the discussions are about conceptualization, the discussing managers view themselves as listeners and use the information for forming the policies independently. Hence, not involving the stakeholders in the decision-making, but rather to provide background information needed in the policy making. (Trapp 2013, 45.)

2.6 Suppliers as stakeholders

The suppliers play a major role in business, as they are the stakeholder, which provides the raw material for the processes of the business. In some cases, suppliers can even provide finished products for the company. Businesses can be reliant on one supplier (usually niche products) or dependent on multiple suppliers (such as large factories), depending on how specialized the manufactured product is. A small company with a specialized product might rely on a single supplier. This increases the risk, since if that one supplier decides against the customer, the business will have to drastically change their offerings. With a larger set of suppliers, the business may not be as dependent on one supplier. (Martin 2019.)

Customers should have a strong say in supplier products, as the customers are the stakeholders that bring profit to the business. When looking at customers from a supplier point of view, there are a couple aspects that need to be taken into consideration. The two main dimensions of customer request importance are the value of customer to the supplier and the level of attractiveness of the business to the supplier. There are four different possibilities within these two dimensions. In the case that the level of attractiveness is low, and the customer procurement value is also low, the buying company is the lowest in their list of priorities and therefore the actions of the supplier will most likely be reactive. If the customer is attractive to them, but does not provide good value, it is due to potential future value gain. In this situation, the supplier is willing t o invest long-term time and money into the procurement company in the hopes of future value gain. When the customer is attractive, the company is more likely to be proactive rather than reactive. The third situation is when the value of the procurement firm is high, but the attractiveness is low. In this case, the business is most likely going to uphold the relationship with the customer, however, will not make particular effort to increase the cooperation with the stakeholder. In this case, the supplier may even exploit the customer by for example raising prices, when they believe that the relationship with the customer is secure enough. Therefore, the supplier’s actions was more towards the reactive side in the above case. The last and best situation is where the customer is of high value and of high attractiveness. These are usually the core businesses of suppliers and therefore a lot of effort will be put into meeting the needs of these customers. When the customer is of high value and attractiveness, the company is more likely to be proactive. (PressBooks 2009.)

In many cases the knowledge gap between the supplier’s senior management and the procurement company is quite large. Communication from bottom to top of a company is a time-consuming process, which is often not taken to the priority that it should be at. Often employees under the senior executives are measured according to numbers, therefore the time spent on the communication about customer relationships to the senior managers is away from the time that employees could be selling and achieving better merits. This means, that often it is up to the procurement company to initiate a stronger bond between the supplier. Better cooperation is beneficial to both companies, but it is also very time consuming. There will always be a knowledge gap between two different companies, therefore one company will be a forerunner. When the forerunner proactively approaches its stakeholders, the stakeholder has a chance to gain knowledge of the specific field in question, whereas the forerunner will complete its goals with the help of the stakeholder. As the cooperation deepens, the knowledge gap shrinks and the trust between the stakeholders increases, which in turn assists in the verification and trustworthiness of data that might be shared (Klöppfer 2014b). (O’Reilly and Scheuing 2007.)

To achieve long-term cooperation between the supplier and the purchasing party, the supplier must overlook the motive of only making sales and acknowledge that there is more than just the pricing that needs to be discussed. The relationship that is born with the cooperation can be an extremely valuable source of feedback for the supplier. In an ideal situation, mutual performance will be assessed in a positive manner. Therefore, instead of using mutual performance indicators as a way to punish poorly performing firms, it should be used as a way to increase mutual benefit. The assessment frequency can change depending on the type of product and the experience of cooperation. To further improve the cooperation between two parties, the customer will have to open their strategy so the supplier may assist in the achievement of it. The purchasing company should be aggressive towards the supplying company to make them a part of the company’s strategic operations. (O’Reilly and Scheuing 2007)

In the best-case scenario, stakeholder relationships can be achieved that work towards the same goals that are agreed upon by the two different companies. The common goals must be in scope of the cooperation though, as it is highly unlikely that the ultimate sustainability goals of a company are the same. Then when looking further into the implementation of sustainability strategies, environmental assessment tools can be an indicator that is created with the co-operation of the two companies. The environmental assessment tool can be used to increase environmental performance internally and to measure the effectiveness of certain stakeholders. Overall, the tools should be used to measure and develop the path towards a common goal between companies that reflects the values and views of all involved parties.

3 EXISTING ENVIRONMENTAL PERFORMANCE ASSESSMENT FRAMEWORKS

To apply a sustainability strategy effectively, a standardized process either internally or externally must be created to help with assessment, comparing, improving and communicating. This section of the thesis focuses on current environmental performance assessment frameworks. Most of these tools are assessment frameworks of the main type of environmental assessment, the LCA method.

3.1 Life cycle assessment

Life Cycle Assessment (LCA) was first introduced in the 1960’s due to the growing concern of resource depletion (SAIC, 2006). International standards ISO 14044 and 14040 have determined a standard for the process to analyze the environmental aspects and impacts of product systems. In ISO 14040, life cycle assessment has been defined as follows: *“Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle”* (SFS-EN ISO 14040, 2). Life cycle assessment challenges conventional wisdom and may change what is commonly known as environmentally preferable (Klöpffer 2014b, 191). A basic product system is shown in figure 2. (Klöpffer 2014a, 1-2.)

3.1.1 Process of LCA

LCA is a comprehensive environmental and human health impact assessment tool. LCA in its most extensive scope starts from the extraction of raw materials and ends in the disposal of products as waste. ISO 14040 and ISO 14044 gives guidance, requirements and principles to the process of LCA works (ISO 14040:2006 and ISO 1044:2006).With the help of life cycle assessment, instead of focusing on the environmental effects that require our immediate attention, the long-term effects, which can be seen in different forms or places, are also taken into examination (Klöpffer 2014b, 190). Other environmental progress assessment frameworks receive the required data with the help of the life cycle inventory process. For example, environment product declaration or product environmental footprint both base the information portrayed by their reports according to the LCA method (EPD 2018a) (European Commission 2018).

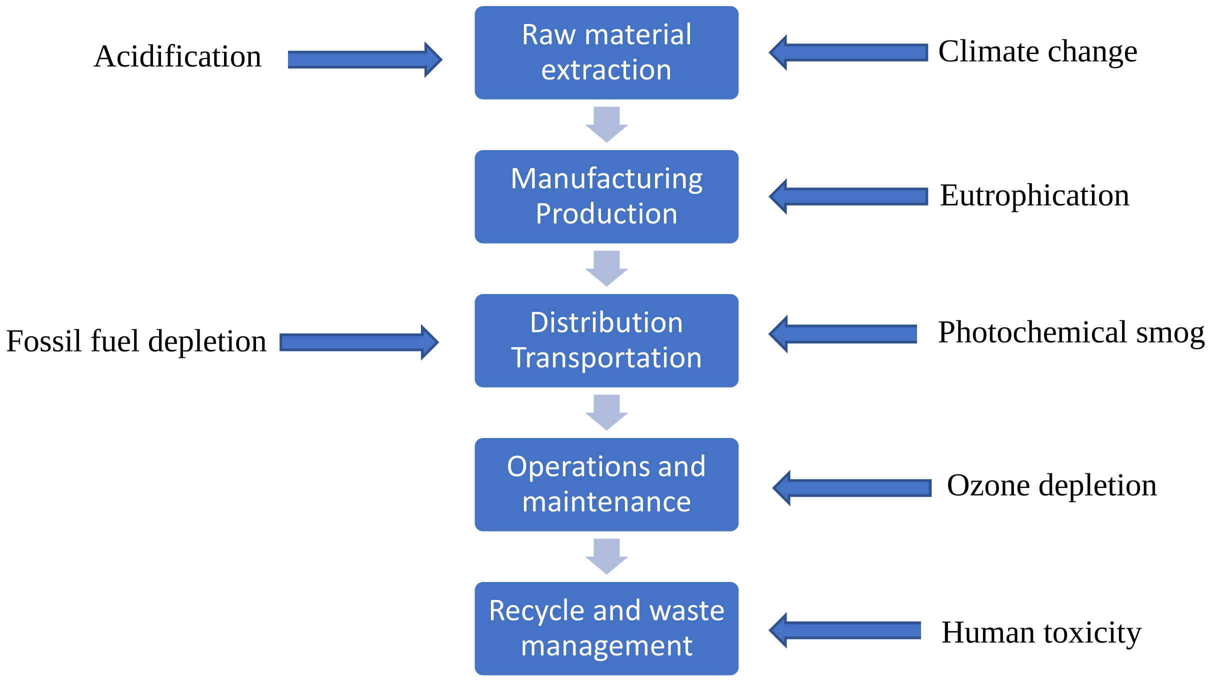

Figure 3: A simplified product system, which is assessed by LCA showing some impact categories of a process. (ICCA, Responsible Care 2014)

An example of figure 2 regarding paper production could be:

Figure 4: An example of possible life cycle assessment stages of corrugated box production

The steps shown in figure 2 is a "cradle-to-grave" type of a life cycle assessment. This type of life cycle assessment takes into consideration everything between the extraction of raw materials to the disposal of the product. Another type of life cycle assessment is the "cradle-to-gate" type, which takes into consideration everything from the extraction of raw materials to when the product leaves production. There are many different modifications of the range of the assessment and it is defined in the goal and scope of the assessment. (Klöpffer 2014a, 2.)

According to ISO, the structure of LCA is: goal and scope definition, life cycle inventory analysis, life cycle impact assessment and interpretation as shown in figure 3 (Klöpffer, 2014, 11-12). Life cycle inventory analysis is "*phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle*". Life cycle impact assessment is “*phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product*”. As shown in figure 3, interpretation stage should be focused on throughout the whole LCA process. (ISO 14044 2006, 2.)

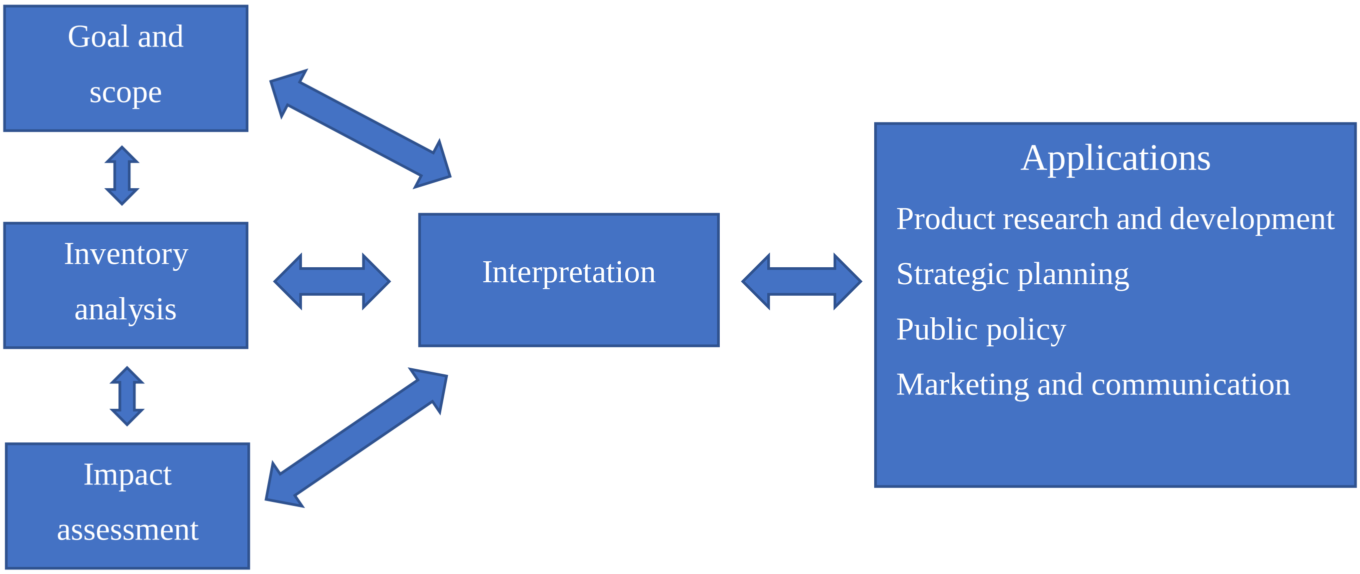

Figure 5: The figure shows different stages of life cycle assessment and the way they interact with each other. (ICCA, Responsible Care 2014)

Life cycle inventory (LCI), is the data collection section of conducting LCA. LCI includes the numerical counting of all the flows in and out of the product system. This includes raw materials, electricity, heating, water, and emissions to water, air and land by specific substance. The assessment that is required in LCI can be extremely complex especially if the assessed process is long and has multiple stages and byproducts. LCI data collection gets very complex since a process can contain many secondary processes and possibly hundreds of different material flows depending on the product and what the goal and scope of the project requires (Athena Sustainable Materials Institute 2018). An example of a complex process can be the production of paper, as it includes many secondary products and a large amount of possible end products.

The purpose of completing the Life Cycle Impact Assessment (LCIA) stage of LCA is to comprehend the impacts of a product or service to human health and the environment through quantifiable indicators. The LCIA part of LCA provides information that is required in the prevention, reduction and remediation processes. The LCIA process can have many different impact categories. Impact categories specify the studied environmental mechanisms to which the specific product is an accelerating factor for. Some impact categories are ozone depletion, ionizing radiation, climate change, toxicity, acidification and eutrophication. The LCIA step was created to cover the three main areas of protection: human health, ecosystem quality and resources. (LC-Impact 2018.)

LCA is currently the most developed environmental assessment baseline and the process is constantly being developed further. The amount of publications on LCA has increased drastically in the past 10 years and two big topics of the publications is the way temporal factors can be taken into consideration and the way bioenergy plays a role in LCA study. The way temporality is considered in LCA study is with yield changes, market response times, carbon payback, process changes throughout the life cycle and carbon storing. The expansion and evolution of the LCA method is facing challenges in four main aspects. The gaps in data and knowledge, implementing dynamic content, lack of comparability due to alternative scenarios and scopes and establishing mechanisms and models. Sometimes companies answer questions with the help of LCA when in practice LCA cannot answer these questions, hence the development of doubt into LCA. The methodology of LCA and the databases for studies has not caught up with the demand. Also, sometimes the tool is used by practitioners who do not understand what the tool is meant to for. This can lead to providing false data presentation and faith is lost towards the tool. (Chryssolouris et al. 2016.)

LCA can be used in many ways to develop and increase the value of products. It opens the company to knowledge about the life cycle impacts of their product, for example if a product uses toxic chemicals, the disposal of the product may be difficult or costly and therefore the company will be encouraged think of alternatives that can provide for the same function but not be as hard to dispose of. The life cycle way of thinking also provides information on the maintenance of products so that they can operate at full capacity and provide the best financial benefits to the customer. LCA can also identify places of weakness and allow for company management to focus on these during development. It can also provide management with common grounds for internal goal setting that support the sustainability strategy. The process of creating LCA becomes easier through the increase of information in databases, therefore as databases and availability of information increases, so does the amount and outcomes of LCA. (Root III 2019.)

3.1.2 Limitations of LCA

LCA is the most developed method for environmental assessment so far, however not without the need for improvement. The biggest problem in LCA is that the quality of data is very hard to be verified properly, and the quality of data influences all the four different stages of the LCA. Some standards do not provide a specific way to communicate, estimate, interpret or manage uncertainty of data. Data quality can include data gaps, proxy or unrepresentative data, data inaccuracy, model inaccuracies or inaccuracies from choices of modelling. Inventory analysis brings forth the biggest problems in data collection. It can be very costly to keep the data up to date, or even collect the data in the first place when it is not readily available, therefore the need for LCA study will be questioned against economic benefits. Data can be considered confidential due to multiple reasons and can therefore limit the amount that can be shared. Even if the data is released to the practitioner, the reliability, collection method, accuracy and the frequency of measuring is hard to confirm. The different databases and methods of calculation also provide very different results and therefore the emissions caused by the same process can be different when a different database is used (Chryssolouris et al. 2016). The difference can differ by 2 to 4 orders of magnitude. however if the same method and database is used, usually the most harmful product will remain the same (Chryssolouris et al. 2016). Some of these databases are not easily accessible and maybe not even peer reviewed to provide reliable data. The quality and collection of data is the biggest problem when conducting LCA study, but in addition all the different stages of the process present their own challenges. (Michalski 2015, 1, 15-16)

In the goal and scope definition, parts of the life cycle of the product may be consciously chosen to not be included in the scope of the project, giving uncertainty in the results due to choices made by the practitioner. Also, the current most common environmental LCA does not consider all necessary aspects such as social or economic impacts. There can also be economic and social trade-offs for environmental performance, which are not considered in the process. Life cycle costing has been attempted to be integrated with LCA, however it has proven to be extremely difficult without even taking the social aspects into consideration. (Michalski 2015, 6.)

The functional unit is also set in the goal and score part of LCA and in the case that a product has multiple uses, the sub-functions are often ignored. Boundaries are also selected in the first stage of life cycle assessment, and in an ideal situation, the boundaries would be set to assess the whole life cycle of the product. This however cannot always be done due to time, financial and resource constraints. The boundaries also vary with the amount of life cycle stages, impacted geographic area and the time horizons. The modification of boundaries can mean that the study does not reflect reality adequately and therefore cannot be compared and possibly not even interpreted correctly. Most standards however do require justifications and maybe even sensitivity studies in case specific parts of the life cycle are left out. Sometimes the practitioner may even be forced to set boundaries according to the availability of data. The boundaries are set by the practitioner and since the practitioner may also be third party consultants, the chances that they know the product perfectly may be quite low, and therefore important parts of the product life cycle may be cut off the study. Often when doing a life cycle assessment of a product, the null alternative or the current situation is not taken into consideration, therefore the carbon handprint would be a good alternative that helps review the positive and negative impacts of change. (Michalski 2015, 7-8.)

Allocation is the most controversial topic in LCA. There are multiple different ways of allocating and some of them are guided by ISO and other organizations, however the guides do not provide a general solution to allocation. Subdivision works well, in the case that the processes are economically and physically independent of each other, however this is rarely the case. Allocation can be avoided with the system expansion approach, which there are two of, the avoided burden approach and system enlargement. The avoided burden approach offsets a demand for virgin material (PE International 2014), where as in system enlargement the co-products are considered replacements to alternatives on the global market (Q-PorkChains 2019). (Michalski 2015, 8-9.)

The topic of assessed impact categories in LCA is another controversial issue. Different practitioners spawn different lists of impact categories, therefore there are multiple impact categories, which also lack standardization and therefore lead to misuse and possibility of ignoring important impact categories. The lack of data to support the way the impacts are assessed, avoiding a category and the unintentional ignoring of a category makes impact assessment prone to errors. Once impact categories are chosen, the indicators for the categories are often not agreed on by practitioners due to multiple reasons. If some emissions are the cause of multiple impacts, they can also sometimes be “double counted” through flaws in models. Double counting problems tend to be less significant as programs and models develop. (Michalski 2015, 10.)

When assessing the impacts of emissions, spatial variation becomes extremely important. Cities or countries with different topographies and land cover all react to emissions in a different way. It is important to note that even when using the same method of calculation and same database, the impacts of the output flows can be different due to different availabilities of raw materials (Chryssolouris et al. 2016). The emissions can also be transferred to many different locations through air, water or land and different environments have different buffers for environmental impacts. This creates the need for different types of LCA, site-generic, site-dependent and site-specific. Site-generic is global and assumes every environment is the global average, site-dependent uses different values for different sites and site-specific focuses on local information and reactions. Also, topography alterations influence the way emissions move in air and the erosion resistance of land. (Michalski 2015, 11-12.)

Temporality is another important aspect that must be considered but is often not. Sometimes the effects of environmental damage can be time-lagged and therefore happen years after the emission has taken place. Temporality also plays a role in the rate of release of emissions and when the emissions are released, for example the severity of some emissions can be more damaging during the summer than winter. Most LCAs lack the ability to assess the history of a site and therefore it is very hard to assess the importance of an impact. (Michalski 2015, 12-13.)

Weighting is subject to human opinion, as the practitioner ranks the importance of each impact category. As it is based on an opinion, the reproducibility of the results can be hard to achieve when weightings and opinions change according to time and importance. Normalizing and then aggregating the results is one option. The collection of data can consist of bias, which is divided into two categories, behavioral and procedural. Procedural bias is the bias caused by information collection techniques, such as wording in a questionnaire or choices of preferable references. Behavioral bias on the other hand is the bias caused by decisions made throughout the process (Onestat 2015). Uncertainty can be categorized in three types, parameter uncertainty, model uncertainty and uncertainty from decisions (Hauschild & Huijbregts 2015, 11). Parameter uncertainty is the imprecision in the collection of data through limited sample sizes, measurement errors or analytical imprecision (Hauschild & Huijbregts 2015, 11-12). Model uncertainties is the lack of knowledge about the relations and mechanisms being studied and the simplifications of them into models, causing it to stray further away from reality (Hauschild & Huijbregts 2015, 12). Decision uncertainty reflects the uncertainty caused by practitioners. Often uncertainty is quantified, but there are times when it cannot be quantified, and practitioners tend to only take into consideration the quantifiable uncertainties. (Michalski 2015, 13-14.)

LCA methodology is largely growing and so are standards that relate to it. The standards and tools try to tackle the above problems by using a set of rules that practitioners must follow to complete the study. Most of the following tools are based on the LCI stage of the LCA process and set their own criterion on the way data is collected and processed. Methods can be either only assessments, and therefore do not make judgements according to the results, or they can be result based and make judgements according to the results. The standards or guides provided by the tools tend to say what to do but does not go too deep into how it can be done. This thesis will continue on to assessing the different types of standards and provide some general information about them.

3.2 Paper Profile

Paper Profile is a voluntary internationally recognized tool for some environmental parameters for products. Paper profile takes into consideration a limited amount of information in comparison with a full LCA with many impact categories. The relevant environmental factors included are the product composition, manufacturing environmental load, environmental management and consumption of electricity. Instead of focusing on a large amount of emissions, the hotspots have been identified beforehand and then the study is focused on those. Paper profile is administrated by Europeans leading paper and board manufacturers. (Paper Profile 2018.)

Paper profile includes the assessment of raw material extraction through forest management certifications such as FSC and PEFC. The values are received as primary data from individual production-lines, but the framework provides workarounds in the case that primary data is not available. Paper profile provides a template for the communication of emission values. Some values can be marked as “not available” in the case that suppliers cannot provide more than 75% of the data. (Paper Profile 2018.)

The data used in the creation of a paper profile must be consecutively sampled for at least three months of production. The data received from external suppliers is considered reliable when the supplier is certified by an Environmental Management System (EMS). The data must be supplied as formal statement signed by an authorized representative from the supplier, but no further auditing has to take place. The allocation of emissions must be production-line specific so that all the emissions add up to 100%. Manufacturing process contains all the operation of the mill, which is related to the creation of the product, such as waste water treatment, waste disposal, extraction of raw materials and manufacturing. (Paper Profile 2018.)

Paper profile does not include any normalization or weighting steps, nor does it tie the emissions to any specific impact category. Paper profile is not third party audited, nor does it take locations into consideration. The lack of normalization and weighting makes the creation of a paper profile easier to do, however leaves the data to the interpretation of the reader. In the case that the reader is not educated in environmental technology, it is possible that the meaning of the values is lost. Paper profile includes assumptions such as that 50% of wood is carbon, to simplify the calculations. Paper profile is a good communication method of environmental statistics on hotspots, however it does not provide extensive information on what the effects of the values are and on what scale. It is therefore viable for the assessment of paper used for corrugated boxes and can be used as a stepping stone towards more comprehensive studies.

3.3 Carbon footprint

The carbon footprint of a product is defined as follows according to ISO/TS 14067:2013: "*Sum of greenhouse gas emissions and removals in a product system, expressed as* CO_2 *equivalents and based on a life cycle assessment using the single impact category of climate change".* Therefore, the carbon footprint is a full LCA, in which instead of multiple impact categories, only one impact category is assessed. The ISO standard of the carbon footprint is administrated by the ISO; however, verification by an independent third party is not mandatory. Unless third party verification is practiced by the company voluntarily. (Finnish Standards Association SFS 2014, 2.)

There are plenty of carbon footprint and ecological footprint calculators online, which gives the carbon footprint according to quantifiable answers to a couple questions. This however is an extremely simplified version of calculating the carbon footprint and not viable for business footprint calculations. The business to business calculation of a carbon footprint includes the collection of LCI data and analyzing the results against the climate change impact category. There are many methods of calculation, for example the Confederation of European Paper Industries (CEPI) ten toes framework, GHG protocol and ISO 14067 (PRé. 2012). All these standards provide guidance on how to conduct LCA study with climate change as the impact category (PRé, 2012). The issues of biogenic carbon emissions, soil carbon change, land-use change, carbon uptake and green electricity is in a major role in the conducting of carbon footprints and these standards provide their own view on these topics (PRé, 2012). Despite the cooperation on developing the standards by these different organizations, the documents do have differences.

The carbon footprint can be a good tool for the assessment of paper used for corrugated boxes regardless of which standard is chosen. The reason is not because the carbon footprint is a comprehensive study, but more that it can be used as a great stepping stone towards a more comprehensive study. Even though the carbon footprint only considers the impact category of climate change, it can be used as a tool to initiate information sharing between stakeholders and then when the relationship is developed enough for more comprehensive studies.

3.3.1 ISO 14067

The ISO standard 14067 is a standard that was announced in 2013 and guides the process of creating a carbon footprint. The ISO 14067 is the vaguer standard out of the carbon footprint standards, however it does provide specific requirements for some aspects such as the use of green electricity (PRé, 2012). The P AS 2050 and the GHG Protocol standards are both more specific with their requirements than the ISO 14067 (PRé, 2012). This means that the ISO 14067 has more space for interpretation and provides less guidance on the topic (PRé, 2012). None of these three standards accept the use of carbon offsetting to reduce the GHG emissions of a product. The ISO 14067 gives a general description of the qualities of the report that portrays the results but doesn’t go further into detail about it. (ISO 14067, 2018.)

The ISO 14067 is a general guidance document and it mentions that if relevant Product Category Rules (PCR) is available it should be used in the case that it applies to the rules of the ISO standards. Leaving out different parts of the life cycle of the product is allowed, however only if it does not significantly affect the outcome of the study. As a general rule, to make a carbon footprint based off of the ISO 14067, the best data available must be used but secondary data is also acceptable if primary data is not available. The standard also encourages the avoidance of allocation through system expansion or dividing the process into sub-processes. If allocation cannot be avoided, the allocation method is free, however must reflect the underlying physical relationships of the two products. (ISO 14067, 2018, 23, 29.)

3.3.2 PAS 2050

Publicly Available Specification 2050 (PAS 2050) is a standard developed by the British Standards Institutions and have been active since October 2008 (PRé, 2012). Since the publishing of the standard, it has been revised and developed. Recent developments have made the PAS 2050 more in line with the GHG Protocol (PRé, 2012). The PAS 2050 is applicable to organizations who are assessing the cradle-to-gate or the full life cycle impacts of a product on climate change. The demand for a standardized method to measure the emissions of goods and services is the reason that the PAS 2050 was developed. PAS 2050 is based off the ISO 14044, but provides further instructions on the way to measure GHG emissions. The benefits of applying the standard includes internal assessment of products, facilitates the evaluation of alternative methods throughout the process, provides a benchmark for improvement, allows comparison between products and supports reporting. The PAS 2050 attempts to provide quantification according to a standard that can be used by customers to compare the impact of products. (PAS 2050, 2011.)

The PAS 2050 takes into consideration both, the amount of emissions emitted, and the amount of emissions absorbed. The standard provides a list of all the different emissions that must be included. Carbon dioxide removals through land use can be troublesome due to lack of data, however PAS 2050 provides a table of data for specific areas and if the area is not mentioned in the table, the GHG emissions and removals due to land use change will be calculated. Carbon offsetting is not allowed either in the ISO or PAS standards. The PAS 2050 requires a 95% completeness in emission and removals data. There are also different rules set about the reassignment of emissions in the case that the process is changed according to plan or not according to plan. The data is valid for a maximum of two years from the assessment. The PAS 2050 does not consider biogenic emissions to be zero-emissions and therefore includes emissions form the production of biogenic fuel and the incineration emissions in its calculations. If the product gets to be reused, the PAS divides the total life cycle GHG emissions (excluding use phase) and emission arising from disposal by the amount of times that the product was used. Therefore, the product in question gains a high advantage in the case that it can be reused multiple times. (PAS 2050, 2011.)

3.3.3 CEPI Ten Toes

The framework has been developed by CEPI. The ten toes framework is a carbon footprint calculation method, which focuses on paper and board. CEPI ten toes identifies ten different elements that must be examined when calculating a carbon footprint. The framework acknowledges that one size does not fit all and making more specific choices at the CEPI level may benefit some companies and limit others. For this reason, the CEPI framework guideline is made as a baseline for companies to further address their individual needs. The goal and scope of the project is extremely important, as a study that is conducted to find points of improvement can be very different when compared to a study that has a goal of assessing the total life cycle emissions and sequestrations of a product. The CEPI ten toes document itself provides a list of five general points of guidance and ten key elements that must be included. Each of the 10 key elements reflects to processes of making paper and the methods of calculation is explained. The key issues or discussion points have been pointed out by CEPI for each of the 10 elements, reducing the amount of contemplation a company must do. The CEPI brings a new aspect to carbon footprint calculation, the aspect of how much of the emissions a company has control over. The idea of not involving the emissions that a company does not have control over is a very controversial topic, as emissions are still emissions regardless of whether the company has control over them. The CEPI ten toes method is a good standard to use for the assessment of paper used for corrugated boxes. (CEPI, 2007.)

3.3.4 GHG Protocol

The Greenhouse Gas Protocol was published October of 2011 by the World Resource Institute and the World Business Council for Sustainable Development (PRé, 2012). The protocol is a multi-stakeholder partnerships which includes businesses, governments and non-governmental organizations (WRI & WBCSD, 2011). The guideline has gone through tests by 60 different companies and is adapted off the ISO 14044 and PAS 2050 standards (PRé, 2012) (WRI & WBCSD, 2011). The GHG protocol life cycle standard does claim that it does not support declarations of environmental superiority with the help of the guideline (WRI & WBCSD, 2011). The guideline is not directed straight towards paper and board and therefore can be applied to many different groups of products (WRI & WBCSD, 2011). The GHG protocol is not only a cradle-to-grave LCA guideline, but it also guides companies with decision-making and identification of business goals (WRI & WBCSD, 2011). The range at which the GHG Protocol works on starts all the way from defining business goals and ends up to the point of setting reduction targets according to the reporting of inventory results (WRI & WBCSD, 2011).

3.4 Product environmental footprint

The Product Environmental Footprint is project under development by the European commission. In December of 2010 the goal of the European commission was to "*develop a common methodology on the quantitative assessment of environmental impacts of products, throughout their life-cycle, in order to support the assessment and labelling of products".* Therefore, the commission will establish two frameworks to measure sustainability, the product environmental footprint and the organization environmental footprint. For the purposes of this thesis, the product environmental footprint will be assessed as the organizational environmental footprint is too broad and not an assessment of one product. (European Commission 2018a.)

The PEF guide provides insight into modelling environmental impacts of flows of material and energy in the life cycle of a product (Virolainen, 2014). The PEF guide discusses how to create Product Environmental Footprint Category Rules (PEFCR). Product category rules are more specific guidelines into the life-cycle calculations of specific products. To create a product environmental footprint, the product must be assessed according to the category rules that are specified to the product in question. The final draft of PEFCR for intermediate paper has been submitted for stakeholder consultation in May 2016. The current process in the creation of PEFCRs has seven steps: Defining the product category scope and the scope of the PEFCR, definition of the product model based on existing representations, PEF screening, Drafting, PEFCR support studies, confirmation of benchmarks and performance classes and the final PEFCR. Figure 4 shows the stages and relevant information about processes. (European Commission 2018b, 32.)

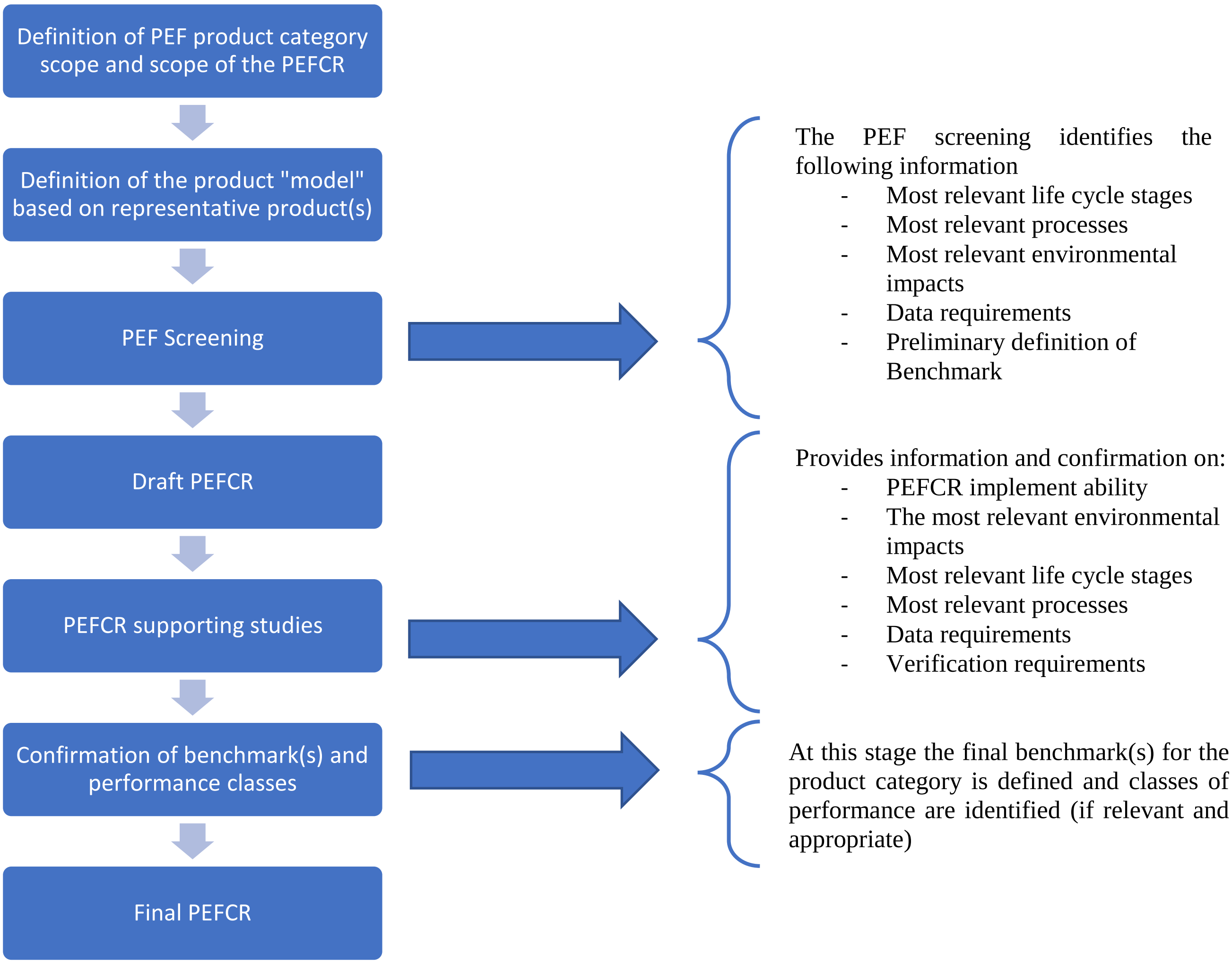

Figure 6: This figure shows the stages and relevant information about the processes of creating a PEFCR. (European Commission 2018, 32)

The development of a PEFCR is not done by the European Commission alone. The development has a transparent and open consultation format between relevant stakeholders. In this case, with paper used for corrugated boxes, the stakeholders could be the suppliers, customers, consumers, public agencies, certification bodies or governmental representatives. Even the Environmental Product Declaration (EPD) System is involved in the development of PEFCRs (EPD 2016). (European Commission 2018b, 27.)

The main application of the PEF could be a tool for optimization of processes and products, a benchmark tool for development, an assessment framework for environmental performance or as an incentive program. The applications could be mandatory or voluntary and have been tested in pilot programs. (Virolainen 2014.)

The PCR provided by PEF is a great tool for the assessment of paper used for corrugated boxes. This is because it is specifically created for it and provides specific rules that must be followed. It will be a costly process depending on how far developed the gathering of information already is but will provide benefits once the study has been conducted. More specific rules in standards tend to provide a better baseline for comparison of products and therefore more market value, hence the PEFCR being a good tool to invest into. If the knowledge of environmental assessment is not too high, it may not be realistic to initiate a PEF study, as the requirements demand extensive knowledge of environmental impacts and information gathering.

3.5 WWF check your paper

WWF Check Your Paper (CYP) is a simplified method to check the environmental performance of the paper the company produces. It evaluates the forest, climate and water footprint of pulp and is under the administration of WWF. The approach of CYP is cradle to gate, since it does not take into consideration the use or disposal stage of a paper’s life cycle but includes the landfilling of manufacturing waste and emissions. Check your paper evaluates three different aspects of paper production: fiber sources, emissions to water, ground and air and quality control. Each of these categories are rated in points, where fiber sources are worth max 40 points, emissions are max 50 points and environmental management systems 10 points, equaling to a total of 100 points. The amount of database information behind the results is high to make the tool user friendly. (WWF 2018a.)

In the fiber sources step, there are several assessment criteria. It is possible to achieve a full 40 points in fiber sources by having 100% of the virgin fiber used be under some certification such as FSC. Another approach to achieve a full 40 points is by the production of a product, which contains 100% post-consumer fiber. Unfortunately, pre-consumer fiber, which is defined as residues generated during intermediate steps in the production of a product, usage can only award 20 points out of the maximum of 40. (WWF 2018a.)

The emissions step of CYP quantifies the emissions to air, ground and water that the final paper product causes. CO_2 acts as the emission to air and the assessment includes the CO_2 emitted during the production of energy in power plants, which provide the energy for the machinery. It however excludes the CO_2 emitted during the harvesting of wood or forest management and transportation of goods. In this case, CO_2 is carbon dioxide originating from non-renewable sources on a human timescale. It is measured in the unit Kg_{CO2}/T of product. Other greenhouse gasses such as methane is addressed within the landfilling parameter, and SOx emissions are not addressed at all, because it is seen to fall under an “umbrella” parameter, CO_2 emissions (WWF 2018b). (WWF 2018a.)

The emission to land is the amount of waste residue that is transported to a landfill on or off-site. The measurement unit is Kg_{waste}/T of product. Lastly the emission to water is calculated by two different values, the amount of Absorbable Organic Halides (AOX) bound to organic compounds in waste water, and the Chemical Oxygen Demand (COD), which is the amount of oxygen needed for chemical oxidation, in outgoing waste water. The AOX amount is measured in Kg_{AOX}/T of product. (WWF 2018a.)

The last step, quality control, is assessed by the percentage of pulp in paper products or market pulps that is manufactured in EMS certified mills (ISO 14001, Eco-Management and Audit Scheme, or equivalent third-party audited systems). Quality control also takes into consideration the percentage of paper in paper product manufactured in EMS certified mills. (WWF 2018a.)

CYP allows 10% of the data to be missing during the first calculation, however later calculations will reduce the percentage to 5%. Due to the simplicity of the tool, CYP provides information to a limited number of focuses and some critical data is missing due to lack of generic information. An example of this is the impact of coating and fillers in the paper produced has not been considered even though the additions have significant impacts on the environment when used. (WWF 2018b.)

CYP is a viable tool for the assessment of paper used for corrugated boxes. It focuses on topics that are relevant for multiple impact categories, however, does not inquire further into the actual impacts of emissions. It may be too dependent on generic data for clear comparisons to be carried out. Since it is dependent on generic data, it does provide a simple, cost effective and user-friendly interface. It also omits some important data, which can also work as a benefit for the implementation of the study, since data collection can be a large challenge. It will be hard to draw clear conclusions and reliable from the CYP results.

3.6 Environmental product declaration

The EPD is a sustainability framework, which portrays transparent and comparable information about the life cycle environmental impacts of a product. Having an EPD does not imply that the product is environmentally superior to others (EPD, 2018a). Different categories of products are given different rules, the same way as in PEF, called the PCR. PCR contains different requirements, rules and guidelines for the development of an EPD. The main goal of a PCR is that companies can produce consistent results when assessing different products of the same category. (EPD 2018b.)

A PCR for corrugated paper and paperboard was created in 2017. The PCR requires separate calculations for three different life cycle stages: cradle-to-entrance, gate-to-gate and gate-to-grave. The first stage is raw material extraction and production, second stage is the manufacturing of the product, and the third stage is the use and disposal stage of the product. The stages are called upstream, core and downstream processes respectively. The different stages are reported separately. (EPD 2017.)

The upstream process includes the production and processing of paper starting from forestry. The upstream process takes into consideration possible recycled materials, which are transported to the manufacturing process. The environmental impacts of fuel, energy, auxiliary products such as detergents, production of other raw materials and primary and secondary packaging are also calculated. (EPD 2017.)

The whole core process is considered. First, the raw material must be transported to the manufacturing site. The raw material is then processed into pulp, afterwards to paper and finally to corrugated board and paperboard. The paper and paperboard can be further processed by being printed on, coated by pigmentation or being cut into packaging shape. The environmental impacts of the production of electricity used in the process needs to be documented. In the case that the electricity is externally produced, the emissions caused by the production must be calculated. If materials are burned during the manufacturing process, the emissions caused by the burning of fuel must be calculated. If waste is being treated throughout the process, the emissions caused by the process are included in the overall calculation. The downstream process takes three different steps into consideration: the transportation of the product to its end user or distribution channel, the transportation of waste to waste processing site and the possible processing of that waste. (EPD 2017.)

There are requirements to what needs to be included in the study and what can be left out. The manufacturing of process machinery, the building of buildings that the process takes place in or other capital goods that are not required. The traveling of employees to work and back or mandatory business travels of is not included in the study. The research and development that has been done to make the manufacturing of the product possible is excluded. The LCI created must reflect the time that the EPD is valid, which is a maximum of three years. The data for the core process, must be from where the process takes place. The data itself should consist of at least 99% of the inflows and outflows and the flows that are not in the data need to be documented. This however does not mean that the last 1% of flows can be used as a way to hide information, but rather make data collection easier. (EPD 2017.)

The emissions must be allocated to any specific product throughout the whole manufacturing process. The allocation process is simplistic in theory for corrugated paper, as any by-product that is created in the manufacturing of paper is usually fed back into the process, therefore no allocation is required for these products. In the case that by-products are created for commercial use; the emissions need to be allocated accordingly, or better yet the emissions caused by the by-product can be specifically calculated by subdivision. System expansion is not allowed in order to avoid allocation, even when it is allowed according to the ISO 14044 standard, because the EPD is based on attributional life cycle and modularity. In the case that allocation cannot be avoided by calculating the emissions caused by the by-product, the allocation rules in ISO 14040 will be implemented. Allocation can be done by comparing the different products according to the relationship between the product and the raw materials used in the process. The products can also be allocated according to the relationship between the functions and products, for example according to the economic value of the products. In the case that economic allocation is chosen, a sensitivity analysis needs to be conducted in order to monitor the possible changes in the results of the allocation process due to market changes. Allocation by mass can also be used when relevant and justified. If allocation according to mass is used, it must be clearly stated. (EPD 2017.)

Primary data is used for core processes. This is for example the mass of raw materials, amount of electricity or other resources of the process. The emissions caused by electricity can have specific data according to different sources. The process that performs the best in environmental criteria is the process that is using renewable energy sources, in this case the renewable energy supplier must have its electricity documented by guarantees of origin or renewable energy certificates. The second approach is to have information on the electricity mix provided by the electricity supplier. The third and least accurate way of calculating the emissions caused by electricity production is by using the national electricity emission values in the area of operation. The chosen method must be documented. (EPD 2017.)

EPD has set limitations to the data qualities that can be used. The data that is used must be adequate in terms of quality, completeness and representativeness. The reference year for the data must be as defined as possible and preferred to be within the last 5 years. As mentioned above, the cut-off criteria must be met, which is that 99% of the energy, mass and overall relevance of the flows must be shown in the calculations. The data must be complete, therefore every elementary flow that influences the impact categories must be studied. The representativeness of the information must in general be lower than +/-5%. Representative is a small piece of data, which represents a larger data set, therefore any given data should differ from the mass by a maximum amount of 5%. In the case that system expansion is required, the negative flows should be changed to zero. Also, if data that is approved by the EPD cannot be found, it can be used, but must be documented and cannot exceed over 10% of the total data. (EPD 2017.)

Overall the EPD PCR would be very viable for the assessment of paper used for corrugated boxes, as the PCR focuses clearly on the intermediate paper and sets quite specific guidelines for the assessment. The summary of the guidelines above is to give an idea of what kind information the standards provide. It can be quite costly to conduct the study and the chances of creating a conclusive comparison between products is slim due to differences in data quality and availability.

3.7 North American PCR

FPInnovation is a non-profit organization specializing in providing scientific solutions for Canadian forest sector companies. FPInnovation provides solutions to complex problems, including the life cycle assessment of paper products. The PCR created by FPInnovation is for the North American market pulp, paper and paperboard products, tissue and containerboard. (FPInnovation 2018.)

The main goal of the PCR document is to create a guideline for conducting LCA and developing EPDs. The document is meant to create business-to-business communication but does not provide comparison between different types of paper or pulp types due to the difference in grades and qualities, and therefore the use of the product. (FPInnovation 2017.)

When comparing North American PCR to the EPD PCR, the North American PCR is more of a guideline instead of a standard. The North American PCR is very well suited for the paper used in corrugated boxes and has simplified rules when compared to most standards. This method may be used as a tool with stakeholders, however further communication and specification development between the included parties is highly encouraged.

3.8 Ecolabels

EU-Ecolabel is a voluntary ecolabel with different criteria for multiple different product categories. The ecolabel is administrated by the EU commission. There is a different eco-label called the Nordic Swan Ecolabel administrated by the Nordic Ecolabelling, which is directed towards the Nordic countries: Denmark, Finland, Sweden, Iceland and Norway. The different product categories provide specific criteria for the product category. Some criteria are mandatory, while others are based on points given and in addition to all the mandatory criterion, a certain amount of points needs to be achieved to successfully receive the ecolabel (Nordic Ecolabelling, 2013). The criterion and requirements differ according to the product category in question. Ecolabelling helps companies find products, which has reduced its environmental impact throughout its life cycle. EU-eco-labelling takes into consideration the whole life cycle of a specific product. Each application for ecolabels is checked by an expert before the approval of the label. Ecolabel criteria is constantly being upgraded to be stricter according to the developments of environmental assessment. (European Commission 2018c.)

The requirements can help steer the environmental performance of a product into the right direction. In the end however, the label is either received or not received and it can be used as a marketing tool. When looking at the EU-Ecolabel and the Nordic Swan label from the paper used for corrugated boxes' point of view, the closest categories are printed paper, graphic paper, converted paper and tissue products. Unfortunately, the focus of these stray away from intermediate paper production and focuses more on the final product. Converted paper may be the closest category, however overall ecolabeling is not focused enough to paper used in corrugated boxes to be applicable for this study, hence won't be a part of the assessment in section 6.1.

4 LCA IN PAPER USED FOR CORRUGATED BOXES

When conducting a LCA study, the goal and scope of the study should be clearly defined. To define the goal and scope of the study, the life cycle of the product should be researched, so that hotspot identifications can be done beforehand. Once the hotspots have been identified, the LCA can then focus on the areas of interest, which usually have the most improvement potential. To further clarify, which stages of production is most crucial for assessment, the general life cycle stages of the production of paper used for corrugated boxes have been explained below. The below process gives an idea of the different raw materials and chemicals that the process can involve.

4.1 Life cycle of corrugated boxes

A corrugated box is a product used in packaging of products, it provides strength onto packaging material without the excess usage of raw materials. The manufacturing of corrugated boards consists of taking virgin and/or recycled pulp and making them into layers called Fluting Medium or Linerboard. The combination of fluting medium and liner creates the structure for corrugated boxes. There are different number of layers that can provide different performances for the product. This is one example of the lifecycle of a corrugated box, some processes may differ from the following. (FEFCO 2018b.)

4.1.1 Upstream: acquiring of raw materials and manufacturing of paper

The raw material in the production of virgin paper for corrugated boxes is wood. Majority of the wood is transported in the form of pulpwood logs, which must be debarked in the barking drum and chipped in the chipper before further processing. Some wood is also transported as ready wood chips from saw mill. The chips are screened during the process to eliminate the amount of saw dust, knots and oversized chips. Oversized chips are not directed into residues, but instead fed back into the process to eliminate the amount of residual waste from the process. The correct-sized chips are stored in chip stores on the premises before being fed into the pulp making process. (FEFCO 2018a.)

The wood chips are usually cooked into pulp for the kraft cooking process. Sodium sulphide and caustic soda act as the cooking chemicals in the highly alkaline cooking process. The mass is cooked in a digester in high pressure conditions and at a temperature of 150-170 ºC. When the cooking process is provided with one ton of dry wood, usually around 550kg of pulp comes out depending on the chemicals and process conditions used. (FEFCO 2018a.)

The production of pulp for corrugated medium is cooked in a slightly alkaline solution and provides a good yield of pulp. Sodium sulphite and sodium carbonate are usually used as the cooking chemicals for the semi chemical cooking process. After the cooking process, the cooking chemicals along with the dissolved wood substance gets washed out of the pulp, concentrated and burnt for steam production and recovery of cooking chemicals. (FEFCO 2018a.)

The highest source of raw material for the process in Europe is recycled corrugated boxes. In 2014, the percentage of raw materials that were recycled was 88% (FEFCO 2015, 16). The preparation that the recycled paper requires is required is slightly different from the preparation of wood. In the recycling process, the first step is quality and contamination control, in which plastics and other harmful materials for the process are filtered with different techniques. Once the bigger impurities have been cleared, warm water from the main process is added along with mechanical energy to start breaking down the corrugated boxes further towards a pulp-like state. In the case that there are some lightweight grains of sand for example, centrifugal techniques can be used to remove those. The pulp is filtered through smaller and smaller filters, until it is almost exactly like pulp. Approximately 85-95% of the material that is received can be used for the main process. Paper from recycled fibers is weaker than that, which is made from virgin fibers. (Ncasi 2017, 68-70.)

After, the pulp solution gets transported into the head box of a paper machine. From the head box the pulp gets pressured onto the wire, in which the pulp is dewatered by gravity and suction, and paper is formed. At this point the paper is still moist but has the characteristics of paper. Further dewatering is required to increase the strength of the paper. Dewatering is done in the next process where the sheet of paper is pressed between two felts. To achieve a dryness level of 91-93%, the sheet of paper transfers through the drying section of the paper machine, where the steam heated cylinders press against the sheet of paper. All the water is then gathered and reused for diluting in the former process steps. (FEFCO 2018a.)

The paper machine has options to tailor the paper type according to the need of the customer. This means that the paper can be coated with various substances to give the final product different properties.

4.1.2 Core: manufacturing of corrugated boxes

Paper used for the fluting medium is shaped into its wave-like shape with the help of moisture, heat and pressure. Glue is used with the help of pressure to attach the tips of the fluting medium to the flat surface of corrugated boxes called liner. The quality and consistency of a corrugated box is measured according to the performance of the corrugator, containerboards and glue in unison. (RISI 2017, 15.)

Corrugated boxes are usually used for the transportation of products; however, it does not only limit to that use. Corrugated board can be used for applications such as inserts, displays and primary packaging. The main function of a corrugated box is to protect the product, the environment around the product and provide a surface to display information. Corrugated boxes are ideal for warehousing as its lightweight and rigid, which provides an ideal structure for stack ability. (RISI 2017, 16.)

Corrugated boxes can have different properties according to what its final function is. The way to achieve these properties are divided into categories. The basic types of corrugated board are single-faced, single-wall, double-wall and triple-wall. Adding more layers corrugated board and liner increases the strength and durability of the board significantly. (RISI 2017, 16.)

The gluing process is taken into careful consideration because it has a very high effect on the final quality of the corrugated box. For the glue to make a good bond between the liner and the flute, the time, temperature and pressure values need to be carefully balanced. Consistent quality requires a carefully monitored and controlled system. The temperature of the board needs to be high enough, that it allows the gelatinizing of glue with the presence of water and the evaporation of water from the cardboard itself. The heating plates at the end of the process determines the final flatness, as the glue strengthens and eliminates the moving parts of the product. The moisture of the containerboard needs to be constant, to avoid the bending and/or warping of the final product. (RISI 2017, 21-22.)

The corrugator is a production line, which gives the fluting medium and linerboard its fluted shape with starch and containerboard reels. Before being fed in between the corrugating rolls, the paper material is preheated and steamed to prepare the paper for the corrugating rolls. The two corrugating rolls are positioned so that the convex shape in one roll fits into the concave shape of the other roll. This will cause a wavy texture to the paper, which provides the main strength in corrugated boxes. After the wavy texture is applied to the paper, the crest of the wave comes into contact with starch. The starch acts as the gluing agent in the process. After the crest has been dipped into starch, it gets pushed against a paper sheet, which in turn is against a pressure roll. (FEFCO 2018b.)

The process can be altered in many ways to suit the needs of the customer. Different designs can be printed on corrugated boxes, such as the barcodes of the products that will be distributed in the package. After the heating plates, the corrugated box material is ready to be cut into specifications provided by the customer. The slitter cuts the corrugated paper combination into required lengths and widths. The rotary knife can be modified in many different shapes and is modified depending on the shape requirement and the design of the corrugated box. The flute type can also be modified according to the function that the corrugated box needs to fulfill. (FEFCO 2018b.)

The corrugator is a series of machinery, which work together to produce corrugated board. The process is continuous to maximize the productivity. The units within the corrugator process are not technically connected to each other, therefore they can be provided by different manufacturers. This also allows the possibility of updating a specific part of the machine. The speeds, at which the corrugator produces corrugated board, has increased by the updating of machinery, however the general process has remained the same for the last 100 years. Modern controlling systems and automation can cause problems when combining machinery from different suppliers. (RISI 2017, 19.)

4.1.3 Downstream: usage and recycling of corrugated boxes

Corrugated cardboard or boxes can have many different applications, however the two most common uses are packaging for products and display stands. The use phase is negligible in life cycle assessments. This assumption has been made in numerous studies and standards. The only significant emission that is caused during the use phase, is the transportation of different products, which the corrugated boxes contain and the transport of the actual corrugated boxes to the use location. (Ncasi 2017, 72-73.)

The end-of-life applications to corrugated boxes tend to lean towards three different usages, one of which is much more common than the rest: landfilling, recycling for new production and incineration. The most common choice is recycling gladly, as in this case, the content can be utilized in the most efficient way possible. Incineration is used less frequently, and the heat energy is usually converted into electricity or used as heat. In the case of landfilling, in the best-case scenarios, landfill gasses can be collected and used further as fuel. (Ncasi 2017, 73.)

4.2 Most relevant impact categories for the forest industry

When conducting a LCA, to progress in the LCIA stage, the practitioner must allocate the emissions gathered in the LCI stage to different impact categories. This section of the thesis will discuss the impact categories that are closely linked with paper used for corrugated boxes and the common challenges and points of interest in them. There are multiple impact categories including climate change, acidification, eutrophication, ozone depletion, noise pollution, thermal pollution and photochemical ozone creation. Some of these impact categories are more relevant to the forest industry than others and most of the impact categories are dependent on temporal or geographical facts. Some impacts are more measurable than others, for example climate change can be measured to a single value, however land use may be too dependent on the location for it to be put down to one figure that suits all. There are seven top impact categories: acidification, eutrophication, global warming, ozone depletion, photochemical ozone creation and primary energy use. These have a couple aspects in common: they all influence the eco-system of the earth; they are quantifiable, and they are universally applicable. This makes them easier to generalize in comparison to the other impact categories. (European Copper Institute, 2015.)

Generally, impact categories are selected in the goal and scope stage of LCA. Once they have been selected and the emissions have been calculated, the emissions need to be classified. Classification is the process of assigning emissions to specific impact categories. This can be done on a case-by-case basis, or by following a predetermined list of emissions. Assigning emissions is straightforward for some impact categories, but for others, like toxicity, the numerous emissions may have different endpoint effects, hence making it hard to classify. As there are so many contributing emissions and lack of overall knowledge, the practice is often not appropriately done. When selecting impact categories, the categories must be relevant to the goal and scope of the study, justified, referenced, internationally accepted, have a clear scientific emission to impact connection and should avoid double-counting. Practitioners can come up with their own impact categories on a case-by-case basis, however it is rarely done. Impact categories can also be chosen anywhere on the spectrum of LCI results to endpoint impacts. Different researchers and practitioners have defined the impact categories in their own way, however there is a constantly changing “default list” of impact categories. Examples of different impact category classification indicators are: IMPACT2002+, ReCiPe, EI99, CML 2002, EDIP 2003, EPS 2000, LIME2, LUCAS, Swiss Ecoscarcity 2006, TRACI 2.0 and ILCD. (Hauschild & Huijbregts 2015, 18-28.)

In the making of paper used for corrugated board, several impact categories should be taken into consideration. The impact categories that multiple studies took into consideration are climate change, acidification, photochemical ozone creation, eutrophication, primary energy use, photochemical ozone creation and particulate matter. It is extremely difficult to choose between the impact categories that should be involved in the study, however the scope of this thesis will limit the impact categories down to eight categories: land use, ionizing radiation, climate change, eutrophication, acidification, ozone depletion, photochemical ozone formation and particulate matter. The impact categories were limited to the above eight, as most of them appeared in many LCA studies done about corrugated boxes (Ncasi 2014, PE-Americas & Five Winds International 2010, Cote 2009). The two impact categories, which did not appear in many of the studies were ionizing radiation and land use. The reason these two were included in the study was since they provide a new point of view on impact category assessments. The European commission has chosen a list of fourteen different impact categories that were viewed as hotspot impact categories for intermediate paper, from which the eight was chosen for this thesis (European Commission 2018a).

The usual challenges in the completion LCIA are separated into three different categories. Most of these impact categories have a challenge in one or even all three of the categories. One is the lack of knowledge about the true value of an input parameter. The second challenge is uncertainty caused by the scope of the study. Third and last challenge is the uncertainty caused by a loss of information, hence the simplification of a study, which strays it further away from reality. The elementary flows of a system can also be separated to two different impact points, the midpoint and endpoint causes. An example of a midpoint cause for a flow of carbon dioxide is climate change and an endpoint would be loss of human life and ecosystem damage through different causes like flooding. When we assess each impact category, the background information on the concentrations of substances in the ecosystem is rarely known, therefore it is hard to assess the severity of the situation. To properly assess the effects of emissions, other nearby processes that accelerate the same endpoint need to be considered. This is the reason LCIAs are often seen as indicators that help compare and optimize processes. The validity of LCAs is hard to determine and often they are based on peer reviewed scientific research. (Hauschild & Huijbregts 2015, 10-11, 172-173.)

Avoiding double-counting in impacts can be complex, however in literature it is suggested that the emission should be divided according to its contributions to the specific impact category. The problem with this is that there is no indication of how the emission can be divided, therefore it is up to the practitioner to divide the emission. The decision as to which impact category an emission is placed in is usually based on the background information of the given area, for example according to already existing concentrations of substances. In practice, this is rarely possible due to lack of information. Sometimes there may not be information on the magnitude of impact to different impact categories. In this case, the impact is usually put in its entirety to all the different impact categories. It has also been suggested that the emissions are equally divided into all the impact categories that they may influence. There has been limited development in this area in the last decade due to the complexity of covering the topic in enough detail LCIA. This may or may not propose a problem when conducting LCA depending on the goal and scope. (Hauschild & Huijbregts 2015, 31-32.)

Something as simple as naming impact categories can also put emphasis on the severity and importance of it. For example, some can be named negatively like ozone layer destruction, loss of biodiversity or respiratory diseases, whereas some can be named positively like particulate matter formation, life expectancy or human health. The name itself already predisposes the reader to the relevance of the impact category. Also, the continuous input on new impact categories predisposes the lengthening of the ‘default list’ up to a point where it cannot be controlled no longer. (Hauschild & Huijbregts 2015, 35.)

4.2.1 Climate change

Climate change is often mistakenly used as a synonym to the greenhouse effect or global warming. It is the increase of temperature in the lower atmosphere through the greenhouse effect. The greenhouse effect is where compounds absorbing infrared radiation, and emitting it back onto the surface of the earth. As more radiation is emitted back onto the surface of the earth, less heat escapes through the atmosphere, hence more heat is captured within the atmosphere, causing the surface of the earth to rise in temperature. As the surface heats further, the temperature change causes the radical weather effects to become more extreme and the ice glaciers to melt, which in turn makes the sea level rise. The temperature change may have an effect on marine productivity, as species can be extremely fragile regarding temperature changes (Hauschild & Huijbregts 2015, 40-41). On a more local scale increased temperatures may cause more deaths in cities (caused by heatwaves), population displacement, malnutrition due to crop damage and even increase of disease outbreaks (Hauschild & Huijbregts 2015, 40-41). Climate change is measured in carbon dioxide equivalents. Any gas emissions that absorbs infrared waves or degrades to CO_2 and has an atmospheric life time of long enough to contribute significantly to the greenhouse effect are considered greenhouse gasses. (Hoffman et al. 2005, 39-40)

The main areas of effect that climate change has is human health and ecosystem quality. For both of those categories, the main effects are the increased number of deaths and morbidities, including the number of threatened species. One of the reasons that climate change gains a lot of media coverage and political campaigns is that it affects people all around the world regardless of whether the country is developing or a developed country. The reason it is considered a global impact category is because the lifetime of many greenhouse in the troposphere gasses is longer than what is assumed to be the tropospheric mixing time, 1 year. Even though it is a global impact category, the increase of extreme weather hazards is local and according to the climate of the area being studied. (Hauschild & Huijbregts 2015, 41.)

When measuring climate change, temporality is an important factor, as many substances have different times that the substance is in the atmosphere. For example, the time which water is present in the atmosphere is much shorter than that of carbon dioxide, therefore over the course of their lifetime, they have a different overall impact on global warming. Due to this fact, the greenhouse effect is measured with time, which is called Global Warming Potential (GWP), and it is usually 20, 100 or even 500 years. Shortening the potential time span increases the focus on the shorter effects of global warming however, neglects the long-term effects. The reason we neglect the long-term effects of global warming is because of the tipping point theory, where once we have passed a certain point, manmade reductions in greenhouse gas production will no longer be able to neglect the self-accelerating nature of global warming, therefore to not reach the tipping point, reductions of emissions has to be done immediately. Some LCIA methods choose to take the long-term effects into consideration with the GWP_{500}, whereas others want to focus further towards the shorter-term effects with the GWP_{100}. The recommendation by the European Commission's International Reference Life Cycle Data System (ILCD) handbook is to use the latest and most scientifically robust studies provided by the Intergovernmental Panel on Climate Change (IPCC), however some LCIA methodologies choose to ignore this for different reasons. The impact category of climate change has a strong agreement within the LCA practitioner community (Klöpffer 2014b). Due to the wide range of impacts caused by global warming, endpoint modeling is harder, even though some methodologies do focus on it. To make the assessment of climate change more precise and accurate, further research on endpoint effects and the way to quantify them must be done. (Hauschild & Huijbregts 2015, 40-45.)

4.2.2 Eutrophication

Eutrophication is defined as "*the enrichment of water by nutrients especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned*" (Ansari et al. 2011, 2). Even though eutrophication does occur naturally, manmade emissions cause disturbances in the nutrients cycle. Excess of nutrients will cause changes in crop yields and can cause the death of different species in the polluted area. Eutrophication can be caused via air or ground and the main emissions that contribute to eutrophication is phosphorus, nitrogen and organic matter emitted to water bodies. (Hauschild & Huijbregts 2015, 183.)

As the emissions can be emitted to air, ground or water, the spatial effect of eutrophication can be very large, as emissions to air can be transferred to multiple different locations. For water emissions, the scale varies depending on the downstream from the source of the emission. For example, phosphorus may travel approximately 1000km. The extent to which marine emission spread is related to the ecosystems of the receiving bodies and therefore the scale of impact can be quite large. The existing levels of nutrients can vary dramatically between different bodies of water. Some factors that influence the nutrients of a body of water: species composition, underlying geology, previous environmental stress and variations in climate. Some bodies of water may have a different limiting reagent in growth, therefore the same emission can have a different effect on different bodies of water or ground. Even if the assumption that the limiting reagent was the same, the same emission may still have different effects on different bodies of water as the already existing amount of the limiting reagent may differ. (Hauschild & Huijbregts 2015, 186-187)

Eutrophication is also susceptible to temporal difference. An example of this is seasonal weather changes. In different seasons, there is a different amount of sunlight, which in turn can speeds the effects of eutrophication. Temporal changes may also have an effect on the spatial changes of eutrophication, as during season with less sunlight, the resources will be used differently and therefore they may travel even further than during seasons with a high amount of sunlight. The amount of sunlight in different areas will also influence the natural nutrient cycles in bodies of water. (Hauschild & Huijbregts 2015, 187-188)

The current development in eutrophication studies is focused on improving the modelling of transport and effect according to geography. The development will allow more accurate modeling of the way inventory data causes changes in the environment. The development in the models increases along with environmental knowledge of how the substances are transferred and how ecosystems react to these substances. The modelling of marine eutrophication effects has proven to be a challenge and is yet to be modelled. Another focus of future research can be the way an ecosystem may not only have one limiting reagent, but instead multiple reagents that either stop or slow down the process. This would require a dynamic model of the temporal effects of eutrophication. (Hauschild & Huijbregts 2015, 190-191.)

4.2.3 Acidification

Acidification is the depositing of nutrients, mainly sulfur and nitrogen, in their acidifying forms into the environment and by that changing the pH of either ground or water. Acidification, as most other impact categories, has a wide range of impacts. Looking at it from a biological perspective, it produces a threat towards reproduction, extinction and growth of species. Soil acidification in turn causes destruction in agriculture and limits agriculture to some acid resistant species only or decrease the yield of production (Soilquality 2009). The reason for this is the switching of pH in the environment and some species are extremely susceptible to changes in pH. Some areas have a higher buffer to acidification compared to others due to different chemical balances, therefore acidification may increase the yield of some products, but decrease that of others. (ESF 2009, 3.)

Acidification can be caused by natural hazards such as volcano eruptions, however with industrialization, the amount of anthropogenic acidification sources has increased significantly. The most significant anthropogenic sources currently are the incineration of fossil fuels, car exhaust and agriculture. A large amount of the manmade CO_2 in the atmosphere is absorbed by oceans, which when absorbed by the ocean, increases the concentration of hydrogen ions in the body of water. Due to the best availability of information and measuring convenience, pH was chosen as the indicator for the acidification. As the data on location specific characterization factors of freshwater acidification is rarely available, freshwater acidity is often disregarded LCA. Marine acidification is not taken into consideration as it has not been researched in the required depth. In the acidification impact assessment, temporal aspects are extremely important, as there can be a delay in the effects of the acidifying substance due to different biogeochemical processes. (Hauschild & Huijbregts 2015, 168-173.)

Current development has focused further towards the development of terrestrial acidification instead of freshwater and marine acidification. The challenges boil down to how to include freshwater and marine acidification in modeling and how to reduce the uncertainty of endpoint modeling. The two aspects that need to be addressed in future research are the effect factors and the assumption that a body of water is homogenous in pH. Also, species richness is a field in need of further research, as with current methods only fish species was considered, despite there being many factors that affect richness of species such as: altitude, pH, environmental location and temperature. This is however location-based, as some areas are more prone to stress than others. (Hauschild & Huijbregts 2015, 173-174.)

Acidification was chosen to be an important factor in the forest industry, as the forest industry uses excess water as raw material and are often placed near flowing water. Some water is consumed throughout the process but usually most of which is released back into downstream. Factories often have a water treatment plant as a part of the process, to make sure that the water that is released to the downstream is either cleaner or the same quality as when it was drawn from the upstream.

4.2.4 Photochemical ozone formation

Photochemical ozone formation is the formation of ozone in low altitudes. In high altitudes, ozone is vital to protect against UV-radiation, however in lower altitudes it can have diverse negative effects all the way from crop damage to increase in respiratory diseases. On a larger scale, ozone can affect the welfare of human beings through its effects on agriculture and it can cause increased mortality through respiratory diseases (Hauschild & Huijbregts 2015, 122). Photochemical ozone mainly forms when Volatile Organic Compounds (VOCs) and nitrogen oxides (NO_x) are emitted in the presence of sunlight. It is measured in kg of ethene equivalents. The main emissions for the forming of photochemical ozone is caused by the burning of fuel. (Bregroup 2019.)

Photochemical ozone formation was chosen as one of the impact categories, as the burning of different fuels to produce steam for the machinery causes NO_x and VOC emissions. It is one of the most important impact categories because the impact can vary extensively, however the local population is usually the population, which suffers the most from it. The local population is also the stakeholder that causes a lot of media focus, which can be harmful for the image of a company.

Photochemical ozone is mainly O_3, forming near ground level. The problems with photochemical ozone formation, is that there are numerous of difference substances in multiple compositions that form ozone and measuring them all is complex. The fact that these substances all have different potentials towards the impact category makes the measurement even more complicated. The Photochemical Ozone Creation Potential (POCP) defines the potential of a substance to create ozone in the troposphere and ethene has been set as a baseline. VOCs have a chance to react by photolysis to create other VOCs, which have different POCP, therefore all VOCs are considered to cause photochemical ozone. There are multiple approaches to POCP measurement, and they all are dependent on the time horizon that is taken into consideration. For example, if the time horizon is only a couple hours, only highly reactive VOCs will contribute to photochemical ozone formation locally, but if a time range of several days is considered, even the less reactive VOCs cause the ozone to form and on a much larger scale. If one needs to consider the full scale of photochemical ozone formation, one would have to consider a time horizon of weeks or even months. Some measurement techniques make a distinction between VOCs that cause damage from a local all the way to global scale. In addition to VOCs having different ozone creation potential, specific conditions, emissions and concentrations of pollutants teamed up with meteorological conditions all influence the creation of photochemical ozone. One of the main challenges in the calculation of ozone creation is that it varies spatially, temporally and according to system boundaries. (Hauschild & Huijbregts 2015, 118-121.)

Further on in the category of ozone formation, the actual impacts are hard to measure. Human health related impacts tend to be quantified with three factors: intake fraction, effect factor and damage factor. The effect and damage factors depend on the location and archetypical characteristics. Regarding ozone, the effect factor is the disease amount per unit of ozone. The damage factor is then the severity of the disease, which can be measure for example by the life expectancy change per incident of infection. The intake fraction is the mass of ozone consumed by humans per the emitted amount of the root cause (in this case NO_x and VOC). Each of these values are calculated in different ways for example, when going deeper into how the intake fraction is calculated, the concentration of photochemical oxidant added, the concentration already existing, the average breathing rate per capita and the number of people in the location all must be quantified. For the purposes of this thesis, the calculation methods will not be further assessed. (Hauschild & Huijbregts 2015, 127-130.)

4.2.5 Particulate matter

Particulate Matter (PM) is the emission of particles of different size into the air. It can be measured in $PM_{2.5}$ or PM_{10} which are the number of particles emitted of less than 2.5μm and less than 10μm respectively. It can also be measured in life expectancy measures such has disability-adjusted life years and quality adjusted life years, number of cases of illnesses and even the number of deaths. Particulate matter is considered as one of the most important impact categories in LCA as it has the clearest effects on human health. The World Health Organization estimated that 800,000 premature deaths can occur annually due to excess particles in air. Particulate matter may cause respiratory diseases, reduced life expectancy, lung cancer and cardiovascular morbidity. Studies have suggested that the effects of particulate matter should be studied in a regional context to increase the confidence in, acceptance of and accuracy of LCIA studies. (Hauschild & Huijbregts 2015, 98)

The effects of particulate matter differ due to multiple indicators. One of these indicators is the population density of the area. For example, if an industry is emitting a lot of particulate matter in the middle of a highly-populated city, the particulate matters are going to affect many more people in comparison to a factory located further away in a less densely populated area. Another indicator, which affects the intensity of effects is whether the particulate matter is emitted inside or outside. If it is emitted inside, the concentrations are most likely going to be much higher than if it was emitted outside and therefore will cause more severe impacts. The height of the emission source also has an effect, as when the matter is emitted at ground-level where people are breathing, the effect will be much higher than when it is emitted higher up, where the concentration will decrease by the time it reaches the ground as weather conditions will make it scatter and transport it to different locations.

Meteorological aspects also need to be taken into consideration as well, as cities located in basins with low winds will experience higher concentrations of particulate matter than cities located near the coast line with higher wind speeds. (Hauschild & Huijbregts 2015, 107)

The intake fraction in particulate matter quantification is represented by the intake of particulate matter by the human population that is exposed to it per the amount emitted. The effect factor is Disability Adjusted Life Years (DALY) per one kilogram of inhaled substance. DALY is the quantification of lost healthy life years, so one DALY is loss of one year of healthy life (WHO 2019). Currently, it is assumed by many methods that PM_{10} does not have an effect on human health, therefore many methods calculate the effect of PM_{10} as the effect of $PM_{2.5}$ multiplied by the fraction of $PM_{2.5}$ in PM_{10}. An example of an obstacle within particulate matter calculation is whether the practitioner should take SO_2, NO_x, NH_3 and CO emissions into consideration, since these can reflect to the human toxicity category also. To inquire further into the calculation of the amount of PM emitted, a secondary PM category has to be considered, since some PM is formed with the help of a precursor forming PM with SO_2, NO_x and NH_3 emissions. The intake fraction for secondary PM is the amount of PM inhaled that is formed by a precursor per the mass emitted of the precursor. In conclusion, PM is prone to double-counting and requires a lot of background data as do most of the other impact categories. (Hauschild & Huijbregts 2015, 100-101.)

4.2.6 Ionizing radiation

Ionizing radiation is radiation that has enough energy to create ions (DOE 2019). Ionizing radiation can influence human health and the ecosystem. The indicator for the measurement of radiation can be based on multiple different sources of data. An example of what it can be based on, is the number of skin cancer patients, or disability adjusted life years. The effects tend to be apparent in the local area around the source of radiation. (LC-Impact 2019)

The reason why ionizing radiation was taken as a part of the thesis, was because some of the case units happen to be located in Finland, which in turn produces 48,4% of its electricity with nuclear power (Statistics Finland 2018). Even though there aren’t direct ionizing radiation emissions, there are indirect emissions through the electricity grid in the location. As to whether this is taken into consideration during the study, is decided by the practitioner. In the case of Finland, if the factory buys electricity, and it is produced with nuclear power, it is highly encouraged that the impact category is considered in the study, for the study to be realistic. This also proves that choosing suppliers of resources is extremely important in the environmental performance of products, hence the need for this study. Radioactivity is measured according to the number of nuclei that decays over a specific amount of time (Institute for Energy and Environmental Research 2012). Radiation can be measured using becquerel equivalents, which is the disintegration per second (Institute for Energy and Environmental Research 2012).

4.2.7 Land use

Land use is an important factor to consider in the forest industry, as forests are renewable only if the source of raw material is used for growing new raw materials. The usual land use impacts generally are linked to the modification of the natural environment into something that is used by humans. The main driver of biodiversity loss is the destruction of natural habitats into croplands. Land use has been discussed in LCA for a long time, however including the impact category has taken its time due to the vast spatial differences of impacts. The calculation of land use impact relates to the transformation of land use to land occupation by humans. The land use category refers to the transformation of land after its use to something different than what it was before. For example, when cutting down forests and not allowing the forest to regenerate on its own, but rather transform the land to something that delays its regeneration. (Hauschild & Huijbregts 2015, 199-200.)

To calculate the land use, a reference line needs to be chosen and recommendations say that the practitioner should use the potential natural vegetation value, however this is due to the availability of data. The setting of a reference line is subjective, and therefore creates further uncertainty. The regeneration time varies highly according to location, as for example warmer and humid climates will have a faster regeneration time than dry and cold climates. Linear models have been made to calculate the speed of recovery. These models have been transformed into ecosystem specific recovery times and uncertainty of models has been quantified. These models are however based on the assumption that the land will regenerate 100% and no permanent damage has been made, which cannot be realistically made. The main challenge with land use change is that the impacts vary drastically according to the location of impact. This is the reason that land use has been avoided in current LCA until the recent years. The development of geographic information systems allows the use of spatially relevant characterization factors. The spatial factors of land use impacts have received a lot of attention, however as the focus has been shifted to spatiality, the effects of temporality are not discussed. Three different impact areas are categorized in the land use impact category, biological, chemical and physical. The biological impact considers aspects like vegetation cover and species composition. The chemical impact considers aspects like pH, salts composition and toxicity. The physical impact considers aspects like compaction and erosion. These then have different impacts on the conditions in the land like the water cycle or the albedo of the land. (Hauschild & Huijbregts 2015, 201-203.)

The land use impact category has developed together with the development of geographical information systems. The general spatial challenges apply to the quantification of land use impacts as even with advanced geographical information systems, the information all around the world differs extremely due to spatial and temporal effects and even the indicators can be different. To create an absolute value of land use impact category, the different impacts must be weighted, and these can be extremely subjective, for example in the case of biodiversity, how would the practitioner weigh the value of the extinction of insect species versus the extinction of a mammal species? Also, is "extinction" considered as global extinction or local extinction? Also, how do we quantify between destructive species versus constructive species? With all this in mind, it can be very hard to aggregate one figure for the impact of land use, however with development, LCA processes may allow companies to determine whether a specific product should even be sourced from a specific location. The land use impact category provides an important decision-making factor, as it can help determine whether to work with suppliers in sensitive areas by proactively promoting good practices and certifications, or to completely change suppliers to locations that are more viable. (Hauschild & Huijbregts 2015, 216-218.)

5 CASE STUDY

Stora Enso is a company, which produces a wide range of products from renewable raw materials. Stora Enso uses wood and biomass to develop and produce solutions that can be applied on a range of industries and applications worldwide. The company creates a sustainable bio-economy by offering a low-carbon alternative to products made from non-renewable materials. Solutions provided by the company can be observed in building, retail, food and beverages, manufacturing, publishing, pharmaceutical, cosmetics, confectionary, hygiene and textiles. The futuristic view of Stora Enso, is that anything that is produced with fossil-based materials can be produced with biomaterials. (Stora Enso 2019b)

Stora Enso is a multinational company, employing 26 000 people in more than 30 countries. Stora Enso is publicly listed in Helsinki and Stockholm stock exchanges. The company's sales in 2018 were EUR 10.5 billion. It has the capacity to produce 5.9 million tons of chemical pulp, 5.4 million tons of paper, 4.7 million tons of board, 1.4 billion square meters of corrugated packaging and 5.6 million cubic meters of sawn wood products. (Stora Enso 2019b.)

The aim of Stora Enso is to provide comprehensive information about the environmental performance of the company's corrugated offering and improve the processes according to the information. The indicators chosen should reflect the environmental sustainability strategy of Stora Enso. The current carbon footprint of Stora Enso is shown in figure 6.

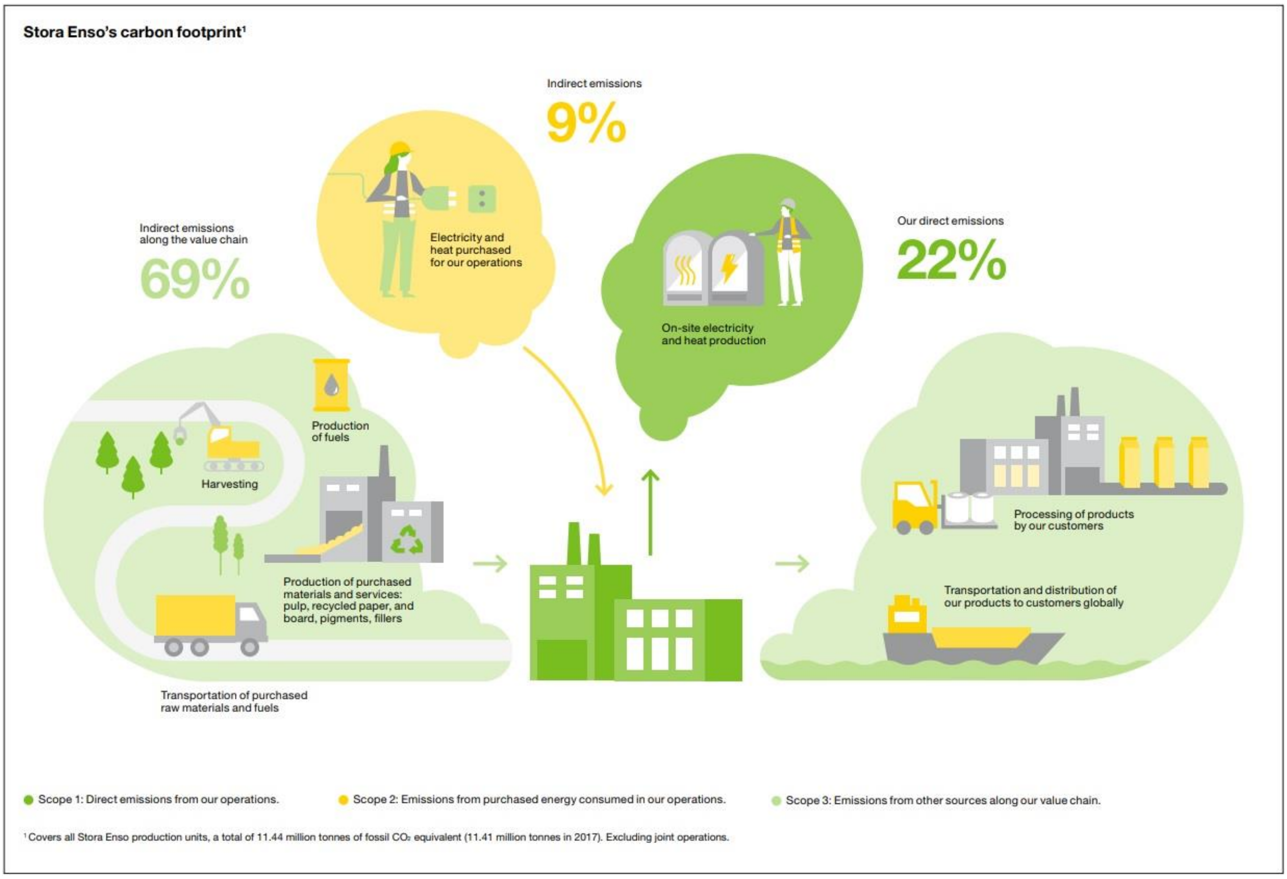

Figure 6: The current carbon footprint of Stora Enso. (Stora Enso 2018)

Greenhouse gasses are reported in three different categories, scopes 1-3. Scope 1 emissions are the emission that are coming from Stora Enso's operations, scope 2 are the indirect emissions such as purchased energy consumed in Stora Enso's operations, and finally scope 3 is the emissions that are created throughout the value chain. As shown in figure 6, the majority of emissions come from scope 3 emissions, which are the emissions along the value chain. Since scope 3 emissions provide for the largest part of all emissions, it may be useful to focus the assessment on these emissions, due to the highest improvement potential. Scope 3 emissions come from the stakeholders of the company and therefore the engagement of these stakeholders, in the way that is described in section 2.5, for their inventory data is necessary. In the case study and production of corrugated boxes, according to multiple studies, most of the emissions come from the production paper, hence why the assessment requires cooperation from suppliers. Stora Enso aims to find a feasible assessment methodology, which provides enough information to satisfy the sustainability strategy of Stora Enso, but also isn't too complex to be implemented in a multi-stakeholder environment.

5.1 Company environmental guidelines

The sustainability strategy in the company covers all the different pillars of sustainability throughout their value chain: environmental, social and economic (Stora Enso, 2019a). The company's sustainable strategy tackles challenges that put further stress on natural resources such as excessive consumerism, urbanization, water scarcity and global warming in a proactive manner by replacing current materials, which are fossil based, with renewable materials that have a smaller environmental footprint (Stora Enso 2017b, 3). This in turn means that the environmental handprint of products is maximized (Stora Enso 2017b, 3). The environmental handprint is a further study, which focuses on the environmental benefits provided by the product in comparison to the current situation or a different product (LUT University & VTT 2018). The environmental handprint is a good way to compare already existing solutions with new solutions, which is exactly what the company wants to achieve according to its strategy. An example of a goal the company has set with the help of science based targets is reducing the CO_2 emissions as close to zero as economically and technically feasible. To achieve these and multiple extra goals, the company has set measurable indicators to follow the progress. To react to this goal as fast as possible, the company could implement environmental handprints to achieve maximum productivity in limited time. The quantifiable goals consist of indicators such as monitoring water usage and material efficiency. (Stora Enso 2017b.)

The company has set three focus areas for each pillar of sustainability to provide further understanding of the triple bottom line. The subcategories for social sustainability are employees and wider workforce, community and business ethics. Economics is based on suppliers, customers and investors. The final and most relevant pillar to the thesis, the environmental, is divided into materials, energy and water, carbon dioxide and forest, plantations and land use. In addition to all the different subcategories, human rights are integrated into all actions. The communication of the progress is published through sustainability reports that are made according to the GRI. Sustainability information is also presented in the quarterly interim reports (Stora Enso, 2017). (Stora Enso 2019a, 5.)

Stora Enso mills apply third-party management systems like the ISO 14001, to systematically work towards a continuous environmental performance improvement and will also start requiring these management systems from suppliers (Stora Enso 2017b, 11). According to the ISO 14001, the organization must determine risks and opportunities within the defined scope of the environmental management systems. Therefore, each business unit must assess their risks and opportunities and then set goals for continuous improvement and the achievement of local obligations. Each environmental objective must be consistent with the environmental policy, measurable where possible, communicated, updated as appropriate and monitored. Documentation for each of these objectives must be created, that show what will be done, what resources will be required, who is responsible, when it will be completed and how the process is evaluated. These will vary according to each mill and therefore the goals of individual plants will not be the same as goals for the whole Stora Enso group. (ISO 14001 2015, 15-17)

The progress of different PIs are regularly monitored at a group level and division level. Figure 7 shows the sustainability approach of the company. Sustainability is led by the executive vice president of sustainability, who in turn reports straight to the CEO. Each business division has its own head of sustainability and reports to the executive vice president of that specific division. The sustainability policy reflects on the everyday work on the operation level personnel. It is extremely important that the supply of raw materials is according to the code of conduct and reflects sustainability strategy of the company, hence the need for this study. (Stora Enso 2017a, 5.)

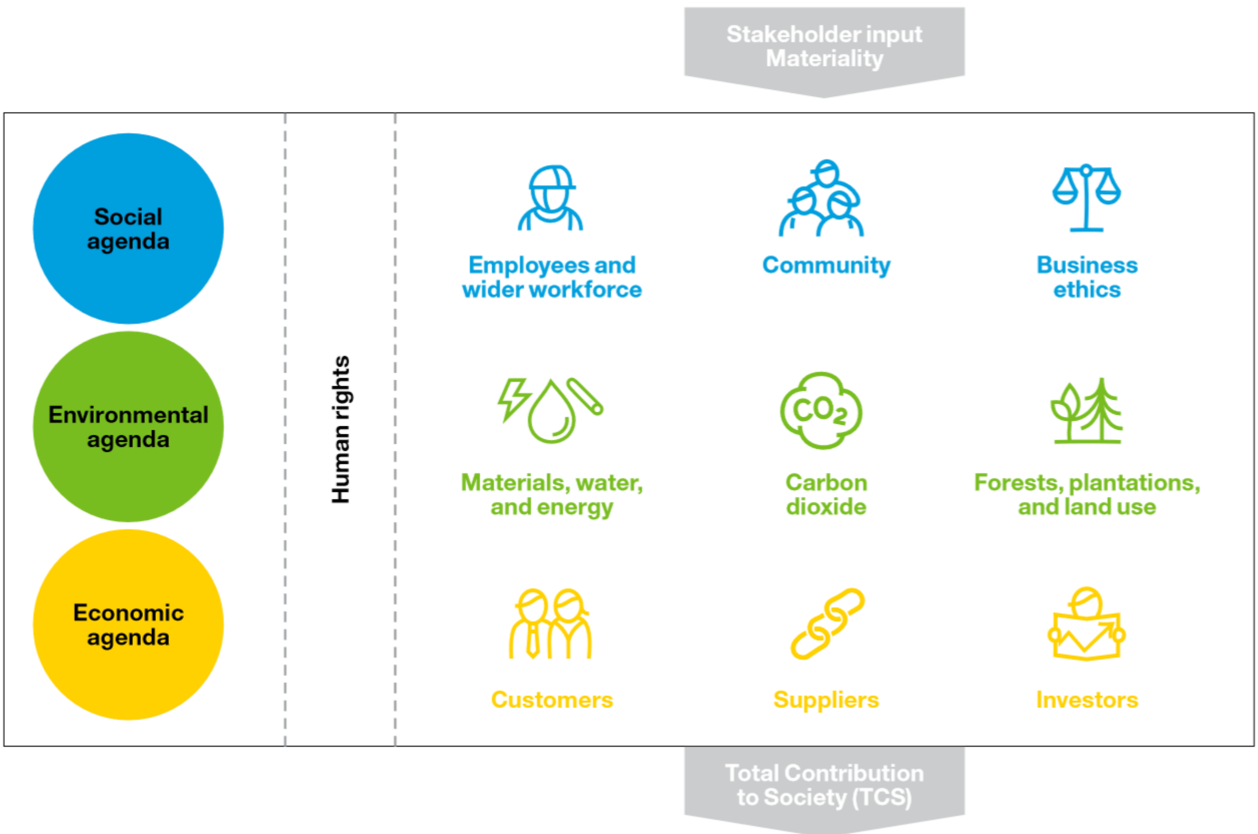

Figure 7: This figure shows the sustainability diagram of the case company. (Stora Enso, 2017.)

Stora Enso develops recyclable and renewable products and services from raw materials that are extracted from sustainably managed forests and plantations. Stora Enso promotes material efficiency to reduce financial costs, environmental impact and to create a larger buffer zone to resource scarcity and global warming. Stora Enso considers the implementation of environmental management systems such as the ISO 14001 as the most important tool to guide continuous improvement in environmental performance and processes. Stora Enso has set a goal that all its industrial operations must implement and maintain a third party certified environmental management system. Stora Enso provides sustainability information about their products, to offer customers a chance to excel in their own environmental performance. (Stora Enso 2017b, 3-5.)

Stora Enso chooses like-minded partners according to their Supplier Code of Conduct and work together with them to increase overall environmental performance. Stora Enso engages suppliers to address sustainability topics. In countries that use fossil fuels to provide energy for Stora Enso processes, Stora Enso investigates the feasibility of using biomass or alternative low carbon energy supplies, which will contribute to a gradual shift towards low carbon solutions in that area. Stora Enso has a target to reduce fossil fuel CO_2 emissions per saleable ton of pulp, paper and board by 35% by 2025 from a 2006 baseline. Another goal of Stora Enso is to reduce specific heat and electricity consumption per saleable ton of pulp, paper and board production by 15% by 2020 from a 2010 baseline. On top of these goals, Stora Enso has implemented the Science-based target that helps set goals for the reduction of GHG emissions, including scope 3 emissions. Another goal that Stora Enso has set, is that 70% of their non-fiber suppliers and downstream transportation suppliers must set GHG emissions reduction targets by 2025 and adopt science based targets by 2030 (Stora Enso 2019d). (Stora Enso 2017b, 12-14)

One major global challenge is the decrease of agricultural land, and the increasing gap between wood demand and wood supply. This brings about the goal to use plantations and forests renewably so that future generations can benefit from them as well. Stora Enso takes on the challenge that ensures the responsible sourcing of wood. To do this, they cooperate with forest owners, monitor forest growth, use forest certification as an indicator to promote sustainable forest growth along with many other forest management activities. All wood and fiber used by Stora Enso can be traced back to its origin to ensure that it has been legally produced and extracted. The wood is utilized in the most efficient way possible to ensure the highest value added from the available resources. (Stora Enso 2017b, 16-19)

In the case study, the stakeholders that are being engaged to increase environmental performance of Stora Enso’s products are the suppliers of paper that is used for corrugated boxes. Data needs to be communicated from the supplier to Stora Enso to monitor the progress of Stora Enso goals. The data provided by the supplier is then assessed according to a framework and can then be further implemented into company decisions, marketing, comparison and the improvement of processes. The company strives to use renewable resources to replace fossil-based materials and reduce environmental burden through recyclability. Assessing the processes and the supply chain is necessary to steer decision making towards the achieving of those goals. According to the above information, the assessment framework must be able to measure the amount of renewable products, material usage, efficient use of water and energy, carbon dioxide emissions and support the sustainable land use of raw material extraction points.

Often the pulping or paper manufacturing processes are completed somewhere other than the final corrugating location, as after corrugating, the product takes a lot more space and therefore transportation to long distances is not economically or environmentally viable. To engage stakeholders, in this case the suppliers, an initial information request on the values and views of environmental assessment of papers must be sent to sustainability personnel of these stakeholders.

5.2 Data collection methods and approaches

There are multiple ways of engaging stakeholders when information is needed, or a project must be initiated. Some engagement methods require more time and effort than others, for example group workshops may require time from multiple people, multiple companies and in multiple places., However a simple online questionnaire will require only a couple minutes of time from one person in the company. A phone interview would have been ideal for this particular study, however the chances of finding a time to contact all the different sustainability personnel in the time frame given was questionable, therefore the risk of not getting answers may not be worth it. With the web questionnaire, the risk of not receiving any answers due to the lack of interest is there, however if it is kept short and simple, the likelihood of getting answers increases significantly. Questionnaires also can be completed whenever suitable for the questioned. For this thesis, a web questionnaire was chosen for information gathering. This is due to the following reasons. The extremely busy nature of sustainability personnel in larger forest industry companies makes it very unlikely that a physical meeting would be possible with all the different chosen suppliers. A web questionnaire helps the processing of data, as the questions can be determined by the person conducting the questionnaire. (O'Haire et al 2011.)

At first to avoid the challenges that were mentioned in section 2.6, a message about the questionnaire was sent in advance to individual stakeholders, in this case the suppliers, to warn them about the upcoming cooperation requests. The warning message was sent by the Vice President, Sustainable Sourcing and Logistics. More than a month later, the questionnaire was sent to eight different paper suppliers. The questionnaire was sent by the person conducting the study. Once the questionnaire was not answered properly by the deadline, suppliers were reminded by the respective sourcing director. According to theory, stakeholders should be engaged in the decision-making process, before the strategy is properly developed. This will allow the stakeholders to bring their own views and opinions, therefore providing a better basis for cooperation and the creation of win-win situations. The questionnaire is shown in appendix 1. The willingness of the stakeholder to answer or ignore the questionnaire was already an indicator on the ideas of the company towards environmental assessment. The questionnaire investigated about their current environmental performance assessment of products and then further on about the plans of the companies.

There are other ways of assessing the willingness and ability of suppliers in environmental performance assessment. The involvement of a company towards different environmental performance organizations can be an indicator that shows the motivation that a company has towards environmental assessment. This was taken into consideration when conducting the study. Examples of these organizations or associations are WWF paper company index, paper profile and PEFCR development. Answering a short questionnaire or being committed to any of these organizations does not necessarily prove the sustainability actions taken by a company, however it is a reference to be used.

5.3 Goals and requirements of the study

According to different studies, in the life cycle of the corrugated box, the paper manufacturing stage is the most environmentally burdening in most impact categories (Ncasi 2014, 18, PE-Americas &

Five Winds International 2010, 10-14, Cote 2009, 20). As some of the company's paper used for corrugated boxes is provided by a supplier outside of the company, it is necessary to gather the most accurate data from the supplier in the case that a meaningful environmental assessment of the whole product is to be made. In the case that data of the most important stage of the life cycle is unobtainable, it will be very hard to use a life cycle assessment to its full potential. Therefore, the study acts as a way to initiate environmental data sharing between stakeholders, which is a step towards the goal of the improvement of environmental performance. A questionnaire was sent to the supplier companies. The questionnaire investigates about the knowledge gap between the suppliers and the company.

The goal of the questionnaire is to investigate what performance assessment method would be favorable to the suppliers and what kind of data they have available. The questionnaire initiates the supplier engagement process, by clearly clarifying the different aspects mentioned in section 2.6, hence avoiding ambiguity. The questionnaire is created and sent before the assessment is done to involve suppliers in the assessment of paper used for corrugated boxes. On a more specific level, the aim of the questionnaire is to inquire on the capabilities and possible conflict of interests between the company and its suppliers. In the end, the goal is to use an environmental assessment tool, with which the company can assess and develop their processes and supply chains and in the best-case scenario provide evidence for the exceptionality of their packaging products. The aimed win-win situation would provide success for both the supplier and the company through market shares and environmental credibility.

6 RESULTS AND ANALYSIS

This section of the thesis will focus on the different assessment tools and attempt to make a comparison between them. The fact that assessment methods may have different purposes, suit different situations and the worth of the assessment tool relies heavily on the practitioner, must be acknowledged throughout this chapter of the thesis. After the comparison, one tool will be suggested for the use of environmentally assessing paper used for corrugated boxes.

6.1 Comparison of methods

The different sustainability assessment methods are to be rated against relevant criteria, which were chosen according to the applicability of standards and the environmental agenda of Stora Enso. The first criterion that was chosen is the assessment range of the method , this shows the initial scope of the study, which can then be further determined later. The second piece of information is the impact categories, because they show clearly what the tool is focusing on and what kind of results the tool will provide. The third criterion is the data quality requirements of the standard. The data quality defines whether the method is a reliable source of information since if the data quality is low, the sturdiness of the study suffers and will result in unreliable results. This is an indicator as to whether the method is trustworthy. The fourth criterion is whether the method requires third party auditing or not. This criterion reflects whether the study is trustworthy but at the same time whether the method can be completed internally. The fifth criterion is the comparability of results with the method. This criterion was chosen because to receive market worth for a product, the company must prove that it performs better than the competing products and profitability of utilizing the method cannot be overlooked. It also reflects whether the method provides great benefits in internal auditing and continuous development. The second last criterion that was chosen is the resources needed for the method . This criterion entails the challenge of stakeholder engagement, data collection, the amount of data required, and the actual calculations required by the standard. The last criterion is the transparency of the method . The transparency refers to the documentation of calculations and the easy access of environmental data. The first assessment and criteria can be seen in table 2.

The first criteria that is extremely important to Stora Enso is forest management, therefore the tool itself should reflect the way forests are being managed in a way that is measurable and quantifiable like for example with the PEFC and FSC certifications. The second criterion is that the tool must include climate change as an impact category, therefore the measurement of GHG emissions is mandatory. The third criterion is resource efficiency. This reflects to the amount of raw material that is being utilized and used throughout the process, and the amount of waste that cannot be utilized. The fourth criterion is the future worth of utilizing the method . The future worth takes into consideration the current development of the methodology and attempts to foresee the data needs of future assessment methodology and the overall relevance of the method to the product being assessed. If the future worth of the method is good, this means that the data collected and the way it is processed will be useful in the future after the development of these tools. The final column of the table is the overall relevance to Stora Enso environmental agenda, this attempts to make a summary of the overall relevance of the method against the Stora Enso environmental agenda. The second assessment and criteria can be seen in table 3.

Table 2: The key information about all the assessment tools.

Assessment method	Assessment Range	Impact areas	Data quality requirements	Third party auditing	Comparability	Resources needed	Transparency
PEFCR	Cradle-to-gate	CC, OD, HT, ET, PM, IR, PCOF, A, E, RD, LU	High	Required	High	High	High
EPD PCR	Cradle-to-grave	CC, A, E, PCOF	High	Required	High	High	High
WWF CYP	Cradle-to-grave	CC, LU, WE	Low	Required	Low	Low	Low
Paper Profile	Cradle-to-gate	FM, WE, AE	Low	Not required	Moderate	Moderate	Low
Carbon Footprint	Cradle-to-gate	CC	Moderate	Not required	Moderate	Moderate	High
North American PCR	Cradle-to-gate	CC, OD, HT, A, PCOF, E	High	Required	Moderate	Moderate	High

Legend: CC – Climate Change, OD – Ozone Depletion, HT – Human Toxicity, ET – Ecotoxicity, PM – Particulate Matter, IR – Ionizing Radiation, PCOF – Photochemical Ozone Formation, A – Acidification, E – Eutrophication, RD – Resource Depletion, LU – Land Use, FM – Forest Management, WE – Water Emissions, AE – Air Emissions, NA – Not Applicable.

Table 3: Table showing the relevance of each assessment method to the environmental agenda and goals of Stora Enso.

Assessment method	Promoting forest sustainability	Reduction of fossil carbon dioxide and other GHG emissions	Increase resource efficiency	Water and soil emissions	Future worth	Relevance to Stora Enso environmental agenda and goals
PEFCR	+	++	++	++	++	++
EPD PCR	-	++	++	++	++	++
WWF CYP	++	-	- -	+	- -	-
Paper Profile	++	+	+	++	+	+
Carbon Footprint	- -	++	-	- -	+	-
North American PCR	-	++	++	++	-	+

The following paragraphs will explain the reasoning behind the assessment results. It is good to keep in mind that there are also different ways of using each method and these different ways may change the assessment result. For example, any LCA studies may be changed according to the different impact categories that are chosen to be included by the practitioner.

Conducting a PEF study is considered to be resource intensive, as there are many specifications included in the study some of which, depending on the development of the site, may require heavy investments and monitoring. PEF studies also requires the use of many different impact categories, complicating both data collection and data processing, however with clear reasoning, some impact categories can be left out. The data quality requirements of PEF are quite strict. There is a matrix and an equation with which the practitioner can calculate the reliability of the data, therefore the quality of the data can be calculated down to one value making it easily comparable to other PEF studies. PEF studies requires a high amount of data from stakeholders; therefore it requires a successful cooperation between companies. The future worth highly depends on how much the methodology has developed in the recent years and how much effort must be put into data collection. The recent development shows how much effort is being put into creating a comprehensive tool and reflects what will be the common tool for environmental assessment in the future. The effort put into data collection will not go to waste, as it doesn’t matter, which of the tools develop fastest, either way data collection cannot be avoided. Therefore, if the challenge of data collection has been addressed already, it will be much easier in the future. Currently the PEFCR provides the best basis for comparison between paper products and between other products due to the specificity of the requirements. PEF is also the only tool that provides a statement that if products are compared, specific specifications should be set to allow comparison. This means that PEF can be used for comparison with the correct scope. The PEF is transparent as the documentation has a clear set of rules and requires the reasoning for the different choices that were made.

The relevance of PEF studies when assessed against the Stora Enso environmental agenda is very high depending on the impact categories that are chosen. The LCI data that is collected in PEF is sufficient to assess all goals with slightly less emphasis on land use, plantations and forests. If the impact category of land use is included in the study, then it is very possible to assess the land use impact, with the limitations of current calculation methodology in mind. In the case of addressing biodiversity, PEF allows the assessing of forest use according to third-party forest certifications schemes, which can simplify the study and satisfy Stora Enso forest management requirements. Resource efficiency can be monitored through the data collection that a PEFCR requires in the LCI stage of the process. Water and soil emissions are considered when including impact categories like acidification and eutrophication. Reduction of fossil carbon dioxide and other GHG emissions can be monitored in the climate change impact category, as the biogenic carbon dioxide emissions are calculated separately.

The EPD study requires a high level of resources, as the requirements are specific. Also, instead of a cradle-to-gate study scope like in PEF studies, the EPD requires a cradle-to-grave study. EPD does slightly relieve the downstream module by not requiring the assessment of the use phase, and only requires the distribution and recycling and waste management scenarios. The data quality requirements are not as high as that of PEF, however the EPD does require specific data from suppliers and therefore generic data cannot be used for manufacturing stages or deliveries. The future worth of the EPD PCR is high, due to recent developments in environmental assessment methodology and the value of stakeholder involvement in the future. The EPD requires effort on data collection and the establishing of data flow between stakeholder will not go to waste in environmental performance assessment if the assessments are to be updated regularly along with the development of methodologies. The comparability provided by the EPD is higher than most of the other tools, however still not high enough to provide good market benefits. The EPD is not made for comparison, however having a PCR already increases the comparability of studies by a lot. The EPD works as a great tool for internal process development. The transparency of the EPD is high as the documentation behind the process is extensive. The amount of impact categories that should be involved in the study is also much lower than that of PEFCR.

The relevance of the EPD PCR to Stora Enso agenda applies in the same way that the PEF study does, if the right impact categories and points of interests are chosen, the relevance will be high. The default list of impact categories does not provide enough information to assess all Stora Enso’s goals. The PCR does not promote the sustainable use of forests, unless the land use impact category is taken into consideration. The EPD also does not recognize forest certification schemes the same way the PEFCR does. The overall relevance to Stora Enso agenda is high and therefore it is a very viable study to conduct that will provide information on the progress of Stora Enso against their goals.

WWF CYP was considered to have low resource needs, as the quality of data is not as important, hence making the data collection stage easier due to current generic data sources.-The last aspect that makes WWF CYP easy to conduct, is that the practitioner does not need to process the data into impact categories in any way. The relevance to Stora Enso targets is high, as CYP covers all the different targets of Stora Enso through different values, for example land use, forests and plantations is covered using FSC and PEFC certification in raw material. CYP does consider the emissions to water, but not at the same level as other assessment tools. The quality of data however is low, as there are no requirements for it, therefore the study itself may not provide a realistic, transparent and trustworthy idea of the environmental performance of the product. The future worth of conducting a CYP study is low, as it does not provide data that can be realistically used in marketing or internal process development, and the study is not comprehensive enough to account for the future development of environmental assessment methods. The fact that CYP is only made for papers also lowers the future and comparability value of the study. Even with only papers, CYP should not be used as a tool for comparison, as it lacks the assessment of many impact categories, which should be considered. The CYP does not consider resource efficiency and does not provide a broad enough list of GHG emissions for it to apply to the reduction of GHG gas emissions goal of Stora Enso.

The Paper Profile was considered to require a moderate amount of resources, since the data quality requirements are quite lenient and the study consists of only data collection and allocation, instead of linking the data to impact categories and assessing these. The data quality requirements for the Paper Profile is low, as for example close to 25% of the data from suppliers can be missing, and yet 75% of the data can be used to create the value for the Paper Profile. The paper profile seems like a realistic method of conducting and LCI with the current development status. It unfortunately does not tie the emissions to any impact categories, and therefore leaves the interpretation of the values up to the reader. The future worth of Paper Profiles lies in the engagement of stakeholders, as the process can initiate a successful sharing of environmental data, the practices can be used with other further developed assessment tools. Paper Profile also mentions that the collection of environmental data is complex and different papers require different material, therefore comparison must be done with caution. For comparison to be possible, further specifications would be required on the way that the study is to be conducted.

The Paper Profile provides high amounts of information towards the development of Stora Enso’s environmental agenda. The carbon dioxide emissions are calculated per ton of final product, forests are considered through PEFC and FSC certification, and resources consumption and quality are also considered. The study does not consider all the relevant GHG emissions and therefore receives a lower mark in the reduction of fossil carbon dioxide and other GHG emissions criterion. The future worth of the paper profile did not receive full marks, because it does not consider all the relevant indicators that should be considered according to the Stora Enso environmental agenda. It also tends to ignore the effective use of resources in processes; however, it does consider the amount of waste that is landfilled, which reflects the utilization of resources. Therefore overall, the paper profile is a great start to environmental assessment, further studies are needed to fully satisfy the requirements and goals of Stora Enso.

The carbon footprint was considered to use moderate amount of resources because even though the study is comprehensive regarding climate change, it only addresses climate change. The relevance to Stora Enso's environmental agenda is low, as only one impact category is being studied. The data quality requirements vary according to the standard being used. The guideline is to use data that reduces uncertainty and bias as far as practical, which leaves the data quality aspect to the interpretation of the practitioner. This is the reason that the comparability of products according to the carbon footprint of the product may not be as reliable as wanted. However, with the implementation of the carbon handprint, two carbon footprint studies could be created with the same specifications and data qualities, in which case the two can be realistically compared. The future worth of the carbon footprint is based on information gathering and immediate changes in processes to satisfy science based targets. The carbon footprint received a higher mark in the resource efficiency criterion, as some of the information that is used to calculate the carbon footprint can also be used to assess a part of resource efficiency. If a carbon footprint study can be initiated and successfully carried out, adding another impact category can be the next stepping stone of the study. This way the company could start off with conducting a carbon footprint study and then upgrade further towards studies like the EPD PCR or PEFCR through adapting new impact categories according to the rules of the more comprehensive standard.

Finally, the North American PCR was considered moderate in resource requirement, because the specifications are less strict than that of the PEFCR and EPD PCR. It does however require the engagement of stakeholders and the studying of multiple impact categories. The data quality requirements are quite strict and can therefore take a lot of resources to fulfill. The PCR provides a clear way of assessing the quality of data and a ranking system according to the assessment. This leaves a lot of the data quality assessment up to the decision of the practitioner, however if the practitioner decides to take data that is less accurate, it will not be overlooked by the PCR but rather be transparently shown on a scale of 1-5. This shows that the PCR takes effort in assessing the quality of data. The future worth of the PCR is moderate and not high because the PCR is specifically made for the North American producers and may not be as applicable in other countries, therefore choosing the north American PCR over PEFCR may not be justified. This however does not necessarily mean that it cannot be applied elsewhere, but if it is applied, the usage of generic data must be carefully implemented, as some databases may be location specific to North America. The comparability was set to be moderate, as the PCR is slightly less specific in the requirements than the PEFCR and the PCR sets rules that comparison is not allowed when comparing different qualities of pulp. The process itself requires transparency through justifications on the decisions made during the study.

The relevance of the North American PCR to Stora Enso's requirements was decent. This was decided because correct impact category choices will lead to being able to assess the performance of the product according to the needs of the practitioner. Land use impact category can however be not sufficient with its current development and the standard does not recognize the use of forest management schemes.

According to the results, out of these assessment tools, the PEF, and further on the PEFCR is considered the most promising towards achieving the goal of Stora Enso and maintaining the proactive approach to environmental assessment. The PEFCR is more directed towards comparison than any other assessment methodology, even if comparison currently may depend too much on the development of data availability. The PEFCR provides specific rules that the practitioner must follow, providing a better baseline for comparison. As data availability increases, so does the value of PEFCR studies due to increase in data quality. The PEFCR is currently being updated according to the latest information on environmental assessment. The downside of the PEFCR is that it is a study that requires a high amount of resources and therefore not viable for stakeholders, which have not allocated resources towards environmental assessment. Initiating a PEFCR study will require a vast amount of resources from multiple companies, if the product goes through different companies during its life cycle. Therefore, based on theory, the study that would be most beneficial regarding environmental performance assessment would be the PEFCR. Further development in the methodology behind assessing and calculating environmental impacts will increase the worth of the PEFCR study. In the case that some impact category is not developed enough to provide indicators for Stora Enso's environmental agenda, other indicators could be used. An example of this could be that since the impact category of land use is not as clear and sturdy now, FSC or PEFC could be used as the indicator until the land use impact category is developed further. Whether the initiating of the study is realistic depends on the state and willingness of the stakeholders that must be involved, which was to be assessed using the questionnaire that was sent to involved stakeholders.

6.2 Supplier analysis

This section of the thesis will analyze the results that were received from conducting the questionnaire and public information acquired from the websites of companies. The questionnaire was sent to eight different companies, four of which answered. The low amount of answers was to be expected, as environmental sustainability assessment frameworks are still under development and can be a sensitive subject for some companies. This is not enough data to make a sturdy conclusions, however it does still tell us a lot about the motivation and maturity of the suppliers. The low response rate is understandable also for the reason that the work load of many sustainability personnel is high and providing information for a master's thesis may not be on the top of their priority list, however it also reflects the lack of motivation to invest time into the development of an environmental assessment framework.

For the four answers that was received some were more positive and productive than others. The four answers are divided in three different levels of development. One is developed, one at a medium level and two at a low level. One of the respondents claimed to have the inventory data on a product level, one on a factory level, one on a production line level and the last claimed to have them all. Even with the low response rate, the inventory data tends to be not calculated for specific products, but rather on a higher level.

Two out of four companies have data verified by an independent third party. Two of the respondents said the data is not verified by a third party but is verified internally. This shows that effort is being put into the verification of data, instead of only accepting the first piece of data available. Three out of the four respondents were familiar with most of the assessment methods, and some assessment methods were already in use. All but one of the respondents were already using the carbon footprint method on different scales. This means that out of all the different environmental assessment methods, carbon footprint is the most recognized by the respondents. This shows that the companies are adapting the life cycle approach that the carbon footprint requires according to CEPI ten toes, ISO 14067 and PAS 2050. Initiating a carbon footprint study would be one of the easiest ways to start cooperation with the suppliers. Unfortunately assessing only climate change will not satisfy the strategy and goals of Stora Enso.

Three out of the four respondents said that PEFCR will not be used and one company had not made any decisions regarding the usage. One of the respondents considered LCI data as confidential and against competition rules, which raises the question as to whether data like this should be confidential in the first place. Further study could be conducted on the process of sharing data.

To complement the information gathered with the questionnaire, the companies were assessed according to their public sustainability information. Public sustainability information will give guidance on how ready the suppliers are to initiate a multi-stakeholder environmental assessment. Their sustainability websites and GRI reporting also give information about their sustainability activities. This will however be not assessed further in this thesis to maintain the anonymous status of the companies.

Out of the eight organizations that were sent the questionnaire, five of them were involved in WWF Paper Company Index (WWF 2019). The paper company index collects voluntary disclosures about the environmental data of a company, to assess over 50 indicators, which WWF considers important (WWF, 2019). The data that is received is displayed in a non-comparative manner (WWF, 2019). As the study is voluntary, being a part of this information sharing opportunity shows the willingness to start transparent information sharing.

The second indicator is the use of Paper Profiles. Five of these companies were already company members of Paper Profile. The reason Paper Profiles were chosen, was because it requires LCI data at some level to show emission values for products. This means that allocation of the data has been made for the specific product, showing that five companies can collect LCI data that the Paper Profile requires.

The last indicator that shows a high level of environmental development is the involvement in PEFCR development. Two of the assessed companies were involved in the development of PEFCR. It must also be noted, that only because the company is involved in the development of PEFCR does not mean that a lot of effort is being put into it. The future benefit of being involved in PEF development is that the PEF standard will have included the wants and needs of the companies involved in developing of it. Whereas the companies, which are not supporting the development of it will have to adapt to the standard later in the case that they want to conduct the study. There is a risk however, in the case that PEF does not become a widely known, universally accepted and used by many companies, it may not bring the market value that was initially hoped for and the resources spent may not have the fastest payback time as said in section 2.4.

To improve the study that was conducted, a visit to the supplier could have been done to provide further encouragement for the suppliers. If a meeting cannot be arranged and no answers are given, then according to theory, the customer may not be as attractive to the supplier as mentioned in section 2.6.

6.3 Suggestion

This section will attempt to bring together the results of the assessment of standards and the realistic involvement of the stakeholders. The suggestion is based on the information from the questionnaire and the theoretical background provided throughout the thesis.

The theoretical results provide evidence that the PEF study is the most comprehensive and specific study that focuses on paper used for corrugated boxes. The PEF study is also the most relevant to the goals of Stora Enso. With the current development rate of environmental importance in industrial activity, the assessment of environmental performance will be encouraged if not made mandatory in the future. If this happens, having initiated a PEF study early on will help comply with all the new rules and regulations, guidelines or indicators, which the company itself may have had their own input in. Therefore, from a theoretical point of view, it is suggested that a PEF study will be initiated once the final version of the PCR is released.

When looking at the results of the questionnaire however, not a lot of interest was shown towards PEFCR, but a rather large amount in the carbon footprint and the paper profile. This shows that some level of environmental data is available, however a study that requires a lot of resources will not be invested into. As the use of environmental assessment frameworks become more popular in the upcoming years (assuming the development continues at current rate), the demand grows and multi-stakeholder cooperation with information sharing is more likely. At the current time, initiating a PEF study is not impossible, but does require heavy effort from people in the management teams of the involved companies. In my opinion, the company has a choice to make on the level of environmental performance assessment that they want to achieve:

1. The company can put effort into being active towards the stakeholders and establish an information sharing project so conducting the chosen study will be easier.
2. The company can retract from involving suppliers in their manufacturing processes and focus on the internal environmental assessment of their products.

During decision making, it is very important to note that the production of corrugated boxes consists of large high capacity machinery, which produces certain qualities of products. This leads to the markets of corrugated boxes being extremely interlinked; therefore, the customers of some companies can also be the suppliers of the same company. This creates a situation where a decision to stray away from suppliers may have an impact on the customer relationship of that same supplier as well.

As the company in question is not fully dependent on suppliers, but have their own paper production, the fastest way to evidently improve the footprint of their corrugated offering is by centering the whole process described in section 4.1 to their own facilities. The sharing of information and communication in general should be easier as the confidentiality of data may not be as big of a challenge within the company. In this way, when the environmental assessment develops further and the demand for it grows, they are ready to provide for the demand. The benefit of the second choice is that the company can also put more effort into helping develop environmental assessment processes and therefore have a choice in the future of environmental assessment studies.

If the company decides to be active towards its suppliers, physical workshops is encouraged and it would be much more realistic to initiate a multi-stakeholder carbon footprint study and open the flow of information. This way both companies start to work from something that is familiar and has been done before. The carbon footprint study should be initiated with the standard that is most known to both parties, as the end goal is to develop it into an information sharing cooperation and further onto the conducting of a PEFCR study. Conducting a carbon footprint study instead of a PEF study can help achieve the goals set with the help of science based targets, which encourages Stora Enso to reduce GHG emissions as soon as possible, because the carbon footprint study can provide results faster. If the carbon footprint proves to not be a challenge, the information gathering can be extended to involve all more emissions. Once multi-stakeholder carbon footprint studies have been conducted and the information sharing code of conducts have been agreed upon, then steps can be taken towards collecting information that the PEFCR requires. It is hoped that by that stage; the impact category calculation methodology has developed far enough so it can provide market benefits for both companies. If the company chooses to stray away from the suppliers that do not share the same environmental values, the company has a much higher chance of conducting full PEF studies as the flow of information will be easier. Also, if the land use impact category is not developed far enough to be applicable, then the forests, plantations and land use environmental agenda of Stora Enso can be measured according to the FSC and PEFC certification schemes.

7 CONCLUSION

The start of outstanding sustainability performance of a company is the correct implementation of a sustainability strategy with the help of stakeholders. The sustainability strategy can fall on a scale from proactive to reactive and for maximum performance, the strategy should be further towards being proactive. Once the company knows what they want, what their values are and how they are planning on pursuing it, the company must set up ways to assess their performance with relevant and accurate PIs. The development of PIs is well on its way and the current obstacle to pass is making these PIs relevant to the impact categories that are being assessed. Involving stakeholders into the assessment requires that the same values are being used for the same impact categories, and this can be achieved with the help of the same standard as a basis for assessment. Therefore, the standard and tool for environmental assessment works to improve the environmental performance of a company by analyzing the current processes and providing information for decision-making.

The most developed way of thinking is to assess the life cycle of a product. There are different ways to assess the life cycle and standards made for them, and each of them consists of collecting inventory data. The data required for the different frameworks are also different depending on what the framework requires, or the practitioner chooses. If the process requires the help of stakeholders, the stakeholders need to be included in the choosing of data gathered, as they know best what type of data they have available and what is easily accessible. The way the data is processed, then differs according to different frameworks. Some implementations of environmental assessment require more effort than others due to the level of detail. The different impact categories that the products are rated against are at different levels of development and some already have multiple ways of coming to an endpoint result. The development of the calculation methods may change the inventory data that is required from the process, hence why the LCI stage of LCA will have to be revisited depending on whether the processes have developed further at the end of the validity of the study. As a part of a sustainability strategy, an assessment framework must be used to assess the progress and find points of weakness throughout the life cycle of a product. There are multiple assessment frameworks for the pillar of environmental sustainability, each with their benefits and hindrances. Choosing the ‘correct’ framework is hard, as the processes vary according to location and type and the collection of correct and accurate data requires different investments that may be hard to justify currently depending on the values of the company, due to indirect market benefits.

Life cycle assessment is the most developed tool for the assessment of environmental performance, however there are parts of it, which needs further development. The future of life cycle assessment is based on the development of data quality and the relevance of the data to the focused impact category. The points of current development is focusing on the theory behind LCIA. There is some lack of common agreement between experts about impact categories and how they are to be calculated. Despite there being some holes in the theory behind the whole process of LCA, initiating LCA studies will not go to waste. Most of the labor in conducting LCA is spent on data collection, availability, quality and maintenance. To be proactive in the development of environmental assessment frameworks, one needs to initiate the demanded stages early with the help of stakeholders. The stakeholder engagement and data sharing process can be extremely time consuming, therefore it should be initiated at an early stage in the process. Initiating a full out LCA study means that the proactive approach will take resources, with the idea that they will pay off in the long run when the methodology has caught up to the demand as explained in section 2.4. If the company is tied to different suppliers, the involvement of suppliers must be initiated very early in the LCA process for the LCA to be smooth. In practice this means that the collection of data for LCI should be initiated as soon as possible, so it is ready for when the LCIA theory is further developed.

The manufacturing of corrugated boxes can be a complex process, but generally is involves the following stages at least: raw material extraction, debarking and chipping, pulping, paper manufacturing, corrugating, gluing, bending and cutting. Out of the process of the creation of corrugated boxes, the most environmentally intensive part is the creation of the intermediate paper, including pulping before the corrugating part. Depending on whether the paper is going to the fluting or liner part of the corrugated boxes, the paper might have different compositions. As in many cases, the paper is produced by suppliers, it can be very important to collect environmental data from them to conduct a comprehensive environmental study.

The aim of this thesis was to identify and suggest a feasible sustainability assessment framework for paper used in corrugated boxes that reflects the sustainability strategy of the case company and readiness of the suppliers to adopt it. The straight-out answer is that there isn’t one single assessment framework, which answers each sustainability target or goal set by Stora Enso comprehensively. Many of the frameworks include similar LCI, with different interpretations of impact categories, allocation methods and LCA type. With the environmental agenda of Stora Enso, the focuses tend to be in the impact categories of climate change, fossil fuel depletion, eutrophication, acidification and land use. The way information is collected can be easier for some units and harder for others, therefore there is not one single process, which is better than others. There are more detailed ones such as the PEF and EPD, and less detailed ones such as WWF Check Your Paper and Paper Profile. Initiating any of the studies explained in section 3 will not go to waste, as for all, the information gathering is the most challenging aspect and this depends on the strategies and motives explained in section 2. The two most standardized, relevant and comprehensive studies to the product being considered are the PEF and the EPD, therefore it would be the most beneficial to initiate one of these studies. Whether it answers the environmental agenda of Stora Enso depends on the impact categories chosen for the study and the availability of information. Both of those methods have their own PCR for paper used in corrugated boxes and they will return results usable in the assessment of the environmental agenda. Choosing one PCR over the other will influence the study, however completing one of the PCRs will aid in the completion of the other as information gathering processes are similar. Out of the two, EPD PCR and PEFCR, the PEFCR is stricter and therefore causes more labor but also has the potential to bring further benefits. Another reason to choose the PEFCR over EPD PCR, is that it encourages the consideration of the land use impact category, which the EPD doesn’t by default and one of the environmental agendas of Stora Enso is forests, plantations and land use.

The research questions were answered throughout the thesis. Question number one was: how can environmental assessment tools be used as a part of sustainability strategy implementation? Environmental assessment tools can be used as indicators to monitor the development of the process and as a tool for decision-making. The environmental assessment tools provide information on the points of interest throughout the life cycle of the product and therefore suggest points of development that should be focused on. The second question was: what are the different environmental assessment tools and what are the advantages and disadvantages of them? This question was answered in the results section, however instead of splitting them into advantages and disadvantages, it was recognized that tools each have their own advantages and disadvantages that suit different situations. Therefore, different criterion was created to analyze the needs of the case company and overall specifications of the methods. This way the company can make a choice according to the current situation and requirements. The third question was: how do the involved stakeholders see the feasibility of different environmental assessment tools? The data that was received for the third question may not be as reliable, however with the data that was received the conclusion was that carbon footprint assessment of products can be a good stepping stone towards more comprehensive environmental assessment methods. The fourth question was: What environmental assessment tool should Stora Enso use for the environmental performance assessment of paper used for corrugated boxes? The answer to this question is the PEF due to the category rules provided. Therefore, to link the comparison of methods with the questionnaire results, it would be good to initiate a multi-stakeholder carbon footprint study and once this study is complete, the basis for information sharing has been established and therefore the completion of more comprehensive studies like PEF may be initiated. In the case that the difference between the resource need of a carbon footprint and PEF is too high, a paper profile could be initiated to start involving more impact categories than just climate change.

Suggestions for further study include the implementation of economics and social sides of sustainability by adding life cycle costing and social life cycle assessment into the framework. Currently life cycle costing and social life cycle is not measured at all in the environmental assessment, however further research may be needed in social life cycles and life cycle costing to fully integrate it with the environmental assessment tool. To further assess the environmental impact of the product, the concept of the environmental handprint could be implemented. This may lead to leasing systems, where recycling is sold as a part of the product. As the environmental assessment tool has been suggested, the next step would be to initiate a cooperation with the relevant stakeholders and start the information sharing to complete the environmental assessment that suits the needs of all customers. After the information has been collected, a full LCA could be initiated. Another way to further study the project, is to see how the sharing of data could be completed and whether it needs to be confidential in the first place. The study could take itself further into the way the impact categories are measured, how they could be developed further into a more standardized form and what are the relevant indicators for them. If the case study was to be inquired further, a specific unit of Stora Enso could have been focused on and the amount of work and investments needed to collect the LCI data for a specific framework could be estimated.

8 SUMMARY

This thesis focused on the environmental performance assessment of paper used for corrugated boxes. The aim of the thesis was to suggest one environmental performance assessment method for the assessment of paper used for corrugated boxes. The challenge was that the assessment method must suit the goals of Stora Enso, while being realistic to conduct with the stakeholders that must be involved.

The resources used for this thesis were literature, webpages, standards, discussions with experts, guidelines and a supplier questionnaire. This thesis started by inquiring into the approaches and drivers of sustainability strategies, performance indicators and the implementation of a sustainability strategy. The thesis then inquired into how environmental performance assessment plays a role in the sustainability strategy of a company and how the data should be collected from the relevant stakeholders, which in this case was the suppliers. Then after identifying that performance assessment is an important part to the monitoring and developing of a sustainability strategy, the possible performance assessment methods were identified.

The different environmental performance assessment methodology and the process of LCA were introduced in section 3. After the methods have been identified, the thesis moved towards the manufacturing process of the product that would be the target of the assessment. After the manufacturing process has been determined, the different impact categories that relate to the it can be identified and assessed. The thesis chose seven different impact categories that relate to the manufacturing process and identified their measuring methodologies along with some limitations associated with them to show the development status of impact category assessment.

The thesis then focuses on Stora Enso by identifying their environmental agenda. With the Stora Enso environmental agenda defined and the environmental assessment methodologies identified, the data collection approaches can be initiated. The theory of stakeholder engagement, the manufacturing process, Stora Enso environmental agenda and the methodologies were combined and made into a questionnaire. Based off the results of data collection approaches in section 2.5. A questionnaire was sent to suppliers, that inquired about their views, opinions and ability level of conducting an environmental performance assessment.

The different performance assessment standards or guidelines were assessed against the environmental agenda of Stora Enso, and out of all assessment methodologies, the PEF assessment guideline stood out as the most relevant towards the agenda. The results of the questionnaire showed interest towards the carbon footprint; however, the carbon footprint does not answer the environmental agenda of Stora Enso properly. Therefore, a suggestion was made that due to the difficulties in supplier engagement, it would be more realistic to start the cooperation with something familiar such as the carbon footprint, and then expand further towards the PEF study.

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APPENDICES

Questionnaire:

We are conducting a confidential study on the environmental assessment of papers used for corrugated boxes and would like to ask you a couple of questions regarding environmental performance data of your products. The respondents of the questionnaire will be sent a link to the final master's thesis report, when it has been published.

1. Contact details: Company name, name and email address (Will only be used to follow up which companies have responded. Only a summary of survey results will be presented in the master's thesis work and no companies or names of respondents will be mentioned.)
2. What inventory data do you have available?
    a. Corporate level
    b. Factory level
    c. Production line level
    d. Product level
    e. Other, please comment
3. Is the inventory data verified?
    a. No
    b. Yes, please explain how in the comments
    c. Yes, by an independent third party
    d. Yes, internally
4. What environmental assessment tools do you already use or are familiar with? (Option include "Already using" and "familiar with")
    a. PEFCR Intermediate Paper (http://ec.europa.eu/environment/eussd/smgp/policy_footprint.htm)
    b. Carbon Footprint (Cradle to gate) (PAS 2050 or ISO 14067) Please mention method
    c. Carbon Footprint (Gate to gate) (PAS 2050 or ISO 14067) Please mention method
    d. EPD PCR Corrugated paper and paperboard (https://www.environdec.com/)
    e. Paper Profile (http://www.paperprofile.com/index.html)
    f. WWF Check Your Paper (http://checkyourpaper.panda.org/)
    g. Others, please explain below which method tool and if you are using the carbon footprint, please mention the standard used

5. Which of the following tools would you be willing to use in the next year? 5 years? (Options include “One year”, “five years” and “not going to be used”)
    a. PEFCR Intermediate Paper
    b. Carbon Footprint (Gate to gate)
    c. Carbon Footprint (Cradle to gate)
    d. EPD PCR Corrugated paper and paperboard
    e. Paper Profile
    f. WWF Check Your Paper
    g. Other, please mention in comments
6. Do you see any obstacles in the sharing of inventory data with Stora Enso?
    a. Yes, please specify what the obstacles may be
    b. No
7. If you do see obstacles in the sharing of inventory data, how could these be overcome?
8. Would you want us to be in contact with you later concerning environmental data collection?
    a. Yes
    b. No
9. Suggestions or comments regarding the environmental assessment of papers used in corrugated boxes