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AN ENVIRONMENTAL MANAGEMENT ACCOUNTING SYSTEM BASED ON THE SOCIAL COST AND THE MARKET-BASED PRICE OF CARBON

Master's Thesis

Accounting

05 2020

UNIVERSITY OF OULU ABSTRACT OF THE MASTER'S THESIS
Oulu Business School

Unit			
Financial and management accounting			
Author: Breukers Leonard		Supervisor: Järvinen J Dean of education, Prof.	
Title: An environmental management accounting system based on the social cost and the market-based price of carbon			
Subject: Management accounting	Type of the degree: Pro Gradu	Time of publication: June 2020	Number of pages: 177, 3 pcs

Abstract

Companies are facing increasing pressure from external stakeholders to integrate sustainability as part of the company's strategy and display their efforts to change social, environmental, and governmental output. Especially the effects from climate-change to business operations has become a popular topic in the business agenda. TCFD has published recommendations for companies to report on their environmental efforts and how those efforts to fight climate-change affect the business. Companies' external and internal reporting on these issues is becoming increasingly popular as portraited by the World Bank's 2019 report on internal carbon pricing and the increasing number of frameworks on sustainability reporting (e.g. ISO, GRI, UN SDGs). This research takes a holistic approach to understand, how environmental issues are part of business operations and how a company could report on environmental issues through environmental management accounting. I focus on the reporting and estimation of carbon dioxide emissions from the perspective of elevator manufacturing. Carbon dioxide emissions are chosen as they are the most contributing GHG-emission to the climate-change, and the elevator industry is facing increasing demand for more environmentally healthy products to slow down the increasing impact on climate-change through urbanization.

The study uses Burritt, Schaltegger and Zvezdov's 2011 framework on carbon management accounting and extend their model on monetary carbon accounting with an environmental profit and loss -statement. The EP&L is based on the PricewaterhouseCooper's 2015 -report and is implemented into a case company KONE to estimate the environmental impact from an elevator MonoSpace 500. Social cost of carbon, marginal abatement cost of carbon and market-based price of carbon are discussed, and the SCC and the market-based estimates are used to estimate the monetary value of carbon dioxide emissions. I estimate the SCC with a meta-analysis following the 2015 PwC's report and use the ECX EUA futures' spot prices to estimate the market-based cost of carbon dioxide emissions. Additional expert interviews are used to decide which pricing method is appropriate considering future expectations, and how carbon pricing is affecting business behavior.

I use an estimate of SCC of USD 40 / tCO_2e and a market-based price of carbon of EUR 25.3 / tCO_2e to estimate the total emissions from the life cycle of one elevator. However, through expert interviews the study concludes that the recommended method for strategic business planning, budgeting, and reporting on carbon pricing is the marginal abatement costing -method. Additional findings include the implementation methodology of an environmental profit and loss -statement based on seven case companies and how the elevator industry can use carbon pricing as means to manage carbon emission through a bonus-malus system.

Keywords
Environmental profit and loss statement, carbon management accounting, elevator industry

Additional information

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INTRODUCTION

” Business…used to be depicted as a primary source of the world’s environmental problems. Today, it is increasingly viewed as a vital contributor to solving those problems and securing a sustainable future for the planet”.

Livio deSimone, the former chairman and Chief Executive Officer of the 3M company and the former chairman of the World Business Council on Sustainable Development, stated this in his “Letter from the Chairman” in 1996 (Najam 1999). This depiction of corporate responsibility, to solve environmental problems rather than to cause them, has increased its significance in the corporate agenda. The demand for environmental consulting has increased (from $28.4 billion in 2013 to $31.9 billion in 2017 and expected to grow to $35.9 billion by 2021) (marketwatch.com) and the likelihood for companies to include environmental risks into decision-making have increased (WEF 2013, 2014, 2018, 2019). Advances have been made by companies and organisations to include sustainable development and carbon management as part of their agenda, but simply slowing down of the cradle-to-grave life cycle of products is not sufficient enough to achieve sustainability (Braungart, McDonough 1998). As Milne and Gray (2013) point out; dematerialization during production does not solve environmental issues, it just creates less.

Why are environmental issues such a growing concern of business? Businesses contribute to climate-change by releasing emissions to the atmosphere as a by-product of production. These can include carbon dioxide, methane and nitrous oxide. Climate-change contributes to global warming (Dutch 2010) and global-warming increases e.g. risk of droughts, floods, water scarcity, poverty, reduction in food availability, lower tourism in climate sensitive areas and loss of natural resources (IPCC Special Report 15). The most contributing emission to climate-change is carbon dioxide (Dutch 2010) and according to the World Resource Institute (see Appendix 2) carbon dioxide emissions are mostly contributed by business operations, especially in energy, industrial, agriculture and waste industries. To fight against carbon dioxide emissions, The European Union has called for its member countries to become carbon neutral by 2050 (ec.europa.eu/2050) and the government of Finland has set a target to become carbon neutral by 2035 (valtioneuvosto.fi/hiilineutraali). For businesses to become carbon neutral, companies can take different approaches to mitigate their direct emissions: companies can buy emissions allowances from the carbon emissions allowance market or they can offset their emissions through e.g. renewable energy or reforestation. All mentioned offsets create costs which need to be recorded to accounting ledgers. I claim that the role of accounting should not be excluded to cost reporting to internalize externalities, but to be extended to analyze the sources of emissions and through management accounting emissions should be mitigated and reduced to meet the external legal compliances of the government like the European Union or Finland.

Therefore, the role of accounting is essential to mitigate the environmental impact in business. It generates, collects and analyses information on the consumption of resources from general ledgers and accounting systems (Ikäheimo, Malmi et al. 2016), which are then used to recognize the environmental performance and impact to and from a company (Bartolomeo, Bennett et al. 2000). However, as the growing demand for environmental analyses increases, so does the need for new research on the role of accounting in the environmental and sustainability spheres (Hopwood, A. G. 2009). Unfortunately, the time for new research on the role of accounting to control and prevent environmental impact is running low. Finnish companies have just 15 years to pursue carbon-neutrality and to consider sustainable development as more than a part of voluntary reporting but as a possibility to improve their business operations through smaller emissions output and to mitigate risks associated with the legal compliance of the Finnish government.

One of the leading trends associated with growing carbon dioxide emissions is urbanization. Urbanization, which is the migration of people from rural to urban areas, is estimated to increase to 68% by 2050 (un.org/2018 urbanization). This will create a higher demand for new buildings and electricity (Crawley 2008), which will create more greenhouse gas emissions (IPCC Fifth Assessment Report 2014) and accelerate anthropogenic climate change (Dutch 2010, europa.eu). One of the sources of emissions comes from the growing need of more electricity, which is partly associated with more elevators. I take a holistic approach to understand how the elevator sector manages its environment impact through accounting and focus especially on management accounting. The decisions made by the management affect the whole organization which eventually affects the environmental policy of a company. But the management needs tools to understand the current and upcoming situation for better decision-making. Therefore, I follow Burritt, Hahn and Schaltegger's 2002 framework on an environmental management accounting system and connect it to carbon management accounting framework by Burritt, Schaltegger and Zvezdov. To investigate possible carbon dioxide emissions sources in a company, I follow the consulting firm PricewaterhouseCooper's 2015 methodology paper on an environmental profit and loss statement and use the method as a basis for collecting emissions information and translating the information from physical units into a unified monetary unit. The carbon pricing methods that I will be addressing during this study are the social cost of carbon, the marginal abatement cost of carbon and the market-based price for carbon.

My research pursues to give answer to the next questions:

RQ1: How a company can determine its internal price for carbon dioxide emissions?

RQ2: How an internal price of carbon dioxide emissions can be attached to carbon management accounting through an environmental profit and loss -statement?

I investigate these research questions through a case company and by transferring information from an environmental product declaration into an environmental profit and loss statement. The information on the impact is then translated into a monetary form and discussed as part of environmental and carbon management accounting system to mitigate emissions from the value-chain of an elevator.

Significant amount of my research is based on the past theoretical and empirical academic literature and on public reports from governments, non-governmental organizations and companies due to a similar secrecy as with private financial reports. Because most of the public environmental reports by companies are voluntary and not necessarily audited by third party auditors, my research relies on past studies, case companies and interviews from experts on the relationship between the environmental issues and business. Additionally, I use data on open prices from the ECX EUA futures to determine the market-based price of carbon and calculate through a meta-analysis my own estimate of the social cost of carbon.

The study has been divided into four chapters. Chapter 2 defines the role of sustainable development in business operations and investigates how companies can lie and cover their non-environmental business operations. This chapter also discusses how international reporting standards and third-party auditors can ensure that the distributed information is certified and valid. Chapter 3 investigates environmental management accounting and specifies the research scope into carbon management accounting. I extend the carbon management accounting framework with an environmental profit and loss –statement and present seven case companies who have used environmental profit and loss –statements to analyze and manage greenhouse gas emissions. Chapter 4 continues the environmental profit and loss –statement by introducing three carbon pricing methodologies to quantify the reported environmental impact. This chapter presents the approaches to calculate the internal price for carbon and compares each method to each other. Chapter 5 present the case company, KONE Corporation, and implements the environmental profit and loss –statement to the MonoSpace 500 life-cycle assessment. Chapter 7 presents my propositions to the case company and introduces policy recommendations based on my theoretical and empirical findings. Chapter 8 summarizes my findings and proposes further subjects for future research studies.

2. SUSTAINABLE DEVELOPMENT

This part investigates the term “Sustainable development” in global business environment and how companies are driven towards more sustainable operations through pressure from its stakeholders. First, the chapter strives to find definition for “Sustainable development” and then how business and the environment are connected through history. Next, I will discuss how companies understand sustainability as part of their operations and continue the chapter on greenwashing and why companies build façades to hide their un-environmental business operations. Lastly, I investigate measures to prevent the distribution of unreliable information by getting to know the international standards and guidelines and the process of environmental auditing.

Sustainable development (SD) is a commonly used term amongst companies and politicians to describe social or environmental actions against e.g. climate change or corruption. However, even if sustainable development has become a common subject to discuss amongst decision makers, the definition for the term itself has not been fully established. This creates many different meanings for sustainable development and provokes many different responses (Hopwood, B., Mellor et al. 2005), which from corporate reporting, and especially from financial reporting perspective creates a problem: what is sustainable development?

Although there is no official definition for SD, most studies and organizations recognize sustainable development according to the 1987 Brundtland -report or the “Our common future” -report (Hopwood, B., Mellor et al. 2005, Abrahams 2017, Najam 1999). This report was conducted by the United Nations World Commission on Environment and Development (UNWCED) and was named according to the chairman at the time Gro Brundtland. In the Bruntland –report, sustainable development is defined as:

“Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs”

Additional descriptions on sustainable development and on sustainability have increased in the academic literature. Alexandru and Sprineau-Georgescu (2011) discuss how sustainability should be seen as a measure of relationship between the community and their environment, rather than a designated goal to be achieved. They also state that sustainable development is not static, but a dynamic concept which changes and evolves continuously. Abrahams (2017) points out two normative definitions for sustainable development in his research on the sustainable development in construction industry. He draws the definitions from the Brundtland -report which are the "Our Common Future"-definition and "Three Pillars of sustainability"-definition. "Our Common Future" description of SD is very close to the original UN -report: "meeting the needs of the present without compromising the ability of future generations to meet their needs". The "Three Pillars of sustainability" description, on the other hand, links economic, social and environmental concerns together (Abrahams 2017). Abrahams confirms that the conceptual framework for sustainable development described through these two normative definitions is the base in academic literature. He also points out how individuals, at least in the construction industry, build definitions of sustainable development according to their own motives: some used it to valorise their professional roles, some used sustainable development to support professional criticism on the industry and some used it to reinforce their personal ideological beliefs. Abrahams does describe in his limitations of the 2017 study, that the undefined term "sustainable development" creates a challenge to pinpoint the concept of SD.

The Brundtland -report is a heavily referred description of sustainable development in the academic literature and in some substantial organizations associated with sustainable development as well (e.g. UN, IISD). However, the definite definition of sustainable development is still under scrutiny as Wackernagel and Rees point out in their 1996 book "Our ecological footprint: Reducing human impact on earth". They discuss the critic against Brundtland –report for not specifying the term "sustainable development" but for leaving it to open interpretation. Additionally, the critic attacks the status quo –approach Brundtland commission has taken to hide economic growth thinking under the new name "sustainable development". Granted, Wackernagel and Rees pursue to drive the ecological footprint –approach and use the lack of definition of sustainable development to contribute their view but studies do recognize the danger and confusion of an unofficial term for global development (Abrahams 2017, Sneddon, Howarth et al. 2006).

Hopwood, Mellor et al. (2005) in their article “Sustainable development: Mapping different approaches” discuss the different meanings of SD and how social, economic and environmental causes have developed through time. Their research collects different views from other studies and presents three approaches on SD: status quo, reform and transformation. These approaches describe the need and actions for change, where status quo recognizes the need for change but does not see the environment or the society as facing insurable problems. Reform acknowledges the problems but does not see a necessity for fundamental change and transformation -approach understands the problems and recognizes a necessary transformation of society and its relation to the environment to avoid these problems. The study concludes that all proponents of sustainable development agree on society’s need to change, but what needs to be changed and which actions and tools to use is a subject of debate. Also, the current dominating approach at the time had been status quo or the top-down -approach to pursue sustainable development (Hopwood, Mellor et al. 2005).

Hopwood et al. (2005) describe the usual model for sustainable development as three separate but connected rings, which are at least in part independent of each other. The three rings are economic, social and environmental aspects (United Nations World Summit 2005) or in corporate sustainability they are called the economic, natural and social capital (Dyllick, Hockerts 2002). Hopwood et al. (2005) describe that the defenders of the status quo –aspect see the lack of sustainable development as the lack of knowledge and appropriate mechanisms for development, rather than a linkage between the three aspects. Hopwood et al. (2005) criticise this view as it allows trade-offs between environmental and social issues, and keeps the environment and humanity separate from each other. Giddings et al. (2002) do not see the three aspects separated but interconnected. Separation of aspects indicates a risk to approach sustainable development issues in a compartmentalized manner and not approaching the problem as connected issues (Giddings, Hopwood et al. 2002). Neumayer (2003) agrees with Hopwood et al. (2005) that the separation of aspects could lead to trade-offs between the three aspects. This is why Hopwood et al. (2005) suggest that the model would be changed to include the different connections between the three aspects. Humans are dependent on the environment, so society is dependent of and exists within the environment, and the economy exists within the society (Hopwood, Mellor et al. 2005). One could argue that this model gives too much emphasis on the economic –aspects as it lies in the centre or too much emphasis on the environmental –aspect as it surrounds the other two aspects. However, Giddings et al. (2002) do mention that these two aspects (economic and environmental) do receive priority in most debates regarding sustainable development. Even in the last 5 years, Google trends reports that the top 5 most related web searches for the term "sustainable development" from the whole world include sustainable development and economic growth next to each other. Table 1 illustrates this list.

Table 1 Top 5 most related web searches for the term "sustainable development" 2014-2019 (Google Trends, 10/10/2019, 10:00)

Index	Related search subjects	% of searches
1	Sustainability	100
2	Sustainable development	94
3	Economic growth	59
4	Sustainable development goals	30
5	Global development	29

Data has been retrieved from Google Trends on October 10th, 2019 at 10:00 am. The scale has been the whole world from the past 5 years from all classes on web searches. Column "% of searches" illustrates the highest searched subject as 100.

The relationship between the economic and environmental aspect can be also seen in the book "Contemporary environmental accounting: Issues, concepts and practise" by Schaltegger and Burritt (2000), where the relationship between changing legislation regarding environmental reporting and financial growth is examined. They explain how it is the benefit of a company to comply with new environmental legislation and prevent possible fines or loss of reputation in the marketplace, which would lead to the loss of investors' trust and market position.

I conclude that there is no official description for the term "sustainable development" but this study uses the term according to the Brundtland –report as it is widely used in academic papers. Because I focus on the economic effects from the environment, the three aspect of sustainable development (economic, social and environment) are reduced to two: economic and environmental. Next, I try to establish the link between economic and environmental aspects from corporate perspective.

2.1 Business and the environment

Schaltegger and Burritt (2000) have proposed two ways for businesses to look into the harmony between environmental protection and economic profitability: companies can practice economically profitable environmental protection, which is to reduce the harmful impact on the environment while keeping constant or increasing profitability. Or, companies can also practice environmentally beneficial economic activity, which is the pursuit of increased profitability through methods which happen to reduce environmental impact as well. The chosen approach depends on the nature of business operations, but risks associated with the environmental impact remain the same regardless of choice.

One of the rising risks corporations will experience are extreme weather events and their side-effects on business operations (WEF Global Risk Report 2019). Currently, the top three most likely and top 4 risks by impact listed on the WEF Global risk report are environmentally related (see tables 2 and 3). Climate-change by millennial timescales can be considered natural, but the current global warming over the past 150 years is most likely caused by human actions (Dutch 2010). One of the contributing factors to the global warming are greenhouse gas (GHG) emissions, which include carbon dioxide (CO_2), methane (CH_4) nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride(SF_6) and natrium trifluoride (NF_3) (europa.eu). Out of these GHGs carbon dioxide is the most contributing to global warming and to mitigate the effects of GHGs on climate, Annex B of Kyoto Protocol was adopted by several countries in 1997 (unfccc.int/Kyoto protocol). It was established for the participating countries to trade and purchase emissions credits (Dutch 2010) and is one example of several countries coming together to pursue climate-change mitigation by changing the behaviour of countries and companies.

The study of occurring costs from GHG mitigation strategies is called the economics of global climate change (Dutch 2010) which combines the required of political, environmental and economic knowledge to pursue global mitigation of global warming (see e.g. WCED 1987, Earth Summit in Rio de Janeiro 1992, Kyoto Protocol in Kyoto 1997 or Paris agreement 2015). The latest global meeting of countries to fight against climate change was the Paris Agreement organized by United Nations Framework

Table 2 Top 5 Global Risks in terms of likelihood 2017-2019 (WEF, Global Risks 2019)

Year	2016	2017	2018	2019
Rank 1	Large –scale involuntary migration	Extreme weather events	Extreme weather events	Extreme weather events
Rank 2	Extreme weather events	Large –scale involuntary migration	Natural disasters	Failure of climate-change mitigation and adaptation
Rank 3	Failure of climate-change mitigation and adaptation	Major natural disasters	Cyber-attacks	Natural disasters
Rank 4	Interstate conflict with regional consequences	Large –scale terrorist attacks	Data fraud of theft	Data fraud of theft
Rank 5	Major natural catastrophes	Massive incident of data fraud/theft	Failure of climate-change mitigation and adaptation	Cyber-attacks

The colours of the table equal to the specific category of the risk: Green = Environmental, Purple = Technological, Red = Societal and Beige = Geopolitical

Table 3 Top 5 Global Risks in terms of impact 2017-2019 (WEF, Global Risks 2019)

Year	2016	2017	2018	2019
Rank 1	Failure of climate-change mitigation and adaption	Weapons of mass destruction	Weapons of mass destruction	Weapons of mass destruction
Rank 2	Weapons of mass destruction	Extreme weather events	Extreme weather events	Failure of climate-change mitigation and adaption
Rank 3	Water crisis	Water crisis	Natural disasters	Extreme weather events
Rank 4	Large-scale involuntary migrations	Major natural disasters	Failure of climate-change mitigation and adaption	Water crisis
Rank 5	Severe energy price shock	Failure of climate-change mitigation and adaption	Water crisis	Natural disasters

The colours of the table equal to the specific category of the risk: Green = Environmental, Purple = Technological, Red = Societal and Beige = Geopolitical, Blue = Economic

Convention on Climate Change (UNFCCC), which entered into force in 2016. The aim is to bring all nations together and fight against climate change and adapt to its effects, by keeping the global temperature rise during this century below 2 degrees Celsius. Additionally, the agreement pursues to limit the temperature increase further to 1.5 degrees Celsius and support countries to deal with the impact of climate change. Major requirement for businesses would be part of the countries' regular reporting of emissions and implementation efforts. (UNFCCC.int.) The UNFCC also states that developed countries should continue to pursue absolute economy-wide reduction targets.

In 2016 at the UN Climate Change Conference in Marrakech, private sector leaders called for countries to fully implement national climate action plans (also known as Nationally Determined Contributions or NDCs) by implementing strong domestic legislation. This way the private sector could speedily implement new legislation into their climate change commitment as the private sector is a major source of GHG emissions. Its participation in the Paris Agreement is crucial for the reduction of GHG emissions (UNFCCC.int/ Paris goals.) Looking at the largest CO_2 emitting industries by country, the largest sectors are energy, industry, agriculture and waste (wri.org) (see Appendix 2). The relationship between large GHG emissions and the private sector is clear, and the private sector has even asked the public sector for new legislation to increase implementation speed and reduce GHG emissions in order to meet the Paris agreement requirements.

Historically, legislation linking business actions with environmental concerns is relatively modern. The Clean Air Act of 1956 posed by the United Kingdom after the London smog of 1952, which decreased the use of solid energy fuels, demanded the use of tall chimneys and relocation of power stations to improve the overall air quality (air-quality.org.uk). The 1969 National Environmental Policy Act in the United States requires environmental assessments and environmental impact statements when airports, buildings, military complexes, highways, parkland purchases and other federal activities are proposed (epa.gov/environmental-policy). In 1970 the Victorian Environment Protection Act was passed in Australia, Canadian Water Act was passed in 1970 (Gunningham 2009) and the Clean Water Act in the United States in 1972 (epa.gov/ clean-water-act). These examples during the 1970s can be considered the modern environmental law, even if pollution control legislation in the United Kingdom stretches to the 1950s (Holliday 2001). Some could argue that the building of a new sewage system in London after the 1858 summer aptly named the “Great Stink” (Halliday 1999) could be considered environmental action similar to the 1956 Clean Air Act. However, as Gunningham (2009) points out, the 1970s was dominated by legislation designed to prohibit or restrict any harmful activities to the environment by using “direct” or “command and control” mechanisms, which were not included in the1858 sewage construction. The mechanism would set a target or a limit to emissions (called “command”) and impose penalties if targets were not met (called “control”) (Gunningham 2009). These mechanisms have continued to this day, but economists debate on the actual benefits of command and control systems (Cole, Grossman 2018). The critic has concerned over offering no incentives to improve beyond the pre-set standards, for being inflexible between firms who can and cannot meet the standards and the risk to compromise by standard-setters’ political agenda (khanacademy.org). To introduce more flexibility, in 2014 the European Union released its Directive 2014/95/EU which sets rules on disclosing non-financial and diversity information from large public-interest companies with more than 500 employees. Under the directive, a company should disclose implemented policies in relation to environmental protection, social responsibility and treatment of employees, respect for human rights, anti-corruption and bribery and diversity on company boards, including age, gender, educational and professional background. The directive gives companies flexibility to report information by the most useful way possible determined by companies themselves. In 2017 European Commission released guidelines to help disclosure of environmental and social information as an extension to Directive 2014/95/EU. On environmental matters, the guidelines state that:

“A company is expected to disclose relevant information on the actual and potential impact of its operations on the environment, and on how current and foreseeable environmental matters may affect the company’s development, performance and position.” (ec.europa.eu.)

On reporting framework, the guideline recommends using widely recognized framework developed with a due process to limit administrative burden and make information easier to compare. The information should be assessed and presented in a fair and understandable way (eur-lex.europa.eu.)

The significance of financial and business sector on climate-change related information seems to be clear with the establishment of a reporting guidance addressed to businesses in Europe, but also the older legislation connecting business activities to environmental protection and improvement (see e.g. 1956 Clean Air Act). Next, I will discuss how sustainable development and the guiding legislation affects corporate sustainable development and environmental reporting.

2.2 Corporate sustainable development

Several studies discuss the growing pressure companies receive from external stakeholders on environmental impact reports or complying with new environmental protection legislations (Boiral, Gendron 2011, Wang, Wang et al. 2019, Schaltegger, S., Burritt 2000, Ciccullo, Pero et al. 2018, Du 2015, Najam 1999). The power of stakeholders can be significant on environmental concerns when it comes to corporate operational, managerial or strategic issues. Companies even consult stakeholders on managerial issues e.g. on reporting, identifying key performance indicators or on risk management and opportunities. (Spitzeck, Hansen 2010) When it comes to corporate sustainability reporting, stakeholder participation has been essential for the top management to become aware of sustainability issues, its risks and opportunities (AccountAbility and Utopies, 2007). However, in business environmentalism is sometimes criticized for costs which do not meet the imagined environmental benefits (Cairncross, 1995). Opposing economic growth for environmental improvement achieves little (Cairncross, 1995), which refers to Giddings et al.'s (2002) ideas on compartmentalization and the sole focus on environmental actions at the cost of the economic aspect. So, a company needs to find a balance of stakeholder cooperation with corporate governance to help top management understand the risks and opportunities of sustainable business without forgetting the economic aspect of sustainable development.

Dyllick and Hokerts (2002) define corporate sustainability as meeting the needs of firms' direct and indirect stakeholders without compromising its ability to meet the needs of future stakeholders as well. To become sustainable, the firms need to maintain and grow the three bases of capital and for this Dyllick and Hokerts add three key elements of corporate sustainability: integrating the economic, ecological and social aspects in a 'triple-bottom line', integrating the short-term and long-term aspects and consuming the income and not the capital.

"Integrating the economic, ecological and social aspects in a 'triple-bottom line'" means that the modern management theory on sustainability, where the economic aspect is emphasized, is not enough to reach long-term sustainability (Dyllick, Hockerts 2002, Gladwin, Kennelly et al. 1995). This view corresponds to the Giddings et al.'s (2002) paper where they suggest interconnection of the three sustainable development aspects, not separation. "Integrating short-term and long-term aspects" means that the has been a short-term emphasis on profit gains rather than a long-term emphasis. This is contrary to the proposed ideology of corporate sustainable development to meet the needs of the stakeholders today as well as in the future. "Consuming the income and not the capital" returns to common business management of capital maintenance, where the company needs to maintain not just the economic capital but also natural and social capital (Dyllick, Hockerts 2002).The message of corporate sustainable development, according to Dyllick and Hockerts is to manage and grow in the long-term period the natural, social and economic capital equally, not emphasizing one capital over the other. For this research, I focus on the management of economic and natural capital and try to establish a link between these aspects in corporate sustainable development.

One of the first tools to connect economic growth with environmental impact is "eco-efficiency" (EE), which most firms opted for as a guiding principle in the early 2000s (Dyllick, Hockerts 2002). The formal definition of EE by the World Business Council for Sustainable Development (WBCSD) states that eco-efficiency is a ratio of two factors: environmental impact and the value of production (Huppes, Ishikawa 2005). Schaltegger and Wagner (2005) define eco-efficiency as measuring the improvement of environmental performance, which is the change of a firm's environmental impact over time. By integrating the economic and ecological performance together, a company can incorporate environmental issues with economic factors for decision-making (Schaltegger, Stefan, Wagner 2005). The purpose of this is to improve production output and use less resources while pursuing sustainable development (Welford 1998). To achieve this, EE uses lean manufacturing, waste minimization or beneficial reuse, investments in new technology and changing energy resources to renewables, like wind or solar power (Korhonen, Seager 2008). The most general example of an eco-efficiency indicator, according to Schaltegger and Wagner (2005), is the ratio of short-run income to environmental impact added during a specific accounting period.

A large amount of companies pursues to become sustainable, but the actual contribution to sustainable development is questionable. SustainAbility 2019 Leaders Survey finds from a survey of 800 experts that the positive perception on the contrition of sustainable development by the private sector has declined from 2018 by approximately 8%, where the percentage of "excellent" –grade on contribution declined from around 28% (2018) to around 20% (2019) (Sustainability 2019). Experts representing business, government, non-governmental organisations (NGOs) and academia define corporate leadership as having characteristics to integrate sustainability values and making sustainability part of the core business model (Sustainability 2019). However, the GlobeScan - SustainAbility 2019 Leaders Survey on institutional progress regarding sustainable development, finds that the NGOs continue to thrive on sustainable development contributions rather than corporations. This means that the trust in corporations to contribute to sustainable development is in downward trend, which can lead to lose of marketplace if investors' or shareholders/stakeholders' trust is jeopardized (Schaltegger, S., Burritt 2000).

2.3 Greenwashing and facades

We touch upon facades and greenwashing to acknowledge the possibility of untruthfully disclosed information, common in the world of accounting (see e.g. Enron 2001 scandal, Worldcom 2002 scandal, and Lehman Brothers 2008 scandal). Later, I will investigate measures to mitigate the untruthful disclosure with international standards and third-party audits.

Corporate sustainable development and its reports have become a regular feature in corporate boardrooms (Cho, Laine et al. 2015). Also, governmental institutions like the European Union, have taken steps to institutionalize non-financial reporting to meet NGOs' like the UN's demands to pursue more sustainable future and mitigation of risks associated with climate-change (see Directive 2014/95/EU and UNFCCC Paris Agreement 2015). However, there has been a significant gap between portrait corporate sustainability and its practice (Spar, La Mure 2003, Malsch 2013, Cho, Laine et al. 2015) as well as criticism over the message of sustainable reporting, fostering positive public image rather than providing meaningful information on the social and environmental impact (Cho, Michelon et al. 2012).

Abrahamson and Baumard (2008) define an organizational façade as a tool for managers to gain new resources regardless of the efficiency or institutional legitimacy on the use of those resources and to hide the true nature of business. The reason for organizational facades, according to Cho, Laine et al. (2015), is external when institutional and social expectations force organization to resort in hypocrisy. This setup provides managers a solution to manage conflicting stakeholder demands (Cho, Laine et al. 2015), which could be related to the Cairncross's (1995) findings on non-cost-effective environmentalism where external expectations for the environment cannot be met cost-efficiently. I conclude that the issue with organizational facades is the motive to conceal the unpleasant truth of the company's operations or to reduce the gap between disclosed information and the reality of sustainability (Christensen, Morsing et al. 2013).

When facades hide the unwanted truth, greenwashing misleads consumers on the company's environmental practices or on the environmental benefits from a product or a service (TerraChoise, 2009). The objective of greenwashing is on the product or service itself, rather than masking business operations from stakeholder demands. When discussing environmental claims of products or services, greenwashing can be classified into three categories: (1) the claim is too vague and does not have a clear meaning, (2) the claim omits important information to evaluate its truthfulness, (3) the claim is false or a lie (Kangun, Carlson et al. 1991). In the EU, article 6 of Directive 2005/29/EC protects consumers from unfair business-to-consumer commercial practices in the internal market (eur-lex.europa.eu/directive 2005/29/EC). Interestingly, consumers choose the more ecological alternative (Kangun, Carlson et al. 1991, Carlson, Grove et al. 1993, Easterling, Kenworthy et al. 1996). A 2018 study showed that greenwashing had only limited short-term benefits when it came to perceived environmental performance, posed major communication threats and gave no competitive advantage in terms of consumers' buying interest (De Jong, Harkink et al. 2018).

To make sure that the information provided is transparent and matches the company's financial and environmental situation at the time, NGOs have established reporting standards and external auditors have provided their services to mitigate the untruthful information.

2.3.1 Global standards of environmental reporting

Legal obligations have significant impact on a company's decision to report on environmental issues (Wilmshurst, Frost 2000, Nyquist 2003). Some major global environmental standards on reporting are the Global Reporting Initiatives (KPMG, 2017), ISO standards of the International Organisation of Standardization, the United Nations Global Compact, the frameworks of International Integrated Reporting Council and the Organisation for Economic Co-operation and Development guidelines for Multinational Enterprises (disphesoftware.com). Next, I will briefly discuss the history, the usage and the critic over these frameworks and standards.

Global Reporting Initiatives (GRIs) have emerged as a key standard for sustainability and triple-bottom line reporting for economic, environmental and social performance (Etzion, Ferraro 2010). The original idea was born in 1997 in conjunction with Tellus Institute and the United Nations Environment Programme to create a global framework as an accountability mechanism to make sure that corporations operate environmentally responsibly (Sethi, Rovenpor et al. 2017). The GRIs on economic and environmental requirements are divided into 14 standards (globalreporting.org). The economic standards are: 201 economic performance, 202 market presence, 203 indirect economic impacts, 204 procurement practices, 205 anti-corruption, and 206 anti-competitive behaviour. The environmental standards are: 301 materials, 302 energy, 303 water and effluents, 304 biodiversity, 305 emissions, 306 effluents and waste, 307 environmental compliance and 308 supplier environmental assessment. According to the

2017 KPMG survey on corporate responsibility reporting GRI remains the most widely used framework for corporate responsibility reporting. Majority of the N100 companies (top 100 companies of total 4900 sample companies worldwide) (74%) and G250 companies (top 250 companies by revenue based on Fortune 500 ranking in 2016) (8, %) are using some king of framework for corporate responsibility reporting, from which 63 percent of N100 and 75 percent of G250 reports apply GRI. It is evident that GRI has major popularity amongst companies, and together with United Nations Global Compact ten principles and sustainable development goals, GRI can reach more organisations and have greater effect on corporate environmental sustainability (Adams, Petrella 2010). There is already evidence on the GRI output effectiveness to promote the spread of sustainability reporting (Barkemeyer, Preuss et al. 2015), but critic has risen from the material value of the reports and the reluctance of GRI to provide definitions for common but vague terms in sustainable reporting, like “sustainability, “sustainable development” or “sustainability principles” (see e.g Wackernagel 2002 via Milne, Gray 2013).

Another major international standard setter on environmental issues is the International Organization for Standardization or ISO. Some state that ISO remains the “de facto monopoly” over most international standards (Wood 2012 p. 82). In its early days (founded in 1947 (iso.org/the-iso-story)), ISO was more concerned with the development of technical standards on products and processes (Sethi, Rovenpor et al. 2017). Later, in 1996, ISO 14000 series standard was introduced for organizations to manage environmental responsibilities (Sethi, Rovenpor et al. 2017). The series is the most commonly used Environmental Management certification by companies around the world (Gupta, Racherla 2016), and the purpose of the standard is to provide a systematic framework which leads company to comply with the environmental regulation by setting measurable environmental targets and regular reviews on effectiveness (Zutshi, Sohal 2004). ISO states that the intended outcome of the environmental management system is to enhance environmental performance, fulfil compliance obligations and achieve environmental objectives (iso.org ISO 14001:2015).

The ISO 14001 contains the basic requirements for an organisation before the implementation of an environmental management system. The ISO 14020 series provides guidance on environmental labels on products and submitting environmental statements. The ISO 14040 series includes principles and the guidelines for evaluating a product's life cycle. ISO 14062 gives practical guidance on product design regarding environmental aspects. ISO 14064 is a guideline and tool to reduce GHG emissions and the ISO 14051 is a guide for accounting material flow costs in the supply chain. (Urbaniak 2017) In Sweden, companies with ISO observed improved relations with stakeholders and new marketing advantages (Poksinska, Jens Jorn Dahlgaard et al. 2003). However, critic has been found as well. Some studies dictate that companies using ISO standards implement them to demonstrate commitment to environmental protection (Poksinska, Jens Jorn Dahlgaard et al. 2003) or implement standards under pressure from customers to meet requirements for environmental compliance on paper (Gupta, Racherla 2016).

Urbaniak (2017) sees the growing interest of businesses on the implementation and certification of environmental management systems in accordance with the regulation adopted by the European Union. On the European Union guidelines regarding climate-related reporting, the guidelines integrate the recommendations of the taskforce on climate-related financial disclosures (TCFD) and the commission's 2018 action plan on financing sustainable growth. The action plan has 3 objectives: reorient capital flow towards sustainable investment to achieve sustainable and inclusive growth, manage financial risks stemming from climate change, environmental degradation and social issues and foster transparency and long-termism in financial and economic activities.

The third global standard-setter for environmental reporting is the United National Global Compact, which has grown to be one of the largest voluntary corporate responsibility initiatives in the world (Rasche, Waddock et al. 2013). Formally the Global Compact was launched in 2000 (Kell, Slaughter et al. 2007) and currently has 9946 companies in 162 countries involved (unglobalcompact.org). The participants of the Global Compact voluntarily commit to the ten principals on human rights, labour, environment and anti-corruption (Kell, Slaughter et al. 2007), in which environmental principles are:

- Principle 7: Businesses should support a precautionary approach to environmental challenges

- Principle 8: undertake initiatives to promote greater environmental responsibility; and
- Principle 9: encourage the development and diffusion of environmentally friendly technologies (unglobalcompact.org/principles).

Another major part of the Global Compact is the Sustainable Development Goals (SDGs) formed in 2015 for the "Agenda 2030" (unglobalcompact.org/sdgs). It is an agreement by the members of the UN to assist each other and build a more sustainable Earth following the Sustainable Development Goals (maailma2030.fi). There are 17 SDGs of which four are directly related to environmental issues: clean water and sanitation, affordable and clean energy, sustainable cities and communities, climate action (unglobalcompact.org/sdg-goals). Besides the popularity, Global Compact has also raised critic from two sides: one side fears global business regulations which would complicate economic growth. The other side fears that companies can use the legitimacy of the United Nations to promote sustainable development, while at the same time continue unjust business practices, sometimes called "blue washing". (Rasche, Waddock et al. 2013, Kobrin 2009) Rache and Waddock (2014) also point out the Compact's need to scale up while improving the quality, transparency and comparability between participants' reports.

The fourth major global standard-setter on environmental reporting is the International Integrated Reporting Council (IIRC). IIRC was established in 2010 with regulators, investors, companies, standard setters, accountant and NOGs. IIRC pursues to spread "integrating thinking" on sustainable economy, which means that companies' resource providers understands the linkage between the most significant components of the company and the external stakeholders. (Salvioni, Bosetti 2014) In other words, this can be called "integrated reporting" where publicly available information on the organisations includes financial and important non-financial information (Soyka 2013). The International Framework on integrated reports is primarily intended for private firms of any size and has been divided into two parts: First part is the introduction to the concept of integrated reporting and the second part gives the guiding principles and content of integrated reports (Integrated reporting framework 2013). Stubbs and Higgins studied 22 organisations' integrated reporting preferences and found that most organisations preferred a voluntary approach. This support is also suggested to increase the use of integrated reporting in the future if left to market forces (2018). Combining financial and non-financial information could strengthen firm valuation, but academic studies are more interested in reporting improvements, which could be a study of integrated reporting improving the quality of social and environmental accounting. The critic over integrated reporting comes from growing concerns over missing common interests, for example of common goals. (Koen van Bommel 2014) Some studies have also questioned the different sustainability reports due to missing common interests as a sustainability cloak to disguise unsustainable business operations and to continue operations without pursuing the absolute reduction of emissions and waste (Milne, Gray 2013).

Last major international standard and the only legally binding principles on sustainable development reporting are the OECD's Guidelines for Multinational Enterprises. The Organization for Economic Cooperation and Development (OECD) was created in 1961 and later in 1976 OECD first approved the Guidelines designed to improve international investment climate and strengthen the confidence between companies and the society in which they operate (Morgera 2005). After the 2010 meeting to update the Guidelines it was agreed to ensure the continued role of the Guidelines as a leading international instrument for the promotion of responsible business (OECD Guidelines for Multinational Enterprises 2011). These guidelines were the first internationally legal document on corporate responsibility (Cernic 2008), which guides policymakers, regulators and market participants in improving their legal, institutional and regulatory framework (Camilleri 2015). The document itself is not legally binging to companies but it is binding to the signed governments, which are required to ensure that Guidelines are implemented and observed (oecdwatch.org). The Guidelines are divided into eight categories: human rights, employment and industrial relations, environment, combatting bribery, bribe solicitation and extortion, consumer interests, science and technology, competition and taxation (OECD Guidelines for Multinational Enterprises 2011). The environmental guidelines are broadly reflected principles and objectives from the Agenda 21 and reflects standards from ISO on Environmental Management Systems (OECD Guidelines for Multinational Enterprises 2011, (Siew 2015)). The Guidelines and the UN Global Compact are closely aligned with the GRI in guiding principles, scope, language, reach and participating companies (Brown, de Jong et al.

2009). The 2011 Guidelines state the benefits of environmental management systems, the need for companies to act fast to prevent environmental damages from companies' activities and the liability charges from not complying with the legislation. However, the Guidelines also state that companies are not required nor bound to follow the guidelines. Only the government which signs the agreement is required to implement them. Adhering governments are also required to set up National Contact Points (NCPs) to further the effectiveness of the Guidelines with promotional activities, handling enquiries and contributing to the resolution of issues arising from the alleged non-observance of the guidelines (oecd.org). This is part of the critic over governments' commitment to implementation and whether the content and language should be adjusted to ensure an efficient implementation today and in the future (Cernic 2008). Christian Aid et al. 2006 report states that the NCPs in the United Kingdom have faced problems with the implementation of the guidelines, due to lack of clear implementation procedure, failure to establish time limits for complaints, unequal treatment of parties, unwillingness to investigate and lack of fact-finding capacity, lack of transparency in complaint process and publishing outcomes, failure to act independently of other government interest, excluding company supply chains even if trade relationships are covered in the Guidelines and the unwillingness to declare breaches of the Guidelines.

These are the most widely used standards and guidelines on sustainable corporate reporting of which the GRI remains the most widely used framework (KPMG 2017) and the ISO 14001 series the most widely implemented environmental management certificate (Gupta, Racherla 2016). The United Nation Global Compact is one of the largest voluntary corporate initiatives in the world (Rasche, Waddock et al. 2013) and the only legally binding guidelines on corporate responsibility are the OECD guidelines (Cernic 2008). A growing framework for sustainability reporting is the integrative thinking of IRCC where financial and non-financial information is combined into one report (Soyka 2013). The OECD guidelines are only legally binding to signed governments (oecdwatch.org) which follows the flexibility efforts of all major standards and guidelines to ensure that only companies which have the resources to report on sustainability do so. This is due to the fear of constraining economic growth which does not correspond to the efforts to equally balance the three sustainability aspects. As most of the reports on sustainability issues are voluntary, critic has risen over standards on the material value of the sustainability reports (Gray, M. R., Milne 2013), the motives for standard implementation (Poksinska, Jens Jorn Dahlgaard et al. 2003), the lack of common goals (Koen van Bommel 2014), the concern over the lack of governmental resources to effectively implement guidelines (Christian Aid et al. 2006) and on the use of initiatives to legitimacy unjust business practices (Kobrin 2009). Unfortunately, companies which pursue sustainability and wish to justify their just business practices do not have many legally solid options to provide stakeholders transparent and reliable information, similarly to financial reporting. These guidelines can assist to prevent facades, but the context of reported information does not necessarily correspond to company's actions.

2.3.2 Third party auditors

According to Alexandru and Georgiana (2011) environmental auditing is a process of methodologically verifying obtained audit documents and evaluating whether activities, events, conditions, the environmental management system or the information related to these issues are one-to-one to the auditing criteria. Federal register issue 50 FR 46504 in the United States defines environmental auditing as: "…a systematic, documented, periodic and objective review by regulated entities of facility operations and practices related to meeting environmental requirements." (Section II. A). The International Chamber of Commerce defines environmental auditing as a management tool for evaluating environmental performance (ICC, 1991 via (Todea, Stanciu et al. 2011) and the Confederation of British Industry defines environmental audit as a systematic examination of interactions between economic and environmental operations (via Todea, Stanciu et al. 2011). Eco-Management and Audit Scheme (EMAS) defines environmental auditing as: "…a management tool comprising a systematic, documented, periodic and objective evaluation of the performance of the organisation, management system and processes designed to protect the environment with the aim of facilitating management control of practices which may have an impact on the environment, and assessing compliance with the environmental policy, including environmental objectives and targets of the organisation" (europarl.europa.eu). Todea, Stanciu et al. (2011) suggest that environmental audit is a systematic analysis of the organisation's environmental impact.

Even if sources are somewhat mixed on the definition of environmental auditing, the responsibility for the audit is with the organisation itself meaning that auditing is most of the time voluntary (Evans, Liu et al. 2011, Todea, Stanciu et al. 2011). Some certification, like the ISO 14001, require an external audit as a condition for the certification (Todea, Stanciu et al. 2011), but Evans et al (2011) point that voluntary initiatives are closely linked to motivation factors for regulated entities to conduct audits. To validate the information of sustainability reports, environmental audit could verify the compliance with environmental requirements (e.g. a company is following the ISO certificate requirements), evaluate the effectiveness of environmental management systems (EMS), identify new opportunities in emissions or waste reduction or assess risks from unregulated practices (Evans, Liu et al. 2011). A traditional financial audit can be divided into four phases: (1) "client acceptance", (2) "planning", (3) "testing and evidence" and (4) "evaluation and reporting" (de Moor, DE Beelde 2005). Environmental audit, according to de Moor and de Beelde (2005) can be divided into three phases: (1) "Pre-audit activities", (2) "Activities on-site" and (3) "Post-audit activities". Table 4 illustrates the phases and steps within the phase. I interviewed an expert on environmental auditing who described the auditing process the following way: the process begins by following the data-trail backwards and verifying how a company collects information from its units. It is important to clarify what types of controls and calculations are used and that all measures are based on internationally accepted principles and documentation. In addition, definitions of these measures should be similar in every country the company operates in.

Initially, environmental auditing focused on technical issues and a company's legislation compliance undertaken by external professionals (Todea, Stanciu et al. 2011). After the first audits from the 1970s (Todea, Stanciu et al. 2011), environmental audit has evolved from complying with environmental legislation into a management-based self-assessment tool (Power 1997). Alexandru and Spineau-Georgescu (2011) point out that the voluntary execution of an environmental audit is no longer just an option but a valid proactive measure to reduce risks from regulators. The 1995 report by the United States General Accounting Office states that public and private organizations with effective environmental auditing system have reported improved compliance with regulations, have reduced exposure to civil and criminal liability and recued environ-

Table 4 Standard auditing phases vs. Environmental auditing phases (adapted from de Moor, De Beelde 2005)

Standard financial audit		**Environmental audit**	
Phase	**Steps**	**Steps**	**Phase**
Client acceptance	Evaluate the background of the client and reasons for the audit Communicate with previous auditor Determine need for the other professionals Prepare client proposal Obtain engagement letter Select staff to perform the audit	1) Select and schedule facility to audit Select audit team members	Pre-audit activities
Planning the audit	Obtain company and industry background information Investigate legal information Perform initial analytical procedures Perform procedures to obtain an understanding of internal control Based on the evidence, access risk and set materiality Understand internal control and assess the risk Develop an overall audit plan and program	Contact facility and plan audit Identify and understand management control system Assess management control system Gather audit evidence	Activities on-site
Testing and evidence	Test of controls Conduct substantive test of transactions Analytical procedures Test details of balances Obtain management representation letter Accumulate final evidence and search for unrecorded liabilities		
Evaluation and reporting	Review for contingent liabilities Perform overall review Perform procedures to identify subsequent events Review financial statements and other report material Perform wrap-up procedures Prepare maters of attention for partners Report to the board of directors Prepare audit report	Evaluate audit findings Report findings to facility Issue draft report Issue final report Action plan preparation and implementation Follow-up action plan	Post-audit activities

Source: (de Moor, DE Beelde 2005) Environmental Auditing and the Role of the Accountancy Profession: A Literature Review mental hazard (US GAO 1995). However, more resent research states that there is little systematic empirical evidence on environmental auditing significantly increasing environmental performance or environmental regulation compliance (Evans, Liu et al. 2011). Some studies do find that changing operating procedures are actually effective in improving regulation compliance at least in the United States (Sam 2010). Evans et al (2011) point out that organisations that undertake audits could learn new methods to improve processes in a cost-efficient way and find better ways to achieve their desired levels.

Concluding the chapter on international standards on corporate sustainable development reports, on third party audits and how they are linked in preventing companies to drift in greenwashing and facades, the message from international standards is not fully practiced by the reporting companies (Spar, La Mure 2003, Malsch 2013, Cho, Laine et al. 2015). Additionally, voluntary audits can increase legislative compliance (Evans, Liu et al. 2011) but the value of audits to stakeholders in terms of increasing trustworthiness similarly to financial audits requires further studies. Compliance with the international standards can be from a need of survival on paper, but the company itself is not able to operate at the requested level (Abrahamson & Baumard 2008). It could also be that for financial benefits, the company does not want to disclose its unpleasant operations but hide them under external reports (Christensen, Morsing et al. 2013). Next, I will discuss corporate environmental reporting, its definition and how it is linked to environmental management systems and environmental management accounting.

3. CORPORATE ENVIRONMENTAL REPORTING

The World Business Council on Sustainable development (WBCSD) (2002, p.7) defines sustainable reporting as "…public reports by companies to provide internal and external shareholders with a picture of corporate position and activities in economic, environmental and social dimensions." The Institute of Chartered Accounts in England and Wales' (ICAEW) definition on sustainable development emphasises on the environmental impact rather than the information provided to the shareholders similarly to the WBCSD's definition. ICAEW's (2004, p.8) definition is: "Sustainability reporting…aims to represent an enterprise's environmental, social and economic performance and the related impact on the world around it". The Fédération des Experts Comptables Européens (FEE) (2000) Environmental Working Party defines environmental reporting as: "the information provided by an entity in respect of the environmental issues associated with its operations". They define the objective of the report as: "the provision of information about the environmental impact and performance of an entity that is useful to stakeholders in assessing their relationship with the reporting entity". Garg et al. (2018) define environmental reporting as the incorporation of environmental issues in the annual reports. Pramanik (2002) describes environmental reporting as an umbrella term for various means to disclose corporate information on environmental activities. To summarize the different definitions on environmental reporting, the objective of reporting would be to provide enough information on sustainable development related to the businesses' operations for the stakeholders who need the information for decision-making.

Because external stakeholders regulate what information needs to be reported by the company, the set-up is similar to the role of corporate accounting. Accounting can be defined as a systematic gathering of qualitative and quantitative information to assists decision-making. The gathered information can include financial and non-financial information and can be traditionally divided into two categories: internal and external. External accounting focuses on external stakeholders and reports according to international and local regulation. Internal accounting or management accounting focuses on the internal stakeholders, namely on the managers (Puolamäki 2007). In some cases internal accounting can be described as cost management accounting, which pursues to understand operational costs or break-even price per product or service (Näsi 2006).

Because my focus is to understand how a company's management can improve and use information to mitigate GHG emissions, the focus of this study is on the internal accounting. However, as the pressure for improvement comes from outside the company, I must touch the subject on external reporting and thus on external accounting as well.

The potential users of corporate environmental reports could be the stakeholders generally mentioned in international accounting regulations: owners or shareholders, potential investors, employees, lenders, product and service suppliers, customers, authorities and the public (Koskinen 1999). FEE (2000) lists their conventional user groups: investors, employees, lenders, suppliers and other trade creditors, customers, governments and their agencies and the public. Kuo et al. (2012) point out that stakeholders usually view disclosed social responsibility information, which is part of the sustainable development aspects, as one of the criteria for measuring company's reliability and legitimacy. Some stakeholders even expect companies to reduce their impact on the environment and report on their environmental engagement (Lee, S., Park et al. 2015). So, the impact and expectations from different stakeholders can have a significant impact on the reporting behaviour of a company.

Most of the environmental reports are made voluntarily, but some follow a structured approach as well (Wangombe 2013). The structured approach follows a mandatory motivator, which is usually a legislative tool like the GRI, and the voluntary approach follows a voluntary incentive (Ritschelova, Sidorov et al. 2008). The reports could be demanded by the government as mandatory (Fallan, Fallan 2009) or by the stakeholders as "solicited" disclosures on corporate sustainable development issues (Van der Laan 2009). However, it is good to remember that the significance of the role of environmental accounting and reporting does not remain in the corporate sphere alone regardless of the motive of the report. The reports contribute to the management of sustainable development of the society as well (Ritschelova, Sidorov et al. 2008)

How and why companies choose to implement certain corporate reporting behaviour has been studied under the institutional theory by Wangombe and Karungu (2013) and is based on the DiMaggio's and Powell's three mechanisms of isomorphism: coercive, mimetic and normative (DiMaggio, Powell 1983). The coercive isomorphic change means that the company begins to resemble other companies due to formal and informal pressures from other organizations and from cultural expectations of the society (DiMaggio, Powell 1983, Wangombe 2013). The mimetic isomorphism imitates other corporations (DiMaggio, Powell 1983). The normative isomorphism can stem from the influence of big audit firms or consultancy service providers (Wangombe 2013). This framework helps to understand which influences companies could follow to integrate environmental issues as part of stakeholder reporting.

As the required information of the stakeholders differs from stakeholder to stakeholder (Puolamäki 2007) the presentation form of the information is different as well. This is because the international standards have requirements on the information but not how the information is presented. I previously discussed how Garg et al. (2018) define environmental reporting as incorporating environmental issues into the annual reporting which is one form to present environmental information (Gray, R., Kouhy et al. 1995). Another form of representation can be on the company's website (Tagesson, Blank et al. 2009), through a sustainability report (according to standards like GRI) or as a standalone report (Ikram, Nekhili Mehdi et al. 2018, Fédération des experts comptables européens. Environmental Working Party 2000). Some companies could have several options to display environmental information, for example by releasing a standalone sustainability report and the same information on the company's website. This differs between stakeholders and can be incorporated to the stakeholder communication strategy. Some of the most important goals of sustainability reporting according to Herzig and Schaltegger (2006) are:

- Legitimation of corporate activities, products and services which create environmental and social impacts
- Increase in corporate reputation and brand value
- Gaining a competitive advantage
- Signaling superior competitiveness, with sustainability reporting activities as a proxy indicator for overall performance
- Comparison and benchmarking against competitors
- Increasing transparency and accountability with the company
- Establishing and supporting employee motivation as well as internal information and control processes

Besides the stated goals and benefits, reporting on environmental issues has been perceived favorable amongst customers and shareholders in firms with better environmental performance (Ikram, Nekhili Mehdi et al. 2018). Some studies have also found that greater economic performance in a company results in larger disclosure of information on environmental investments and pollution control costs (Liu, Anbumozhi 2009). In the Western countries, voluntary disclosure on environmental issues tends to increase with the company's size and with the environmentally-sensitive industries like oil, gas or chemicals (Cormier, Gordon 2001).

However, standardization of reporting frameworks has not been efficient when it comes to the quality and content of sustainability reports between companies from different institutional environments (Fortanier, Kolk et al. 2011). Also, efforts to reach shareholders and investors on environmental issues has been tried with Carbon Disclosure Project (CDP) which pursues to inform on investor concerns on climate change and to provide information for the investors about the company's risks associated with climate change (Stanny, Ely 2008). But CDP is also voluntary and subject to self-selection bias (Hsu, Wang 2013). From investor perspective, carbon disclosure is perceived as bad news and investors can become concerned over costs associated with global warming (Lee, S., Park et al. 2015). However, this can be mitigated this risk by releasing carbon news periodically before its major disclosure (Lee, S., Park et al. 2015) through various communication channels (Stanny, Ely 2008).

Companies need to choose the correct form of communication and tailor the reports according to the characteristics of their operations as well as according to the needs of the stakeholders (Barkemeyer, Preuss et al. 2015). But the information should not be selected simply due to positive actions on the environment (Hahn, Kühnen 2013) and should be as realistic as possible. Unrealistic reports run greater risk of punishment due to misinformation (Lyon, Maxwell 2011) and it is rare for companies to disclose environmental and social issues at the same extent as their financial information (Gray, M. R., Milne 2013).

Schaltegger and Burritt (2000) stated that it is necessary for companies to use monetary and non-monetary-values on determining environmental performance for sustainability management and Birkin (1997) (as cited in Bartolomeo, Bennett et al., 2000) encourages to track and analyse non-financial information at the same importance as financial information for management accounting to take the environment seriously. It seems that the non-financial information should be treated at the same importance as financial information in decision-making and performance measurement (Kaplan, Norton 1996) for a successful management accounting practice on sustainability. One of the tools for management to use non-financial and financial information on environmental matters is called the environmental management system (iso.org).

3.1 Environmental Management Systems and Accounting

Environmental Management System (EMS) as a concept was first introduced in 1985 in the Netherlands (Alexandru, Spineanu-Georgescu 2011) and is usually established by applying the ISO 14001 requirements (KOTHARI, JAROLI 2018) or through the European Union's Eco-Management and Audit Scheme (EMAS) (Ritschelova, Sidorov et al. 2008). EMAS is a management tool for companies operating in the European Union and in the European Economic Area from which a company can receive a seal of approval. To receive the seal, a company needs to meet six requirements, which are: conduct an environmental review on company's activities, establish an environmental management system, carry out an environmental audit, provide an environmental performance statement, verify previous requirements with an EMAS verifier and make the environmental review, EMS, audit procedure and performance statement publicly available. Most of the requirements in EMAS are similar to the requirements of the ISO 14001, besides providing the performance statement and making information publicly available (oecd.org.)

ISO defines environmental management systems as "part of the management system used to manage environmental aspects, fulfil compliance obligations and address risks and opportunities" (iso.org). The OECD report undertaken by the OECD Environment Policy Committee and the OECD Investment Committee from 2003 to 2004, defines EMS's objective to help an organisation achieve its environmental goals through consistent control over its operations. And as environmental management system is not based on a standard form, the flexibility gives organisations possibility to design their own systems based on their own aspirations, business goals, capacity and experience.

The OECD Guidelines for Multinational Enterprises recommends companies planning for EMS to: "Establish and maintain a system of environmental management appropriate to the enterprise". This includes the collection and evaluation of information on environmental, health and safety impact, the establishment of measurable objectives and targets and regular monitoring and verification of the progress to these targets and objectives. The goal of an EMS is not just compliance with legislation and minimization of financial risks associated with climate-change, but also to continuously improve environmental performance, to ensure a good public image and achieving greater competitive advantage (Alexandru, Spineanu-Georgescu 2011).

Emilsson and Hjelm (2005) state that an EMS should organise a company's environmental perspective so that the environmental performance improves continuously. Massoud et al. (2010) add to this by describing the EMS as a control tool, which allows a systematic evaluation of processes and ensures that the company specific goals and targets are met. Environmental management systems can offer cost-saving benefits from improved efficiency while building legitimacy for the company's operations from stakeholder perspective (Salim, Padfield et al. 2018). It is argued that an EMS can also be an instrument to reorient consumption and productions patterns to secure natural resources and prevent ecological damage (Massoud, Fayad et al. 2010). To conclude the definition, an environmental management system is a certificate granted either by the ISO or EMAS for a particular site and not for the whole enterprise (Naciones Unidas, United Nations Department of Economic et al. 2000) to collect and evaluate environmental impacts on company's activities, to establish targets for improved environmental performance, to monitor the progress to targets and help organisations reach environmental goals.

To form a clear perspective on the total environmental effects from the complete organisation, "full-cost accounting" should be used (White, Savage 1995). Even though full-cost accounting -term is used to describe the allocation of manufacturing, sales and administrative costs to products in the accounting profession, the meaning of the term has experienced an expansion and covers environmental costs as well (Ditz, Ranganathan et al. 1995). It assists to determine which costs should be allocated to produced products (Zachry, Gaharan et al. 1998) and to manage these costs, organisations could use environmental management accounting (EMA) systems which are related to environmental management systems (Naciones Unidas, United Nations Department of Economic et al. 2000). EMA has emerged as a bridge between management accounting and environmental management (Bennett, Bouma et al. 2002) and Rikhardsson et al. (2005) describe EMA as a form of managerial technology or a tool for management which combines knowledge, methodology and practice. It is a system which assists companies to manage, allocate and recognize environmental costs and helps to develop performance indicators for management decision-making with both financial and non-financial information (Frost, Wilmshurst 2000). Definition for an environmental management accounting system could be also approached from its main audience: the management. Managers who are the main users of internal reports (Jasch 2003) need relevant and useful information, including financial and non-financial information to assist on decision-making which can be provided through the EMA (Bennett, Bouma et al. 2002). It can be used for measuring and reporting purposes as well (Lee, K. 2012) and EMA can reduce environmental risks and impacts to the company, it can increase the efficiency of use of materials and it can increase cost-efficiency of environmental protection with monetary, cost and material flows (Jasch 2003). A major focus of EMA is to raise management awareness on the environmental impact from economic performance (Burritt et al. 2002b). However, information from an EMA is not enough to pursue sustainable development but needs to be incorporated with planning process, strategic goal setting, capital allocation and performance evaluation (Riccaboni, Luisa Leone 2010).

Environmental management accounting is part of environmental accounting (IFAC. 2005), which Gray et al. (1987) define as a process of communicating organisations social and environmental impacts due to economic actions to stakeholders and to society at large. This involves extending the traditional role of accounting from solely providing financial information and assuming a wider responsibility than simply providing monetary benefits to shareholders (Gray et al. 1987). Matthews (1993) states that environmental accounting is voluntary disclosure of financial and non-financial, qualitative and quantitative information made by the organisation to a range of audiences. There seems to be differences in determining whether environmental accounting disclosures are voluntary or complying with local and global legislations or whether the disclosures must be quantitative or financial (Mathews 1997), but in its core environmental accounting is an extension of an organisation's disclosure into non-traditional areas (Mathews, Perera 1996).

Bartolomeo et al. (2000) address four approaches to environmental accounting at firm level: external financial reporting, social accountability reporting, energy and materials accounting and environmental management accounting. The first two are part of external reporting while the last two are part of internal decision support. External financial reporting indicates the financial impact of environmental factors on companies and informing the external stakeholders. Social accountability reporting extends the scope of accounting from conventional financial stakeholders to general external stakeholders and to society. Energy and materials accounting points out the importance of tracking and analysing the flow of physical substances related to environmental impacts. Environmental management accounting underlines the understanding of environmentally-related financial costs and benefits as an extension to conventional management accounting (Bartolomeo, Bennett et al. 2000).

The reason for the development of an environmental management accounting system is due to the disadvantages of a traditional accounting system when it comes to the gathering and use of information on management reports (Schaltegger, S., Burritt 2000, Burritt et al. 2002b, Ditz, Ranganathan et al. 1995, Naciones Unidas, United Nations Department of Economic et al. 2000, Bennett, Bouma et al. 2002, Chung, Cho 2018, Jasch 2003). The main difference between a traditional accounting system and an EMA for information gathering, according to Burritt, Hahn and Schaltegger (2002b), is that an environmental accounting system identifies, measures, analyses and interprets information on environmental issues while in a conventional accounting system the distinction which aspects are recognized, measured, analysed or interpreted is somewhat unclear. Often conventional systems transfer environmental costs to overhead accounts, which hides the extent of these costs from the managers and makes decision-making to improve company's environmental performance difficult (Epstein, Young 1999, Naciones Unidas, United Nations Department of Economic et al. 2000). The issue when using a conventional management accounting system on environmental issues is that the management could be making decisions based on inaccurate or misinterpreted information and as a result may misunderstand the negative financial effects of a poor environmental performance and disregard potential cost-savings of an improved environmental performance (IFAC, 2005). According to Kapardis and Setthsakko (2010) the development of EMA requires increased “green” knowledge, a wider understanding of corporate responsibility throughout the organisation and government promotion to environmental management accounting.

According to Jasch (2003), major objects for EMA -data are: estimates for annual environmental costs, product pricing, budgeting, investment appraisal, estimates for environmental project costs, establishment and development of environmental management systems, estimation, measurement and comparison of environmental impacts, target setting, improvement of environmental production, eco-design projects, external reporting on environmental costs, investments and debts, external sustainable development reports, and other regulatory environmental reporting. Latan et al. (2018) studied 107 ISO 14001 certified Indonesian companies through questionnaires and found positive and significant influence between corporate environmental strategy, top management commitment and environmental uncertainty on the use of EMA. However, effective collection, identification, analyses and evaluation of environment-related data is not easy. For example, the lack of guidelines on how to recognize present or future value of environmental costs makes measuring and recognizing present and future liabilities difficult (Johnson 1993, Schaltegger, S., Burritt 2000).

Implementation of an EMA system into a company ranges from simple adjustments to current accounting system to more complicated practices that link monetary and non-monetary values of environmental activities (IFAC, 2005). Before implementation, a company should consider three aspects: (1) identification of significant issues regarding the environment which the economic entity wants to turn to economic cost objects, (2) identifying relevant data in order to include the determined cost objects within costs, (3) defying the system to collect the data (Vasile, Man 2012). After consideration of these aspects, one approach to develop an environmental accounting system is to connect environmental management with financial accounting through environmental cost objects. By identifying corporate activities associated with environmental impact, the relationship between environmental management and costs becomes clearer. If these activities and the resources they use are quantifiable through costs, the costs and benefits of administrating environmental issues comes closer to managers’ level through which financial responsibilities and objectives may be assigned. However, the traditional accounting framework may not identify the necessary data for environmental management accounting. The focus of traditional frameworks may actually “loose” environmental costs to general overheads rather than to the activities that generate these costs. (Vasile, Man 2012)

Burritt, Hahn and Schaltegger (2002b) have proposed a framework for EMA, which illustrates both financial and non-financial information and sixteen tools and approaches to support environmental management accounting. Table 5 illustrates the framework which is based on two main groups of environmental impacts related to company’s activities: environmentally related impacts on the economic situation of the company and company-related impacts on the environmental systems (Schaltegger, S., Burritt 2000). When the environment affects the economic system, it is reflected through monetary environmental information. And when company’s affect the environmental system, it is reflected through physical environmental information. Monetary environmental information addresses all impacts against the economic system on its past, present and future financial stocks and flows expressed in monetary units. These impacts could be fines from breaching environmental-protection laws, expenditures on cleaner production or monetary values of environmental assets. On the other hand, physical environmental information addresses all past, present and future material and energy amounts affecting the ecological systems expressed in physical units (e.g. kilograms, joules, and cubic meters). From these two the monetary environmental information can be considered as an expansion of conventional accounting in monetary units as it is based on the methods of conventional accounting systems (Burritt et al. 2002b) So, monetary environmental management accounting (MEMA) handles the environmental issues of corporate activities in monetary units and physical environmental management accounting (PEMA) handles the impact of corporate activities to the environment expressed in physical units (Vasile, Man 2012). Together, the monetary and physical environmental information form the basis for environmental management accounting (Burritt et al. 2002b). Burritt, Hahn and Schaltegger use Bartolomeo et al.’s (2000) figure to illustrate how MEMA and PEMA are part of environmental accounting and what is the relationship of MEMA and PEMA to EMA (Figure 1).

Table 5 Framework of EMA (adapted from Burritt et al. 2002b)

		Environmental management accounting (EMA)			
		Monetary environmental management accounting (MEMA)		**Physical environmental management accounting (PEMA)**	
		Short term focus	**Long term focus**	**Short term focus**	**Long term focus**
Past oriented	Routinely generated information	1. Environmental cost accounting (e.g. variable costing, absorption costing)	2. Environmentally induced capital expenditure and revenues	9. Material and energy flow accounting (short-term impacts on the environment – product, site, division and company levels)	10. Environmental (or natural) capital impact accounting
	Ad hoc information	3. Ex post assessment of relevant environmental costing decisions	4. Environmental life cycle (and target) costing. Post investment assessment of individual projects	11. Ex post assessment of short-term environmental impacts (e.g. of a site product)	12. Life cycle inventories. Post investment assessment of physical environmental investment appraisal
Future oriented	Routinely generated information	5. Monetary environmental operational budgeting (flows). Monetary environmental capital budgeting (stocks)	6. Environmental long-term financial planning	13. Physical environmental budgeting (flows and stocks) (e.g. material an energy flow activity-based budgeting)	14. Long-term physical environmental planning
	Ad hoc information	7. Relevant environmental costing (e.g. special orders, product mix with capacity constraint)	8. Monetary environmental project investment appraisal. Environmental life cycle budgeting and target pricing	15. Relevant environmental impacts (e.g. given short run constraints on activities)	16. Physical environmental investment appraisal. Life cycle analysis of specific project

Source: (Burritt et al. 2002b)

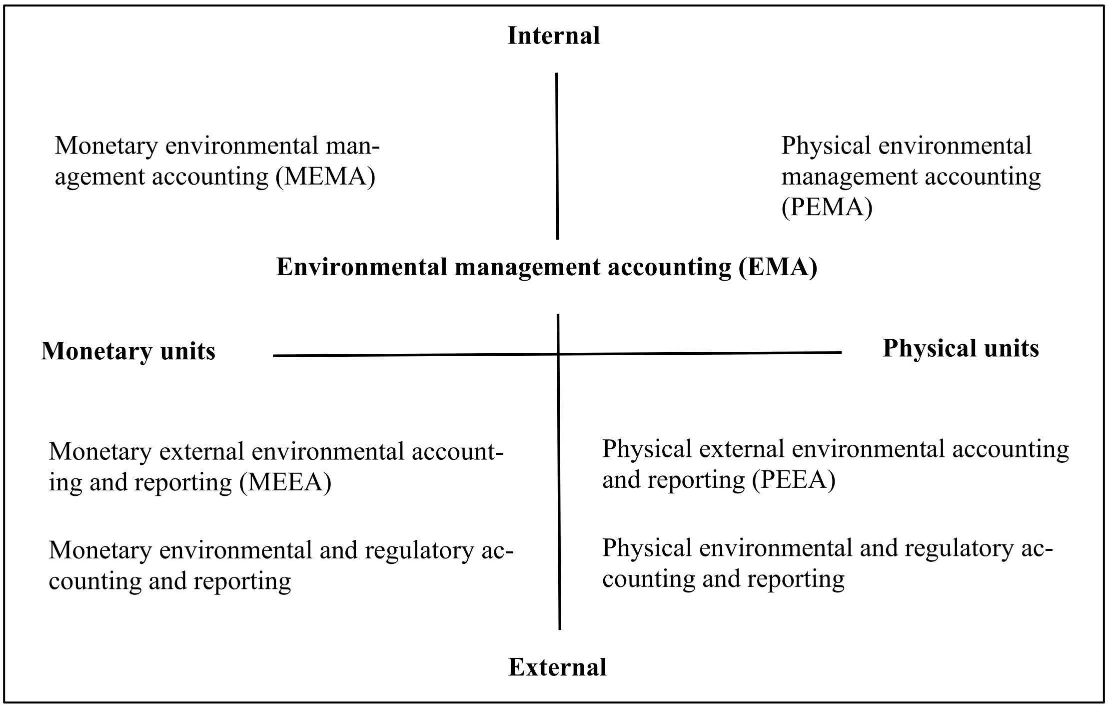

Figure 1 Environmental accounting system (adapted from Burritt et al. 2002b)

Kapardis and Setthasakko (2010) studied pulp and paper companies in Thailand and found barriers on environmental management accounting development. They identified the root causes to these barriers: the lack of building organizational learning, a narrow focus on economic performance and absence of guidance on EMA. The lack of building organizational knowledge leads to inefficiency in environmental knowledge and skills and restricts integration of environmental aspects to accounting systems. The narrow focus on short-term economic growth could limit future opportunities to prevent emissions, reduce waste or identify environmental risks. This is similar to the Giddings's et al. (2002) and Dyllick's and Hockerts's (2002) criticism over corporate sustainable development. Kapardis and Setthasakko (2010) conclude their list with the absence of guidance to EMA which they say causes difficulties to assess or allocate environmental costs, revenues, assets and liabilities resulting in sub-optimization risks. This would result challenges in environmental performance evaluation and benchmarking e.g. waste management and pollution prevention (Kapardis, Setthasakko 2010). Next, I will focus on MEMA and PEMA to understand how accounting information is gathered and reported from monetary and physical perspectives.

3.1.1 Monetary Environmental Management Accounting

When the environment impacts an economic system, the impact is reflected through monetary environmental information. It addresses all company-related impacts on past, present or future financial stocks and flows expressed in monetary units. (Burritt et al. 2002a) These costs can include environmental protection expenditures (expenditures to prevent, control or reduce waste etc.) (EPEs) (IFAC, 2005), disposal, clean-up and treatment costs, (Smit, Kotzee 2016) expenditures on cleaner production or cost of fines from breaking environmental legislation or monetary values of environmental assets (Burritt et al. 2002b).

Monetary data can be collected from an organization, from a particular site, from input materials, from waste streams, process or equipment lines or from product or service lines. This depends on the intended use of the information. (IFAC, 2005.) Sometimes, organizations wish to extend the reach of gathering data and include information from suppliers, customers and from other elements of the supply chain. IFAC (2005) calls this Supply Chain Environmental Management and I will discuss this during a chapter on environmental profit and loss statements. This chapter combines supply chain management with environmental management accounting and emphasises the MEMA approach to value the environmental impact.

3.1.2 Physical Environmental Management Accounting

In contrast to MEMA, physical environmental management accounting focuses on company’s activities impacting the environmental system. This is expressed in physical units e.g. kilograms, cubic meters or joules and includes all past, present and future materials and energy amounts. (Burritt et al. 2002b) For an organization to manage its material related to environmental performance, tracking of the flow of energy, water, materials and wastes is important (Jasch, Savage 2008). The importance derives from the relationship of used resources to environmental impact: the use of energy, water or materials drives the company’s impact and the cost to purchase these resources is financially related to the environmental impact (IFAC, 2005). Organisation’s material inputs are any energy, water or other materials that enter an organization and outputs are any products, waste or other materials that exit the organisation (Jasch, Savage

2008). Any output that that does not results from a product is considered a non-product output or NPO. For example, the service sector can use energy to produce services, but the material input eventually turns into NPO (IFAC, 2005.) Examples of NPOs can include solid waste, hazardous waste, wastewater and air emissions, generated in two ways: material inputs become NPOs due to poor equipment efficiency and maintenance, inefficient operating practices, production losses, product spoilage, poor product design etc. Another way NPOs are generated are through material inputs that were never intended to become part of product outputs. (IFAC, 2005.)

For PEMA, data can be collected from several different sources, including: the entire organisation, a site, input materials, waste streams, a process or an equipment line, a product of service line etc. For a complete picture on the use of resources, the details of material flows must be traced through all material management steps which can include material procurement, delivery, inventory, internal distribution, use and product shipping, waste collection, recycling, treatment and disposal etc. This is sometimes referred to "materials flow accounting". (IFAC, 2005.) Figure 2 illustrates the relationship between material input, product output and NPOs

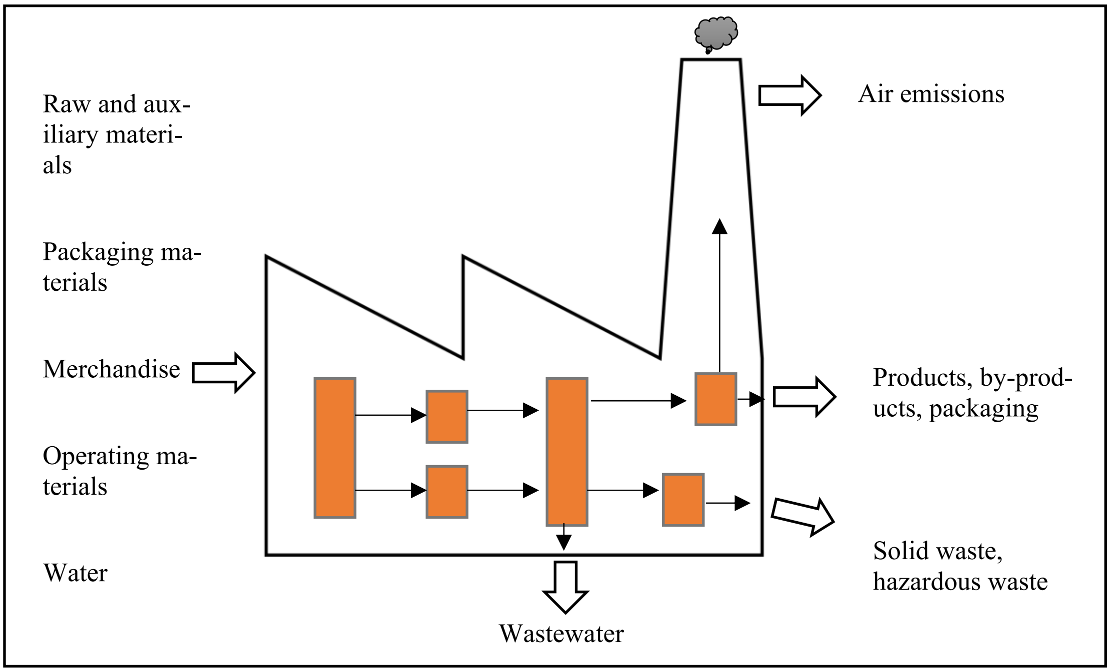

Figure 2 Material flow accounting (adapted from IFAC 2005)

Ricoh Group's 2010 sustainability report (Figure 3) illustrates how their environmental management activities for environmental conservation were realized in profit. Figure 3 shows how different steps during product planning, design process, manufacturing and sales/service have reduced the environmental impact and realizes in profit.

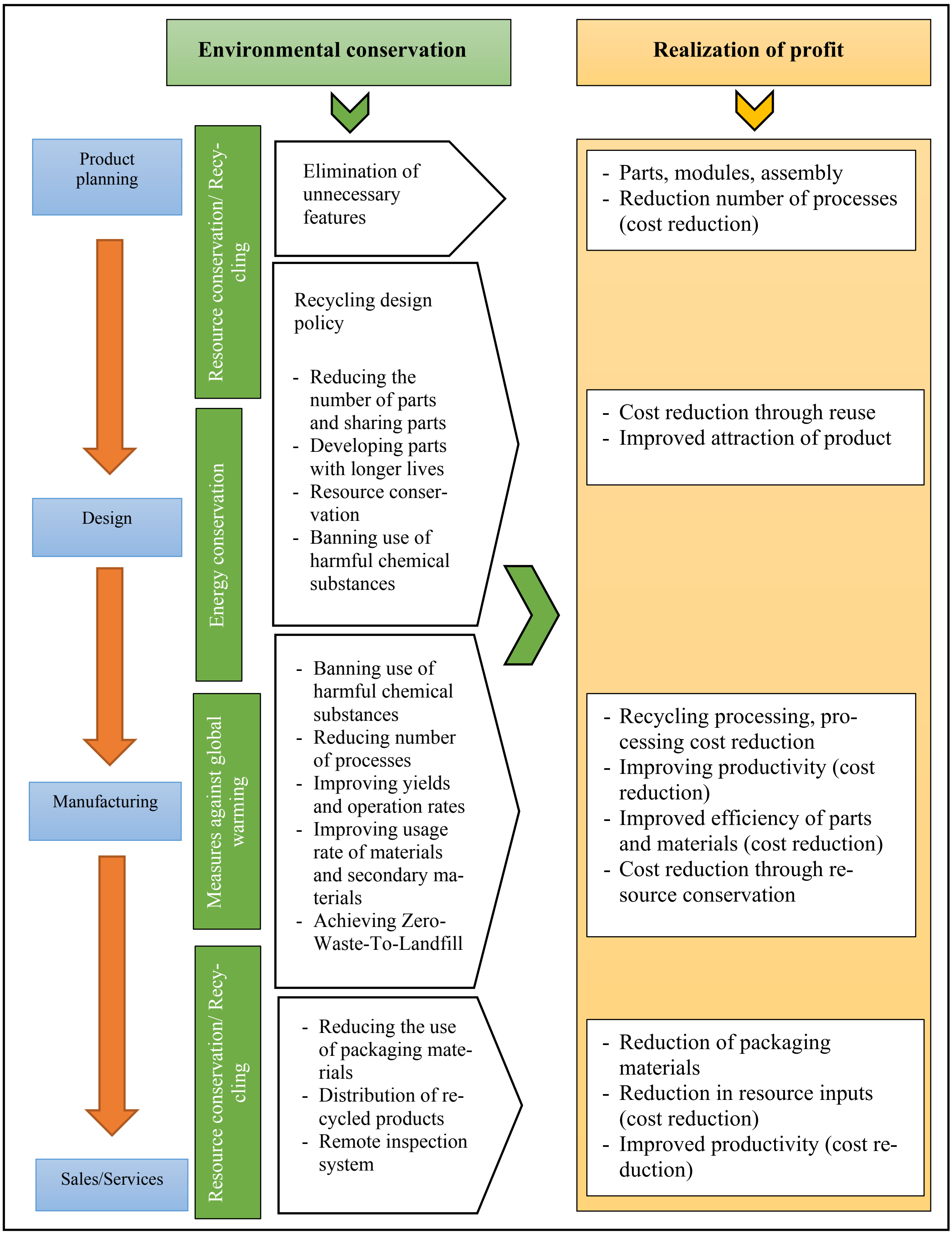

Figure 3 Ricoh Group's environmental management activities (adapted from Ricoh Group's 2010 sustainability report)

The next chapter rings the focus of EMA, MEMA and PEMA into carbon dioxide emissions and concentrates how these emissions can be managed through the principles of traditional management accounting.

3.2 Carbon management accounting

Finding a specific definition for carbon accounting is difficult because the definition changes according to the area of discussion. Burritt, Schaltegger and Zvezdov (2011) describe carbon management accounting (CMA) as part of sustainability accounting designed to provide information for decision-makers on short-term and long-term carbon emissions issues. Ascui and Lovell (2011) identify five frames of reference for carbon accounting: physical, political, market-enabling, financial and social/environmental modes. I concentrate on the financial and social/environmental perspectives during this research.

The financial carbon accounting perspective focuses on companies operating in carbon markets or emissions trading schemes or cap and trade systems. This means that companies own liabilities, assets and financial flows that need to be accounted for in their financial reports. The Internal Accounting Standards Board, a group of accounting standards setters (ifrs.org), focuses on the accounting of tradable emissions rights and obligations from emissions trading schemes (IFRS, 2008). The Accounting Board of Finland has dictated that emissions rights in accounting law KILA 1767 (2005) are under accounting regulation 1:6 subjection 1" Immaterial rights". The focus of carbon dioxide emissions accounting is in emissions trading due to its effects on companies' balance sheets (Ascui, Lovell 2011). When it comes to voluntary disclosure, the Climate Disclosure Standards Board's (CDSB) climate change reporting framework (2012) states that required disclosed content shall include: (1) strategic analysis, risk and governance related to climate change and (2) greenhouse gas emissions. High quality GHG emissions data is needed to benchmark current and future risks of climate-change impacts and the effects of future regulations intended to restrict or minimize emissions (CDSB 2012). The complying global standards are the Greenhouse Gas Protocol, the ISO 14001 series (2012) and the 2012 Framework recognizes emissions from Scope 1, 2 and 3. Scope 1 includes all direct emissions of the company, scope 2 includes all indirect emissions from company purchasing sources of energy and scope 3 includes all other indirect GHG emissions (CDSB 2012) However, scope 3 emissions are optional (CDSB 2012). This recognition of GHG emissions is at corporate level when the accounting of emissions rights is closer to the market-level (Ascui, Lovell 2011).

As the financial perspective focuses on the accounting procedures of companies to disclose the use of emissions permits or the level of emitted GHGs, the social/environmental perspective of carbon accounting focuses on the corporate sustainability reporting and product Life Cycle Analysis (Ascui, Lovell 2011). Life Cycle Analysis (LCA) is described by ISO 14040 as a methodology to analyse and assess environmental impact of a material, product or service along its entire life cycle (Senvar 2018). This means that the social/environmental perspective concentrates on the reporting and emissions aspect from the entire life cycle of a material, product or service. Compared to the financial perspective, the focus of social/environmental perspective is on the physical output and reporting of carbon dioxide emissions when the financial perspective focuses on the financial reporting and the actual costs to mitigate these physical outputs.

Risks associated with carbon, according to Bebbington and Larinaga-González (2008), can be divided into two categories: regulatory risks and competitive risks. Regulatory risks come from national and international policy-setters and instruments aimed to reduce carbon emissions. One example of regulatory risk is the emissions trading scheme, where governments can impose risks to companies through a possibility of restricting the number of allowances during that year (Bebbington, Larrinaga-Gonzalez 2008). Some companies only pursue to comply with the legal requirements to avoid fines or loss of licence but other companies actively manage carbon emissions beyond compliance and gain competitive advantage (Burritt, Schaltegger et al. 2011). Competitive risks arise from the possibility that changing prices, technologies and demand patterns for less carbon-intensive products and services lead the existing core competence to become obsolete (Kolk, Levy et al. 2008). However, even if additional costs associated with carbon legislation and restrictions would affect businesses, there are still opportunities in carbon management, for example by minimising additional costs more effectively than competitors, differentiating products by bundling carbon credits into product portfolio or turning the company’s capability to supply additional carbon allowances into a profit centre (Schultz, Williamson 2005). Some studies state that the actual challenge for the management of an organization lies in its ability to reduce the total costs and associated risks. Even if the organization is disclosing the risk of impact from climate-change and risks to accelerate climate-change via CDP (Innovest 2003 as cited in Ascui, Lovell, 2011) the management needs to look for new opportunities to gain competitive advantage in a carbon constrained world (Schultz, Williamson 2005).

Now, why do I discuss external carbon accounting when my focus is on assisting managers in carbon management accounting? Generally, the information needed by the management to manage business is the same information that is disclosed to assess the company's financial performance (CDSB Climate change reporting framework 2012). Because the externally reported information is generally statutory, the internal information should by minimum needs cover the requirements of external information. This is why I want to discuss the requirements of external carbon dioxide emissions disclosure which should be extended with voluntary reporting. This is the purpose of carbon management accounting which closely follows the previously discussed environmental management accounting. Next, I discuss the carbon management accounting systems and how they are related to environmental management accounting systems.

CMA systems are information gathering systems to report GHG emissions for regulatory, market and informational requirements (Burritt, Schaltegger et al. 2011). A global example would be the Kyoto Protocol which has a real time monitoring and accounting system to gather information on expected emissions per member country (Stern 2007). Besides gathering information, another objective of a CMA systems is to design sustainability reports and to excel in sustainability ratings designed for financial investment analysis (Burritt, Schaltegger et al. 2011). In short, a CMA system gather data for regulatory reasons, assists in designing sustainability reports and helps to excel in sustainability ratings according to Burritt, Schaltegger and Zvezdov (2011). According to Schaltegger and Wagner (2006) the management of carbon performance requires a solid accounting management system which links carbon management with competitive strategy and integrates carbon information with economic information and carbon reporting. A comprehensive and integrated carbon management system pursues to link emissions reductions with business processes rather than only focusing on reporting (Gibassier, Schaltegger 2015). Next, I will discuss some approaches companies can use to integrate carbon management accounting into their operations.

Burritt et al. (2011) state that companies approach CMA in a number of different ways, including:

- amount of emissions trading certificates that can be avoided as direct savings
- the payoff of saved energy from invested effort
- market advantage by labelling products carbon neutral
- pressure from the industry to disclose information on emissions

Lee (2012) found that the mapping of carbon flow in production provides opportunities to improve carbon performance and eco-control can improve the relationship of the company's carbon management strategy and carbon performance measurement. Eco-control can be defined as formalized procedures and systems that use a company's financial and ecological information to change or maintain its environmental activity (Henri, Journeault 2010). Schaltegger and Burritt (2000) claim that embedding eco-control into corporate practices, the company embeds financial and strategic control methods to the achievement of corporate environmental management. Eco-control is also an approach to quantify environmental actions of the company and integrate environmental issues into the firm's organizational routine (Lee, K. 2012). Lee also pointed the EMA's, MEMA's and PEMA's connection to eco-control and how the data from EMA framework can be used to manage the carbon strategy. Burritt et al. (2002b) famously developed a framework for EMA, which was later extended by Burritt, Schaltegger and Zvezdov (2011) as a framework for carbon management accounting (CMA). Table 6 illustrates this framework.

The CMA framework consists of management information divided into physical and monetary dimensions. The time frame of decision-making is divided into past, present and future, and the length of time frame is between short or long term. Additionally, the routine to generate information is divided into regular or ad hoc information. This framework provides a guide for the decision-makers on the most relevant information

Table 6 Carbon Management Accounting framework (adapted from Burritt et al. 2011)

		Carbon management accounting (CMA)			
		Monetary carbon accounting		**Physical carbon accounting**	
		Short term	**Long term**	**Short term**	**Long term**
Past oriented	Routinely generated information	1. Carbon cost accounting (e.g. establishing the revenues /costs from carbon emissions certificates sold and purchased weekly on the market)	2. Carbon capital expenditure accounting (e.g. collecting data on annual capital expenditures on carbon reduction technologies)	3. Carbon flow accounting (e.g. collection of daily emission flow information related to production)	4. Carbon capital impact accounting (e.g. calculation of the carbon footprint reduction of a business over 10 years)
	Ad hoc information	5. Ex post assessment of short-term/relevant carbon costing decisions (e.g. assessing the cost savings each month from changing to the use of long-life light bulbs)	6. Ex post assessment of carbon reducing investments (e.g. assessment of the cost savings from an investment in solar panels for electricity)	7. Ex post assessment of short-term carbon impacts (e.g. collection of information about the reduction in travel miles of an executive as part of a short-term carbon reduction programme)	8. Ex post assessment of physical carbon investment appraisal (e.g. review of the carbon reduction achieved by investment in the introduction of a carbon reduction logistics network)
Future oriented	Routinely generated information	9. Monetary carbon operational budgeting (e.g. expected monthly monetary savings from carbon reduction)	10. Carbon long-term financial planning (e.g. forecasting future financial benefits from planning to permanently reduce carbon footprint)	11. Physical carbon budgeting (e.g. expected reduction in CO2 after staff training in green awareness techniques)	12. Long-term physical carbon planning (e.g. expected reduction in emissions of CO2 from R&D projects)
	Ad hoc information	13. Relevant carbon costing (e.g. calculating the change in revenue of CO2 costs on dirty products are included in the price charged from customers)	14. Monetary carbon project investment appraisal	15. Carbon impact budgeting	16. Physical environmental investment appraisal

Source: (Burritt, Schaltegger et al. 2011) needed and how the information is linked to the practise. It also provides a workflow to collect and manage carbon information. (Burritt, Schaltegger et al. 2011)

Ricoh Group has published a sustainability report in 2010 based on their version of environmental management. This report describes the management system and how it helps to promote environmental management and links business operations with decision-making efforts. The Group uses a concept called "Comet Circle" which expresses the environmental impact reduction plan. The concept assists to identify and reduce the total environmental impact at all stages of the product's lifecycle and is implemented through 3 steps: (1) Identification and reduction of the total environmental impact at all stages of the lifecycle, (2) Prioritizing inner loop recycling and promotion for a multitier recycling system and (3) Establishing a partnership at every stage. The first step identifies the environmental impact from every stage of the life cycle by using a sustainable environment management information system. This system is designed to identify, promote and collect environmental data of overall operations to assists with environmental planning, decision-making, environmentally- friendly product design promotion, improving activities of each division, processing corporate environmental accounting and disclosure of information. This cover all processes from all parties (the Group, suppliers, customers, and recycling companies). The second step is to prioritize reusing and recycling of products and part. The third step is to establish close, information-sharing relationships with partners, including customers, to reduce the environmental impact. (Ricoh Group, 2010.) This is one example of a tool to identify carbon dioxide emissions sources during the life cycle of a product/service and manage the reuse and recycling of those products and services with all stakeholders. Ricoh Group is also using corporate environmental accounting to identify environmental conservation costs and the economic benefits of these costs. The company also follows the reduction of environmental impact and the total environmental impact. Tables 7 and 8 illustrate this accounting where Table 7 displays the economic benefits of costs related to improvement of environmental performance. Table 8 shows the gained social benefit from reducing environmental impact and the total social cost of the company's environmental impact.

However, there are inherent problems with environmentally related cost data and data collection. Direct measurement of environmental impact is often difficult, which means that other parameters need to be used to gain that information. This can include input and output measurements or conversion formulas which can impact the results with certain margins of error. These errors can be considerable, especially in large companies. (Bartolomeo, Bennett et al. 2000) Bartolomeo et al. (2000) suggest higher degree of standardization on terms and techniques, but as I established earlier, further standardization may complicate sustainable development implementation. Mere identification of environmental and social costs is not enough to make an influence on the company's management. Environmental information needs to be integrated into the company's activities, in the form of an e.g. cost objective or a budget (Bartolomeo, Bennett et al. 2000). Next, I will continue carbon management accounting and carbon accounting procedures by implementing these elements into an environmental impact management and reporting tool: the environmental profit and loss statement.

Table 7 Environmental investment costs and benefits (adapted from Rich Group, 2010)

	Costs			Economic benefits		
Item	Environmental investment	Environmental costs	Main costs	Monetary effects	Category	Item
Business area costs	2.9	12.7	Pollution prevention…………1.3 Global environmental conservation cost…………………………..2.3 Resource circulation cost……9.1	28.3 39.1 10.1	a1 b c	Energy savings and improved waste processing efficiency Contribution to value-added production Avoidance of risk in restoring environments and avoidance of lawsuits
Upstream/Downstream costs	0.0	125.2	Cost of collecting products, turning recycled materials into saleable products, and so forth	235.5 [21.1]	a1 S	Sales of recycled products, etc. Reduction in society's waste disposal cost
Administration costs	0.5	34.4	Cost to establish and maintain environmental management system; costs of preparing environmental reports and advertisements	10.6	b	Effects of media coverage, environmental education and environmental advertisements
Research and development costs	2.0	26.9	Research and development costs for environmental impact reduction	43.5 [8.2]	a2 S	Contribution to gross margin through environmental research and development Reduction in user's electricity expenses thanks to improved energy savings
Social activity costs	0.0	0.9	Costs for nature conservation and green landscaping outside business sites	-	-	None
Environmental remediation costs	0.3	0.6	Costs of restoring soil and environmental related reconciliation	-	-	None
Other costs	0.0	1.2	Other costs for environmental conservation	-	-	None
Total	5.7	201.7		367.0		

Costs are displayed in ¥100 million. Items are defined by the Environmental Accounting Guidelines 2005 by the Japanese Ministry of the Environment. Environmental investments correspond to the financial account "investments in fixed assets" and environmental costs correspond to the financial account "period costs". Categories are divided into 5 benefits; a1=substantial effects, a2=estimated substantial effect, b=secondary effect, c=incidental effect, S=social effect. Substantial effect means that the economic benefit falls into either of the two following categories: (1) cash or cash equivalent was received as benefit and (2) Amount saved in costs which would not have occurred if environmental conservation activities were not conducted. Estimated substantial effects means that there is substantial contribution to sales or profits, but the value cannot be measured without estimation. Secondary effect is the expected amount of contribution in case that expenses on environmental conservation activities are assumed to have contributed to Ricoh Group's profits. Incidental effect means that the expenditure on environmental conservation activities can help to avoid occurrence of environmental impact. Social effect means that the impact or effect of environmental conservation activity is felt by the society and not the Ricoh Group. Economic benefits are referred to as benefits from obtained environmental conservation activities which contributed to Ricoh Groups profits.

Table 8 Effects of environmental conservation and the environmental impact (adapted from Ricoh Group, 2010)

Effects of Environmental conservation				**Environmental impact**			
Environmental Impact Reduction (tons)	Conversion coefficient	Converted Quantity of Reduction	Social Cost Reduction values	Total (tons)	Conversion Coefficient	Converted quantity of impact	Social cost
Reduction in environmental impact caused at business sites				Environmental impact caused at business sites			
CO2 ……………………..…. 11,224.0	1.0	11,224	1.59	CO2 ………………………… 287,657	1.0	287,657	40.76
NOx …………………………..…. 5.7	19.7	112	0.02	NOx ……………………..……. 154	19.7	3,031	0.43
SOx …………………………......... 1.6	30.3	48	0.01	SOx …………………...…..…... 6	30.3	177	0.03
BOD …………………………... 2.2	0.02	0.0	0.00	BOD ……………………………. 6	0.02	0.1	0.00
Final amount of waste disposal … 129.3	104.0	13,451	1.91	Final amount of waste disposal … 277	104.0	28,817	4.08
Emissions of environmentally sensitive substances ………………………..	(Ricoh standards per substance)	2,222	0.31	Emissions of environmentally sensitive substances …………	(Ricoh standards per substance)	16,244	2.30

Environmental impact reduction in lifecycle as a whole				Environmental impact in lifecycle as a whole			
CO2 ……………………… 356,145	1.0	356,145	50.47	CO2 ………………….. 4,915,481	1.0	4,915,481	696.56
NOx ……………………… -11,256	19.7	-221,748	-31.42	NOx ………………… 14,486	19.7	285,378	40.44
SOx ………………………. -6,260	30.3	-189,685	-26.88	SOx …………………...16,627	30.3	503,792	71.39
Fossil fuel ……………….. -	(Ricoh standards per substance)	351,924	49.87	Fossil fuel …………… -	(Ricoh standards per substance)	7,279,791	1,031.60
Mineral resources ……….. -	(Ricoh standards per substance)	139,786	19.81	Mineral resources ….... -	(Ricoh standards per substance)	2,487,402	352.48
Other …………………..…. -	(Ricoh standards per substance)	179,701	25.46	Other ………………... -	(Ricoh standards per substance)	2,960,801	491.57
Total environmental impact reduction at business sites		27,057	3.83	Total environmental impact reduction at business sites		335,926	47.60
Total environmental impact reduction in lifecycle as a whole		616,122	87.31	Total environmental impact reduction in lifecycle as a whole		18,432,645	2,612,03

The accounting period for costs and total environmental impact is from 01.04.2009 until 31.05.2010. Environmental reduction figures are generated from fiscal period 2008 to fiscal period 2009. Effects of environmental conservation refers to the actions to prevent and control occurrence of environmental impact and to eliminate and remove such impact. Emission reductions are reported as a difference between the current year and the previous year. Conversion coefficients are weighting coefficients deemed to identify different environmental impacts as in similar units. This means changing the GHG emission into similar unit from different units with coefficient weights. In this case, Swedish EPS method is used. Converted quality of reduction is the multiplied value of environmental impact/impact reduction and the conversion coefficient. The values are converted into t-CO_2 figures. Social cost reduction values are financial figures, which are the result of multiplying the converted quantities of reduction with specific social cost factor. The used social cost factor is 108 EUR/ t-CO_2 of EPS from year 2000. The environmental impact –side is mostly similar to the left side, but now Ricoh Group has calculated the emitted environmental impact from the current fiscal year.

3.3 Environmental Profit and Loss statement

To enhance their competitive advantage, companies are looking for ways to measure results from an environmental perspective (Bebbington, Unerman et al. 2014). These methods can range from physical to economic in terms of the company's impact on the environment (Jones 2010), which corresponds to the EMA framework on monetary and physical impact. Arena, Conte and Melacini (2015) point out that the base idea of integrating corporate actions and the economic impact is to extend the analysis of environmental impact to corporate actions which were previously considered outsourced. This mean internalizing the environmental impact and recognizing the economic impact from general overheads into specific cost objectives. Recently, a trend has been emerging to express the environmental impact of the company in monetary terms. This allows for the transformation of environmental information from physical units into the lingua franca of business: money. (True Price, 2015.) Some managers may even prefer to follow environmental indicators in monetary terms rather than in physical units. For example, the interest of a manager may not be on the total amount of wastewater generated each year (physical indicator) but on the estimated total costs of treatment of wastewater each year (monetary indicator) (IFAC, 2005.) This expression of environmental impact in monetary terms allows a business to forecast their actions to the bottom lines and helps to manage risks, innovation and reputation (True Price, Deloitte, EY and PwC, 2014).

One tool for the monetization of a company's environmental impact is called the environmental profit and loss -statement (EP&L). This tool attempts to summarize environmental impact across the supply chain (Reefke, Sundaram 2017) and monetize the ecosystem in which the company and the company's supply chain are operating (Etzion, Gehman et al. 2017). The central focus of an EP&L analysis is to provide insight into the company's environmental impact in a credible and understandable form for the decision-makers (PwC, 2015). EP&L can also be seen as an effort for tighter integration of financial and sustainability reporting to move the corporate priorities into more sustainable spheres (Etzion, Gehman et al. 2017). The Danish Environmental Protection Agency in their 2014 report "Novo Nordisk's environmental profit and loss account" state that an EP&L refers to the placing of a monetary value on the environmental impact along the entire value chain. This involves taking the lifecycle of a product or a company and modelling the environmental damages in monetary form throughout the supply chain (Sovacool, Munoz Perea et al. 2016) or in some cases throughout the value chain (Nordisk 2014). EP&L was first proposed in the 90s as an instrument for combined economic and environmental performance reporting (Arena, Conte et al. 2015). The first company to use an EP&L has been claimed to be BSO/Origin which combined three different approaches to display their environmental impact: the cost of preventing the environmental impact, the cost of repairing the environmental damage and the value lost by communities due to environmental damage (Huizing, Dekker 1992). This form of presenting the environmental impact from a company's operations is similar to the Ricoh Group's presentation of impact on Table 7 and Table 8.

EP&L is based on combining the traditional profit and loss accounts with figurative revenues and costs related to environmental impact (Sabeti 2011). The "profit" in EP&L refers to any activity by the company which benefits the environment and the "loss" refers to any activity which is harmful to the environment (Sovacool, Munoz Perea et al. 2016). The net value to the environment from an environmental profit and loss statement is the difference between the profit and loss. In most companies the net value, according to Sovacool et al. (2016), is deficit due to the net cost to the environment (e.g. see Table 8). Lauesen (2019) describes an EP&L as a monetary valuation and an analysis of the company's environmental and/or social and economic impact from a life cycle perspective. This is similar to the financial and social/environmental perspective approach to carbon accounting as proposed by Ascui and Lovell (2011). From the product's life cycle perspective, an EP&L internalizes externalities of the company and monetizes the LCA results as a cost to nature and/or society(Lauesen 2019).

Externalities can be positive or negative and they take place when important societal benefits and costs are "external" (Sovacool, Munoz Perea et al. 2016). For example, negative externalities can be asthma from air pollution due to burning of coal in power plants (Sovacool, Munoz Perea et al. 2016). On the other hand, positive externalities can occur from enhanced manufacturing competitiveness due to investments in local made wind turbines (Sovacool, Munoz Perea et al. 2016). EP&L displays costs from these externalities and indicates the direct and indirect impact to the environment and/or society (Lauesen 2019). Lauesen (2019) point out the benefits of internalizing external environmental costs as financial costs as it reflects a more trustworthy picture of the societal and environmental impact of conducting business and improves the company's motivation to reduce the impact.

Sovacool et al. (2016) claim that an EP&L can offer valuable business insight to decision-makers on the direction of sustainability efforts, managers and investors can perceive environmental risks related to the business and consumers can receive a better understanding on a product's impact on the environment and /or society. They also claim similar benefits to EMA in a form of improved environmental performance through increased market-value or optimized efficiency. Lauesen (2019) invokes similar benefits in an EP&L to create more transparency in the supply-chain and more visibility to the focal points of sustainable development. This holistic perspective provides a suitable tool for supply-chain management, new opportunities to improve managerial decision-making in terms of environmental risks, greater managerial understanding of the company's environmental, social and economic performance, and improved risk analysis and accounting procedures (Lauesen 2019). Also, EP&L can work as an internal motivator for a company's management to convert sustainability and shared value into actionable performance metrics. For example, sports brand PUMA integrated the triple bottom line concept into an EP&L for benefit measurement and to improve the management's understandability over the triple bottom line (Sroufe 2017). Novo Nordisk, a Danish healthcare company, states that an EP&L can be applied into an organisation in four different ways; as an awareness and transparency tool, for identification of environmental hot spots, for risk management or for sustainable supply chain management (2014). Earlier in this study I discussed on the effects of international standards to environmental reporting and the European commission's 2018 action plan on financing sustainable growth. Part of this plan is to reorient capital flow towards more sustainable investments for a more sustainable and inclusive growth. With an EP&L, companies could achieve the same when an extensive LCA displays emissions from the whole supply chain of the company. This can bring up new cost-saving and investment opportunities to reduce the environmental impact and cost associated with the impact. Associated benefits of an EP&L's monetary valuation, according to PwC (2015), include simplified environmental metrics to a single unit for better comparability, prioritization and target setting, improved understanding with senior decision-makers and better basis for stakeholder communication.

When it comes to LCA modelling, choices on system boundaries and which processes to include within the boundaries have become decisively important in terms of results (Rebitzer, Ekvall et al. 2004). And because an EP&L -statement's LCA simulations involve several different company activities it is very important that a detailed description of the scope and goals of the assessment are made (Lauesen 2019). EP&L as a concept should be also taken with a grain of salt as the application has been scarcely applied (Sovacool, Munoz Perea et al. 2016). Companies that have published EP&L -statements include PUMA, Kering Group, Stella McCartney, Novo Nordisk, Philips, Asus, Vodafone, IC Group, Axfoundation and YorkshireWater. During this research I cite two documented EP&L implementations by PricewaterhouseCooper (PwC) and Novo Nordisk. Namely the PwC's 2015 document "Valuing corporate environmental impacts: PwC methodology document" and two documents from the Danish healthcare company Novo Nordisk named "Novo Nordidk's environmental profit and loss account" (2014) and "Methodology report for Novo Nordisk's environmental profit and loss account" (2014). The reasons why I base my research to these three documents are the limited resources, the scale of this research and limited amount of accurate documentation on an EP&L -statement implementation.

First, I want to establish the PwC's methodology and its relation to a case company PUMA. Then, I will compare this implementation to Novo Nordisk's methodology and discuss how the results from PUMA, PwC and Novo Nordisk are related to four additional case companies Kering Group, Stella McCartney, Asus and Vodafone. From all seven case companies, I will form an implementation path to establish an EP&L -statement.

3.3.1 PUMA's and PwC's implementation of an EP&L -statement

One of the most famous implementations of an EP&L -statement has been by a sportswear brand PUMA (see e.g. True Price (2015), PwC (2015), (Arena, Conte et al. 2015, Sovacool, Munoz Perea et al. 2016, Sroufe 2017, Etzion, Gehman et al. 2017). PUMA is one of the world's leading sport brands established in 1948 with estimated revenue of 4.6 billion euros in 2018 (puma.com). The company implemented the EP&L into its operations and supply chain with outputs of greenhouse gas emissions, water use, land use, air pollution and waste. The methodology and implementation were conducted together with PwC and Trucost in 2010 and the statement was extended to products in 2012 (True Price 2015). The results from the statement suggest that most of the environmental impact is caused by the company's supply chain (around 94%) (puma.com/newsroom) and around 80% of environmental impact resides in production and sourcing (True Price, Deloitte, EY and PwC 2014).

PwC methodology is divided into six parts consisting of different emission types: air pollution, greenhouse gases, land use, solid waste, water consumption and water pollution (PwC 2015). Because my study focuses on monetization and management of carbon dioxide emissions, I will focus on the greenhouse gas emissions. PwC (2015) has also conducted a robustness assessment of the overall literature regarding GHG emissions methodologies, including; the scale and quality of the academic literature, the degree of consensus in the underlying literature and the applicability of the underlying literature to the measurement or valuation of corporate environmental impacts. This assessment gave GHG emissions 5 on science and 4 economics with a legend of 5. This is the second highest in terms of legend only behind air pollution.

PwC's (2015) customers state that the implementation process itself poses benefits for companies and help to; connect teams and data owners within the business, get new functions and decision-makers to engage with environmental information, broaden and deepen the understanding of environmental impact along the value-chain and establish or enhance environmental datasets across environmental impact areas. To estimate the scale of environmental impact, PwC proposes to follow the next three steps:

1) Quantify environmental emissions or resource-use in biophysical units
2) Understand how corporate emissions or resource-use cause change to the natural environment
3) Value the impact of associated changes in the environment on people

A traditional environmental report commonly stops at step 1 to understand the scale of emissions and used resources but an EP&L extends this to steps 2 and 3 to understand the effects of these emissions and used resources on people and on the environment. The methodology does not consider non-linearities and threshold effects, nor does it cover all possible classes of environmental impact e.g. noise and light pollution, littering or indoor environmental impact (PwC 2015).

To value the environmental impact, PwC begins by defining the impact drivers, environmental outcomes of these drivers and the societal impact of these outcomes. To estimate the societal impact, a company must build a framework with three steps:

1) Obtain environmental metric data
2) Quantify environmental outcomes
3) Estimate the societal impact

It is essential for an accurate evaluation of environmental impact to have high quality input data. For GHG evaluation, two types of data are needed: environmental metric data and other data relevant to quantification. Environmental metric data is the quantity of GHG emissions released into the atmosphere due to corporate activities, also expressed as a unit of tonnes of carbon dioxide. (PwC 2015.) These are expressed in the unit of tonnes of carbon dioxide equivalent (tCO_2e) (PwC 2015), which represent the total radiative forcing in terms of carbon dioxide which would give that similar forcing (Change, Intergovernmental Panel On Climate 1990). Rest of the data needed consists of factors derived from academic literature which are used to convert metric data into value estimates (PwC 2015).

Some companies only value GHG emissions from direct operations but CO_2 emissions can occur from other stages along the value-chain as well. If companies do not already collect data from these stages, they can use life cycle inventories (LCI) or environmentally extended input-output (EEIO) modelling to obtain this information. (PwC 2015.) Once the data is collected, GHG gases should be converted into tCO_2e by using IPCC's global warming potentials (Stocker 2014). Table 9 displays global warming potentials (GWPs) or conversion coefficients for GHS from a 100-year period. After obtaining the environmental data and converting the GHGs into the same unit (tCO_2e), the emissions should be valued with a selected quantification approach (PwC 2015).

Table 9 IPCC Global warming potentials from 100 year-period according to IPCC fifth assessment report

Greenhouse gas	Global warming potential
CO_2	1
CH_4	34
N_2O	298
HFC-134a	1,550
CF_4	7,350
CFC-11	5,350

Source: IPCC 2013

PwC proposes three different approaches to quantify emissions, which are the social cost of carbon (SCC), the marginal abatement cost of carbon (MAC) and the market-based price of carbon. I will discuss and compare the specifics of each method later during Chapter 4 but in short, the SCC values GHG emissions in terms of a cost per tCO_2e which societies experience from released emissions. MAC estimates the cost of carbon dioxide emissions by comparing different abatement options within a company to each other. The market-based price is based on the European Union's emissions trading scheme which determines the price per tCO_2e from traded emissions allowances. Because the SCC is based on the theory of welfare economics and measures changes in human well-being associated with a company's environmental impact, PwC has decided to use this approach to quantify emissions in an EP&L.

PwC (2015) continues to establish the SCC value through a meta-analysis which derives the estimate by analysing many existing estimates from other academic papers. Other mentioned approaches to obtain an estimate are primary estimation, adopting a single SCC estimate from a single existing study or through meta-analysis. There were two reasons for choosing the SCC meta-analysis. Firstly, the SCC is under significant research and new primary estimation without the latest knowledge would results in marginal benefit. The second reason is the lack of consensus amongst researchers on a preferred approach to calculate SCC which would result in difficulty to justify a single value from a single research (PwC 2015.) I will later discuss on the specifics of calculating the social cost of carbon and for now summarize the results of the cost estimate by PwC. SCC consists of costs and benefits accrued over time and then discounted to present day by using a societal discount rate (SDR). To calculate SDR, Ramsey's model is used which dictates that the societal discount rate is the sum of pure rate of time preference and the multiple of the elasticity of marginal utility to the future economic growth rate (PwC 2015.) PwC uses a pure rate of time preference of 0 percent and an income elasticity to economic growth of 2 percent. The resulting SDR is 2 percent with an SCC estimate from the meta-analysis as an arithmetic mean of USD 78/tCO_2e and median of USD 62/tCO_2e. Because of the several steps to calculate SCC estimate mean and median, these values are highly sensitive to the decisions on the parameters and ethical decisions.

Now that the PwC's methodology is established, I will investigate the EP&L implementation process from PUMA's perspective. PUMA defines EP&L in its 2010 report the following way: "An Environmental Profit and Loss Account is a means of placing a monetary value on the environmental impacts along the entire supply chain of a given business." PUMA mentions the benefits of an EP&L to business as a strategic tool, as a risk management tool and as a transparency tool.

Because PwC and Trucost were both assisting PUMA to develop its EP&L- tool, the implementation process is very similar to what I have discussed earlier. PUMA's (2010) supply chain environmental impact drivers are water use, GHG emissions, land use conversion, other air pollutions and waste. The process for an EP&L implementation is divided into four steps:

1) Scope and boundary of the EP&L
2) Measuring the drivers of environmental impact
3) Modelling of drivers of environmental impacts
4) Valuing the environmental impacts

PUMA (2010) limited the scope of the project to cradle-to-gate which means from the production of raw materials up until to the point of sale. The second step on PUMA's implementation is the measurement of the drivers of environmental impact. To measure the impact PUMA divided its outsourced supply chain suppliers into four Tiers, where Tier 1 represents manufacturing, Tier 2 product parts production, Tier 3 raw material processing and Tier 4 raw material production. Most of the production of products is outsourced, only the closest business activities (e.g. running shops and offices, warehouses, business travel, logistics, IT) are considered PUMA's own operations. The sources of data to measure the environmental impact can be divided into two: first part comes from PUMA's own operations and from selected Tier 1 suppliers. Second part comes from the remaining suppliers from Tiers 1 to 4. The first part represents 16 percent of the total impact while the second part represents the 84 percent of the total impact. The data from PUMA's own operations is collected via company's own internal environmental management system and selected Tier 1 suppliers provided the requested environmental data. The remaining data is collected from Trucost's econometric input-output model. (PUMA 2010.) Input-output models were first developed by the United States economist Leontief in 1936 (Leontief 1936). His models traced all transaction throughout the supply-chain network up until the final demand of the consumer. Once all economic purchases for a given final demand bundle are calculated across all supply chains in the economy, any environmental interventions can be estimated in the form of environmental impact per monetary unit (Huang, Lenzen et al. 2009). When this model is extended to include environmental issues it is called an environmental input-output analysis (Kjaer, Høst-Madsen et al. 2015).

The third step of implementation for PUMA (2010) is the modelling of environmental impact drivers. The econometric input-output model collects the use and emissions from environmental resources by integrating the expenditures and sectors of PUMA's Tier 1 suppliers to the resources. This estimates the volume of GHGs, other air pollution, water abstraction and waste generation from the 2010 financial year for each supplier's own operation and supply chain. To enhance the integrity of data across the supply chain, primary data was validated against the modelled econometric input-output data. The model assumes that the suppliers are typical in their industrial sector with an average level of economic and environmental performance for each unit of output. The geographical accuracy of suppliers is deficient as the exact information of the location of the suppliers from Tier 2 to 4 was not available. This generates a national average for specific environmental impacts rather than country-region level accuracy which can make decision-making on these specific suppliers difficult. (PUMA 2010.)

The fourth step in PUMA's EP&L implementation is "valuing the environmental impact" which means that the collected information is transformed from physical units into monetary value. PUMA uses an estimate of SCC to monetize GHG emissions. To calculate the SCC PUMA uses a sub-set of 232 SCC estimates provided by Tol's (2009) paper "The economic effects of climate change". PUMA uses social discount rate of 3.4 percent with a pure rate of time preference of 0 percent and a future economic growth rate of 3.4 percent. Older SCC estimates in the sub-set were increased by 3 percent per annum which is the mid-point of IPCC's 2 to 4 percent range similar to PwC's 2015 report. PUMA averages the valued damage of climate change and accounts for catastrophic risk. PUMA does not use equity weighting to adjust the damage values to reflect the differences in income and material wealth between countries. The resulting mean estimate of the SCC in 2010 euros is 66€/tCO_2e or 87 USD per tCO_2e. (PUMA 2010.) Next, I will compare the PwC's methodology to Novo Nordisk's implementation process of an EP&L -statement.

3.3.2 Novo Nordisk's implementation of an EP&L

Novo Nordisk is a global healthcare company born from a merger of two Danish healthcare companies Nordisk Insulinlaboratorium and Novo Terapeutisk Laboratorium in 1989 (novonordisk.com/history). Currently, the company is a world leader in diabetes, obesity and haemophilia care (novonordisk.com/history). In 2014, Novo Nordisk published two documents on its environmental profit and loss account –project: "Novo Nordisk's environmental profit and loss account" and "Methodology report for Novo Nordisk's environmental profit and loss account", from which the first presents the results and conclusions of the 2011 EP&L –project and the second describes the methodology of EP&L implementation and contribution (Nordisk 2014).

Novo Nordisk's EP&L pilot-project was initiated by the Danish Ministry of Environment. The project was conducted by three consulting-firms: NIRAS A/S, Trucost PLC and 2.-0 LCA (Nordisk 2014). NIRAS is a consulting company focusing on engineering feats (niras.com/about-niras), Trucost PLC is a consulting company which provides data, tools and insight on carbon emissions management, sustainable finance and natural capital management (trucost.com/about-trucost) and 2.-0 LCA is a life cycle assessment consultancy firm (lca-net.com/about). NIRAS was responsible for project management during the EP&L –project and Trucost specialized in environmental data collection and valuation. 2.-0 LCA focused on advanced LCAs and the development of country specific environmentally extended input-output (EIO) tables. EP&L quantified and analysed three environmental key performance indicators (eKPIs); greenhouse gas emissions, air pollution and water. Additionally, indirect land use change was analysed as a case study eKPI. (Nordisk 2014)

Novo Nordisk (2014) follows seven steps to apply an EP&L: (1) scope and boundary, (2) map the value chain, (3) impact assessment, (4) collect environmental data, (5) fill data gaps, (6) quantify and value changes in environmental quality and (7) calculate EP&L (Nordisk 2014). If this is compared to the PwC's methodology (2015), there are three steps which only cover quantification, estimation and monetization of environmental impact. The PwC's implementation does not carry out the first five steps of Novo Nordisk's implementation path. This is because PwC does not describe the estimation nor collection methods of GHG emissions but has focused on the quantification of impact. Data collection is described in greater detail in Novo Nordisk's two reports. This is the reason I want to combine the two implementation paths together to form a good framework for an EP&L implementation. This is also part of the carbon management accounting framework to collect data from the supply-chain and/or value-chain.

Novo Nordisk explains that the first step (Scope and boundary) creates the basis for an EP&L analysis: which environmental impacts to assess, which business units and services to include and which parts of the value chain should be included. Novo Nordisk's value-chain covers all production lines and support functions from the cradle to the grave and it also covers the purchase of products not directly used in production e.g. computers, furniture, travel expenditures etc. Raw material extraction, processing of materials, production sites, production distribution between production sites and from production sites to affiliates, direct customers and importing distributors are included in the scope of the study. This does not include the distribution from affiliates nor the impact from in-use or end-of-life of the product. Novo Nordisk has also excluded the initial investments in new factories and operations of R&D functions outside of Denmark. The reason was due to the structure of the data. (Nordisk 2014)

The second step is the mapping of the value chain, which Novo Nordisk mapped from the raw materials to finished products and includes the distribution between tiers, the end users and the disposal of the product (Nordisk 2014). EP&L assists to improve the transparency over a supply-chain to understand the focal points of sustainable development (Lauesen 2019) which in Novo Nordisk's case would be to understand the value-chain from raw materials to the end product and how much GHG emission the different tiers produce. Novo Nordisk has divided its tiers into 3: Tier 1 finished products and services, Tier 2 processed materials and Tier 3 raw materials (Nordisk 2014).

After establishing the Tiers, mapping the value chain and establishing the scope and boundaries of the analysis, Novo Nordisk moves to the third step which is "Impact assessment". The three consulting and expert firms conducted an initial impact assessment and identified the preliminary hotspots through key person interviews. Additionally, the five largest spend categories were chosen for further analysis. Spend can be divided into direct and indirect spend where direct spend relates to the production of pharmaceuticals and devises and covers processed materials from Tier 2. Indirect spend relates to the products and services which are not part of the final consumer product and are sourced from Tier 1. Only the largest spend of the five continued to further analyses with secondary LCA data. (Nordisk 2014)

The next two steps in the implementation process focus on data collection from the value chain and assessment of the impact. Because the company had already pursued to measure and reduce environmental impact within the value chain before the EP&L –project, obtaining large amounts of data in a relatively short time span was possible. Also, due to regulation from the National Drug Agencies Novo Nordisk had already high-level visibility to the value chain. (Nordisk 2014) There are four data sets: operational, distribution, indirect spend and direct spend. Operational data is primary data and includes all on site data from Novo Nordisk's own facilities. Distribution data and indirect spend are modelled through an EIO model. Because the total data only covers a fraction of the total spend by Novo Nordisk due to the lack of consistent coverage from logistics companies, Novo Nordisk uses an estimate of environmental impact from spend on distribution. Indirect and direct spend include distribution expenses, in which all expenditure related to transportation of semi-finished and finished products are allocated to direct spend and all other distribution expenditures not direct related to the company's products are allocated to indirect spend.

Indirect spend data includes all purchases in monetary value derived from Corporate Procurement and affiliates sourced from Tier 1 suppliers. This data can include the purchase of e.g. IT equipment, office furniture or production machinery. Total indirect spend covers over 500.000 transactions with 310 individual spending categories. These categories are divided into 16 top level categories and some were joined to form total of 11 categories. All categories are further divided into three purchase areas: high impact, medium impact and low impact. Direct spend data includes all input materials in kilograms and is managed by the Strategic Sourcing Team. The data was modelled with an EIO and LCA hybrid, which collects approximately 75 percent of the total environmental cost. (Nordisk 2014) This is because most of the modelled data was derived from suppliers outside Novo Nordisk's operational control (Nordisk 2014) and would require new initiatives aimed at all suppliers (Kjaer, Høst-Madsen et al. 2015).

Now that I have established which data sets Novo Nordisk is using to calculate its EP&L, I continue the implementation by establishing LCA and EIO models and how these can help researchers estimate the total environmental impact in a value chain. An LCA is a methodology to analyse and assess the environmental impact of a product along its entire life cycle (Senvar 2018). This is one way for a company to establish an understanding of used resources and environmental release hotspots in direct and indirect operations (Ewing, Thabrew et al. 2011). Now, because Novo Nordisk is a global company it uses EIO tables to improve its geographical scope. These tables have been reported to be a promising approach to quantify the impact from the whole supply chain (Matthews, Small 2000, Junnila 2008, Hendrickson, Horvath et al. 1998). To add accuracy to an EP&L, companies could use additional EIO tables matching the geographical location of the company's spend and consumption. These models combine environmental data and economic flows to calculate the environmental impact through supply chains. EIO methodology is similar to an LCA -study in emissions calculation but displays the measured activities in monetary units rather than in physical units, e.g. in kilograms. The advantage of an EIO analysis over traditional LCA is the ability to take every economic transaction into account, while LCA presumes that some impacts are outside the boundaries of the analysis. (Nordisk 2014) This presumption could underestimate the actual emissions by as much as 50% (Schmidt, Weidema 2009). However, the EIO tables operate on a very high level due to limited number of sectors in the economic matrix which leads to a more general result compared to an LCA (Nordisk 2014). Additional advantages and disadvantages of EIO tables are listed on Table 10.

Table 10 EEIO tables advantages and disadvantages (adapted from Novo Nordisk 2014)

Advantages	Disadvantages
Completeness, avoids truncation error	Often limited environmental extensions available
Good starting point	Generic nature of sectors
Fast, practical, and relatively inexpensive	Inventories are not always current
Helps identify 'hotspots'	Difficult to model capital investments
Used by governments for similar purposes	Static models do not take account of changing cost and pricing structures of sectors and impact of technological change
Possibility of applying multiregional tables	Limited country specific EIO tables are available

Source: Novo Nordisk, 2014. Methodology report for Novo Nordisk's environmental profit and loss account

Novo Nordisk (2014) recommends to offset this granularity by performing a detailed analysis on specific spend categories with an LCA -study. This is called hybridisation where both methods are used (Nordisk 2014) and it is sometimes referred to as an EIO LCA in the academic literature (Kjaer, Høst-Madsen et al. 2015, Ewing, Thabrew et al. 2011). EIO LCA is a top-down approach to analyze the environmental impact of an entire supply chain and estimates the upcoming life cycle of emissions (Kjaer, Høst-Madsen et al. 2015). The main difference between a traditional LCA and an EIO LCA are the transactions between activities which are measured in monetary terms with an EIO LCA and in physical units with an LCA. LCA is also process-based where data is collected from all processes that have been identified as important inside the system boundaries. This has a disadvantage of truncation error due to subjective evaluation of which processes are included. (Kjaer, Høst-Madsen et al. 2015) However, EIO LCA approach has been criticized for being too aggregated especially in product and industry categories (Suh, Lenzen et al. 2004), which may incorrectly reflect to a particular process or product (Hendrickson, Horvath et al. 1998). Novo Nordisk uses two regional EIO tables: one representing the Danish market drawing on the markets for Europe 27 and the other representing the rest of the world. To quantify the environmental impact, the company applies two EIO models: FORWAST EIO matrix for quantification of eKPIs on GHGs, air pollution and land use, and US EIO for the quantification of water. (Nordisk 2014) FORWAST is a so-called hybrid database, based on the economic data from national accounts as well as process-specific data from life cycle inventories (Kjaer, Høst-Madsen et al. 2015).

To calculate the carbon footprint, Nova Nordisk uses SimaPro to analyse EIO tables and LCA databases. For this, LCA data from EcoInvest was merged with EIO model. To quantify the received GHG results to a uniform unit CO_2e, Stepwise quantification method is applied. For this, IPCC's global warming potential for 100 years (GWP100) is used. Novo Nordisk uses two methods to monetize the environmental impact: the recommendations in the Danish Guidelines in socioeconomic analyses and the Trucost method. Danish Guidelines focus on the Danish environmental impact while Trucost method focuses on Novo Nordisk's global impact. The valuation of the quantified emissions is based on the Trucost approach. (Nordisk 2014)

The Trucost approach uses a forward-looking price on global annual external costs of greenhouse gases which means that future social costs from emissions are discounted to present day based on Stern Review's social cost of carbon (Stern 2007, Nordisk 2014). Stern in his 2006 report "The economics of climate change" calculates the social cost of carbon to be $85 per tonne of CO_2 in 2000. He used a social discount rate of 1.4 percent (Ackerman, Stanton 2012) with a per capita consumption growth rate of 1.3 percent and time preference rate of 0.1 percent with an elasticity of marginal utility of one (Sterner, Persson 2008). Novo Nordisk inflates the carbon cost from 2000 to 2011 prices using World Bank of Consumer Price Inflation resulting in carbon price of US$113 per tonne of CO_2 (Nordisk 2014).

The Danish guidelines approach uses CO_2 prices based on the quotas from EU Emissions Trading System (ETS). If most of the emissions of Novo Nordisk are related to operations in Europe, the Novo Nordisk 2014 report recommends using quoted prices from the EU ETS because it is more robust than using a SCC which has more uncertainty. The quota used by Novo Nordisk in 2011 was approximately 18 euros per tonne.

EP&L has assisted Novo Nordisk to internalize externalities and made the company aware of possible risks related to high carbon products, e.g. in case of a carbon tax on products with a high carbon footprint (Kjaer, Høst-Madsen et al. 2015). Because EP&L quantifies the environmental impact from the whole value chain, and even if the period of investigation is only one year, EP&L can encourage Novo Nordisk's production facilities and management to invest in green technologies and optimization in energy and water consumption. Also, it has allowed to mitigate future risks by considering the environmental impact of future investments and their relation to carbon management regulation (Kjaer, Høst-Madsen et al. 2015) Risk avoidance seems to be often the main driver for supply chain related programs (Jira, Toffel 2013) however, measuring and monitoring actual environmental impact reductions is still not common (Kjaer, Høst-Madsen et al. 2015) especially on companies' actions to reduce suppliers' environmental and social impact (Kogg, Mont 2012).

3.3.3 Additional case companies with EP&L –statements

Next, I will investigate other companies who are known to implement an EP&L –statement into their environmental management system. I will not describe the different implementation methodologies in the same detail as I did with PwC, PUMA and Novo Nordisk for two reasons: first, the available information on the implementation either was not available or does not significantly differ from previously explained methods. Second, because the scale of this study is limited, I cannot focus on every implementation methodology but rather focus on major studies which have investigated the subject in detail.

Kering Group, a major luxury brand management company has published EP&L –statements since 2011 (kering.com/historic-commitment). PUMA used to be part of the group but exited in 2018 (kering.com/exit-puma). PUMA's eyewear business is still under Kering Eyewear (keringeyewear.com), which means that the famous EP&L –project conducted by PUMA, PwC and Trucost in 2010 has been migrated to Kering group (kering.com/open-sources) as a tool for highlighting environmental impact from the supply chain and to assist in environmental management (Kering EP&L –report 2017). Kering uses the EP&L -statement internally as a decision-making tool and externally publishes annual reports on the environmental impact. External reporting helps to create transparency while an EP&L assists to develop more resilient business models. (WBCSD 2018.)

The Kering group's methodology of implementing EP&L –statement very similar to the Novo Nordisk's implementation and has more details compared to PUMA's implementation process. Kering has seven steps: (1) Decide what to measure, (2) Map the supply chain, (3) Identify priority data, (4) Collect primary data, (5) Collect secondary data, (6) Determine the monetary value of the data and (7) calculate and analyse the results (kering.com/methodology). The Group has experienced some benefits from implementing an EP&L –statement including the translation of environmental impacts into a common business language. Additional benefits are comparability between different impacts and the ability to compare brands and business units in terms of environmental impact. This has given the group an ability to identify the most significant environmental impact drivers, to understand the impact of decisions, to develop more robust business policies against environmentally related risks, to implement targeted projects on the choice of materials or manufacturing process, to monitor and forecast the progress of sustainability strategy and to become more transparent in the eyes of the stakeholders (Kering EP&L –report 2017.) In short, EP&L has provided the Kering group a method to understand which sourcing and manufacturing locations have the biggest environmental impact and insight into the most cost-efficient ways to avoid or reduce potential impact (True Price 2014). Two largest emissions from the 2017 EP&L –report are GHGs (32 percent) and land use (32 percent). The highest environmental impact Tier is Tier 4: raw material production (66 percent of all impact). A key challenge for the Kering's EP&L according to the 2018 WBCSD article "Reporting matters" has been the absence of any natural capital accounting standards, which results in companies collaboratively working together to establish their own environmental accounting systems. Even if there are methods of quantify the value of environmental impact, there is no theoretical consensus on how to measure sustainability (Hák, Janoušková et al. 2016).

Another case on the use of EP&L –statement to improve a company's environmental impact management is by the fashion house Stella McCartney (stellamccartney.com/first-environmental-profit-and-loss-account). The company was established as a 50/50 joint venture together with Kering group in 2001 and brands clothes, accessories, fragrances and eyewear. The fashion house also represents beliefs on vegetarianism and state that they do not and have never used leather or fur in their designs. (stellamccartney.com/about-stella.) The first environmental profit and loss statement was published in 2015 but the actual goal to measure natural capital with an EP&L together with more traditional profit and loss management tools already began in 2013 (stellamccartney.com/first-environmental-profit-and-loss-account). The first EP&L was completed in 2013 and quantified the environmental impact from six environmental impact drivers: GHG emissions, air pollution, water pollution, water consumption, waste and land use. The implementation methodology was conducted according to the Kering Group's experience with EP&L through PwC. (Stella McCartney EP&L –report 2015.) The steps are as follows:

1) Quantify environmental footprint of direct operations and the supply chain
2) Estimate likely environmental changes resulting from the impact
3) Value in monetary terms the change in wellbeing of the people affected by these environmental changes

Stella McCartney collects three types of data to value and quantify the previously mentioned steps: material, financial and environmental. Material data is collected in terms of what materials are used, how much and from where are the raw materials sourced. Financial data is collected in terms of how much is spent with suppliers and environmental data is collected from suppliers' sites and Stella McCartney's own direct stores, offices and warehouses. The collected data is combined with data from LCA and EEIO –models and industry statistics. PwC's 2015 valuation methodologies are used to evaluate the environmental impact. As a results, 90 percent of the total environmental impact occurs from the supply chain and raw materials represent 57 percent of the total EP&L. Biggest environmental impact driver is the GHG emissions (29 percent of total impact) and next is water pollution (27 percent of total impact). (Stella McCartney EP&L –report 2015.)

The next company is ASUS, an IT technology firm founded in 1989. The company specializes in building computer motherboards, monitors, graphics cards, routers and other related technology solutions. (asus.com/asus-history.) In 2017, Asus made its first EP&L project to monetize its social value generated by public welfare activities to compare environmental emission to each other (csr.asus.com). The company quantified four environmental impact drivers: GHG emissions, water consumption, solid waste and water pollution (csr.asus.com) and laptop computers were chosen as the target for analysis (ASUS EP&L –report 2018). The analysis is based on the 2015 PwC methodology and the evaluation process is based on the 2016 Natural Capital Protocol (NCP) by the Natural Capital Coalition (NCC) (ASUS EP&L –report 2018).

The implementation process follows the 2015 PwC methodology and is divided into three steps: (1) Definition of the scope and boundary of the analysis, (2) Data and assessment process of the analysis and (3) Impact valuation. ASUS decided to limit the EP&L –project to laptops and used 2008 to 2009 version on Product Category Rules of laptop computers to define 16 categories on major components (ASUS EP&L –report 2018.) Supply chain was divided into 4 tiers: Tier 0 AUSTeK operation, Tier 1 OEM assembly, Tier 2 manufacturing of major components and Tier 3 mining and manufacturing of raw materials. Data was collected from primary and secondary sources. Primary data is collected from Tier 0 and Tier 1 and secondary data is collected from Tiers 2 and 3. Primary data is collected through fieldwork from environmental systems while secondary data is collected through the Ecoinvest database version 3.0 LCA software SimaPro. The largest impact of ASUS laptops is from water pollution (72.62 percent of total impact) and the next largest is from GHG emissions (26.38 percent). The largest Tier in terms of emissions is Tier 3 with 90.06 percent impact from the total impact. (ASUS EP&L –report 2018.)

The last EP&L –statement implementation I will be discussing is by company Vodafone. Vodafone is a mobile, broadband and TV service provider, and innovator and service provider on internet of things –, cloud – and carrier service –solutions (vodafone.com/what-we-do). Because the company provides communication services globally, the major source of emissions is from Scope 2 category electricity (vodafone.com/sustainability). Vodafone Netherlands performed an EP&L analysis from

2014 until 2015 to improve decision making on the reduction of negative environmental impact and to increase positive impact. The analysis was conducted on 4 different categories and on 5 different products. The high-level categories are buildings, network, servicing customers and products. The five product categories are: handsets, tablets, Vodafone Thuis, dematerialisation and M2M. The company lists five reasons for the development of an EP&L –statement: (1) gaining strategic insight into the environmental impact from the whole value chain, (2) gaining insight into the possible risks from upcoming regulations and standards and understanding the link between the environmental impacts and the effects of market dynamics, (3) forecasting possibilities to predicts customer demand and manage environmental risks, (4) increased transparency to share- and stakeholders and increased internal awareness of sustainable business, and (5) to benchmark Vodafone Netherland's results against other companies. (Vodafone Netherlands EP&L –report 2015.)

The implementation of the EP&L –project was conducted in five steps: (1) decide what to measure, (2) map the value-chain, (3) collect data, (4) valuation and (5) calculating EP&L. Scope of measurement was divided into three levels: business, value chain and impact. The 4 high level categories and 5 product categories correspond to the business scope. Value chain scope includes the entire life cycle of each business area, except for office buildings in which Vodafone operates. Environmental indicators are GHG emissions, air emissions, water consumption, water pollution, waste production, land use and biodiversity. To map the value chain, Vodafone uses information from an LCA and from direct suppliers and divides the entire value chain into four life stages: production, distribution, use and end of life. Data is collected from primary and secondary sources: primary data was retrieved from Vodafone's direct operations. Secondary data was used to fill the gaps. The company uses multiple LCAs over time with the help of suppliers to take regional differences into consideration. To assess the positive impact to the environment, Vodafone estimates the opportunity costs of customers communicating effectively through Vodafone's services versus having to travel to discuss matters. Valuation of collected environmental impact was converted into monetary terms through CD Delft's "The Shadow Pricing Handbook" and carbon emissions were valued by using US EPA's 2013 study "The social cost of carbon". The last step is to calculate EP&L by valuing the amount of emissions by monetary factors. Circa 9 percent of the total impact of 21.6€ million is associated with Vodafone's core operations while the rest lie outside the scope of core operations on the value chain. (Vodafone Netherlands EP&L –report 2015.)

The implementation and benefits from EP&L are very similar to the findings from PwC, PUMA and Novo Nordisk. Table 11 compares the different implementation methodologies of all discussed companies and Table 12 highlights my findings on the EP&L implementation, environmental impact quantification methodologies and parameters used to calculate the final societal cost of the environmental impact created by a company.

Table 11 Summary of EP&L implementation methodologies and implementation steps by companies

Steps	PwC		PUMA		Novo Nordisk		Kering group		Stella McCartney	
1	Quantify emissions or resource use	Obtain environmental metric data from different sources	Scope and boundary of EP&L	Choose the scope of the EP&L analysis. Include as many Tiers from the value chain as possible.	Scope and boundary	Describe the scope and boundary of the EP&L analysis.	Decide what to measure	Identify parts of the business to include in EP&L. Separate supply chain into Tiers.	Quantify environmental footprint of direct operations and the supply chain	Decide the scope of the analysis, map the supply chain, assess the level of environmental impact
2	Estimate change in the environment	Quantify environmental outcomes by estimating the cost of carbon to the society.	Measuring the drivers of environmental impact	Collect data from the closest operations and Tiers and fill in with econometric I-O models.	Map the value chain	Understand the business, products and value chain within the scope and boundary. Identify Tiers.	Map the supply chain	Outline the production process of each product from raw materials to product assembly. Identify suppliers. Collect data on activities performed for the brand.	Estimate likely environmental changes resulting from the impact	Collect data: material, financial and environmental. LCA + EEIO + industry statistics
3	Value impact on people	Estimate societal impact using Societal cost of carbon or marginal abatement cost of carbon or market price of carbon.	Modelling of drivers of environmental impact	Model the environmental impact from the supply chain using econometric I-O or similar models.	Impact assessment	Identify preliminary hotspots by conducting research with key persons of the company, supply chain and industry. Identify direct spend categories for the analysis.	Identify priority data	Identify data relevant to EP&L and define a system for collecting it across supply chain. Classify data.	Value in monetary terms the change in wellbeing of the people affected by these environmental changes	SCC according to PwC 2015

4		Valuing the environ-mental im-pact	Value the envi-ronmental impact using social cost of carbon, mar-ginal abatement cost of carbon or the market price of carbon. Com-bine all collected data and form an EP&L –report.	Collect en-vironmen-tal data	Collect operational data, distribution data, indirect spend and direct spend.	Collect pri-mary data	Collect data from suppliers. Validate collected data and extrapolate for groups of similar suppliers
5				Fill data gaps	Use modelled data to fill in data gaps. LCA + EIO + EIO LCA hybrid models.	Collect sec-ondary data	Supplement primary data by drawing on available external sources. Pool re-search. Calculate en-vironmental footprint using collected data.
6				Quantify and value changes in environ-mental quality	Calculate carbon footprint and convert emissions into uni-fied environmental indicators by using standard quantifiers. Use social cost of carbon, marginal abatement cost or market price ap-proach to value changes.	Determine the monetary value of the data	Identify changes in the environment and costs incurred by the public due to impact. Calculate coefficients to convert the data into impacts on hu-man wellbeing. As-sess the environmen-tal impact. Analyse costs and environ-mental benefits.
7				Calculate EP&L	Combine all data ac-cording to Tiers and impact drivers.	Calculate and analyse the results	Consolidate results to EP&L. Present and communicate results.

Table 11 continues

Steps	Asus		Vodafone	
1	Scope and boundary	The definition of supply chain coverage, including PCR component categories and Tiers. The geographic location of the supply chain according to Tiers. Considerations of environmental impact according to the manufacturing process and definition of impact drivers.	Decide what to measure	Identification of what should be included in the EP&L –statement. Which parts of the business are included? How far back in the supply chain or forward to the customers is included? Which types of environmental impact are taken into account
2	Data and assessment process	Data collection through different sources: primary and secondary data. Primary data through fieldwork Secondary data through database models. Monetary valuation according to PwC 2015 methodology.	Map the value chain	Mapping the value chain and identifying the key areas on each stage of the value chain, including transport. Information on value chains is derived from LCA or from suppliers.
3	Impact valuation	Analysis of environmental impacts after monetary valuation	Collect data	Primary data: based on company's own operations Secondary data: sourced from suppliers, LCA
4			Valuation	Valuating the environmental impact in monetary format. CD Delft (2010) "The Shadow Pricing Handbook" and EPA (2013) "The social cost of carbon" on carbon emissions.
5			Calculating EP&L	Collected data translated into financial values and summarised in an EP&L.

Source: PwC 2015, Puma 2010, Nordisk 2014, kering.com/methodology, Stella McCartney EP&L –report 2015, ASUS EP&L –report 2018, Vodafone Netherlands EP&L –report 2015

Table 12 Highlighted results on EP&L implementation methodology, quantification methodology and parameters used (modified from Lauesen 2019)

	Company					
Metrics	**PUMA**	**Kering Group**	**Stella McCartney**	**Novo Nordisk**	**Asus**	**Vodafone**
Years of reporting	2011-2017	2013-2018	2015-2016	2014	2016	2014-2015
Publication year	2011	2018	2016	2014	2017	2015
Output metrics	Greenhouse gasses Water consumption Water pollution Air pollution Land use Waste	Greenhouse gasses Water consumption Water pollution Air pollution Land use Waste	Greenhouse gasses Water consumption Water pollution Air pollution Land use Waste disposal	Greenhouse gasses Water consumption Air pollution Land use change	Greenhouse gasses Water consumption Water pollution Solid waste	Greenhouse gasses Other Air emissions Water Consumption Waste production
EP&L methodology	PwC 2015 methodology	PwC 2015 methodology	PwC 2015 methodology	PwC 2015 methodology	PwC 2015 methodology	CE Delft, EPA, previous EP&L implementations
Data collection methodology	Internal environmental management system, supplier reporting, econometric IO model	LCA, EIO	LCA, EIO	LCA, EIO, EIO LCA	Fieldwork data collection, LCA, Ecoinvest databasw, SimaPro	Through suppliers and LCAs.
GHG impact (tons of CO_2e)	717.500	N/A	N/A	178.000	N/A	95.685
Quantified GHG impact (M EUR)	47	173.9	2.08	171	73.84*	9.11

Highest carbon dioxide contributors	Tier 4: Cattle rearing, rubber plantations, cotton farming, petroleum production, other material production	Tier 4: Raw material production	Tier 4: Raw material production (62% of total impact)	Tier 3: Raw materials	Tier 3 Mining and manufacturing of raw materials	Scope: Production (extraction of raw materials, production of components & subparts, product assembly, customisation, transport)
Future economic growth rate (%)	3.4	N/A	N/A	1.3	N/A	N/A
Pure rate of time preference (%)	0	0	0	0.1	N/A	0
Social discount rate (%)	3.4	N/A	N/A	1.4	N/A	“low”
Social cost of carbon (USD/tCO2e)	87	N/A	N/A	113**	N/A	126

*Exchange rate according to 31.12.2017. 1 USD = 0.833 EUR. Original value from ASUS 2017 EP&L –report, 91.06 MUSD. Source: https://www.xe.com/currencytables/?from=USD&date=2018-03-31 (cited 16.12.2019 12:00)

** Displayed in 2011 prices according to the World Bank of Consumer Price Inflation. Carbon cost has been inflated from 2000 to 2011. Source: (Nordisk 2014)

To summarize my findings on EP&L implementation, I combine the implementation steps from all companies and list the steps below from the beginning until the end.

1. Decide the scope and boundaries of the analyses
2. Map the value-chain
3. Assess the possible environmental impact from value-chain activities
4. Collect primary data from available data sources
5. Secondary data collection with environmental-economic models
6. Quantification of collected data
7. EP&L calculation and data consolidation
8. Analyze and report findings to stakeholders

Ian Ellison (2015), the sustainability manager of Jaguar Land Rover vehicle company, states that the management should prioritize their efforts to reduce the environmental impact and pursue to maximize the value of the value chain by mitigating the environmentally related risks. This could be done through design optimization, material selection, process design or value chain design leading towards re-use strategy, re-manufacturing strategy, re-cycling strategy and considering value chain geography. Management can approach risk mitigation also from investment perspective where negative environmental effects on an investment are reduced while positive effects are increased (KPMG True Value 2014). Geography should be considered when quantifying environmental impact because the scale of the impact can be significant when compared between developed and developing countries and their environmental output (PwC, 2015). Because this study focuses on GHG emissions and especially on carbon dioxide emissions, my report does not have to consider the geographical location in terms of environmental impact (PwC, 2015). Next, I will investigate the three different quantification methods introduced in PwC's 2015 EP&L methodology to quantify the environmental impact into monetary form. The three methods are: the social cost of carbon, marginal abatement cost of carbon and market-based price of carbon.

4. CARBON PRICING METHODOLOGIES

During this research, I have pursued to understand how the environment has affected businesses, why it is important for companies to reduce the GHG emissions, how environmental management is affecting the accounting for emissions and how accounting can assist companies to report and to manage carbon impact. Last part of the equation is to understand a methodology to monetize the environmental impact. One method to quantify the impact is the social cost of carbon and during this chapter, I will present two other approaches as well: the marginal abatement cost of carbon and the market-based price of carbon. I compare the three methodologies to each other and pursue to understand which approach suits to which occasion.

In 2006, Lord Nicolas Stern released a report to estimate the global effects of climate change for policymakers (Stern 2007). The report states that at the time, the stabilization of climate-change requires the reduction of annual emissions by more than 80 percent. Carbon dioxide is especially important as it consists around three-quarters of anthropogenic climate-change (Stern 2008). Climate-change is described by Lord Stern as “the greatest market failure the world has ever seen” and to response this failure, Stern recommends three elements of policy: pricing of carbon, supporting innovation and deployment of low-carbon technologies, and actions to remove barriers of energy efficiency and educate individuals on their opportunities to respond against climate change. Carbon pricing is significant, and Stern suggests taxes, trading and regulation to determine the market price or country tax for carbon. It is an essential climate-change policy, which internalizes the external carbon emissions and gives people a figure of their actions against the environment. Combined with carbon reduction regulation and taxation, businesses should have an interest to invest in low-carbon alternatives and reduce high-carbon investments or in other words find the cheapest economically efficient option. (Stern 2007) Currently, providers in the value-chain who have issues to reduce carbon emissions under the agreed limit are often obligated to implement the ISO 14064 guidelines into their operations (Hsu, Wang 2013).

Companies which have used carbon pricing in their strategy to improve their environmental performance include Microsoft, ExxonMobil and Saint-Gobain (nature.com) from which Microsoft uses internal carbon fee to tax business groups from their profit-and-loss statements (Microsoft carbon fee 2013). Currently, the internal fee of Microsoft is USD 15 per metric ton of carbon emissions (blogs.microsoft.com) and the gathered funds are allocated towards improving environmental performance (Microsoft carbon fee 2013). However, the fee is much lower than the US Government estimate on SCC of USD 44 per tonne of carbon emission, which is common in companies with internal carbon charges (nature.com). According to the 2017 CDP report on climate change, Exxon Mobile uses proxy prices on carbon to reflect regulatory changes impacting the demand for oil and gas in the future (cdp.net/Exxon). Saint-Gobain in its 2018 climate change report to CDP has reported two internal carbon price levels: (1) fixed €30 per ton of carbon emissions applied to industrial investments and (2) €100 per ton carbon emissions for R&D investments in breakthrough technology for supporting low-carbon investments (cdp.net/Saint-Gobain).

It is common to use carbon price as a management tool to control and reduce negative environmental impact as displayed by the World Bank's 2019 report "State and trends of carbon pricing": "About 1300 companies, including more than 100 Fortune Global 500 companies… have disclosed the use of internal carbon pricing or plans to implement internal carbon pricing within two years" (World Bank, 2019). The report states that the used carbon price ranges from USD 0.3 per ton of carbon dioxide equivalent to USD 906 per ton. The very high difference between estimates makes it difficult to compare environmental reports between companies and additionally Tol (2008) points that the economic estimates on the impact of climate change increase over time. Now that the trend and the potential effectiveness of carbon pricing has been established, I will discuss three approaches to carbon emissions pricing: the social cost of carbon, the marginal abatement cost of carbon and the market-based price of carbon.

4.1 Social cost of carbon

Social cost of carbon is the price of damage caused by one additional ton of carbon dioxide or equivalent substances (Arena, Conte et al. 2015) estimated either through the cost-benefit analysis (CBA) or the marginal cost (MC) approach (Clarkson, Deyes 2002). CBA calculates the optimum level where the marginal cost of reducing emissions is equal to the marginal damage of emissions (Clarkson, Deyes 2002). The MC approach calculates the future damage caused by a marginal change to the current level of emissions (Clarkson, Deyes 2002). When using the CBA to estimate a SCC, the approach gives a shadow price of emissions which is equal to the marginal costs only if the current and future emissions follow the optimal emissions path (Clarkson, Deyes 2002). To calculate the SCC, a researcher needs to use an Integrated Assessment Model (IAM) (van den Bergh, Botzen 2015) which condenses information on economic growth assumptions, carbon emission forecasts, abatement cost estimates and global warming damage functions into a single model (Clarkson, Deyes 2002). The future climate damage is estimated from a period of 100 or 200 years or longer and then discounted to present day by using a societal discount rate (SDR) (van den Bergh, Botzen 2015). Three widely used IAMs are DICE, FUND and PAGE which calculate how GHG emissions change according to the GHG concentration in the atmosphere, how the change in concentrations cause global warming and how a change in temperature causes economic damage. To model the pre-mentioned uncertainties, FUND and PAGE use probability distribution of key parameters and DICE calculates average parameter values (van den Bergh, Botzen 2015)

Stern (2008) points out two major problems when pricing GHG emissions: (1) estimates are highly sensitive to ethical and structural assumptions on the future and (2) there is a risk of major losses from the uncertainty on the level of atmospheric concentration of GHG emissions. Van den Berg and Botzen (2015) conclude that SCC depends on several issues, including expectations on the future economic growth and on the ethical viewpoints of welfare levels between generations, similar to Stern’s points (2008). Clarkson and Deyes (2002) point out several uncertainties when it comes to estimating a SCC with the CBA or the MC. They divide these uncertainties into two categories: scientific and economic valuation. Scientific uncertainty includes:

- measurement of present and prediction of future emissions
- translation of emissions levels according to the changes in the atmospheric concentration of carbon
- estimation of climate impact related to an increase in the atmospheric concentration
- identification of the physical impact resulting from climate change

Main economic valuation uncertainties include:

- estimating monetary value for non-market impacts
- prediction on the change of relative and absolute value of impact in the future
- determining a way to aggregate damage estimates across regions with different levels of national income
- determining the discount rate of future impacts

Earlier, I presented the PwC's 2015 methodology to calculate an EP&L -statement for PUMA. Now, I continue the method and explain how PwC estimated their social cost of carbon to quantify the GHG impact. PwC uses a meta-analysis approach from a subset of 33 selected studies. Selected studies are chosen according to specified restriction criteria: the age of the study, the quality of the study, the discount rate, and treatment of outliers and equity weighting of estimates. After selection, PwC normalizes the estimates to include monetary inflation, growth rate of SCC over time and application of multiple estimates weighting. (PwC 2015.)

The quality of the study criteria limits the number of cases to those which have been peer-reviewed which, according to PwC, is the only widely accepted measure of quality for SCC related studies. However, the risk of selecting only peer reviewed studies is to include bias from the academic community. But, due to the high standards and diverse views of the academics, the risk of academic community bias is small (PwC, 2015.) The discount rate used by the academic studies to aggregate the costs and benefits accrued over time to present day is the SDR (PwC 2015). Another description for SDR comes from Freeman et al. (2018) where SDR represents the estimate of how society values consumption at different points in time. Broad academic consensus to calculate SDR is to use Ramsey's model (Ramsey 1928), which is the sum of pure rate of time preference and the future economic growth rate elasticity of marginal utility with respect to income. The formula for SDR is,

$$SDR = p + \eta g,$$

where p is the pure rate of time preference, η is the elasticity of marginal utility with respect to income and g is the future economic growth rate (PwC 2015, Freeman, Groom et al. 2018). p can also be the utility discount rate determined by an equation:

$$p = \delta + L$$

where δ is the pure time preference and L is the type of determined risk, used by the HM Treasury (Freeman, Groom et al. 2018). These parameters are difficult to estimate and subject to some disagreement (Freeman, Groom et al. 2018) which results in different discount rates (Tol, Richard SJ 2011). Additional critic over the Ramsey model used as social discount rate equation comes from its origin as a purely consequentialist Utilitarian social welfare function that has a specific functional form. Also, it does not account for project risks nor does it consider relative price changes in terms of consumption equivalent of costs and benefits. (Freeman, Groom et al. 2018) The SDR is also known as the consumption discount rate (PwC, 2015) and can be described the following way (Traeger. 2009):

$$\mathrm{r(t) = p + \theta g(t)}$$

Associate professor Christian Traeger from the department of economics from the University of Oslo has described this equation in his 2009 spring lecture on the economics of climate change in University of California Berkeley. During lecture 17 part 4 "Discounting", Traeger described the equation as follows: r (t) is the optimal productivity of capital during time t, p is the rate of pure time preference which describes impatience, θ is the consumption elasticity of marginal utility describing how fast marginal utility decreases in consumption and g is the growth rate of how fast consumption increases (Traeger, 2009). Freeman et al. (2018) points out critic for using Ramsey's model on cost-benefit-analysis: it does not reflect the opportunity cost of public fund, it is derived from purely consequentialist Utilitarian social welfare function, the parameters in the model are difficult to estimate, the model does not account for project risk or uncertain growth in consumption, it does not treat intra-generational distributional issues and it assumes that all costs and benefits can be placed in terms of consumption equivalent. To derive the equation for Ramsey's model, the readers can refer to the original 1928 work "a mathematical theory of saving".

Pure rate of time preference (PRTP) embodies the preference to receive a given amount of money now rather than later. A value larger than zero carries the implication that benefits accruing to future generations are inherently less valuable than those accruing to ourselves. (PwC 2015.) Ramsey (1928) describes choosing the weight on the utility of different generations as “ethically indefensible”, Harrod (1948) describes pure rate of time preference as “a polite expression of greed” and “the conquest of reason by passion”. Choosing the correct PRTP is an ethical argument (Trager, 2009). Drupp et al. (2018) point out a significant disagreement between experts on the correct value of pure time preference. The modal value is 0 percent representing the focal point and 38 percent of all the studies analysed by Drupp et al. lie in this Ramsey-Stern view (Ramsey-Stern view comes from the names “Ramsey” and “Stern review” on the subject of PRTP ranging from 0 to 0.1 percent value). The median of their study is 0.50 percent and maximum recommendation 8 percent (Drupp, Freeman et al. 2018). PwC (2015) have restricted the number of estimates on SCC with a PRTP of 0 percent because it represents the ethical perspective of treating future generations the same as the present.

The elasticity of marginal utility of consumption has been estimated by Groom and Maddison (2019) to be 1.507 in the UK and the empirical estimate tends to range between 0.5 and 2 (Freeman, Groom et al. 2018). The growth in capital consumption, in terms of expected long-term global growth, has been surveyed with an average predicted growth of 1.7 percent with responses from experts ranging from -2 to 5 percent (Drupp, Freeman et al. 2018). PwC (2015) uses a PRTP of 0 percent with product of economic growth and income elasticity of 2.0 percent. Because some of the studies in the sub-set do not disclose their SDR, PwC (2015) investigates these studies with SDR average of 2.0 percent. Freeman et al. (2018) find that expert recommendation for SDR median is 2 percent and mean is 2.3 percent. Groom and Maddison (2019) have calculated a risk-free SDR of 4.5 percent with 1.5 percent PRTP, 1.5 elasticity of marginal utility and a 2 percent growth in capital consumption. Stern in his 2006 paper “The economics of climate change” uses a SDR of 2 percent with PRTP of 0 percent, elasticity of marginal utility of 1 and 2 percent growth in capital consumption. Freeman et al. (2018) add that the estimates on SDR range with a lower bound of 1 percent and upper values of 4.5 percent.

The next criteria for chosen studies is the age of the study. PwC (2015) used 10 most recent studies which also covered all the pre-mentioned criteria. Even with restrictions, the estimated range of SCC ranges from \$6 to \$622 per tCO_2. To treat the outliers, PwC includes SCC estimates with three standard deviations from the mean which considers so called “fat-tailed” distribution of values due to the possibility of catastrophic climate outcomes. Another criterion for SCC estimation is to consider the treatment of accrued costs and benefits across countries or “equity weighting”. This procedure discounts developed country income relative to developing countries, e.g. flood damage of \$10 million in Bangladesh has greater weight compared to \$10 million damage in Germany. (PwC 2015.) PwC does not restrict their sample according to the use of equity weighting due to its diminishing effect to the number of estimates. For this reason, PwC’s sample includes both studies which apply and do not apply equity weighting. It should be noted that equity weighting has an increasing effect on the SCC estimate as pointed out by Tol (2005). PwC does not include damage valuation from climate change on their SCC estimate. Damage valuation approach includes physical and economic damage from climate change, and they are difficult to predict and value. (PwC, 2015.) Tol (2008) raises concern over total cost estimates over climate-change. The total cost of estimates tends to omit some of the impact of climate-change due to reliance on few extrapolated case studies, changing climate on a static society, use of simple climate change adaptation models, ignorance of uncertainties and the use of controversial valuation methods and benefit transfers. These issues are complex and uncertain which would require multidisciplinary knowledge (Tol, Richard SJ 2008). PwC (2015) does not consider damage valuation as a criterion in their sample selection but the chosen studies estimate SCC using nine underlying estimates of the total damage caused by climate change. This means that the final PwC’s SCC estimate reflects the average or median of these nine estimates over total damage of climate change (PwC 2015).

After selecting the sub-set, PwC normalizes the SCC estimates by executing multiple estimates weighting, by correcting the monetary inflation since the date of estimate, by applying the growth rate of SCC to present day and aligning different units between studies. PwC begins by conducting a multiple estimate weighting according to Tol’s 2011 study “The social cost of carbon”. This method is used when a single research paper contains more than one estimate of SCC and by using the multiple estimates weighting, each SCC estimate is give a weight and the sum of all weights in a single research paper is equal to one (PwC 2015(Tol, Richard SJ 2011).

Because the remaining studies have estimated SCCs over different points in time, PwC converts the SCC estimates into present day using an adjusted global GDP deflator for changes in the PPP. This way, the nominal SCC estimate is inflated from a study in a certain point in time to present-day US dollars. While some studies estimate the SCC's value in today's currency using a single social cost discount rate, it assumes a constant PPP held across all countries from the date of the study into the future. PwC (2015) shows that the monetary inflation of the world averaged almost three times US's inflation rate at the same period while the nominal exchange rate between US and the trade weighted basket of world currencies was almost identical from the same period (from 1995 until 2011). As a result, the assumption for a constant PPP across all countries does not hold and PwC had to convert the SCC estimates by multiplying the PPP ratio of each country by its nominal GDP expressed in US dollars. If a study has not disclosed the year at which the SCC estimate is calculated, the publication date of the study is rounded down to nearest five-year interval and inflated to present-day using an estimate of the PPP adjusted GDP deflator from that nearest point. (PwC 2015.)

To estimate the growth rate of SCC over time, PwC has decided to use an estimate of 3 percent growth per year (PwC 2015). This is in relation with the 2007 IPCC's Fourth Assessment Report with an estimated growth rate between 2 and 4 percent and a suggested growth rate of 2.4 percent per year (IPCC 2007. Chapter 20). The reason for a SCC to grow over time is related to GHGs staying in the atmosphere for a certain amount of time building up extra tonnes of greenhouse gases (PwC 2015).

The last step is to convert the units from different studies to one uniform unit (PwC 2015). The unit used is USD per tCO_2e and estimates need to be converted from units expressed in USD per tCe (PwC, 2015) or the price of one metric ton of carbon equivalent in US dollars (Tol, Richard SJ 2011). To do this, PwC multiplies the former units with a ratio of the weight of a single carbon atom and the weight of a molecule of carbon dioxide. The ratio is:

$$\frac{\text{Weight of a single carbon atom}}{\text{Weight of a molecule of carbon dioxide}} = \frac{12\text{u}}{44\text{u}} = 0{,}27$$

After normalizing and converting the SCC estimates, PwC (2015) calculates the arithmetic mean and the median from these estimates. The company explains that there can be different reasons for choosing the arithmetic mean or the median depending on the wanted expression on the effect of climate change impact. Arithmetic mean considers potential catastrophic climate scenarios while the median reflects the consensus on climate change impacts without the catastrophic scenarios (PwC 2015.) The final estimates of the SCC are:

Arithmetic mean	**Median**
\$78 / tCO_2e	\$62 / tCO_2e

Stern (2006. Chapter 22) finds that the social cost of carbon in 2006 with an assumption of Business-As-Usual, is USD 85 per ton of CO_2 which is higher than both PwC estimates in 2010.

Table 13 displays some estimates from substantial studies on the SCC including the name of the study, the year the study was published, the methodology to estimate SCC and the SCC estimate.

Table 13 Social cost of carbon estimates

Study	**Publication year of the study**	**Estimation methodology**	**SCC estimate USD/ tCO_2e**	**Year of price USD**
Anthoff, Rose et al.	2011	FUND	8,00	2010
Anthoff, Tol et al.	2013	FUND	51,40	1995
Hope	2013	PAGE09	106,00	2010
Nordhaus	2008	DICE	6,00	2000
Nordhaus	2014	DICE-2013R	18,60	2005
Nordhaus	2017	DICE-2016R	31,20	2010
Novo Nordisk	2014	Meta-analysis	113,00	2011
PwC	2015	Meta-analysis	62,00	2012
Stern	2006	PAGE2002	85,00	2000

The first column displays the name of the study, the second column displays he publication year of the study, the third column tells which estimation methodology the study has used, the fourth column shows the estimated SCC value and the fifth column displays in which years US dollars the estimate has been calculated.

4.2 Marginal abatement cost

When a SCC estimates the monetary value of the future damage from climate-change discounted to present day (Clarkson, Deyes 2002, Arena, Conte et al. 2015), marginal abatement cost of carbon (MAC) is the cost of avoiding emitting same unit of carbon relative to another business-as-usual scenario (PwC 2015). It can also be described as the cost of incrementally reducing emissions (Stern 2006. Chapter 22) which provides a benchmark for decision makers on best possible abatement options (Tol, Richard SJ 2005). A MAC analyses varying GHG emissions abatement options and the cost of the reducing emissions is the cost for the technology and the amount of reduced emissions gives the cost for one unit of emitted GHG. The different options form a MAC curve. (PwC 2015.) PwC (2015) recommends for a company to form a MAC curve from individual GHG abatement measures when private financial costs are considered. Figure 4 illustrates an example for a MAC curve.

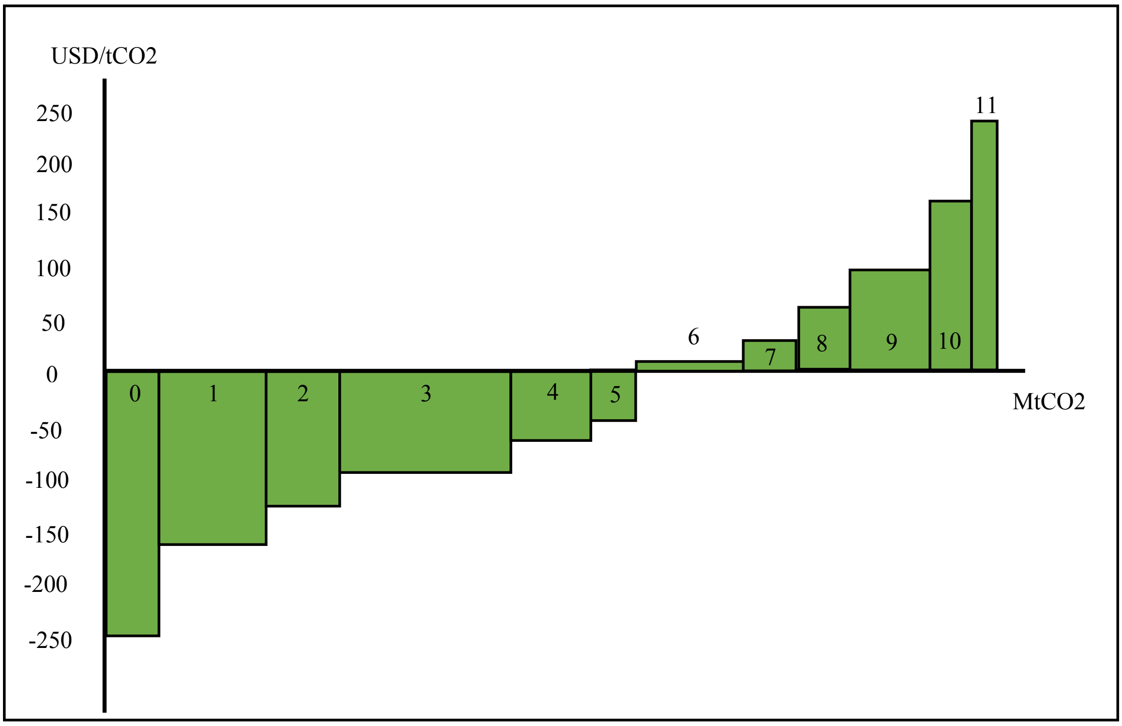

Figure 4 Marginal abatement cost curve

To calculate the curve for an individual company, PwC (2015) recommends first mapping of all available abatement technologies and their costs at a given point in time. These options can range from planting trees to new energy efficiency measures. Once each potential technology is examined and its costs estimated, all options are placed in an ascending cost order to form a time-specific MAC curve (PwC 2015). The horizontal line of Figure 4 displays the potential emissions reduction in millions of tons of carbon dioxide and the vertical line displays the cost per metric ton of carbon dioxide reduced. Each bar represents a different technology option, where the width is the amount of GHG abatement potential, and the height is the cost per unit of abated emissions if the technology is installed to its maximum mitigation potential. Technology opportunities vary from negative to positive costs which represent how the abatement will affect the target scope of the analysis. For example, a company which has similar abatement options as Figure 4 can save more money with option 3 compared to option 9. This is because some technologies actually have negative costs and save money (Stern 2008) while other options have positive costs and are considered as an expense. So, if a company would like to reduce emissions by 3 $MtCO_2$ it would require a price of around USD -100 per ton of carbon dioxide. If the same company would like to reduce more emissions, let us say 9 $MtCO_2$, the price would be around USD 100 per ton of carbon dioxide. The options with negative costs should be considered first as they create the least cost. However, the total emissions savings from any option depends on the replaced technology (Stern 2008).

McKinsey (2013) recommends that the MAC curve should be used to compare size and cost of different emissions abatement opportunities as it gives the basis for discussion on prioritization in terms of the most effective emissions abatement option. However, the opportunities do not include transaction and program costs of full integration of an opportunity nor can the curve be used to forecast carbon dioxide prices (McKinsey 2013) which needs to be considered before final decision-making. Tol assumes that the marginal damage costs of carbon dioxide emissions are unlikely to exceed USD 50/tC when the marginal damage cost from climate change is analysed. The issue with climate-change marginal damage cost analyses is the right-skewness of uncertainty which results in higher mean values (Tol, Richard SJ, Downing et al. 2001). In 2009, Kuik, Brander et al. collected 62 observations of MAC for years 2025 and 2050, with a mean of EUR 24.8 per ton of CO_2e in 2025 and EUR 55.8 in 2050. The median value for 2025 is EUR 16.2 and EUR 32.2 in 2050. However, the spread of Kuik, Brander et al.'s (2009) results are large; in 2025 the minimum estimate is EUR 0.0 and the maximum estimate is EUR 199.9, while in 2050 the minimum estimate is EUR 1.4

and the maximum estimate is EUR 209.4. In terms of the evidence, using MAC to estimate the cost from climate-change results in same uncertainty as with the SCC approach.

From a company's perspective, Microsoft has used internal carbon fee tax to reduce emitted carbon emissions since 2012 (blogs.microsoft.com) and use the collected fees to fund improvements on environmental performance (Microsoft carbon fee 2013). In 2018, the price of carbon was USD 8.03 per metric ton of carbon dioxide emissions. The fees are collected into a carbon fund and used to offset emissions through investments in renewable energy, carbon offset community projects, sustainability grants and track-and-report projects. The used price per emitted carbon dioxide is based on the total investment strategy to reduce emissions, achieve targets and drive innovation based on the MAC curve (Microsoft CDP on climate change 2018.)

There is a clear difference in MAC estimates when compared between public and private sectors as the scope of analysis becomes extensively larger in the public sector. However, some governmental recommendations on the cost of carbon are based on the MAC approach which can support companies implementing an EP&L -statement to follow the regulatory recommendation when reducing carbon emissions. MAC can also help companies understand different emissions abatement options when an EP&L has been implemented. The combination of the two can assist decision-making when prioritizing investment options in the value-chain to reach specific environmental goals. (PwC 2015.) This way, the MAC approach can be used as a simulation tool for different scenarios (McKinsey 2013) and could assist companies to quantify different strategic paths and build a budget-EP&L to compare different investment options (Kjaer, Høst-Madsen et al. 2015). A company could also calculate the carbon price of the entire company at a specific point in time when abatement technologies, their costs and abatement potentials have been mapped and the required reduction of emissions for that particular time has been established by the management.

4.3 Market-based price of carbon

World's first international emissions trading market was first established in 2005 and approved by the European Parliament and the Council, but the UNFCCC parties in

1997 in Kyoto, established the beginning to internationally limit GHG emissions through trading mechanisms (ec.europa.eu/Kyoto Protocol). The intention of the Kyoto Protocol was to legally bind limits of GHG emissions in industrialized countries and keep control costs of emissions low with market-based mechanics (ec.europa.eu/Kyoto Protocol) from 2008 until 2012 (UNFCCC.int/emissions trading). This is referred to as Annex B (UNFCCC.int/emissions trading). These emissions are traded in the European Trading Scheme (ETS) according to a cap and trade principle. The "cap" is the total amount of allowed GHG emissions, and the "trade" part is the market-mechanism for companies to trade emission allowances according to the needs for these permits. Over time, the amount of emissions is decreased to reduce the total emissions (ec.europa.eu/EU ETS) and, according to article 17 of the Kyoto Protocol, countries which have spare emissions permits can sell these permits to countries which have exceeded their emissions targets (UNFCCC.int/emissions trading).

The Kyoto Protocol has three market-based flexible mechanisms: emissions trading, joint implementation and clean development mechanism. Emissions trading allows countries to meet their emissions targets through trading emissions allowances between each other. Joint implementations are emissions reduction projects by two countries in a country which has emissions targets. Clean development mechanism refers to projects in developing countries which have no targets. (ec.europa.eu/Kyoto Protocol.) According to the article 17 of the Kyoto Protocol, there are four units that can be traded through emissions scheme: assigned amount units (AAUs), removal units (RMUs), emissions reduction units (ERUs) and certified emission reductions (CERs). AAUs are the allowed emitted emissions and RMUs are based on land-use, land-use change and forestry. ERUs are generated through joint implementation projects and CERs are generated from clean development mechanism projects. (UNFCCC.int/emissions trading.)

Emissions trading scheme is one of the three listed main methods of restraining GHG emissions according to Stagliano (2017): command and control laws and regulations, carbon taxes and cap and trade schemes. Stagliano looks at the 2007 carbon dioxide emissions data and compares countries which have implemented carbon tax and trading scheme (e.g. in Denmark, Finland and Sweden) to countries which have only used carbon tax (e.g. in Norway) or trading scheme (e.g. in Germany and the United Kingdom) to reach their 2012 goals. Surprisingly, countries with only carbon tax or tax and trading scheme performed worse in terms of reaching their environmental goals compared to countries which only used trading scheme to modify their production processes. If companies would implement either tax or trading scheme to control carbon dioxide emissions, the system would create new costs and presents new reporting opportunities on accountability. (Stagliano 2017) According to the 2019 report on the functioning of the European carbon market, around 43 percent of all available allowances will be allocated free while 57 percent will be auctioned (EU Commission report on carbon market 2019). Received allowances are divided inside the country to companies according to their National Allocation Plans (Stern 2006). The clearing prices for general allowance auctions have had a significant upward trend from 2013 until 2019. The price on the 1st of January 2013 is around EUR 6 per ton of carbon dioxide and on the 1st of January 2019 the price is around EUR 23 per ton of carbon dioxide. (EU Commission report on carbon market 2019.) The price has increased over three times its original value from 2013. Compared to the ECX EUA Futures prices, the opening price on the 2nd of January 2013 was EUR 6.55 per ton of emitted carbon dioxide equivalent and on the 20th of January 2020 the opening price was EUR 25.3 per ton (quandl.com). The similarity between futures' prices and reported auction prices is significant and the price development is illustrated on Figure 5. Figure does not include empty values from the collected data.

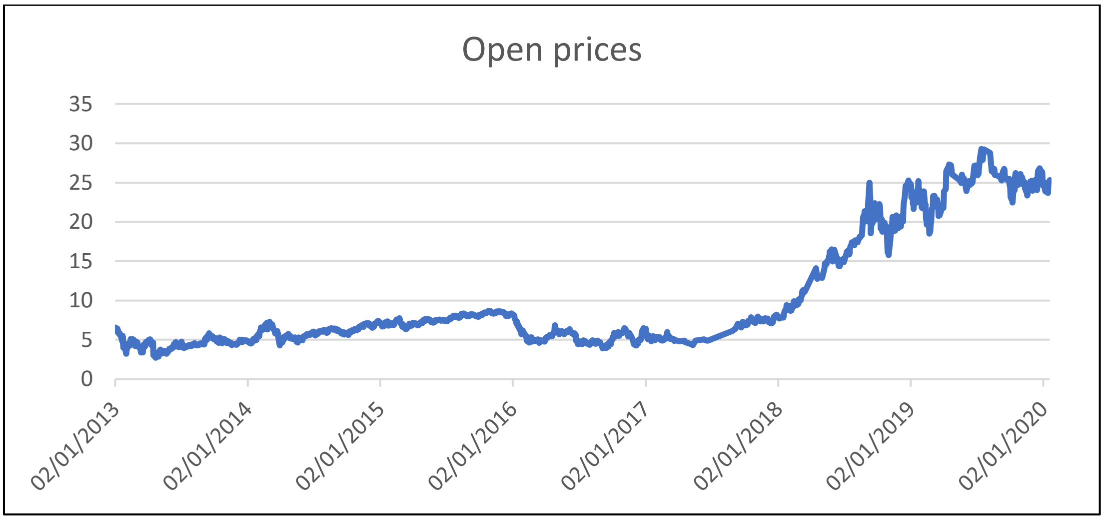

Figure 5 ECX EUA Futures opening prices from 2013 until 2020. Source: quandl.com

The upward trend of futures price should be considered if used to quantify the environmental impact in an EP&L –analysis and later used as an internal policy to determine the internal tax for carbon dioxide emissions. Increasing external price can create difficulties for business units inside an organization, especially in sectors with high emissions levels due to the nature of business processes. Environmental performance should be enhanced in all sectors of an organization but rapidly increasing internal taxes can burden extra costs for heavy emitting processes and create pressure for the management to reach financial and environmental targets. These targets do not necessarily correspond to each other and the rate of technological improvement does not necessarily meet the rate of increasing taxes which can make investment in emissions reducing technologies unprofitable.

Enkvist et al. (2007) points out a 2005 survey conducted by McKinsey & Co on behalf of the European Commission that half of the energy-intensive industries in Europe regard EU ETS as one of the main affecting factors in long-term investment decisions. The external pressure from emission markets on industries and companies seems to push the decision making on environmental investments. If investments are not an option, the actual emission levels in a company may not change until the improvement rate of technology reaches the increasing rate of taxes which can result in heavy offset measures not included in an EP&L –statement and to a negative environmental impact report even if measures to decrease total environmental impact have been implemented. Stern (2006) points out that the sectors with expensive abatement options should not be excluded from carbon pricing but higher prices should not be allocated to them to reach abatement targets from an efficiency perspective.

Similar market-mechanism as EU ETS have been implemented internally by companies, including the energy company BP in 1998. BP capped its emissions to a specific level during a fixed period and divided allowances to emit between organizational units. Those units which had lower pollution-reduction costs sold allowances to units with higher reduction costs, resulting in lower overall costs to BP compared to a scenario without the flexibility of an allowance market. Eventually BP reduced their emissions by 10% from 1990 to 2010. (nature.com.)

Alternative markets to current carbon emissions allowance market have risen, including company Nori which pursues to build a carbon removal marketplace. The market-mechanic is similar to the EU ETS but rather than companies paying for allowances to emit carbon, Nori's marketplace connects parties who have an interest to remove carbon with parties who actually remove carbon emissions. This means that a company which wishes to remove emitted carbon can pay another party for the removal of emitted carbon emissions. (Nori.com.) However, the scale of the market is still small and does not refer to governmental decisions made by the EU ETS which is why this study does not focus on alternative carbon trading marketplaces.

4.4 Comparison of methods and the choice for an EP&L -statement

To quantify the environmental impact for an EP&L -statement, a suitable pricing methodology needs to be applied which requires an understanding of the benefits and disadvantages of each methodology to a company and to the value-chain of a product. It is essential to understand how the results from an EP&L affect the environment as the chosen approach can alter results which can further affect the prioritization of resources, understate the significance of impact, complicate the upkeep of an environmental management accounting system or even threaten the company with legal fees for understating the reported environmental impact. First, I will investigate the pros and cons of each method while referring to previously cited studies and then compare the benefits and disadvantages to each other.

The social cost of carbon –methodology calculates the price of damage caused by one ton of carbon dioxide equivalent (Arena, Conte et al. 2015). The calculation can be done by using a cost-benefit analysis or a marginal cost approach where CBA calculates the equilibrium of marginal cost of reducing emissions and marginal damage of emissions and MC approach calculates the future damage of current level of emissions (Clarkson, Deyes 2002). To calculate a SCC, Integrated Assessment Models need to be used to compress information on several assumptions related to economic growth, carbon emissions and global warming (Clarkson, Deyes 2002) and then the damage from a period of 100 years or longer is discounted to present day by using a societal discount rate (van den Bergh, Botzen 2015). Most often, the SDR is based on Ramsey's model (Ramsey 1928). A SCC estimation has two major problems: the estimates are highly sensitive of ethical and structural assumptions on the future and there can be major losses due to the uncertainty of atmospheric concentration of GHG emissions (Stern 2008). Additionally, SCC depends on the future expectations of economic growth (van den Bergh, Botzen 2015), it has several scientific uncertainties including the measurement of present and the prediction of future emissions and presents economic valuation uncertainties of monetary value for non-market impacts. Also, the prediction on how the relative and absolute value of impact will change in the future, how damage estimates should be aggregated across regions with different levels of national income and how the discount rate should be determined are part of the uncertainties. (Clarkson, Deyes 2002) SCC estimates also depend on the IAM model used as pointed out by van den Bergh and Botzen's 2015 research paper. They displayed how the US Department of Energy calculated SCC in 2010 US dollars using three different IAM models and all three gave different estimates, even if emission and socio-economic scenarios and discount rate values were the same. Additionally, SCC estimates valued in 2010 USD by PwC (2015), Anthoff et al. (2011) and Hope (2013) all range from 8 to 106 dollars with meta-analysis (PwC), FUND (Anthoff et al.) and PAGE09 (Hope) approaches. However, the advantage of a SCC is its objective to estimate the actual social and environmental damage of a country or a company in terms of monetary value. This approach takes the marginal damage effects of climate change to the society into account and tries to turn it into a measurable form. This is the reason why PwC, Novo Nordisk, Stella McCartney, Asus, Kering Group, PUMA and Vodafone use a SCC to estimate the environmental impact of their value-chain as other methodologies do not calculate the direct cost of damage from climate-change.

Another approach to quantify the environmental impact is the marginal abatement cost of carbon –approach. MAC estimates the cost of avoiding emitting the same amount of carbon relative to another scenario (PwC 2015) or the cost of gradually reducing emissions (Stern 2006). This approach compares different emissions reduction options to each other (PwC 2015) from which decisions can be made on which reduction options should be done first and which options generate the highest amount of emissions reduction at a specific time period. Microsoft has used a MAC approach to estimate the price per carbon in terms of total investment strategy to reduce emissions (Microsoft CDP on climate change 2018) and academics have been trying to estimate the marginal cost from climate change, which ranges from 14 (Tol, Richard SJ 2005) to

30 USD (Stern 2008). In a company, calculating MAC curve would require a thorough investigation on current technological options in terms of environmental impact and assessment on the total costs of investment options (PwC 2015). PwC states this as a disadvantage as it requires a lot of time and resources to evaluate all options in business operations and in the supply-chain. Additionally, because the evaluation is only valid at a specific point in time due to the available technology, fast rate of technological improvements can make the upkeep of a MAC –analysis expensive. PwC also points out that MAC does not measure the value of a company's environmental impact on society but rather the cost of reducing the environmental impact. However, as Microsoft points out, by using a MAC to improve their environmental performance the approach is useful when setting a price for carbon that is consistent with an organisation's emissions reduction goals. MAC is also a useful tool to compare and prioritise environmental improvement options with e.g. a carbon tax, buying carbon credits or buying carbon offsets. The third advantage is that MAC has less uncertainty in terms of carbon price because the costs associated with emissions reduction options are already known. (PwC 2015.) Also, if a company uses government's estimate on MAC, company's environmental strategy is connected to the governmental environmental strategy which reduces risk of legal fees from not abiding to the environmental legislation.

The last approach I discussed is called the market-based price of carbon. The idea of this methodology is simple: the price per metric ton of carbon is derived from trading carbon allowances which legally enables companies to emit GHG emissions. World's first and largest market for carbon emissions allowances is based in Europe called the EU ETS (ec.europa.eu/EU ETS). The market has three mechanisms: emissions trading, joint implementation and clean development mechanism which enable countries to trade emissions allowances with each other and take into consideration joint projects in countries with and without emissions targets (ec.europa.eu/Kyoto Protocol). To make sure that the total emissions are reduced in the future, the market is based on a cap and trade –system where a limited amount of allowances are distributed to countries and the total amount of allowances distributed is reduced every year (ec.europa.eu/EU ETS). This is called the cap and the trade part considers countries which cannot meet the emissions targets with the amount of distributed allowances resulting in trade those countries which have excess of them (unfcc.int/emissions trading). Trading creates a price for an allowance which represents one ton of emitted carbon dioxide equivalent. Because this price is external and is determined by the market, it fluctuates according to the need of the parties. The fluctuation can be investigated through the ECX EUA futures prices on carbon emissions, which has had an upward trend from 2013 until 2019 (quandl.com). However, even if the prices have risen, on average the prices tend to be lower than majority of social cost of carbon estimates meaning that the true extend of externalities from emissions is not reflected by the market price (PwC 2015). Additional difficulties can arise from fluctuating prices including decisions on which price to use and how the increasing market price will affect business operations with naturally high carbon emissions. PwC (2015) also points the same issue with the market price method as with the MAC approach: it does not directly measure the environmental impact a company has on the society and instead measures the private financial cost of environmental impact under specific policy regime. Another disadvantage of market price is the non-uniform climate policy between countries and firms which makes choosing the correct price to reflect he climate policy of the company difficult (PwC 2015). Despite these difficulties, the market approach seems to be one of the only ways to efficiently compare EP&L results between companies in terms of the monetary value of environmental impact. Even if choosing the correct value to suit a specific company can be difficult, the reflected climate policy can help to collectively analyse how regional decisions affect companies' decision to improve their environmental performance. Also, at a specific point in time, with the market price of carbon, EP&L -statements of different companies are comparable to each other from financial perspective. From an environmental impact perspective, the market-based price is not sufficient to tell how much damage a company is causing to the society.

Table 14 gathers the pros and cons of all the previously explained approaches to price carbon dioxide emissions. It helps to compare the advantages and disadvantages of each method, but I would like to highlight some defining differences between approaches in terms of using the methods to quantify the collected environmental impact in an EP&L –statement.

The SCC approach is by far the most criticized for its multiple variables, assumptions and contradictory results in terms of using the Integrated Assessment Models. However, compared to the MAC and the market-based price approaches, the SCC is the only methodology which monetizes the damage cost of climate change caused by the company. This possibly makes the SCC approach the most popular method of quantifying carbon dioxide emissions from an EP&L perspective. However, the clarification of this statement would require further research on the use and popularity of different GHG emissions valuation and monetization methodologies by companies. Further studies on the different SCC estimates would also be required as the spread of different estimates is by far the largest compared to the two other methods.

SCC methodology is the only approach presented in this research which estimates the impact of the company to the environment. MAC and market-based price approaches do not evaluate how a company affects the environment, but the costs associated with emissions abatement technologies and policies and internalizes external policies decided by the government organizations. From a causal perspective of the environmental impact, the SCC approach is the most appropriate. However, it is also uncertain and controversial (Tol, Richard SJ 2019a) and compared to other approaches difficult to implement in a company. This is due to the several estimation models, the ethical and economic growth assumptions regarding SCC calculation and the large variety of estimation results dependent of the research methodology. The MAC approach includes the environmental policy of the company, but the market-based price approach only includes the environmental policy of the government. For these reasons, both SCC and MAC are difficult to compare between companies as both approaches include independent environmental policies, which reflect on different prices. Additionally, the case companies during this research do not always fully report the used parameters, including the ethical choices of pure rate of time preference or the societal discount rate which can have significant effect on the final estimate (van den Bergh, Botzen 2015, Anthoff, Tol et al. 2013, Tol, Richard SJ 2011, Tol, Richard SJ 2009). This makes the comparison between companies or industries or organisations very difficult.

The marginal abatement cost –approach is based on the costs of different abatement options. As previously mentioned, this does not estimate the direct impact a company has on the environment, but the costs associated with abatement technologies and/or policies. This gives a consistent price within an organisation and possess less uncertainty compared to SCC. Given the nature of a MAC, there is a possibility to expand the scope of calculation from a single company to the whole supply- or value-chain of a product or service in an EP&L –analysis. MAC is also a useful tool to prioritize abatement options, which adds to the need of improving a company's environmental performance and would be useful together with an EP&L's benefit of highlighting environmental hot spots or processes in need of environmental improvement. The downside in a MAC approach is the calculation process which requires a thorough analyses and assessment of emissions abatement options to form a complete MAC curve. If the analysis is done together with an LCA –analysis in accordance with the ISO 14044, the process of mapping different abatement technologies could be done more efficiently. However, the upkeep of information would possibly require an establishment of new incentives for the management to continuously search for new abatement options until the rate of technology development has reached the rate of environmental improvement. Additionally, the cost of investing in such technology should be considered as well.

The easiest presented approach to determine the price for carbon is the market approach where the price is given by the emissions trading market. It is easy to observe, it does not rely on future assumptions like the SCC, it is the only method between the three approaches which is directly comparable between companies, the trading mechanism allows resources to flow to fill the needs of those with the highest demand and globally reduces the risk of companies moving production to less environmentally restricted countries. However, the market-based price does not measure the cost of carbon to the society but the financial cost of environmental impact under a specific policy regime (PwC 2015). Additionally, as pointed out by the PwC (2015), by average the price tends to be under the SCC estimates even if the price for emissions allowances has risen from 2013. This means that the reflected environmental impact of the market price does not fully correspond to the total social cost of the same impact. In this case the SCC estimate is more appropriate to translate the environmental impact into monetary from, but the estimates can be highly difficult to calculate and can possess significant uncertainty and critic from analysts.

The choice for a suitable approach to evaluate the carbon price for an EP&L –statement requires answers to a multitude of questions by the implementing company: what needs to be measured, how much resources are available to upkeep the system, what needs to be reported on, who is the target audience of the environmental reports, does the target audience understand price changes, what is the environmental policy of the company, is the price used as a carbon tax in the environmental policy, should the price be used as a tool to assist the company to reduce the environmental impact or should it be solely used on external reports?

It seems that the best option for an internal carbon price estimation methodology is dependent on the message of the company. With the SCC, the company states how much it costs to the society when the company releases emissions. With the MAC, the message is the cost of mitigating carbon emissions or "how much has to be spent to reduce one ton of carbon dioxide equivalent". On the other hand, the market-based price informs the cost of authorization to release emissions from business operations. MAC and market-based price are both closely associated with accounting costs, whereas SCC is an external price not accounted in traditional accounting ledgers. This is not beneficial to carbon management accounting which extends the traditional accounting procedures and internalizes general overhead costs. Besides translating the emissions into a monetary form, the message from a SCC can become unclear to the management when it is based on a multitude of decisions out of control of the managers.

Next, I will investigate case company and industry of this study and implement findings from the EMA, EP&L and carbon pricing to build an EP&L –statement for the company. I choose to quantify the environmental impact by using the social cost of carbon and the market-based price of carbon. I use the SCC for it is the only approach which determines the true cost of carbon to the society from all three investigated methods. It is also the most popular amongst other case –companies I have previously presented. I choose the market-based approach as well as it is the simplest approach to quantify the environmental impact and represents a reportable cost to the accounting ledgers as "Intangible assets". This makes the market-based approach the only method related to accounting as the SCC and the MAC are not required to be reported on the financial statements.

Table 14 The Pros and Cons of social cost of carbon, marginal abatement cost of carbon and market price of carbon approaches to carbon pricing

Social cost of carbon		**Marginal abatement cost of carbon**		**Market price of carbon**	
Pros (+)	**Cons (-)**	**Pros (+)**	**Cons (-)**	**Pros (+)**	**Cons (-)**
Calculates the estimated impact of the company to the environment.	Several uncertain estimates, difficult to choose which should be used.	Consistent price within an organization or a company.	For complete decision-making benefits, requires a thorough technological assessment on a company's operations and supply-chain	Avoids the need to calculate MAC curves or agreeance on emissions reduction target.	Does not directly measure the company's environmental impact on society.
Comparable between companies if the calculation methodology is the same.	Depends on several ethical and moral assumptions about the future.	Useful tool to prioritize different interventions to reduce emissions.	Does not measure the environmental impact of a company but the cost of reducing the impact.	Directly observable.	Boundaries of climate policy regimes are not aligned with the boundaries of a firm, making the choice of a correct value unclear.
	Not comparable between companies if different calculation methods and assumptions for the parameters are used.	May have a narrower range of uncertainty compared to a SCC.	It is not comparable between companies unless MAC has been calculated by a common governmental organization.	Does not rely assumptions of the future.	In most cases does not meet the social cost to the society, which means that it does not meet the true externalities imposed on the society.
				Comparable between companies.	
				Trading mechanics allows reductions to occur were they are the cheapest.	
				Can be used to introduce carbon prices without carbon leakage and competitiveness between business units.	

Source: PwC 2015

5. CASE STUDY

The case company is KONE Corporation (here after referred to as KONE) from Finland. KONE is a global manufacturer of elevators, escalators and sliding doors and provides maintenance and repair services for its products (kone.fi/tietoa-meistä). The company was established in 1910 in Helsinki as an electric engine repair shop and manufactured the parts of its first elevator in 1918. KONE was a subsidiary of a company Strömberg before it became independent in 1924. Sustainability became part of its products in 1996 when its innovative product MonoSpace elevator was launched. The elevator used a thin, round disk to lift the elevator up in the elevator shaft and was considered the most environmentally friendly elevator at its time. In 2012 the MonoSpace was redone with increased eco-efficiency, travel comfort and design (kone.fi/historia.)

KONE focuses on people flow which targets the optimization and understanding of people's movement, mostly in an urban environment (Sekimoto, Shibasaki et al. 2011). Company's vision is to build cities with smooth and safe transitions inside and between buildings with the best user experience during the whole life cycle of the building. KONE's choice to focus on people flow, comes from two big trends in the industry: urbanization and rapid change in technology. (kone.com/visio-ja-strategia.) Urbanization means that there is an increase in migration to urban areas due to multiple of different reasons, e.g. an increased level of industrialization in a country or the need of expansion of natural resource exports (Gollin, Jedwab et al. 2016). IPCC (2019) has stated in its latest report on climate change and land-use that both global warming and urbanization can have significant effects on cities' climate. Because urbanization requires more services and apartments for the migrated population, it also requires more new buildings. IPCC's Fifth Assessment Report (2014) has investigated the energy use and GHG emissions from buildings sector since 1970 until 2010. 19% of global GHG emissions from 2010 occur from the building sector and most of the emissions are indirect carbon dioxide emissions from the use of electricity in buildings. Direct emissions have stayed more or less the same (IPCC Fifth Assessment Report 2014). Because elevators, escalators and sliding doors use electricity to function, these are also part of the source of indirect emissions inside the buildings. To improve the energy efficiency of their products, KONE embraces the rapid change in technology, another megatrend in the elevator industry (KONE sustainability report 2018).

Next, I will present the case problem followed by an explanation of the study methodology. I follow this by discussing and comparing the case industry and competitors in terms of environmental reporting, environmental achievements and the current situation of environmental accounting procedures and the use of accounting to reduce the direct and indirect environmental impact of buildings and business operations. Lastly, I will propose a solution to the case problem.

5.1 Case problem

the case company of this study is KONE and the focus of the study is to investigate the possibilities of an EP&L –tool, in terms of carbon management and how an EP&L can assist to establish a price for carbon dioxide emissions. I will focus on the production and use of elevators when discussing mitigation options on the product level.

5.2 Study methodology

The case problem is studied by calculating an environmental profit and loss -statement on MonoSpace 500 elevator and by reviewing several academic studies on environmental management, environmental accounting and carbon pricing. Also, expert interviews have been conducted for further understanding of the current situation on carbon pricing and on the different methodologies. The elevator industry is investigated from environmental reporting perspective and this study focuses on methods and company strategies to mitigate carbon dioxide emissions. The literature on the industry is based on public reports and discussions with the industry insiders. Information on the products and processes has been provided by the case company.

5.3 Case industry and sustainability

According to the PR Newswire's (2015) report "Elevator Industry 2015-2017 Global and China Regional Research Report", the major global companies operating in the elevator industry are OTIS, Hitachi, KONE, Schindler, thyssenKrupp, Toshiba and Fujitec. According to the case company KONE, the closest competitors are OTIS, Schindler and thyssenKrupp, so I will focus on these three when describing the elevator industry. Because all four companies have major impact in the industry and are closest competitors to each other, leaving out Hitachi, Toshiba and Fujitec does not completely distort the analysis when the geographical focus of this study is in Finland and Europe.

KONE Corporation is included in the FTSE4Good index series (KONE sustainability report 2018), ranked 43th on the Corporate Knights list of world's most sustainable companies (kone.com/media/23.1.2019), it is ranked in the Forbes "most innovative companies "–list as 59th and is part of Nasdaq OMX GES sustainability index, STOXX Global ESG leaders, ECPI indices, Solactive ISS low carbon index and Thompson Reuters/S-Network ESG best practices (kone.com/sustainable investment). On its products, KONE has received classification "A" for energy efficiency according to the ISO 25745 standard for KONE 3000 TransSys and 3000 MiniSpace elevators and Singapore Green Building Product certificate for three of its elevators. MonoSpace 500 and Monospace 700 elevators also received an approved Byggvarubedömningen assessment and MonoSpace 700 received the company's first Health Product Declaration. (KONE sustainability report 2018.) KONE pursues to be the leader in sustainability (KONE sustainability report 2018) which is also one of the company's strategic targets (KONE CDP on climate change 2018). To reach this target, KONE has identified four focus areas: driving innovation and improving efficiency, providing the most sustainable offering, being the best employer and attracting talent and enabling partners and society prosper. The first two areas focus on environmental issues and include several management systems related to sustainable development: ISO 14001, ISO 9001, KONE's supplier excellence certification, ISO 50001 on energy management, KONE quality and environmental policy, KONE's corporate quality and environmental manual, KONE global facilities policy, KONE global vehicle fleet policy and ISO 25745 energy performance of lifts, escalators and moving walks. 100 percent of the company's corporate, major manufacturing and R&D units are ISO 14001 and ISO 9001 certified and 90 percent of the strategic suppliers are ISO 14001 certified. KONE follows the GRI guidelines and is committed to the UN Global Compact principles and the UN SDGs. The key SDGs KONE follows are numbers 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities), 12 (responsible consumption and production) and 13 (climate action). (KONE sustainability report 2018.) According to the 2018 sustainability report, most of the key impact areas focus on the urbanization trend where building sustainable cities is done through eco-efficient operations, sustainable sourcing and recycling and taking into consideration the energy efficiency and GHG emissions during operations. The company's environmental policy pursues to maximize the positive environmental impact and minimize the negative impact throughout the life cycle of the product or service, including raw material extraction and recycling of materials. The focus of this policy includes 8 areas, which do not include the reduction of GHG emissions but focus on the reduction of energy consumption, material use and water consumption. However, KONE is committed to reduce the carbon footprint relative to net sales by 3 percent annually which supports the UN SDG number 13. According to KONE's global facilities policy, the company's objective is to reduce facility-related carbon footprint by 15 percent by 2022 compared to 2017. Ways to achieve this goal have been listed as: improvement of space efficiency, optimization of energy use, increasing the share of green electricity, setting on site renewable energy production units, promoting electrical vehicles, improving material efficiency, reduction of waste, improvement on recycling and preferring eco-efficient service suppliers. In addition to the 15 percent reduction target, there are two other environmental targets: increase of the share of green electricity to 50 percent by 2021 and 0 percent landfill waste at manufacturing units by 2030. (KONE sustainability report 2018.)

The effects of energy industry to the release of GHG emissions is clearly shown in Appendix 2 as one of the most emitting industries in the world. However, a possible reason for the focus on energy and recycling could be due to the Finnish government which has established new sustainable development targets to become a carbon neutral country by year 2035 (valtioneuvosto.fi/hiilineutraali). To further pursue the environmental goals of the European Union, the Finnish government has taken its own steps to become carbon neutral which includes the reduction of energy production with non-renewable energy options and the increase of local carbon sinks (valtioneuvosto.fi/hiilineutraali). This is unique compared to the other three elevator companies which do not have their headquarters situated in Finland, and thus are not similarly affected by the local government. According to the 2018 CDP on climate change report, KONE is not regulated by the EU ETS and the company anticipates using an internal carbon price in the next two years. Because the 2019 report was submitted by the time of this research but not scored by the CDP, I will not include any non-scored reports in this study. Certain management level people at KONE can be entitled to monetary incentives for reaching goals in line with KONE's strategic targets on being a leader in sustainability. The people entitled for incentives are, for example, the Chief Operating Officer (COO), the Chief Procurement Officer (CPO), environmental directors, environmental managers and environmental and/or technology experts. The targets for the COO and the CPO can include resource and cost-efficiency and consequently, emissions reductions and energy savings. The environmental directors', managers' and experts' monetary incentives can be based on reaching targets on the company's carbon footprint reduction and/or energy-efficiency. (Kone CDP on climate change 2018.) The company's sustainability reports are audited by an independent Finnish sustainable development consulting firm Mitopro Oy and audits are conducted according to the International Standard on Assurance Engagements 3000 (KONE sustainability report 2018).

OTIS is an elevator company from the United States and part of the United Technologies Corporation (UTC) (UTC Sustainability report 2018). Origins of the company can be traced to Elisha Otis in 1853 and the company introduced the first electric elevators by the turn of the century. In 1975 the elevator company became part of the United Technologies Corporation, in which it has remained to the present day. (case.edu/Otis.) On sustainability issues, UTC has been involved in creating a more sustainable business since 1992. In the UTC 2018 sustainability report, UTC takes urbanization into consideration but focuses on the technological perspective by stating "…urban migration will result in…challenges for cities as they become more densely populated…requiring buildings to be more expansive, intelligent and connected.". The company considers the energy usage of its elevators and uses new technology to capture heat and turn it into energy. The elevators can also be turned to stand-by mode to save energy. The environmental, health and safety (EH&S) performance goals of OTIS are reset every five years. One of these goals is to reduce the GHG emissions by 15 percent. UTC's EH&S follows ISO 14001 standard and the data on energy use and GHG emissions is reviewed by an independent party following the ISO 14064 criteria. The company has set a target of 3 percent reduction in absolute GHG emissions following the recommendations of the IPCC to limit the average global atmospheric temperature rise to a maximum of 2 degrees Celsius by 2100. UTC routinely performs energy audits to identify additional energy-efficiency improvement projects and the company focuses on energy reduction to mitigate the GHG impact. UTC reports annually to CDP on the climate change mitigating projects and relevant executives, facility and environmental managers have environmental goals attached to their annual performance evaluation. UTC follows the GRIs on environmental reporting standards covering all GRI 305 standards. (UTC Sustainability report 2018.) According to the 2018 CDP report on climate change, UTC follows ETS, RGGI and UK Energy efficiency Scheme on carbon pricing regulations and uses an internal price on carbon. The internal price on carbon is based on the market-based value of carbon in the United Kingdom and the subsidiary Pratt & Whittney uses the shadow price of carbon to assess the environmental impact of its emissions efficiency and reduction projects. The price of carbon varies between USD 10 and USD 22.5 per metric ton of carbon dioxide. (UTC CDP on climate change 2018.) This price range is closer to the examined market price of carbon compared to estimates on SCC. Also, the CEO, business unit presidents, EH&S and facility operations vice presidents, directors and facility managers are compensated for reaching their emissions reduction targets. (UTC CDP on climate change 2018). However, it is not specified if OTIS uses an internal price for carbon.

Schindler Holding AG is a Swiss company established in 1874 (schindler.com/history) specializing in elevators, escalators and moving walks (schindler.com/products). The company offers maintenance services on their products (schindler.com/products) and according to the 2018 financial and strategic SWOT analysis review by GlobalData, one of its strengths is in R&D and leading innovation in Internet of Elevators and Escalators (IoEE) which connects and analyses cloud-based data of smart elevators and escalators. This service is part of the Schindler Ahead product (Schindler Sustainability report 2018). The company focuses on easing the urbanization trend through updated, high-technology elevators meant to reduce the global energy consumption of buildings. The company’s sustainability strategy has six priorities: enhance safety, attract diverse talent, create value in communities, pioneer smart urban mobility, lower vehicle fleet emissions and increase sustainability performance of suppliers. Schindler has connected its strategy to the United Nations SDGs. Lowering vehicle fleet emissions involves reducing carbon dioxide emissions of global vehicle fleet by 25 percent compared to 2017 emissions. This is done by installing more fuel-efficient technology, optimization of daily routes, remote monitoring of products, use of public transport when possible and use of electric and hybrid vehicles. Additional measures to reduce emissions is done by reviewing optimal transport solutions, right-sizing vehicle to the task, analysing driving behaviour and using incentives to change behaviour. Suppliers' sustainability performance is increased by periodically evaluating partners and valuing supplier's safety, quality and environmental management with ISO 45001, ISO 9001 and ISO 14001, which includes an LCA -analysis according to ISO 14040 and 14041. Improvements are also done through an EcoVadis platform, a third-party sustainability rating company of procurement operations. Schindler has planned over the next three years to increase data sharing between suppliers to identify new procurement opportunities. (Schindler Sustainability report 2018.) This is similar to the EP&L -methodology of identifying environmental information from the supply-chain for improvement prioritization. However, Schindler does not mention that it uses environmental accounting measures to improve its supply-chain's environmental impact. Schindler is also following the GRI standards on environmental reporting. According to the 2018 CDP report on climate-change, Schindler is not regulated by a carbon pricing system, which means that they do not take part in the ETS nor in a cap and trade carbon tax -system. The company also at the time is not using an internal carbon price. Schindler provides a monetary reward for the procurement manager for reducing the carbon dioxide emissions in new purchased vehicles and for the environment/sustainability manager for reaching the Group's emissions reduction targets. Additionally, all employees are entitled for recognition incentive if the behaviour of employees has become significantly more ecological. (Schindler Holding AG CDP on climate change 2018.)

thyssenKrupp is a German industrial company establish by a merger of Thyssen and Krupp in 1999 but both companies have a long history of steel manufacturing, reaching to the early 19th century (thyssenKrupp.com/history). Because of their long history, the company has established a large portfolio of steel related products ranging from automotive, aerospace, oil and gas and food and beverages packaging to chemical, mining and engineering industry (thyssenKrupp.com/products). The elevator technology operations include elevators, escalators, moving walks, stairlifts and passenger boarding bridges (thyssenKrupp CDP report on climate-change 2018). According to the company's annual report from 2018, there are three indirect financial targets for the environmental management, energy management and for the company's energy efficiency. There are a total of seven indirect financial targets of which one covers the implementation of an ISO 14001 based environmental management system and the two other targets cover the implementation of an energy management system according to the ISO 50001 and a target for annual energy-efficiency gains (thyssenKrupp.com/sustainability-target-and-strategies). Energy-efficiency is improved through Groupwide Energy Efficiency Program which includes measures on the use of waste heat, the reduction of stand-by times and the replacement of plant components. The company has a Groupwide climate program called CAPS (Climate Action for Sustainable Solutions), which is in accordance with the Paris Agreement and pursues to make the production processes much more efficient and defines targets to reduce emissions. Group's actions are driven towards the Agreement by innovating products and services which significantly reduce the total GHG emissions during the use of the product. (thyssenKrupp annual report 2017/2018.) thyssenKrupp has a compensation system for executives which includes the indirect financial targets in a form of bonus-malus factor called a sustainability multiplier. The multiplier is based on the indirect financial targets and the bonus lies in the range of 0.8 to 1.2, which means that the multiplier adjusts the achieved financial target up or down by 20 percent. (thyssenKrupp compensation report 2018/2019.) The 2018 CDP report states that 89 percent of the total Scope 1 emissions by thyssenKrupp are covered by the EU ETS and that the company engages with key customer to jointly develop carbon accounting and commitment to targets. The Group also uses the market-based prices of carbon to navigate the GHG regulation, change internal behavior of the company, drive further energy efficiency, drive for low-carbon investments and identify and seize low-carbon opportunities from Scope 1. The price in 2018 is EUR 15 per metric ton of GHG emissions which is derived from the current market price of EEX at the time of the report (July 2018). (thyssenKrupp CDP report on climate-change 2018.)

Comparing all four companies to each other, all four focus their environmental policies on energy reductions which is consistent with the IPCC's Fifth assessment report's findings on the GHG emissions from buildings. Only thyssenKrupp has a bonus-malus system and with KONE, OTIS and Schindler sustainability rewards are based on reached targets. Only thyssenKrupp is using an internal price for carbon and OTIS could be using an internal price but it is not specified in the UTC's 2018 CDP report. Compared to KONE and Schindler, KONE is not using an internal price of carbon and Schindler is not planning to use an internal price. thyssenKrupp uses a market price for carbon based on the market price of EEX at the time. UTC in the UK is using the market value of carbon as an internal carbon price, but Pratt & Whittney are using a shadow price of carbon (UTC CDP on climate change 2018), which is a more versatile version of the SCC and takes into consideration the environmental policy and the technological environment rather than the global effect of climate-change (Price, Thornton et al. 2007). All four companies consider the energy management as part of their reduction strategy of GHG emissions, however KONE and Schindler also take part in reducing the suppliers' emissions and all four pursue to reduce the emissions during the use of the product when installed at the customer's premises. All four use an ISO 14001 based EMS, but none state to use an environmental management accounting system although a system for data collection does exist. Only thyssenKrupp states to use and develop carbon accounting measures.

My findings on the standards and guidelines from all four companies have been summarized on Table 16. Interestingly, only half of the companies are using some form of an internal carbon price. The global trend of large firms, according to the 2019 World Bank report seems to move towards using an internal price as more than a hundred Fortune 500 companies are planning to or are using carbon pricing within the next two years. This follows the TCFD recommendations to use an internal carbon price to disclose climate related risks (World Bank 2019), however only thyssenKrupp has publicly stated to follow the TCFD recommendations on reporting. Additionally, none of KONE's competitors has reported interest on an environmental profit and loss –statement or to use an internal carbon price as an internal carbon tax to reduce emissions. Interestingly all four companies are working with large supplier networks to provide raw materials, manufacturing and logistics to final customer, but in addition to a LCA–analysis, none of the companies have publicly stated to map the current technological options similarly to a marginal abatement cost –approach or to use an environmental

Table 15 Sustainability reports, standards and followed practices

Standards	KONE	OTIS	Schindler	K
ISO	x	x	x	x
CDP	x	x	x	x
GHG Protocol	x	x	x	x
GRI	x	x	x	x
UN SDG	x		x	x
UN Global Compact	x			x
TCFD				x
IIRC				x

"X" means that the company has applied some standard or practice from the different options into their environmental report. This means, for example, that some ISO standard on environmental issues has been implemented by all four companies. This information should be taken as a grain of salt as public reporting does not necessarily include all possible abided guidelines and standards.

profit and loss statement to analyze the supply-chain in relation to the total environmental impact. All companies recognize the need to change and report on environmental issues and rely on technical innovation to reduce the GHG emissions but also pursue to change the behavior of its employees, managers and partners to achieve wider environmental impact.

Now that the current understanding of the situation of the elevator industry has been established from the environmental management, environmental reporting and carbon management perspective, I continue by implementing an EP&L and an internal carbon price for KONE Corporation.

6. EP&L IMPLEMENTATION

To answer the case problem how an EP&L –tool can assist KONE to establish a price for carbon emissions, I will be implementing an EP&L -statement according to the Kering Group's methodology and monetize the environmental impact of the Mono-Space 500 elevator (here after referred to as "MonoSpace") through the 2017 environmental product declaration (EPD) document provided by KONE. Additionally, I will be citing recommendations by experts regarding carbon pricing and information on EPD retrieved from discussions with the employees at KONE. I will follow step by step the recommended implementation process of Kering Group and reference to other EP&L implementation processes as well to form a solid framework.

MonoSpace is a machine-room-less volume elevator and 90 percent more energy-efficient than the elevators manufactured during the 1990s (MonoSpace EPD 2017). MonoSpace has been through an LCA –assessment based on the ISO 14044 to receive an environmental product declaration (EPD) (MonoSpace EPD 2017) which describes the environmental impact of a product during its life cycle (rakennustieto.fi). This is the first EPD issued to the European market that also complies with the product category rules (PCRs) (MonoSpace EPD 2017). PCRs are needed to develop an EPD and provide requirements, guidelines and rules needed for the development (environdec.com). According to the KONE employees, after estimating the environmental impact of MonoSpace with an LCA –assessment of the value chain, PCRs based on the ISO 14025 are used to create an EPD.

I previously mentioned the seven steps of Kering Group's EP&L implementation process. I will continue by following this path while implementing processes from other investigated companies as well, especially from Novo Nordisk and PwC.

6.1 Decide what to measure

The first step of Kering Group's methodology is to decide what to measure. This step identifies which parts of the business should be included in an EP&L and, when decided, the supply chain should be separated into Tiers (kering.com/methodology). I have decided to focus on a single product called MonoSpace 500. The details of MonoSpace are gathered on Table 17 and Table 18, in which Table 17 includes values chosen for the LCA –calculations and Table 18 includes the summary of materials used to build one MonoSpace 500. The elevator in the LCA -study is used in Brussels, Belgium. The Belgian average mix of energy is used on energy consumption during the use of the elevator. The estimated lifetime is 25 years and is serviced twice during which a rope was replaced.

Table 16 Specifics of a MonoSpace elevator

Index	Values	Representative values chosen
Type of installation	New generic lift	
Commercial name	KONE monospace 500	
Main purpose	Transport of passengers	
Type of lift	Electric	
Type of drive system	Gearless traction	
Geographic location	Brussels, Belgium	
Rated load	302…1,150 kg	630 kg
Rated speed	0,63-1,0-1,6-1,754 m/s	1,0 m/s
Number of stops	Up to 24 floors	5 floors
Travelled height	Up to 75m	12 m
Number of operating days per year	365	
Applied usage category (UC), according to ISO 25745-2	UC1…UC6	UC2*
Designed reference service life (RSL)	25 years	
Geographic region of intended installation	Europe	
Number of trips per day		125
Annual electricity consumption		534 kWh
Optional equipment		No regenerative drive

* UC2 is the "Usage category 2" of ISO 25745-2 which describes how many times the elevator is used per day
Source: Modified from Table 1 of MonoSpace 500 EPD 2017

Table 18 summarizes the materials and the amount needed in kilograms for one MonoSpace elevator and during the full life cycle of the elevator. The list of material categories is provided by the PCR (2015) and the second column illustrates the materials used to make one unit of MonoSpace without spare parts or packaging and the third column includes the spare parts and packaging from the full life cycle.

Table 17 Summary of MonoSpace materials

Materials	One unit (kg)	Full life cycle (kg)
Ferrous metals (zinc-coated steel, stainless steel, cold rolled steel, cast iron, NdFeB magnet)	1760	1910
Non-ferrous metal (aluminium, copper)	32.7	32.7
Plastics and rubbers (acrylonitrile butadiene styrene, polyamide, polycarbonate, polypropylene, polyurethane, polyethylene, unidentified plastics, polyester resin, polystyrene, poly vinyl chloride, ethylene propylene rubber	15.5	39.5
Inorganic materials (concrete, glass)	786	786
Organic materials (wood, plywood, cardboard)	0	378
Lubricants, paintings, coatings, adhesives and fillers (glues)	1	1
Electric and electronic equipment	90	90
Batteries and accumulators	2.46	2.46
Refrigerants in car air conditioners	0	0
Other materials	0.29	0.29
Total	**2690**	**3240**

Source: MonoSpace EPD 2017

Novo Nordisk (2014) recommends in its implementation methodology to first define the scope and boundary of an EP&L –analysis. My scope includes the impact from raw material supply, the processing of raw materials, production of components from processed raw materials, product distribution between production sites, the distribution of products to customers, the installation of the product, the direct use of the product by the customers, the maintenance of the product and the end-of-life treatment of the product. I bound my analysis to this scope and focus on the elevator MonoSpace. Next, I will divide the value-chain of MonoSpace into Tiers following Kering Group's recommendations.

Kering has identified five Tiers from raw material production to direct business operations: (4) production of raw materials, (3) processing of raw materials, (2) production of items needed to assemble the finished product, (1) final assembly of the finished product, (0) direct operations (kering.com/methodology). My study uses and modifies these five Tiers to establish my own set of four Tiers for MonoSpace's value-chain, which is based on the 2017 EPD -report. The identified four Tiers are as follows: production and processing of raw materials (Tier 3), production of components (Tier 2), final assembly of the finished product (Tier 1) and direct operation, use and end-of-life treatment (Tier 0). Tier 3 includes the production and processing of raw materials by raw materials suppliers. This Tier also includes the transportation from raw materials suppliers to processes included in Tier 2. Tier 2 includes the production of components by outsourced and in-house manufacturers. Tier 1 includes the final assembly of the finished elevator at the construction site. This also includes the transportation from the component manufacturers to the building site and the actual installation of the elevator to the building. Tier 0 includes the direct operations by KONE to the elevator, the use of the lift and the end-of-life treatment of the product. The direct operations would include additional services by KONE to the product e.g. maintenance services. The use of the elevator is done by the customer and the end-of-life treatment includes disassembly, recycling and waste.

PwC (2015) recommends clarifying the drivers of the environmental impact which means to understand the causes of the impact. The driver of environmental impact for the EP&L –statement of this study is the GHG emissions generated from the production, distribution, transportation, installation, use and the end-of-life treatment of MonoSpace. Earlier, I established the effects of GHG emissions to the climate change and how carbon dioxide emissions are the most contributing GHG emission to the climate change (Dutch 2010). Because of this causal effect between GHG emissions and the speeding of climate change, PwC (2015) established that the negative effects on the environment are felt globally which means that defining a specific geographic location to the GHG emissions is not necessary. Therefore, mapping the specific location of suppliers and manufacturers is not necessary when this study only focus on the impact from GHG emissions.

I hypothesize that most of the GHG emissions are generated from the production and supply of raw materials. This is based on the previous experiences from Novo Nordisk, Kering Group, Stella McCartney, Asus, PUMA and Vodafone (see Table 12). The highest source of GHG emissions from the use of electricity is hypothesized to occur from Tier 0, from the direct use of the elevator. KONE pursues to reduce the environmental impact of its products and operations which are measured through four KPIs: the reduction of carbon footprint by 3 percent relative to net sales, the reduction of carbon footprint of facilities by 15 percent by 2022 compared to 2017, the reduction of fleet emissions by an absolute value of 1.5 percent annually and a connected KPI in a form of a target to increase the total share of renewable energy to more than 50 percent by 2021. These KPIs are part of the company's vision and environmental strategy. (KONE sustainability report 2018.)

6.2 Map the value-chain (Nordisk 2014)

This part of the implementation refers to the Novo Nordisk's (2014) implementation methodology because Kering refers specifically to the supply-chain (kering.com/methodology) and KONE's 2017 EPD refers to the value chain of MonoSpace. The value-chain has been identified to include seven steps and appropriate suppliers and production countries have been identified as well, except for raw material suppliers which are not tracked by KONE. The value chain of MonoSpace has been illustrated on Figure 6 together with specified Tiers and PCR's (2015) description of processes on the value-chain.

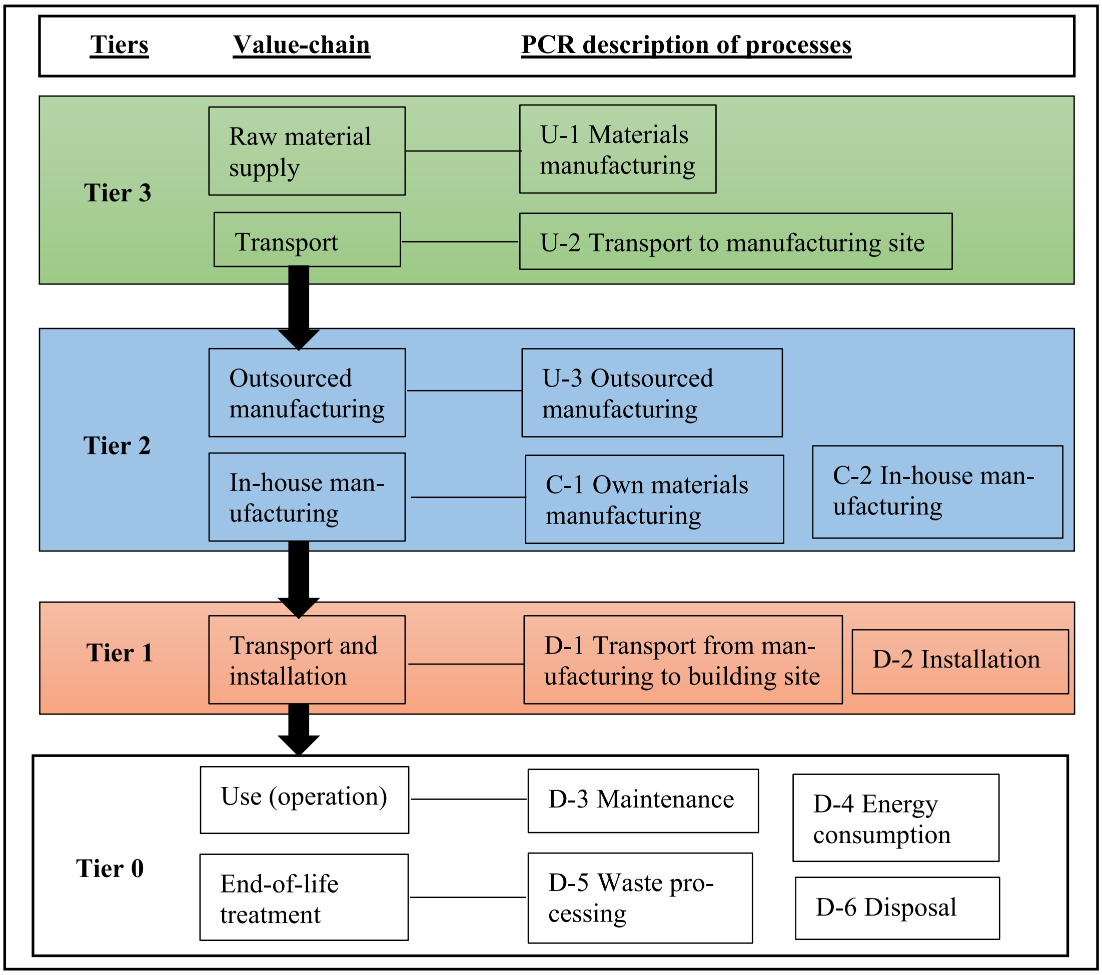

Figure 6 MonoSpace value-chain. Source: MonoSpace EPD 2017

“U-1 Materials manufacturing” consists of the extraction and production of raw materials, including spare parts during maintenance. “U-2 Transport to manufacturing site” includes the transportation from direct suppliers, which should include journeys before U-2 as well. “U-3 Outsourced manufacturing” includes outsourced manufacturing and the manufacturing of spare parts used in maintenance until they are ready for transportation to the lift manufacturing site. “C-1 Own materials manufacturing” includes the extraction and production of the company’s own raw materials used for different parts and components, including spare parts or other components for maintenance. “C-2 In-house manufacturing” is in-house manufacturing and the assembly of components until they are ready to be transported to the building site in phase D-1 “Transport from manufacturing to building site”. After the transportation in D-1, the elevator is installed during phase D-2 “Installation”. After the installation, the use of the elevator includes two phases: D-3 “Maintenance” and D-4 “Energy consumption”. These include emissions from the maintenance and the energy consumption of the elevator during its life cycle. The maintenance process includes the transportation of the workers to the building site, the materials and energy used and the treatment of waste from spare part packaging. At the end of the life of the product, the waste from the disassembled elevator is processed (D-5 Waste processing) and disposed (D-6 Disposal). According to the employees, KONE does not process the waste nor does it handle the disposal of the sold elevators which are left to the final owner.

6.3 Identify priority data

Kering’s methodology suggests identifying the relevant data to an EP&L and define a system to collect it across the entire supply-chain. The second step in the process classifies the type of data that needs to be collected. (kering.com/methodology.) The priority data for MonoSpace, in terms of calculating the total GHG emissions, comes from the production of raw materials, transportation of raw materials, components and products, and emissions during the production from outsourced and in-house manufacturing, emission from the use of electricity while using the elevator, emissions from vehicles during the transportation of the maintenance unit, emissions from waste handling after maintenance and emissions occurring from the end-of-life treatment of the elevator.

Next, I will map the emissions information from the different steps of the value-chain based on the 2015 PCR rules. Phases U-1, U-2 and U-3 include the inflow of raw materials, auxiliary materials and the energy and water needed for the production. U-1 includes the emissions from the extraction and production of raw materials for parts and components. U-2 includes emissions from transporting the raw materials to manufacturing site and U-3 includes emissions from production of consumed energy, the use of water, the production of operating and auxiliary materials consumed, the production of intermediate packaging materials, and the direct emissions to air, water or soils and the treatment of generated waste from manufacturing and assembly of main parts. Internal transportation between or inside factories has been excluded. Phases C-1 and C-2 include the inflow of raw materials, auxiliary materials, energy and water needed for the production of the elevator, the production and use of energy and water, the production and use of auxiliary materials consumed, production of intermediate packaging materials, direct emissions to air, water or soils, treatment of waste generated from the manufacturing and assembly of main parts. Internal transportation between companies' own factories has been excluded. Phases D-1, D-2 and D3 include the inflow of raw material, auxiliary materials, energy and water needed to operate the lift and the elevator's further end-of-life treatment. D-1 includes the before mentioned emissions from transporting the elevator and from the production of packaging materials to protect the lift during transportation. D-2 includes before mentioned emissions from installation, including the auxiliary materials and energy used and the treatment of generated waste from lift packaging. The maintenance phase D-3 includes emissions from transporting the workers, the auxiliary materials and energy used during maintenance activities and the treatment of generated waste from spare parts packaging. D-4 should include the expected energy consumption of the lift, calculated according to the ISO 25745-2. The calculation includes the same performance characteristics as the PCR 2015 determined functional unit, which is used to compare the different value-chains to each other. (PCR 2015.)

D-5 includes the re-use, recycling or energy recovery according to a generic scenario determined by the company which performs the tasks. This should also include the emissions from the preliminary steps to disassembly and from the transport to waste processing. D-6 emissions from the disposal of the elevator are estimated according to a scenario defined by KONE. (PCR 2015.) According to the KONE employees, the calculations of D-5 and D-6 are based on the most likely scenario of processing the waste and disposing of the product. These scenarios can include e.g. emissions from the use of energy to burn the plastics or recycle metals used in the elevator. The data is collected from the suppliers, logistics companies and factories by using pre-planned templates. These templates are filled, and the data is sent to KONE for validation. Data on raw material and energy production and modes of transportation are collected from Ecoinvent v3.2 databased (MonoSpace EPD 2017).

Next, I will describe how the LCA –analysis is performed according to the ISO 14044 standard, how the emissions data is collected and how the potential environmental impact is evaluated using a CML –methodology.

6.4 Collect primary data

Kering states that a company should collect and validate its primary data from suppliers (kering.com/implementation). Novo Nordisk (2014) suggests collecting operational and distribution data from the value-chain. PwC (2015) recommends estimating emissions directly from information provided by companies or indirectly through an LCA or EEIO analysis. In KONE's 2017 EPD the collection of data is done through templates and the environmental impact is estimated through an LCA –assessment.

In an LCA –assessment, there are four phases: (1) defining the goal and scope, (2) the inventory analysis, (3) the impact assessment and (4) the interpretation. An LCA – study should include the intended application, the reasons for carrying out the study, the intended audience and whether the results are intended to be used in a comparative assertion and disclosed to the public. The scope of the study should be considered and defined through the next subjects: the product system studied, the functions of the product system, the functional unit, the system boundary, the allocation procedure, the LCIA methodology and types of impact, interpretation to be used, data requirements, assumptions, value choices and optional elements, limitations, data quality requirements, type of critical review and type and format of the report required for the study. (ISO 14044 2006.) The goal of this LCA –study is to quantify the use of material and energy resources during the production of MonoSpace. The functional unit is based on the specifics illustrated on Table 17 but will not be used during this study as I shall not compare MonoSpace to other value-chain systems. The system boundary has been described earlier in Figure 6. The types of impact chosen by KONE for the 2017 EPD are global warming, acidification potential, eutrophication potential, photochemical ozone creation potential and abiotic depletion potential of elements and fossil fuels. Data is validated by KONE by investigating anomalies in the collected mass and energy balances.

The second phase of the LCA is also called the LCI or life cycle inventory analysis and during this phase, the input/output data is collected into an inventory from the product system. A simplified process of an inventory analyses follows the next steps: goal and scope definition, preparing for data collection, data collection, validation of data, relating data to unit process, relating data to functional unit, data aggregation, refining the system boundary and completed inventory. (ISO 14044 2006.) The data for raw material and energy production and transportation for MonoSpace are covered by Ecoinvent v3.2 database (MonoSpace EPD 2017) and the rest of the data is collected from suppliers. After collection, KONE validates the data and validates calculations with a third-party auditor. The results from the Ecoinvent LCI database and from the LCI analyses are listed in Table 20.

The third phase is also called the LCIA or life cycle impact assessment, which helps to provide more information to assess the LCI results. Mandatory information of LCIA includes a selection of impact categories, category indicators and characterization models, assignment of LCI results to the selected impact category, calculation of category indicator results. (ISO 14044 2006.) The chosen impact categories have been described earlier. The LCI results from Table 20 are assigned to these impact categories, and to assess the environmental impact, a CML method is used (MonoSpace EPD 2017). This method restricts the quantitative model at midpoint level without normalization or weighting, as requested by PCR’s 2015 guidelines, to limit uncertainties (gabi-software.com). The results are grouped according to chosen categories e.g. global warming (gabi-software.com) and IPCC’s 2013 global warming potentials for the 100 years (see Table 9) are used to unify GHG emissions into kg carbon dioxide equivalent (MonoSpace EPD 2017). The potential environmental impact during the MonoSpace’s entire life cycle are illustrated on Table 19.

Table 18 Potential environmental impact of MonoSpace during its full life cycle

Value-chain steps	**GWP 100a (kg CO2e)**
U-1 Materials manufacturing	6,200
U-2 Transport to manufacturing site	160
U-3 Outsourced manufacturing	5.06
C-1 Own materials manufacturing	-
C-2 In-house manufacturing	378
D-1 Transport from manufacturing	663
D-2 Installation	179
D-3 Maintenance	273
D-4 Energy consumption	3,440
D-5 Waste processing	74.5
D-6 Disposal	*
Total	11,400

*KONE instructs that each material and component should be collected and recycled separately in Europe, which is why the EPD does not include information on Disposal.

Source: MonoSpace EPD 2017

Table 19 LCI results from the use of resources during the entire life cycle of MonoSpace

Value-chain steps	Non-renewable energy resources (energy) (MJ)	Non-renewable material resources (materials) (kg)	Renewable energy resources (energy) (MJ)	Renewable material resources (materials) (kg)	Secondary energy resource (MJ) ***	Secondary material resources (kg) ****	Recovered energy (MJ) *****
U-1 Materials manufacturing	83,300	5150	7,710	588	N.A*	891	N.A*
U-2 Transport to manufacturing site	2,250	91.9	24.2	1.87	N.A*	N.A*	N.A*
U-3 Outsourced manufacturing	77.9	0.381	12.8	0.721	0.116	N.A*	N.A*
C-1 Own materials manufacturing	-	-	-	-	-	-	-
C-2 In-house manufacturing	4,430	25.9	1,660	123	20.3	N.A*	0
D-1 Transport from manufacturing	10,700	796	11,500	1,610	N.A*	0.255	N.A*
D-2 Installation	2,500	86.2	66.3	8.44	1.26	N.A*	N.A*
D-3 Maintenance	3,790	125	133	16.2	5.57	N.A*	N.A*
D-4 Energy consumption	48,300	272	10,500	1,060	1,120	N.A*	N.A*
D-5 Waste processing	1,060	43.6	16.5	1.35	N.A*	NA*	N.A*
D-6 Disposal	**	**	**	**	**	**	**
Total	156,000	6,590	31,600	3,420	1,150	891	N.A

*NA means that data on secondary materials, energy or recovered energy flows are not available.

** KONE is not responsible for the disposal and only instructs that each material and component is collected and recycled separately in Europe.

*** Secondary energy resources only include the amount of waste incineration in each country where electricity is used directly. Energy consumption within the Ecoinvent LCI datasets is not considered and the rest of the life cycle stages cannot be defined with full certainty. These are marked as not available.

**** Secondary material resources only consider the amount of iron and copper scrap that are used for steel, copper or cast-iron production. Other possible secondary materials use not found from Ecoinvent LCI dataset are marked as not available.

***** Possible recovered energy is not reported in the Ecoinvent LCI datasets and there is no recovered energy in C-2. Rest of the life cycle stages cannot be defined with full certainty and are marked as not available.

Source: MonoSpace EPD 2017

6.5 Collect secondary data

Kering discusses supplementing the primarily collected data with secondary data from external sources (kering.com/methodology). Novo Nordisk (2014) recommends filling the data gaps from a LCA –assessment with data from an EIO or an EIO LCA hybrid model. Novo Nordisk uses SimaPro to create a hybrid model combining EIO tables with an LCA –study. This study will not collect secondary data from MonoSpace due to limited resources on collection tools.

6.6 Determine the monetary value of the data

Kering's implementation methodology suggests identifying the changes in the environment and the cost incurred by the society due to the environmental impact. After recognizing the environmental changes, the data should be converted to represent the impact on human wellbeing and the total cost of the impact should be assessed and analysed. (kering.com/methodology). Novo Nordisk (2014) suggests calculating the total carbon footprint of the company first and then convert the emissions into unified environmental indicators with standard quantifiers. This could be done, for example, with the IPCC's global warming potentials. After unification, the carbon emissions are converted to monetary cost of the environmental impact using SCC, MAC or other similar conversion methods. (Nordisk 2014) This is similar to the PwC's (2015) methodology which recommends the quantification of the physical changes in the environment from the obtained environmental data. To quantify the results from Table 19, I will present two studied prices for carbon and quantify the emissions. I will first present the social cost of carbon estimates and then the market-based price for carbon determined by the current price of EUA futures.

I have collected a sub-set of SCC estimates listed on Appendix 3 to estimate my own social cost of carbon following to the 2015 PwC methodology. The required criteria for the chosen sub-set are the age of the study, the quality of the study, the discount rate used, equity weighting of estimates and damage valuation. Additionally, the collected sub-set is treated with outliers and the monetary value is inflated to the present-day value. All the studies have been conducted between 2013 and 2019 and all are peer-reviewed. There are two reasons I have limited the research to studies as recent as 2013: one, the average estimates on SCCs have stabilized from the 1980s to the 21st century due to enhanced estimation methods (Tol, Richard SJ 2011) and two, the IPCC's fifth assessment report was published between 2013 and 2014 which might have benefitted studies for more accurate estimates. I have chosen to limit studies with pure rate of time preference lower than 2% and have conducted a Grubbs's test to exclude outliers outside the 91% confidence interval. The reason I include studies three standard deviations away from the mean is due to the "fat-tailed" distribution of the SCC estimates (PwC, 2015). Studies which have been using equity weighting have been included in the sub-set and studies which have applied damage valuation approach are discarded. Monetary inflation has been taken into account and estimates have been inflated into 2020 US dollars following the Novo Nordisk's (2014) methodology. I use the world inflation rates of average consumer prices from the International Monetary Fund (imf.org/inflation). Because the year of the SCC calculation is not disclosed on every study, I follow the PwC's (2015) rule and round down to the nearest five-year interval. After rounding, I will inflate the estimates to the year 2020 according to the inflation rates documented by the IMF. The annual growth rate of SCC is 3% which is the midpoint of the IPCC's 2007 fourth assessment report on how additional tonnes of CO_2e rise over time (PwC 2015). After the increase of the sub-set from the nearest five-year interval and after inflating the estimates to the closest present-day value, I transform all estimates from USD per tCe into USD per tCO_2e. This is done by adjusting the tCe with a single carbon atom to a molecule of carbon dioxide ratio of 12/44. The ratio is multiplied with the SCC estimate. Lastly, I will calculate the arithmetic mean and median from the sub-set which gives two values for the SCC:

Arithmetic mean	**Median**
USD 50 / tCO_2e	USD 40 / tCO_2e

I follow PwC's recommendation and choose the median value which is used to estimate the environmental impact in USD. This is displayed on Table 21. The SCC estimate on kg per carbon dioxide equivalent has been calculated by dividing the original estimate by a 1000 thus giving the units in kilograms. Table 22 presents the market-based price approach and quantifies the emissions from Table 19 into euros using the EUA futures open price during 20.1.2020. The spot price is 25.3 euros per one metric tonne of carbon dioxide equivalent. On Table 19 this value is transformed into a unit of kg per carbon dioxide equivalent by dividing the spot price by 1000.

Table 20 Quantifying the environmental impact into monetary form with SCC

Value-chain steps	GWP 100a (kgCO2e)	SCC (USD/kgCO2e)	Environmen-tal impact (USD)	%
U-1 Materials manufacturing	6,200	0.04	248	54,5
U-2 Transport to manufacturing site	160	0.04	6.40	1.4
U-3 Outsourced manufacturing	5.06	0.04	0.20	0
C-1 Own materials manufacturing	-	0.04	-	-
C-2 In-house manufacturing	378	0.04	15.12	3.3
D-1 Transport from manufacturing	663	0.04	26.52	5.8
D-2 Installation	179	0.04	7.16	1.6
D-3 Maintenance	273	0.04	10.92	2.4
D-4 Energy consumption	3,440	0.04	137.60	30.2
D-5 Waste processing	74.5	0.04	2.98	0.7
D-6 Disposal	-	-	-	-
Total	**11,372.56**	**0.04**	**454.90**	**100.0**

Source: MonoSpace EPD

Table 21 Quantifying the environmental impact into monetary form with market price of carbon

Value-chain steps	GWP 100a (kgCO2e)	Market price CO2e per ton (EUR) *	Market price CO2e per kg (EUR)	Environmental impact (EUR)**	%
U-1	6,200	25.3	0.0253	156.86	54.5
U-2	160	25.3	0.0253	4.05	14
U-3	5.06	25.3	0.0253	0.13	0
C-1	-	25.3	0.0253	-	-
C-2	378	25.3	0.0253	9.56	3.3
D-1	663	25.3	0.0253	16.77	5.8
D-2	179	25.3	0.0253	4.53	1.6
D-3	273	25.3	0.0253	6.91	2.4
D-4	3,440	25.3	0.0253	87.03	30.2
D-5	74.5	25.3	0.0253	1.88	0.7
D-6	-	25.3	0.0253	-	-
Total	**11,372.56**	**25.3**	**0.0253**	**287.73**	**100.0**

* 20.1.2020

** Rounded values

Source: MonoSpace EPD 2017, quandl.com

6.7 Calculate and analyze the results

Kering Group's last step in the EP&L –implementation process is to consolidate the results into an EP&L and then present and communicate findings (kering.com/methodology). Novo Nordisk (2014) recommends to combine all collected data and divide it between Tiers and impact drivers. I have divided my results from the environmental impact quantification to Table 23 and the environmental impact in terms of social cost has been translated into euros using the exchange rate of 1 USD = 0.90219 euros on the 20th January 2020 (xe.com). The social cost per tonne of carbon is higher than the market-based price of carbon which follows my findings from Table 13 and Figure 5. This study's SCC estimate of USD 40/tCO_2e is below the average value of 53.47 and median value of 51.4 calculated from Table 13 which consist of different SCC estimates using different estimation methodologies and IAMs. However, the value is still higher than the spot price of emissions allowances which was noticed by PwC in their 2015 report.

From Table 23 it is evident that the highest costs of environmental impact occur from U-1 Materials manufacturing and from D-4 Energy consumption. Both findings correspond to my hypothesis on the highest impact and on the 2017 EPD report by KONE. Next, I will propose an internal price of carbon according to the EP&L -results and a model on a carbon taxation system integrated into an environmental management system. Additionally, I will present a proposition to further study possibilities of MAC in determining an internal carbon price.

Table 22 Combined environmental impact from SCC estimate and market price

Tiers	Value-chain steps	Environmental impact, SCC (EUR)	Environmental impact, market price (EUR)	Total Tiers SCC	Total Tiers Market
3 Production and processing of raw materials	U-1	223.74	156.86	229.51	160.91
	U-2	5.77	4.05		
2 Production of components	U-3	0.18	0.13	13.82	9.69
	C-1	-	-		
	C-2	13.64	9.56		
1 Final assembly of the finished product	D-1	23.93	16.77	30.39	21.3
	D-2	6.46	4.53		
0 Direct operations, use and the end-of-life treatment	D-3	9.85	6.91	136.68	96.09
	D-4	124.14	87.3		
	D-5	2.69	1.88		
	D-6	-	-		
Total		**410.41**	**287.73**	**410.41**	**287.73**

7. CASE PROPOSITIONS

NGOs like the IPCC's (2014) and academics like Sovacool (2017) have stated the need to improve the energy efficiency of buildings to reduce the total environmental emissions and for the Nordic countries to reach their low-carbon goals. For KONE, the additional pressure from the Finnish government to reach carbon neutrality by 2035 before the EU target of 2050 brings further need for the management of the elevator company to understand how an environmental impact can be recognized and how to mitigate the risks from the negative impact. Using an EP&L to further enhance transparency over negative and positive emissions throughout the value-chain and to use an internal price for carbon management and different supply-chain policies to mitigate negative emissions and encourage positive environmental impact could help KONE achieve its strategic goal to become the leader of sustainability in the elevator industry and reach the governmental goals in Finland by 2035.

Before analysing the results and suggesting next steps for the EP&L, the study needs to determine the internal price for carbon for KONE. I have presented and discussed three different methodologies on carbon and concluded that the only approach to measure the cost of carbon to the society is the social cost of carbon. Additional methods MAC and market-based approach do not measure the societal cost of carbon emissions but the costs from avoiding carbon emissions (MAC) and the cost of a permission to mitigate carbon from operations (market-based). After discussing on the presented carbon quantification methodologies with experts, I have gathered the upcoming points from these interviews.

Expert, Professional Services Company: The TCFD assists companies to become more transparent on the effects of climate-change. It suggests reporting on the impact from climate-change to the company rather than measuring the environmental impact of a company. TCFD proposes risk and opportunity KPIs which consider how much revenue carbon neutral products produce and, roughly speaking, how to turn previous emissions outputs into monetary outputs. This also assists financial analysts who can understand costs associated with taken actions to reduce the environmental impact rather than the total emissions output. TCFD takes into consideration how the change in e.g. materials or energy costs due to changing regulations affects companies and how companies invest to mitigate these risks. On the other hand, social cost of carbon pursues to value the true cost from companies' environmental impact which explains how the current situation should change when compared to future targets. It is difficult to combine the environmental impact of a company to a long-term strategy if the economic and financial systems cannot translate the impact into a monetary form. Therefore, the marginal abatement cost and internal carbon tax approaches are closer to combine environmental concerns with environmental reporting. Marginal abatement cost is a good example of combining investment decisions with the environmental impact.

Expert 2: The social cost of carbon approach pursues to value the negative effects of carbon, whereas marginal abatement cost pursues to determine which price should be used to reduce emissions in a company or organization. On business operations, a marginal abatement cost model makes sense as it is comprised of emissions mitigation investments. It determines what the least-cost-point is and what are the investment options to reduce emissions. On the other hand, investors mostly use market prices to determine the effects of changing emissions allowance prices to the target companies, based on accounting records. On the external sustainability reports, many companies do not use the market-based approach to value their environmental impact.

Both experts suggest using MAC approach to determine the price for carbon as it has closer relations to the actual emissions policy of the company. Both experts also touch on the social cost of carbon but do not specifically recommend it because the measure does not calculate how the climate-change affects a company in monetary terms and what actions the company has taken to reduce the risks from climate-change. It can become difficult to combine the environmental impact to the long-term strategy of a company if the negative output from business operations to the environment is measured but it does not assist companies to understand what can be done to mitigate the input from the negative output. Earlier, I compared the benefits and disadvantages of all three proposed methodologies and concluded that the most accurate measurement of the environmental impact is the social cost of carbon. This is also recognized by Expert 1 as the search for the true cost of the impact from carbon emissions. However, as I have pointed out, the SCC methodology is subject to several assumptions e.g. on the future economic growth, on the ethical choice of pure rate of time preference and on the IAM model used to estimate the future impact. It could be that by taking large enough group of estimates into a meta-analysis, like PwC (2015) or Tol (2013) have done, could generate a close estimate of the SCC. However, according to my research it is still uncertain and debatable which calculation parameters should be chosen for a global price of carbon and what is a correct method to measure a SCC to mitigate emissions efficiently. Additionally, to maintain and upkeep the value would eventually require more resources for research and study of atmospheric concentrations and geographic differences as time goes by. Therefore, this study does not recommend for KONE to use a social cost of carbon methodology to quantify its environmental impact. This leaves two options for quantification: MAC and market-based approach. As pointed out by Expert 2, the use of market-based approach to quantify environmental impact is not common and is more relevant in terms of scenario analysis on the effects of increasing or decreasing of carbon emissions allowance prices relative to the total emissions volume. Expert 1 points out the recommendations of TCFD to focus on the company's monetary effects from climate-change. The market-based price of carbon does include, as pointed out by PwC (2015), the regulatory demands and are internalized by a company if used as a pricing methodology. Additionally, the approach enables the effects of climate-change on companies to be comparable which does help analysts and investors assess the amount of risk involved in rising emissions allowance market prices (see Figure 5). However, the market-price does not measure the company's preparations to mitigate future emissions of its business operations but tells how much it has paid to the governing emissions system to be able to emit. Additionally, KONE does not participate in emissions trading and thus is not affected by the rising prices of emissions allowances. Therefore, I do not recommend using market-based price for carbon when quantifying emissions as the sole benefit of comparison between industry enterprises for the benefit of analysts does not relate to the long-term strategy of KONE to reduce future emissions.

The last presented methodology and a method recommended by both Experts is the marginal abatement cost approach. Due to time and resource constraints, I have not estimated the marginal abatement cost of carbon emissions of KONE but together with an EP&L, KONE could map its emissions sources in the value/supply-chain categorised into specific impact drivers and use MAC approach to assess different abatement options at different price points. This gives flexibility for the company to determine total amount invested to mitigate emissions to the level which meets the international requirements, e.g. Paris Agreement and Finland's 2035 carbon neutrality. To assess the price of carbon dioxide for a specific environmental driver on an EP&L -statement, this study would need to include the volume of abated emissions during the reporting period and the monetary value of euros to abate these emissions. On an EP&L, this would be considered as "profit" as emissions abatement creates positive environmental impact. The "loss" would be considered as the emitted amount of emissions from the reporting period times the cost per ton of emissions to abate these emissions. However, the downside of MAC is that the euro per ton of carbon dioxide equivalent increases over time. This means that abatement through technological options becomes more expensive as more mitigation is needed. At some point, KONE should consider offsetting approaches as well when the cost of technological improvement becomes higher than the gains for environmental improvement.

Additionally, I claim that monetization with marginal abatement cost approach disposes less risk on presumed greenwashing or facades accusations compared to SCC. This is because the value of SCC only reports the impact created on to the society and does not include the pre-measured actions of the company to mitigate impact drivers. On the other hand, MAC is compiled of different emissions abatement options which discloses how a company is planning or has planned to mitigate emissions. If correctly communicated, MAC could enhance the sustainability message of a company as a single KPI with a message "how much do we need to spend to keep the future clean from negative emissions". Additionally, from the Burritt, Hahn and Schaltegger's (2002b) monetary environmental accounting perspective, the MAC approach fits the framework on environmental life cycle costing when environmental investments on individual projects are assessed.

To use a MAC approach to quantify the emissions from KONE, the total abated emissions from the previous reporting period would have to be estimated, the data needs to be validated, emissions categorized and then calculate how much cost occurred from emissions mitigation. The cost is divided by the abated tCO_2e which gives the measure euros per metric ton of carbon dioxide equivalent. The measure is then transferred to current realized emissions as a "loss" or how much must be spent by minimum to have the same amount of abatement this year as last year. The "profits" are the savings from abated emissions. However, this only reflects historical emissions and spend to different abatement options which requires less resources to collect information than continuous mapping of new abatement options and estimating a potential price for carbon. A problem with the MAC approach comes from the related sources of emissions as quantification of environmental impact from a supply-chain takes only into consideration the environmental abatement policy of KONE. As pointed out by this study, the highest emissions occur from sources outside the direct control of KONE. Both U-1 and D-4 are difficult to control from value-chain management perspective. Options to control the emissions from companies outside KONE's control are limited and gives further challenge from the environmental management accounting perspective.

To reduce the energy consumption during the using –phase of the elevator, KONE could collaborate with governmental and standard setting agencies to promote the use of green-energy in buildings. Another option is to increase R&D development of energy-saving elevators but the possible increase in costs and price could reduce the demand for low-energy consumption elevators. Methods to motivate customers to become more environmental in their use and purchase of elevators would require further study. Currently, 90% of all strategic suppliers of KONE already abide the ISO 14001 certification and 100% of corporate units, major manufacturing units and R&D units are ISO 14001 certified (KONE sustainability report 2018). The issue comes from the distance of raw material suppliers and producers in relation to the company. These producers and suppliers could be incentivized with bonuses if they complied with specified standards and targets or pressure could be applied through Tier 2 suppliers and manufacturers to the raw material producers. However, the focus of this research is not on supply-chain relations, so the different options to change the environmental behavior of supplier should be studied separately. I conclude that MAC approach could be used to quantify the environmental impact from the whole value-chain as a commitment of the company to reduce future emissions at a specific cost per ton of carbon dioxide equivalent.

I do recognize that the estimated EP&L is deficient as it does not recognize the total emissions from all possible operations from KONE. It also does not include emissions based on secondary data, like e.g. Kering Group and Novo Nordisk have done. This is due to the limited resources of time and tools to collect secondary data from environmental input-output tables. This step would have to be completed and LCA –study would have to be conducted for all products and services combined with additional emissions from KONE's operations. These include emissions from Scopes 1 (vehicle fleet, heating fuels, cooling gases), 2 (electricity consumption and district heat) and 3 sources (logistics, business air travel and waste), direct and indirect energy consumption, waste and water consumption. This study only focuses on GHG emissions as they are the major contributors to climate-change but to complete the analysis, this study would have to quantify the rest of the environmental drivers and add the environmental impact from these drivers to appropriate categories. This way, the EP&L –analysis would become complete in terms of the total negative impact. The positive impact would have to be collected as abated emissions and used as the basis for MAC. For KONE to include the positive impact and calculate the net environmental value would give an advantage against its competitors as none of the competitors have publicly stated to consider an environmental profit and loss account as an analysis tool of the supply/value-chain. An EP&L would provide further recognition of risks and opportunities on emissions mitigation, and quantification of impact with MAC would present a metric which can assist the management to determine how much resources needs to be spent to arrive at a certain level of mitigation. From carbon management accounting perspective, this is central information for decision-makers to understand and mitigate short- and long-term emissions which could be expanded to cover all environmental impact drivers from a company as part of an environmental management accounting system.

7.1 Policy recommendation

Based on the findings from this research, I would like to present an alternative policy approach for KONE in the form of an internal carbon tax -system based on carbon management accounting and internal carbon pricing. This is based on how marginal abatement cost of carbon has been utilised as an internal carbon tax -system to manage the environmental impact of a company (see e.g. Microsoft Corporation). To enhance the environmental performance of its facilities, KONE could try to use an internal tax for carbon emissions be based on the MAC approach. The tax rate is multiplied by the net value of emissions. Net value in this case is the total emissions minus possible offsets which gives the incentive to invest in offsets or reduce operational emissions through investments. The total taxed value is transferred into a specified account from which funding is given to investments to reduce the direct and indirect emissions. I do not recommend including offsets as fundable investments because the focus should be to mitigate the absolute direct and indirect emissions and can give a wrong message to the stakeholders. Another problem with this system is its inflexibility; some facilities are such high maintenance that they are not able to reduce emissions without high spending and even with high-spending would require more spending on offsets, which again does not reduce the absolute volume of emissions.

Next, I will present a proposed tax system which defines separate taxes for each KONE's facility flexibly and is based on the realized emissions. The steps are as follows:

1) KONE management sets a target for the upcoming year's emissions. Targets should be distributed geographically so that areas with larger needs to become carbon neutral have higher targets than areas with less need to change impact.
2) The geographic emission targets are distributed to facilities according to weights. The weights are determined by the nature of operations of the facility, if the previous target was achieved and how much emissions were emitted during previous assessment period. The sum of all previous three variables determines the weight which is the ratio between the facility's sum and the sum of all facilities. The ratio is then multiplied by the new total target for all the facilities, giving each facility its own new target.
3) At the end of reporting period, realized emissions data is collected and compared to targets. What happens next depends on two options:
    1. If the facility manager has succeeded in reaching the target, he/she should be rewarded with a bonus. thyssenKrupp uses a multiplier of 1.20 or 20% to be added on top the total bonus from other met targets. KONE could use a similar model.
    2. If the manager does not reach the target, the ratio between actual emissions and the emissions target becomes the tax –percentage rate which is multiplied by the sum of income from the current reporting period. More specifically: (Actual emissions/Target)-1 = tax percentage rate.

Alternatively, MAC –based price can be used as a tax -rate and multiplied by the difference between realized and targeted emissions.

4) Facilities which have not reached their targets transfer the taxed amount to an account for future emissions abatement projects.
5) KONE management sets new targets
6) The geographic emission targets are distributed to facilities according to weights.
7) Facility managers plan the future projects to reduce the environmental impact (not including offsets) and introduce their plans and an assessment of required funds to reach the new target.
8) Based on the plan and the current level of emissions, the decided funds are transferred to facility managers who then further invest the funds into abatement projects. Funding is not given to offsets, but this does not mean that the facilities cannot invest in offsets.

The advantage of this system is in its flexibility to acknowledge the nature of business operations and the previous achievements on different locations. However, KONE needs to decide whether to use the tax rate determined by the actual emissions to target emission -ratio or to use the MAC as an internal price to tax carbon. The issue with actual to target -ratio as a basis for a tax rate is the possibly low incentive to pressure management to achieve set targets. If the bonus for the facility manager is not high enough or the tax rate is too low to efficiently affect the business operations, there is little to no incentive for the facility manager to pursue the target and the low tax is paid without significant changes to business operations. Another issues with using a MAC as a tax rate is the rising cost per ton of carbon dioxide equivalent when more emissions are mitigated. This is counter-intuitive to have an incentive to abate emissions when the tax for not reaching a target increases year-to-year because of emissions abatement actions. This system can become particularly difficult in facilities with high emissions-levels which need to be reduced but have difficulties to achieve it due to the nature of their business operations.

8. CONCLUSION

The Earth's climate is warming due to the release of harmful emissions from business operations into the atmosphere, especially carbon dioxide. To decrease the level of harmful emissions, external stakeholders have increased the legislative pressure on companies to comply with environmental issues (see e.g. EU Directive 2014/95/EU). The risk of losing competitive edge or customers and risk over growing costs from not complying with the local legislation have increased the popularity of tackling with environmental and sustainable development issues in the corporate agenda. The European Union has declared to become carbon neutral by 2050 (ec.europa.eu/2050) and Finland has set its own carbon neutrality goal by 2035 (valtioneuvosto.fi/hiilineutraali). Additionally, urbanization has created a higher demand for new buildings and electricity (Crawley 2008), which generates more carbon dioxide emissions (IPCC Fifth Assessment Report 2014). This study pursues to assist the elevator sector to become more environmentally friendly by recognizing and managing emissions through management accounting. Management accounting pursues to inform the internal stakeholders of the company on the current risks and possibilities through data collection, analyses, and reporting. Traditionally, this has been solely integrated into managing a company's financial wellbeing. I propose to expand the traditional accounting measures by internalizing previously assumed externalities, to meet the expectations of the different stakeholders. The social responsibility of business is debatable but the responsibility of business to stakeholders and shareholders remains undisputed. Environmental compliance can e.g. increase competitive advantage (Herzig, Schaltegger 2006), it can benefit the outlook of the company in the eyes of its customers (Ikram, Nekhili Mehdi et al. 2018) and it can assist the management to make better decisions based on sufficient information on the environmental impact (IFAC 2005).

This research has taken a holistic approach to environmental management accounting and has set two research questions:

RQ1: How a company can determine its internal price for carbon dioxide emissions?

RQ2: How an internal price of carbon dioxide emissions can be attached to carbon management accounting through an environmental profit and loss -statement?

Interest for an internal carbon price has grown among major global companies (see World Bank's 2019 report). How the price for carbon dioxide could be determined and how the price could be used as a management tool to mitigate emissions from business operations have been central themes during this investigation. The theoretical framework on sustainable development is based on the description by the Brundtland –report. This is academically the most commonly referred description on sustainable development (Abrahams 2017) and can be used to corporate sustainable development as well (Dyllick, Hockerts 2002).

This research focuses on the natural capital of sustainable development and how a direct and indirect environmental impact can affect a company. It follows an environmental management accounting framework by Burritt, Hahn and Schaltegger (2002a) with monetary and physical environmental management accounting, and focuses on the environmental impact from GHG emissions. This research pursues to combines the GHG output from a company's operations to a carbon management accounting framework by Burrit, Schaltegger and Zvezdov (2011), a carbon specific version of the Burritt, Hahn and Schaltegger (2002a) model. This framework is divided into short- and long-term time frames and into monetary and physical carbon accounting. My focus is on the monetary carbon accounting and to connect the expenditures and investments to abate and offset emissions into an environmental profit and loss -statement in order to map the sources of environmental impact from the entire life cycle of a product or service. The research follows PricewaterhouseCoopers' 2015 description of an EP&L and integrates the implementation methodology collected from six other companies on EP&L implementation. Novo Nordisk's 2014 and Kering Group's current methodology are used extensively to establish the scope, the value-chain, to assess the environmental impact and to collect the primary and the secondary data for an EP&L. To quantify the environmental impact from the value-chain and to answer the first research question, I follow PwC's recommendations and investigate three approaches to introduce an internal price for carbon dioxide emissions: the social cost of carbon, the marginal abatement cost of carbon and the market-based price of carbon. This research especially implements findings by Anthoff, Tol et al. (2013), Foley et al. (2013), Greenstone, Kopits et al. (2013), Hope (2013), Lintunen and Vilmi (2013), Moyer et al. (2014), Nordhaus (2014, 2017), Nodhaus and Sztorc (2013), Tol (2019b), van den Bijgaart et al. (2016) and from Weitzman (2013) to estimate the social cost of carbon following the PwC's 2015 meta-analysis methodology. To estimate the market-based price for carbon I use the ECX EUA futures spot prices between 2013 and 2020. Marginal abatement cost of carbon is not estimated during this research due to limited resources and time to conduct an extensive and sufficiently accurate estimate for MAC.

This research has investigated 11 different companies of which seven study the environmental profit and loss –statement (PwC, Novo Nordisk, Kering Group, PUMA, Stella McCartney, Asus, and Vodafone) and four focus on the elevator industry (KONE Corporation, OTIS, Schindler Holding AG and thyssenKrupp). The four elevator companies are major competitors with each other, especially in Europe. Additionally, interviews have been conducted with open-ended questions from August until September 2019. For the EP&L -statement, the collected data was retrieved from the 2017 environmental product declaration for an elevator MonoSpace 500. This includes an LCA –study of MonoSpace and is implemented into the EP&L –statement. The environmental impact is monetized by using an estimate on the social cost of carbon and a spot price for the emissions allowance futures. I chose to use the SCC and market-based price approaches. SCC was chosen for its nature to be is the only methodology in this study which reports the true cost of carbon to the society in terms of the impact of climate-change. It is also the most widely applied quantification methodology among the seven case –companies who have implemented an EP&L. I also chose to apply the mark-based price for carbon emissions for its simplicity to quantify emissions and for its prevalence in the accounting community as a metric of cost to mitigate emissions based impact.

To summarize the results from this study, the total generated emissions through the life cycle of the MonoSpace 500 elevator are 11.372 tons of carbon dioxide emissions equivalent. The emissions were unified into carbon dioxide equivalents by using the IPCC's Fifth Assessment Report from 2014. I estimate a social cost of carbon to be the median value from a set of 12 studies with different IAM approaches and estimation methodologies. The estimated cost for the social cost of carbon is USD 40 / tCO_2e which I translated into euros by using a currency exchange rate of 1 USD = 0.90219 euros. In euros, the SCC is 36.09. This is under the ceiling value of USD 50/tC estimate by Tol, Downing et al. (2001) and higher than the market price which only estimates the cost abatement during a specific governmental policy (PwC 2015). The market-based price for carbon is EUR 25.3 / tCO_2e cited on the 20th of January 2020. The total environmental impact from the full life cycle of a MonoSpace 500 elevator in terms of social cost is 410.41 euros. The market-based cost to mitigate the full life cycle of the same elevator is 287.73 euros. The results from the SCC state that the MonoSpace 500 generates a cost to the society worth 410.41 euros through the entire estimated life cycle from raw materials to disassembly. The market-based results communicate that the case company needs to use 287.73 euros on the 20th on January 2020 to have a permission to generate 11,372.56 kg of emissions from the entire estimated lifetime of one MonoSpace 500 elevator.

My findings from expert interviews conclude that the current trend to estimate an internal price for carbon emission of a company should be valued as a cost to the company from environmental impact rather than the cost to the environment from economic activity. This suggests that the SCC approach is not gaining popularity as it estimates the social cost of pollution. The market-based approach would be more appropriate but the popularity to estimate the total cost from environmental impact based on an external price from the emissions allowance market has not gained significant interest. According to the interviews, this approach is more appropriate for financial analysts to build scenarios on the effects of price-changes to the financial statements. Both experts have concluded that the marginal abatement cost approach would be the most appropriate method to estimate an internal price for carbon dioxide emissions in a company. Additionally, this research displays internal and external reporting benefits from the MAC approach: it reduces reputational risks related to facades as the price is related to the environmental strategy of the company, it is easy to estimate compared to the SCC approach, it represents the internal emissions abatement strategy and not an external abatement strategy, if applied to an internal carbon tax the MAC is understandable and the management can influence the level of abatement cost, when combined with an EP&L the MAC approach presents abatement options to the emissions hot spots displayed by the EP&L and the historical monetary costs to abate carbon emissions can be recorded into the accounting ledger and quantified environmental impact can be used to forecast on how much a company should spend to abate the same amount of emissions as last year. The downside of the MAC approach is in its upkeep to map abatement options and look for financially beneficial abatement options whereby investing in an abatement technology the physical output from business operations decreases with the monetary cost of operating the business. I conclude that the case company should quantify its environmental impact and estimate an internal price of carbon with the marginal abatement cost approach.

To answer the second research question, I have investigated the Ricoh Group's carbon accounting system and conclude that an ISO 14001 certified environmental management system can be used as basis for an environmental management accounting system (Naciones Unidas, United Nations Department of Economic et al. 2000). Ricoh Group's example of collecting environmental information and recording the impact is very similar to an environmental profit and loss –statement, however in an EP&L analyses the emissions are produced during a life-cycle rather than a specific period similarly to the financial accounting. By introducing an EP&L as an analysis tool to indicate the highest sources of environmental impact and by quantifying the environmental impact with MAC to introduce the cost to abate emissions, a company can estimate the volume of environmental impact, map the sources of the impact and evaluate the required spending to mitigate future emissions.

Additional findings from this research include the implementation path for an environmental profit and loss –statement collected from seven case companies. The implementation path has eight steps and is heavily influenced by the 2015 PwC's report on EP&L as five out of the seven case companies (excluding PwC) have reported to use the 2015 report during their implementation process. The steps are: (1) decide the scope and boundaries of the analyses, (2) map the value-chain, (3) assess the possible environmental impact from value-chain activities, (4) collect primary data from available data resources, (5) secondary data collection with environmental-economic models, (6) quantification of collected data, (7) EP&L calculation and data consolidation and (8) analyse and report findings to stakeholders.

For the case company KONE, I introduce policy recommendations regarding the use of an internal carbon price as a tax –rate to mitigate carbon dioxide emissions in the company's facilities. The system distributes geographic targets to facilities based on the nature of the facility's business if the previous emissions targets are met and how much emissions the facility did emit during previous assessment period. A ratio between the sum of all three parameters and the total sum of all facilities is the distribution weight for a new target. The incentive system is based on a bonus-malus system similar to thyssenKrupp company where facilities who meet their targets are paid with a bonus and facilities which do not meet their targets have to pay a tax for the exceeding emissions. The tax rate is determined by MAC and paid taxes are transferred to an account from which the next year's emissions project are partially funded. Offsets are not funded but facilities can invest in offsets from their own profit. The system is flexible but requires decisions on a correct bonus and tax rate to have the correct incentive. It should be noted that the value of MAC increases year by year when the cost of emissions abatement technologies increases and the amount of emissions decreases. This can be counter-intuitive to encourage facility managers to reduce their absolute emissions and focus on offsets.

It is difficult to assess the validity of the results from the SCC meta-analysis as there is no "true" estimate of a SCC. Previous estimates from academic studies focus on testing different Integrated Assessment Models which can give different results even with the same data. This study follows the PwC's methodology as it integrates multiple estimates from multiple models and is widely used in the business community as part of an environmental profit and loss –statement. The results from this study are in line with Tol, Downing et al. (2001) but should be re-assessed with experts on social cost of carbon modelling. The applied market-based price of carbon is from a reliable source and accurate when compared to the EU Commission's report on the carbon market from 2019. The interviews with the two experts do contain a risk of biasness as both experts have close relations with the case company. However, the interviews were conducted with open-ended questions and were not focused on the elevator industry or the case company specifically. A wider group of experts should be interviewed on the same topic from different geographic regions to improve the generality of my findings. A similar issue of biasness can be stated from the seven case companies as six out of seven use the same methodology and one of the six companies has developed the methodology. Also, four out of the six companies have had close business relations with each other. The generality on the implementation methodology should be improved by investigation a larger group of companies who have implemented an

EP&L. The LCA results on the MonoSpace 500 elevator have been validated by the KONE Corporation.

Improving the study

To improve this study, I would first conduct a further analysis with EP&L on the total emissions from MonoSpace 500. Secondary data should be collected with EIO or LCA EIO models and implemented into the current data. Secondly, I would increase the amount of SCC estimates on the meta-analysis to further improve the median estimate. Additionally, I would verify the calculation methodology with external auditors or environmental consulting experts to make sure that the methodology is up to date. I would also have a larger pool of interviews and possibly conduct the interviews with pre-planned questionnaires send to experts and environmental leaders of related industrial energy, steel and manufacturing industries. There is an inherent biasness with interviewed experts as both companies are directly linked to the case -company but have pursued to give an unbiased general opinion on the chosen approach to calculate an internal carbon price.

Propositions for future studies

For future studies, I propose empirical investigations on environmental management accounting systems and how they are directly affecting the environmental performance of a company. This can be expanded to include behavioral studies on how monetized value of environmental impact affects managerial performance. I also propose to study how environmental behavior of suppliers and customers can be influenced with environmental management accounting. Lastly, I suggest larger empirical studies on suggested benefits and disadvantages of EP&L to supply-chain and environmental management.

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APPENDICES

Appendix 1 Information on the expert interviews

Expert, Professional Services Company

Date: The 5th of August 2019

Time: 15:00 - 15:30 (UTC +2)

Company: PricewaterhouseCoopers Oy Finland

Expert 1

Date: The 27th of September 2019

Time: 13:30-14:30 (UTC +2)

Company: Mitopro Oy

Appendix 2 Top 10 most emitting countries by industry in CO_2e

Country	Sector	Emissions by CO_2e	Percentage of global GHG emissions
China	Energy	9430.2 MT	21.56%
	Industry	1408.4 MT	3.22%
	Agriculture	697.9 MT	1.6%
	Waste	198.5 MT	0.45%
United States	Energy	5495 MT	12.56%
	Industry	270 MT	0.62%
	Agriculture	351.6 MT	0.8%
	Waste	163.2 MT	0.37%
EU 28	Energy	3474.8 MT	7.94%
	Industry	202.2 MT	0.46%
	Agriculture	407.2 MT	0.93%
	Waste	140.2 MT	0.32%
India	Energy	2027.9 MT	4.64%
	Industry	192.6 MT	0.44%
	Agriculture	628.3 MT	1.44%
	Waste	60.3 MT	0.14%
Russia	Energy	1960.3 MT	4.48%
	Industry	75.2 MT	0.17%
	Agriculture	91.7 MT	0.21%
	Waste	71.9 MT	0.16%
Japan	Energy	1240.1 MT	2.84%
	Industry	87.5 MT	0.2%
	Agriculture	21.2 MT	0.05%
	Waste	4.5 MT	0.01%
Brazil	Energy	481.3 MT	1.1%
	Industry	54.8 MT	0.13%
	Agriculture	436.8 MT	1%
	Waste	45 MT	0.1%
Indonesia	Energy	489.1 MT	1.12%
	Industry	30.2 MT	0.07%
	Agriculture	160.3 MT	0.37%
	Waste	64.7 MT	0.15%
Canada	Energy	629.2 MT	1.44%
	Industry	23.3 MT	0.05%
	Agriculture	63.3 MT	0.14%
	Waste	22.6 MT	0.05%
Mexico	Energy	497.7 MT	1.14%
	Industry	41.4 MT	0.09%
	Agriculture	83.5 MT	0.19%
	Waste	110.4 MT	0.25%

Source: https://www.wri.org/blog/2017/04/interactive-chart-explains-worlds-top-10-emitters-and-how-theyve-changed

Appendix 3 List of studies of SCC estimates

Study	Estimate of the social cost of carbon (USD/tCO2e)	Year of the price	PRTP
Anthoff, Tol et al. (2013)	374	1995	0.1%
Foley et al. (2013)	55	2010	1%
Greenstone, Kopits et al. (2013)	21	2010	1.5%
Hope (2013)	106	2010	0.1%
Lintunen, Vilmi (2013)	29.9	2010	1%
Moyer et al. (2014)	16	2010	1%
Nordhaus (2014)	18.6	2015	1.5%
Nordhaus (2017)	31.2	2010	1.5%
Nordhaus and Sztorc (2013)	18	2010	1.5%
Tol (2019a)	55.4	2010	0%
Van den Bijgaart et al. (2016)	31	2010	0.02%
Weitzman (2013)	266	2010	1%