Integration of Sustainability Approaches in Companies: an Exploration of Narratives and Internal Organizational Functioning

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Integration of Sustainability Approaches in Companies: an Exploration of Narratives and Internal Organizational Functioning

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PhD Thesis

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Preface

This PhD thesis presents the work conducted within the PhD project entitled "Integration of Sustainability Approaches in Companies: an Exploration of Narratives and Internal Organizational Functioning". It was completed as part of a co-tutelle collaboration between (i) the Division for Quantitative Sustainability Assessment, at the Department of Management Engineering, at the Technical University of Denmark (DTU), and (ii) the Department of Design, at the Faculty of Architecture and Design, at the Norwegian University of Science and Technology (NTNU). As part of the co-tutelle agreement, two PhD projects were conducted in parallel, with one PhD student (Raphaëlle Stewart) based at and employed by DTU, and another PhD student (Faheem Ali) based at and employed by NTNU. The present thesis includes the PhD project conducted by Raphaëlle Stewart, which took place between September 2015 and October 2018, under the supervision of Associate Professor Niki Bey (DTU main supervisor), Professor Michael Zwicky Hauschild (DTU co-supervisor) and Professor Casper Boks (NTNU main supervisor). Two two-month external stays were done in 2016 and 2017 at the Department of Design, at NTNU, under the supervision of Casper Boks. One three-month external stay was done by Faheem Ali in 2017, at the Division for Quantitative Sustainability Assessment, at DTU, under the supervision of Niki Bey. Besides regular full-team meetings and interactions between the two PhD students, these three research stays and additional shorter stays allowed both PhD students to collaborate in the same location in their related projects over a period of nine months.

This thesis presents the conceptual background, main results and follow-up steps of six appended scientific articles, listed below, which constitute the backbone of this PhD research. Four of the articles have been published; the two others are included as draft manuscripts.

Article I Stewart R., Fantke, P., Bjørn, A., Owsianiak, M., Molin, C., Hauschild, M.Z., & Laurent, A. (2018) Life cycle assessment in corporate sustainability reporting: Global, regional, sectoral and company-level trends. Business Strategy and the Environment DOI: 10.1002/bse.2241.

Article II Stewart, R., Bey, N., & Hauschild, M.Z. Life cycle thinking in the Nordic apparel industry: a review of corporate sustainability reports (draft manuscript).

Article III Stewart R., & Niero, M. (2018) Circular Economy in corporate sustainability strategies: a review of corporate sustainability reports in the Fast-Moving Consumer Goods sector. Business Strategy and the Environment DOI: 10.1002/bse.2048.

Article IV Stewart, R., Ali, F., Boks, C., & Bey, N. (2018) Architect, Catalyst, Advocate, and Prophet: A Four-Lens View of Companies to Support Ecodesign Integration. Sustainability, 10(10), 3432. DOI: 10.3390/su10103432.

Article V Stewart, R., Bey, N., & Boks, C. (2016) Exploration of the barriers to implementing different types of sustainability approaches. Procedia CIRP 48, 23rd CIRP Conference on Life Cycle Engineering, 22-24 May 2016, Berlin, Germany, pp. 22-27. DOI: 10.1016/j.procir.2016.04.063.

Article VI Ali, F., Boks, C., Stewart, R., & Bey, N. Company personas as a tool for improved Design for Sustainability implementation (draft manuscript).

Abstract (English)

Intensively discussed in the international scene, as illustrated with the Sustainable Development Goals launched by the United Nations, sustainable development and sustainability have been well established as central topics for our societies. Recent scientific work urges to reduce environmental sustainability pressures so that Earth's life-supporting functions can be maintained, and economies and societies nested in the Earth system can keep thriving. The role of companies in supporting the transition towards sustainable societies has been emphasized by researchers, policy-makers and companies themselves. In this context, companies increasingly develop their own *sustainability approaches*. Sustainability approaches can take various forms such as environmental management, sustainable supply chain management, and cleaner production. In this PhD project, a product life cycle perspective was taken, which relates to viewing companies as the major providers of goods and services (hereafter referred to as "products"), with their embedded life cycles, in our economies. The decisions made during the product development activities have typically been considered to determine a large share of products' environmental sustainability impacts along their life cycle. Hence, companies have a key role to play through the development and delivery of products, which is the focus of ecodesign research. Sustainability approaches can be researched on different layers, ranging from internal organizational functioning, over operational sustainability practices and companies' narratives, to functioning of the overall business ecosystem. In this PhD project, sustainability approaches from a product life cycle perspective were researched based on two different layers of sustainability approaches, namely company narratives and internal organizational functioning.

First, although life cycle thinking has been driven by various industry and policy-making initiatives, and been considered to constitute a *shared worldview* of environmental management, the extent to which it is actively used in industry to guide sustainability approaches remains unclear. This PhD project set out to research this question based on company narratives, and more precisely based on corporate sustainability reports. Corporate sustainability reports deliver insights on how companies understand that their sustainability efforts should be best presented, and, hence, contain concepts and reasoning lines considered critical by the companies' themselves for their official communications. In this context, the first research question (RQ1) addressed in this PhD project is: "*To what extent is life cycle thinking present in company narratives of their sustainability approaches provided in corporate sustainability reports?"* Second, recent developments in ecodesign integration literature have called for a deeper embracement of both formal aspects (e.g. organizational units, processes and targets) and informal aspects (e.g. individual aspiration, routines, and power relationships) of organizational functioning. A framework from general management literature, the four-lens view of organizations, was identified as a candidate conceptual framework to address formal and informal aspects of organizational functioning. In this context, the second research question (RQ2) addressed in this PhD project is: "*To what extent can the four-lens view of organizations help investigating and supporting ecodesign integration in formal and informal organizational functioning of companies?"*

The presence of life cycle thinking in companies' narratives provided in corporate sustainability reports was explored using three different indicators: (i) references to life cycle-based methodologies; (ii) extent to which reported environmental sustainability operational practices covered the different life

cycle stages; and (iii) presence of life cycle thinking elements in companies' narratives (product life cycle system, hotspots in the life cycle, tradeoffs in the life cycle or across environmental problems, and product environmental sustainability budget related to the idea of ecological limits). The main findings are:

1. The idea of product life cycle was found present in corporate sustainability reports as a concept or through operational practices addressing the different life cycle stages.
2. The Life Cycle Assessment methodology in itself was found with a rather weak presence in corporate sustainability reports globally; yet, in smaller and targeted samples, presence of life cycle-based methodologies was found more frequent;
3. Life cycle thinking was found only limitedly used to critically analyze and reflect about environmental sustainability problems associated with product life cycles.

A set of literature and empirical studies were undertaken to answer RQ2, and overall consisted of (i) mapping measures in favor of ecodesign integration in the four-lens view framework; (ii) uncovering cross-lens effects, i.e. interactions between lenses, and (iii) deriving applications of the four-lens view in ecodesign integration activities. The main findings are:

1. Lens dominance was revealed among measures in favor of ecodesign integration in literature and empirical data, although measures corresponding to all lenses were found.
2. Indications of cross-lens effects, i.e. indications that measures corresponding to a given lens enhance factors at the core of other lenses, were found in the literature and in the empirical data.
3. Three hypothesized applications of the four-lens view in ecodesign integration activities were derived including continuous improvement, problem solving and training or recruitment of employees.

Together, the two tracks of this PhD project had in common to allow "*getting closer to companies*"- to the companies' understanding of how to best present their sustainability efforts, and to the companies' internal organizational functioning, respectively. This PhD research provides complementary insights on how to strengthen the integration of sustainability approaches in industry, from a product life cycle perspective. The first track identified the need for an increased use of life cycle thinking in companies' narratives for critical analyses and reflections about existing product life cycle systems, and the environmental sustainability challenges they are associated with. The second track paved the way for further testing of the analytical and practical value of the four-lens view of organizations to investigate and support ecodesign integration in companies, with a broad horizon of what internal organizational functioning entails. These two tracks were conducted independently to a great extent, and opportunities for their cross-linking are outlined for future research.

Abstract (Danish)

Intensivt diskuteret på den internationale scene, som illustreret ved Verdensmålene for bæredygtig udvikling, som De Forenede Nationer har lanceret, har bæredygtig udvikling og bæredygtighed været veletablerede som centrale emner for vores samfund. Det nylige videnskabelige arbejde opfordrer indtrængende til at reducere det miljømæssige bæredygtighedstryk, således at jordens livsstøttende funktioner kan opretholdes, og økonomier og samfund, der er indeholdt i jordsystemet, kan forblive intakte. Virksomhedernes rolle i at understøtte overgangen til bæredygtige samfund er blevet understreget af forskere, beslutningstagere og virksomheder selv. I denne sammenhæng udvikler virksomhederne i stigende grad deres egne bæredygtighedstilgange. Bæredygtighedstilgange kan tage forskellige former såsom miljøledelse, bæredygtig forsyningskædeforvaltning og renere produktion. I dette ph.d.-projekt blev der taget et produkt livscyklusperspektiv, som betragter virksomheder som de vigtigste udbydere af varer og tjenesteydelser (i det følgende omtalt som "produkter") med deres indlejrede livscykluser i vores økonomier. Beslutningerne i produktudviklingsaktiviteterne er typisk betragtet som at bestemme en stor del af produkternes miljømæssige bæredygtighedseffekter over deres livscyklus. Derfor har virksomhederne en central rolle at spille gennem udvikling og levering af produkter, som er fokus for forskning indenfor miljøvenlig produktudvikling (ecodesign). Bæredygtighedsstrategier kan undersøges i forskellige lag, lige fra intern organisatorisk funktion, over operativ bæredygtighed og virksomhedernes fortællinger, til fungeren af det overordnede erhvervsmæssige økosystem. I dette ph.d.-projekt blev bæredygtighedstilgange i et produkt-livscyklusperspektiv undersøgt baseret på to forskellige lag af bæredygtighedstilgange, nemlig virksomhedsfortællinger og intern organisatorisk fungeren.

For det første, selv om livscyklus-tænkning er blevet drevet af forskellige industri- og politiske initiativer og blev anset for at udgøre et fælles verdensbillede af miljøforvaltning, er det uklart, i hvilket omfang den aktivt anvendes i industrien til at lede bæredygtighedstilgange. Dette ph.d.-projekt har til formål at undersøge dette spørgsmål baseret på firmafortællinger og, mere præcist, baseret på virksomhedernes bæredygtighedsrapporter. Disse rapporter (Corporate sustainability reports) giver indsigt i, hvordan virksomheder mener at deres bæredygtighedsindsats bør være fremlagt bedst muligt, og dermed indeholder de begreber og ræsonnementslinjer, der anses for kritiske af virksomhederne selv for deres officielle kommunikation. I denne sammenhæng er det første forskningsspørgsmål (RQ1), der behandles i dette ph.d.-projekt: "I hvilken grad er livscyklus-tænkning til stede i virksomhedsfortællinger om deres bæredygtighedsstrategier, der fremgår af virksomhedernes bæredygtighedsrapporter?" For det andet peger seneste udviklinger inden for litteratur omkring integrering af miljøveling produktudvikling på en dybere inddragelse af både formelle aspekter (f.eks. organisatoriske enheder, processer og mål) og uformelle aspekter (f.eks. individuelle aspirationer, rutiner og magtforhold) af organisatorisk fungeren. Et rammeværk fra den generelle ledelseslitteratur, nemlig ”organisationers fire-linse-perspektiv”, blev identificeret som en mulig konceptuel ramme for at imødegå formelle og uformelle aspekter af organisatorisk fungeren. I denne sammenhæng er det andet forskningsspørgsmål (RQ2), der behandles i dette ph.d.-projekt: "I hvilket omfang kan organisationernes fire-linse-perspektiv hjælpe med at undersøge og understøtte integration af ecodesign i virksomhedernes formelle og uformelle organisatoriske fungeren?"

Tilstedeværelsen af livscyklus-tænkning i virksomhedernes fortællinger, som præsenteret i virksomhedernes bæredygtighedsrapporter, blev undersøgt ved hjælp af tre forskellige indikatorer: (i) referencer til livscyklusbaserede metoder; ii) omfanget af, hvilke rapporterede miljømæssige bæredygtighedstiltag der dækker de forskellige livscyklusfaser og (iii) tilstedeværelse af elementer af livscyklus-tænkning i virksomhedernes fortællinger (konkret: produkt-livscyklus-system, hotspots i livscyklussen, trade-offs i livscyklussen eller på tværs af miljøproblemer, og produkt-miljø-bæredygtigheds budget relateret til ideen om økologiske grænser). De vigtigste resultater er:

1. Idéen om produktets livscyklus blev fundet værende til stede i virksomhedernes bæredygtighedsrapporter som et koncept eller gennem operativ praksis, der tager sigte på de forskellige livscyklusfaser.
2. Livscyklusvurderingsmetoden i sig selv blev fundet med en ret svag tilstedeværelse i virksomhedernes bæredygtighedsrapporter globalt, men i mindre, målrettede prøver af virksomheders bæredygtighedsrapporter blev forekomsten af livscyklusbaserede metoder fundet hyppigere.
3. Livscyklus-tænkning blev kun fundet i begrænset omfng til kritisk at analysere og reflektere over miljømæssige bæredygtighedsproblemer i forbindelse med produktets livscyklus.

Et antal litteratur- og empiriske undersøgelser blev gennemført for at besvare RQ2 og bestod i alt af (i) kortlægning af tiltag omkring integration af ecodesign der støtter fire-linse-perspektivet og (ii) afdækning af tvær-linse-effekter, dvs. interaktioner mellem linser og (iii) efterfølgende anvendelser af fire-linse-perspektivet i ecodesign-integrationsaktiviteter. De vigtigste resultater er:

1. Linse-dominans blev identificeret blandt tiltag, der støtter ecodesign-integration i litteratur og empiriske data, selvom der også blev fundet tiltag svarende til alle linser.
2. Indikationer af tvær-linse-effekter, dvs. indikationer om, at mål svarende til en given linse forøger faktorer i kernen af andre linser, blev fundet i litteraturen og i de empiriske data.
3. Tre mulige anvendelser af fire-linse-perspektivet i ecodesign-integrationsaktiviteter blev udviklet, herunder løbende forbedring, problemløsning og uddannelse eller rekruttering af medarbejdere.

Sammen har de to spor i dette ph.d.-projekt til fælles at muliggøre at "*komme tættere på virksomheder*" - til virksomhedernes forståelse for, hvordan de bedst kan præsentere deres bæredygtighedsindsats og til virksomhedernes interne organisatoriske fungeren. Denne ph.d.-forskning giver komplementær indsigt i, hvordan man kan styrke integrationen af bæredygtighedstilgange i industrien, ud fra et produkts livscyklusperspektiv. Det første spor identificerede behovet for øget brug af livscyklus-tænkning i virksomhedernes fortællinger om centrale analyser og refleksioner omkring eksisterende produktlivscyklusystemer og de miljømæssige bæredygtighedsudfordringer, de er forbundet med. Det andet spor banede vejen for yderligere afprøvning af den analytiske og praktiske værdi af organisationernes fire-linse-perspektiv for at undersøge og støtte ecodesign-integration i virksomheder med en bred horisont af, hvad intern organisatorisk fungeren indebærer. Disse to spor blev fulgt i stor udstrækning uafhængigt af hinanden, og mulighederne for deres kombination er skitseret for fremtidig forskning.

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I would like to thank my friends and family for accompanying, supporting and boosting me during the past three years. I would like to thank my parents, my brother and my sister, for encouraging me and always believing in me. I would like to thank my boyfriend for his presence and endless support throughout the long and bumpy journey, and for making me feel strong.

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List of Abbreviations

CDP	Carbon Disclosure Project
CE	Circular Economy
CEO	Chief Executive Officer
CR	Corporate Register
CS	Corporate Sustainability
CSR	Corporate Social Responsibility
DJSI	Dow Jones Sustainability Index
DTU	Technical University of Denmark
EC	European Commission
EEA	European Environmental Agency
EHS	Environment Health and Safety
EIM	Environmental Impact Measuring
EMF	Ellen MacArthur Foundation
EOL	End-of-Life
EP&L	Environmental Profit and Loss
EPD	Environmental Product Declarations
EPR	Extended Producer Responsibility
ErP	Energy related Products
EU	European Union
FMCG	Fast-Moving Consumer Goods
GHG	Greenhouse Gases
GRI	Global Reporting Initiative
ISO	International Organization for Standardization
KPI	Key Performance Indicator

LC	Life cycle
LCA	Life Cycle Assessment
LCI	Life Cycle Initiative
LCM	Life Cycle Management
LCT	Life Cycle Thinking
LOI	Leadership Orientation Instrument
NTNU	Norwegian University of Science and Technology
OEF	Organization Environmental Footprint
PDCA	Plan-Do-Check-Act
PEF	Product Environmental Footprint
PLA	Polylactic Acid
PwC	PricewaterhouseCoopers
QSA	Quantitative Sustainability Assessment
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
R&D	Research and Development
RoHS	Restriction of Hazardous Substances
RQ	Research Question
SASB	Sustainability Accounting Standards Board
SDG	Sustainable Development Goal
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environmental Program
US	United States
TBL	Triple Bottom Line
WBCSD	World Business Council for Sustainable Development

WCED	World Commission on Environment and Development
WEEE	Waste Electrical and Electronic Equipment

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1 Introduction

In this introductory chapter, I intend to position my PhD work within the broad picture of sustainability in a business context. I first introduce the concept of "sustainability" and the understanding of this concept adopted in my PhD project, which explains the project's emphasis on environmental sustainability (**Section 1.1**). In **Section 1.2**, I introduce the idea of "sustainability approaches" in the context of a company, and different layers on which approaches can be researched. In **Section 1.3**, I present the standpoint that companies have a key role to play in the transition towards sustainable societies through the products (including goods and services) they develop and deliver to our economies, thereby explaining the product life cycle (LC) perspective taken in this PhD research. In **Section 1.4**, I introduce and justify my focus on two layers of sustainability approaches related to addressing two different research needs, before setting out the two research questions which guided this PhD project.

1.1 Understanding of "sustainability"

Intensively discussed in the international scene, as illustrated with the launch of the Sustainable Development Goals (SDGs) by the United Nations (UN, 2015), sustainable development and sustainability have been well established as central topics for our societies. The commonly agreed definition of sustainable development, as a "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" was established by the Brundtland Report (WCED, 1987). On the other hand, what sustainability is and *what* has to be sustained is not agreed on in the scientific community (Sala et al., 2013). Sustainability is regarded as a wicked problem, i.e. open to the subjectivity and interpretation of various stakeholders (Meckenstock et al., 2016).

Different definitions of corporate (or business) sustainability coexist in academia. In his review of literature, Montiel (2008) found two distinct ways of defining corporate sustainability (CS) among CS scholars, with a first group adopting an "ecological sustainability" understanding and relating CS with the environmental dimension of business, while the second group adopts a tridimensional definition of CS including economic, social and environmental dimensions. This latter definition relates to the "Triple Bottom Line" (TBL) concept, which implies that companies should achieve economic responsibility, social equity, and environmental integrity (Montiel, 2008), or from a risk perspective, take into consideration financial, social, and environmental risks (Bertels et al., 2010). The TBL concept in business sustainability was found associated with the risk of sidelining ecological aspects, by promoting weaker definitions of sustainability, whereby social, economic and environmental capitals can compensate for each other (Milne and Gray, 2013; Hauschild et al., 2017).

The ecological interpretation of sustainability, which considers that the aim is to "*improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans*" (Goodland, 1995, p.3), has found strengthening in recent scientific work arguing that the maintenance of life-supporting functions is required for economies and societies nested in the Earth system to keep thriving, as shown in Figure 1 (Hauschild et al., 2017). There has been a call in business sustainability literature for further embracing the ecological interpretation of sustainability (Whiteman et al., 2013). The ecological interpretation was adopted as the understanding of sustainability in this PhD project. Hence when referring to "sustainability" hereafter, the emphasis is on environmental aspects.

The relatively newly established Planetary Boundary framework contributes to our understanding that certain thresholds should not be overpassed in order for our societies to remain within Earth's "safe operating space" (Rockström et al., 2009). It implies that the impacting man-made activities overall should remain within certain pressure levels. Hence, from this perspective, sustainability ultimately requires to be addressed at a socio-technical system level and cannot be defined in isolation, at an individual company level (Ceschin and Gaziulusoy, 2016). Yet, companies have a key role to play in the transition towards sustainable societies as introduced in the next sections.

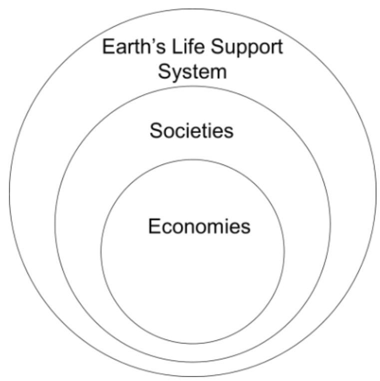


Figure 1. Ecological interpretation of sustainability showing that economies are nested in societies, themselves nested in Earth's life support system, adapted from Hauschild et al. (2017).

1.2 Companies' sustainability approaches

The role of companies in supporting the transition towards sustainable societies has been emphasized by researchers, policy-makers and companies themselves. The PwC 2014 annual Chief Executive Officer (CEO) survey (with around 1300 respondents from various countries) revealed that 75% of CEOs agreed that "*satisfying societal needs (beyond those of investors, customers and employees) and protecting the interests of future generations is important*" (PwC, 2014, p.3) and that 46% of CEOs agreed that *"resource scarcity and climate change megatrends will transform their business"* (PwC, 2014, p.3). The 2010 McKinsey executive survey (with around 2000 respondents from various industries and regions) found that the majority of executives recognized the importance of sustainability challenges, although only 30% indicated proactively seeking opportunities to invest in sustainability or embedding sustainability in business practices (McKinsey, 2010). Renewed attention to the role of businesses in sustainable development is anchored in the UN SDGs (UN, 2015), and more specifically in the UN SDG 12, focusing on production and consumption systems, and for which radical changes are needed, as shown for example by Bjørn et al. (2018) for the challenge of climate change.

Integrating sustainability considerations in business is gaining increased attention in industry due to concerns of policy-makers, other external stakeholders (e.g. customers and Non-Governmental

Organizations), and companies' own agendas related to strategic and market positioning interests (Bey et al., 2013). In this context, companies increasingly develop their own sustainability approaches. An "approach" can generally be defined as the "way of dealing with a situation or a problem" (Oxford dictionaries, 2018). In the context of business sustainability, a sustainability approach can be defined as "the way and method developed by a company for addressing its sustainability challenges".

Companies' sustainability approaches can be researched on different layers, as shown on Figure 2. At the core, sustainability approaches may affect internal organizational functioning through the company organizing and adapting in order to address its sustainability challenges, e.g. implementation of new procedures or training of employees. Companies may develop specific operational sustainability practices which are concrete interventions aimed at mitigating given environmental problems, e.g. a number of eco-labeled products in its portfolio. In the surface layer, companies may deliver narratives of their sustainability approaches, where narratives are defined as "the materials produced by companies themselves and made publicly available in which they describe and explain their sustainability efforts". Sustainability approaches of an individual company should ultimately be understood in its broader business ecosystem, consisted of its suppliers, customers, competitors, regulators and any other stakeholders interacting with that individual company. After defining what is meant by "sustainability approach" and the different layers on which sustainability approaches can be grasped, the next consideration pertains to the different levels on which companies face sustainability challenges which is the object of the next section.

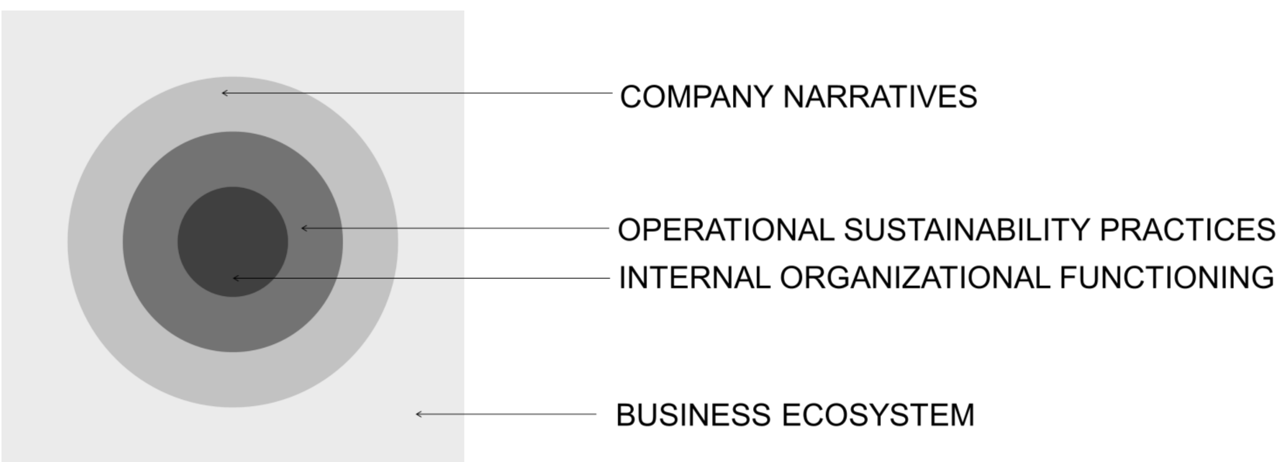


Figure 2. Layers on which a company's sustainability approach can be researched.

1.3 The product's life cycle in focus

From the perspective of a manufacturing company, its given factories may be highly energy-demanding, cause pressures on local biodiversity, and release hazardous wastes which, if not properly handled, could negatively impact surrounding ecosystems. This is the traditional perspective of environmental management. From an alternative perspective, companies may be viewed as the major providers of goods and services, with their embedded LCs, in our economies. Following this perspective, life cycle thinking (LCT) is a frame used by researchers, practitioners and policy-makers to structure our understanding and account for environmental sustainability problems (Heiskanen, 2001; Pennington et al., 2007; Sala et al., 2013). At its core is the interpretation that "*the environmental burden of a product equals the sum of environmental burdens of processes constituting the product system, which is made of physically and energetically linked processes and extends from raw materials acquisition to final disposal*" (Heiskanen, 2001, p. 36). Although factors such as the local energy mix, consumer behaviors and waste management systems influence a product's environmental sustainability performance, the decisions made during the product development activities have typically been considered to determine a large share of a product's environmental sustainability impacts along its LC (Luttropp and Lagerstedt, 2006; McAloone and Bey, 2009; Alänge et al., 2016).

In this light, companies have a key role to play through the development and delivery of goods and services. Such perspective is at the core of ecodesign integration in companies defined as "a proactive management approach that integrates environmental considerations in product development and related processes (e.g. purchasing, marketing and research & development) [and] aims to improve environmental performance of products throughout their LC" (Pigosso et al., 2015). Here "product" is understood in the International Organization for Standardization (ISO) perspective, which includes both goods and services (ISO, 2006). Ecodesign, and its associated *LC perspective* and *product LC optimization*, is the currently dominant way of conceiving product sustainability (Dyllick and Ross, 2017). The growing field of sustainable business design has taken companies' influence on product's environmental sustainability performance one step further through an overarching approach of production and consumption models. Radical innovation in products has been argued to be rarely pulled by users, hence companies having a key role to play in driving new models of production and consumption (Aschehoug et al., 2013).

The market of products labelled as environmentally superior has noticeably been thriving (European Commission (EC), 2018a). In the European Union (EU), regulations such as the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulation and the Restriction of Hazardous Substances (RoHS) directive, as well as the Energy related Products (ErP) and the Waste Electrical and Electronic Equipment (WEEE) directives (Fargnoli et al., 2013). These respectively require the avoidance of substance of concerns (REACH and RoHS), energy efficiency measures (ErP) on e.g., home appliances and motors, and producer extended responsibility measures on electrical and electronic equipment (WEEE) (Fargnoli et al., 2013). Nevertheless, there is an urgent call for more radical changes in production and consumption patterns that would enable a transition towards sustainability.

Empirical studies have shown that companies face challenges to develop and successfully implement proactive ecodesign practices (Short et al., 2012; Pigosso et al., 2013; Poulikidou et al., 2014). The 2011 McKinsey survey of executives (with around 3200 respondents from various sectors, regions and company sizes) found that *"leveraging the sustainability of existing products to find new growth or committing R&D resources to bring sustainable products to market"* was not a main focus area for executives. Else, higher focus was set on increasing energy and material efficiency at the organizational level due to associated cost saving opportunities (McKinsey, 2011). The 2014

McKinsey survey of executives (with around 3400 respondents from various sectors, regions and company sizes) found that a minority of sustainability-leading companies were "*taking more action to manage the LC of their products*" (McKinsey, 2014).

These perspectives show that there are both a high relevance and a challenge in achieving more effective integration of sustainability approaches in industry from product LC perspective, which explains the positioning of this PhD research on the product's LC perspective of sustainability approaches.

1.4 Research delimitation

The landscape of companies is varied and in the business sustainability literature, scholars have typically made a difference between larger and smaller companies on the one hand (Johnson and Schaltegger, 2015), and between incumbent companies (i.e. already established) and new ventures (Boks and McAloone, 2009; Arnold and Hockerts, 2011) on the other hand. Large incumbent companies have been the main focus of existing CS literature (Hockerts and Wüstenhagen, 2010), and are also the focus in this PhD project. Sustainability efforts in incumbent companies have been highlighted as particularly promising considering the breadth of their potential reach, thanks to their established market presence, client base, brand name, quality standards, service systems and potential economies of scale for production and distribution (Vogtländer et al., 2013; Hockerts and Wüstenhagen, 2010). Larger companies are expected to develop overarching sustainability approaches including multiple issues, to rely on management systems, and to have a better overview of their sustainability performance through the use of sophisticated reporting systems (Hockerts and Wüstenhagen, 2010). On the other hand, incumbent companies might lack ambition, be anchored in a "business as usual thinking", and hence remain more conservative in terms of innovation, with a primary focus on leveraging current competencies and existing assets from past investments (Hockerts and Wüstenhagen, 2010; Kennedy et al., 2017).

With this PhD project, I intended to research sustainability approaches from a product LC perspective based on two different layers, namely company narratives and internal organizational functioning, as explained in detail in **Sections 1.4.1 and 1.4.2**, respectively.

1.4.1 Life cycle thinking in company narratives provided in corporate sustainability reports

LCT from the perspective of a product means that all processes necessary for its production, use and disposal are in the scope when optimizing its environmental sustainability performance. Hence, it is a way to conceive product environmental sustainability performance and accordingly address environmental sustainability issues associated with products. LCT has been driven by various industry and policy-making initiatives and been considered to constitute a *shared worldview* of environmental management (Heiskanen, 2001). The use of LCT in industry has been studied through the adoption of the Life Cycle Assessment (LCA) and other LC-based methodologies which operationalize LCT into assessment methodologies (Frankl and Rubik, 2000; Rex and Baumann, 2007; Häkkinen et al., 2013), and more sparsely, through investigations of life cycle management (LCM) practices in companies (Remmen et al., 2007; Holgaard et al., 2007; Nilsson- Lindén et al., 2018a). Yet, the extent to which LCT is actively used in industry to guide sustainability approaches remains unclear. Increasing such knowledge is critical, as the non-addressing of multiple interpretations of sustainability in a business context could be an obstacle to the achievement of sustainability transitions (Lankoski, 2016). Company narratives were chosen as a layer to explore the extent to which LCT is present in sustainability approaches in industry. There are different channels through which companies can provide narratives of their sustainability efforts, e.g. advertising campaigns, interviews, websites and press releases. Among these, one channel increasingly used by companies to describe their sustainability efforts is the sustainability report (Kolk, 2003; Lozano, 2012; Siew, 2015; KPMG, 2015). These reports can take the form of "corporate sustainability reports", "citizenship reports", and "Corporate Social Responsibility (CSR) reports", among other appellations (Roca and Searcy, 2010; Kolk, 2010) and aim "*to provide internal and external stakeholders with a picture of corporate position and activities on economic, environmental and social dimensions*" (Heemskerk et al., 2002, p.7). These reports will be referred to as corporate sustainability (CS) reports hereafter.

Appraisal of CS reporting in academia is divided. On the one side, critical perspectives question the extent to which CS reporting genuinely addresses sustainability issues and presents substantive actions from companies, and emphasize the role of symbolic disclosures aimed at strengthening corporate image and reputation (Hopwood, 2009; Hrasky, 2011; Milne and Gray, 2013; Tregidga et al., 2014; Gold and Heikkurinen, 2018). On the other side, managerial perspectives emphasize that CS reports play both external and internal roles (Pérez-López et al., 2015). From an external perspective, CS reporting is an instrument used by ranking agencies and investors to assess and compare CS efforts in industry (Herzig and Schaltegger, 2006). From an internal perspective, CS reporting has been found to serve as guidance to initiate sustainability work at companies (Hedberg and von Malmborg, 2003), to improve employee awareness and engagement by legitimating the company, celebrating progress, and bringing visibility of employee activities (Searcy and Buslovich, 2014), and to go hand in hand with organizational change for sustainability in a mutually reinforcing process (Lozano et al., 2016).

A third perspective on CS reports can be found in Mikler's (2007, p. 13-14) view: *"What these reports do represent is the culmination of the efforts of teams of people qualified in, and tasked with, the presentation of information that casts their firm in the best possible light. There are therefore two important reasons for examining environmental reports. First, these reports reveal what firms […] perceive as constituting 'the best possible light'. What do they see as most convincing and brand-enhancing for their readerships? What do they think will inspire confidence? What do they think will convince readers that they are a firm committed to environmental concerns and acting on them? These reports thus present firms' understanding of how their environmental strategies should be 'best' presented. Secondly, because considerable effort goes into publishing a written report, it presents what each company believes to be its key messages. While it is true that all the firms examined here have websites that contain environmental information, these are updated regularly and change over time. However, a written report endures and presents, in one comprehensive document, the activities a firm believes are most important to communicate for the period it covers."* Such view also echoes Perrini's (2005, p. 612) claim that "*reporting-based analyses represent the right way towards an overall comprehension of what practitioners consider efficient and appropriate socially responsible behavior*". From these perspectives, CS reports can be appraised as unobtrusive (i.e. produced without the intervention of a researcher (Bowen, 2009)) “entry points” on companies’ understanding of how their sustainability efforts should be “best” presented.

Departing from the first released corporate environmental reports in the early 1990s, CS reporting has since then become mainstream practice for large companies across the world (Kolk, 2003; Kolk, 2010). The annual number of released CS reports has almost tripled between 2007 and 2016 (CR, 2018a). The 2017 KPMG survey reported that across the world, 72% of the largest companies in their home countries released a CS reports in 2017, against 41% in 2005 (KPMG, 2017). Moreover, each sector was found to have a 2017 CS report release rate above 60%, which shows that CS reporting practice is spread in all types of industries (KPMG, 2017). The number of companies publishing CS reports has recently been proposed as an indicator to monitor the target, under UN SDG 12, to *“encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle”* (UN, 2017, p.16). The publication of non-financial information is increasingly required through regulations in different parts of the world (KPMG, 2015; EY and GRI, 2014), e.g. the European Directive 2014/95/EU (EC, 2014), the Environmental Protection Law of the People’s Republic of China (WBCSD, 2018) and the King II report in South Africa (Stolowy and Paugam, 2018).

CS reports provide high-level, one-sided, senior management-approved, narratives of companies’ sustainability efforts meant for public availability. They deliver insights on how companies understand their sustainability efforts should be best presented and hence contain concepts and reasoning lines considered critical by the companies’ themselves for their official communications. Moreover, the growing body of CS reports and relative time and resource efficiency of using document analysis as a research method in comparison with field methods makes it possible to capture companies’ narratives of sustainability approaches at the scale of sectors and geographical regions. From these perspectives, studying the presence of LCT in CS reports enables appraising the prominence of the concept in the sustainability agenda of broad samples of companies. Hence, the first research question which guided this PhD work is:

- **RQ1: To what extent is life cycle thinking present in company narratives of their sustainability approaches provided in corporate sustainability reports?**

1.4.2 Ecodesign integration in formal and informal organizational functioning

Since the call by Baumann et al. (2002) for ecodesign literature to focus less on tool development, and more on implementation aspects and change in organizations, research has been conducted in this direction (Boks and McAloone, 2009). Concretely, scholars have developed frameworks to support the integration of ecodesign aspects in business organizations, e.g. in project management (Brones et al., 2014; Bonou et al., 2016; Hallstedt and Pigosso, 2017), at different decision-making levels (operational, tactical and strategic – (Brones et al. 2017)), and in business procedures and strategy (Pigosso et al., 2013). Since 2011, the ISO 14006 standard provides guidance for the implementation of ecodesign in companies as a management system (Arana Landín et al., 2011; Landeta-Manzano et al., 2015). Yet, many of the challenges experienced by companies relate to their internal organizational functioning, e.g. lack of integration in existing processes, communication issues, and resistance associated with human factors (Dekonink et al., 2016; Verhulst and Boks, 2012a), hence there is a need for further investigating and supporting ecodesign integration in companies' internal organizational functioning.

Until now approaches have mainly focused on formal aspects of organizations, i.e. "the structures, processes, systems which are designed to motivate and facilitate individuals in the performance of organizational tasks" (Nadler, 1981). Although instrumental to support ecodesign integration in companies, a primarily formal approach was found (i) to neglect sociological, psychological, and emotional factors (Boks, 2006); (ii) to somewhat naively overemphasize top-down cascading of "organizational greening" to the detriment of deeper understanding of organizational cultures (Harris and Crane, 2002); and (iii) to overlook the managerial styles of modern organizations, where command-and-control mechanisms are to be complemented with increasing team autonomy (Brones et al., 2017). More recently, informal aspects of organizations, i.e. the "patterns of communication, power, and influences, values and norms which characterize how an organization actually functions" (Nadler, 1981), have started to come into focus together with formal aspects in ecodesign integration research (Epstein and Buhovac, 2010; Verhulst and Boks 2012a; Brones and Monteiro de Carvalho, 2015; Skelton et al. 2016; Brones et al. 2017; Sroufe, 2017). However, there is a need to strengthen these recent developments by further exploring integration frameworks which enable embracing formal *and* informal aspects of internal organizational functioning.

During my masters' studies, I came across and used a framework from the general management literature whose aim is to investigate and act in organizations through different perspectives covering both formal and informal aspects of organizations. This framework, called "the four-lens view of organizations" and developed by Bolman and Deal (2008), combines four groups of management theories depicting organizational functioning from different perspectives. Organizations are viewed on the one hand as *formal* structures designed to fulfill a given mission, applying specific procedures, systems, and roles corresponding to a "structural lens". On the other hand, firms are *informal* communities where employees have needs, aspirations, preferences and fears ("human lens"), personal or group agendas with possibly conflicting objectives ("political lens"), as well as a shared understanding of "how things work around here" (e.g. habits and routines) ("symbolic lens"). The idea behind the four-lens view is to support managers, leaders and change agents (i.e. employees driving change) in organizations through the use of reframing, i.e. using the different lenses of organizations in order to better understand complex situations, identify levers and adopt relevant courses of action.

Because it was originally designed as a framework to uncover and address the richness of organizational functioning with a focus on formal (structural lens) and informal aspects (human, political and symbolic lenses), the four-lens view of organizations was considered as a relevant candidate conceptual framework for investigating and supporting ecodesign integration in internal organizational functioning. From this perspective, the second research question which guided my PhD research is:

- **RQ2: To what extent can the four-lens view of organizations help investigating and supporting ecodesign integration in formal and informal organizational functioning of companies?**

This second part of my PhD project was conducted in collaboration with Faheem Ali (co-tutelle PhD student) who addressed a complementary research gap identified in existing literature, namely the lack of accounting for companies' contextual specificities in investigation and support of ecodesign integration. His research departed from the observation that existing academic studies of ecodesign integration have tended to focus on uncovering common success factors (Johansson, 2002), common challenges (Deutz et al., 2013; Alblas et al., 2014; Poulikidou et al., 2014) and to elaborate general integration frameworks (e.g. Ritzén and Beskow, 2001; Handfield et al., 2001; Pigosso et al., 2013; Brones and Monteiro de Carvalho, 2015). On the other hand, several scholars called for more attention to the specific context of companies (Kivimaa et al., 2008; van der Heijden et al., 2010; Verhulst and Boks, 2012b; Domingo et al, 2015; Alänge et al., 2016). Faheem identified the concept of "persona" from the design literature as a candidate conceptual framework to understand companies' specificities factoring in ecodesign integration efforts. User personas are developed by designers to draw pictures of the users whose needs will be addressed by a given good or service. Main advantages of personas are their ability to place the user at the center of the stage, bring the focus on a set of priorities, avoid false assumptions about users or self-referential assumptions before the design process starts, and create empathy for users among designers (Miaskiewicz and Kozar, 2011). Building on an analogy between users and companies, the elaboration of company personas in the context of ecodesign integration was intended to understand companies' contexts before providing tailored recommendations for ecodesign integration. Outcomes from this complementary research are included in this thesis under the form of a draft manuscript (**Article VI**) and will be discussed in the perspective of **RQ2 (Section 4.6)**.

1.4.3 Overview of research delimitation

Figure 3 illustrates the research delimitation of this PhD project, its focus on the product LC perspective, and the specific research questions which guided the research. This PhD project did not address the layer of operational sustainability practices, i.e. what the company does from an operational perspective to tackle the identified challenges. In the context of product environmental sustainability approaches, this would mean for example design for light weight, material choice, or business model design. As it ultimately determines the extent to which companies contribute to sustainability, this layer is critical to research for the total picture, at the scale of specific sectors or companies because of its high context specificity. However, the focus of my PhD project on company narratives and internal organizational functioning was made in accordance with the project's angle to address sustainability approaches from a broad perspective in terms of industry and company contexts, as opposed to an in-depth investigation of sustainability challenges in one specific sector or company-context.

Moreover, in this PhD project I took the perspective of individual companies, as opposed to a business ecosystem perspective, in which suppliers, customers, competitors, regulators and other stakeholders would be in equal focus. As part of the total picture, the business ecosystem is another key layer to be researched because companies' sustainability trajectories can barely be understood in isolation of the institutional context they belong to (Larrinaga-Gonzales and Bebbington, 2001; Harris and Crane, 2002). Current infrastructures, regulations, and competitors' behaviors influence companies' sustainability approaches, and sustainability challenges need to be addressed at the social-technical level, hence requiring collective systemic approaches with cooperation across supply chains, within and across sectors (Whiteman et al., 2013; Ceschin and Gaziulusoy, 2016). Yet, taking an individual company's perspective in this PhD project was considered relevant as a building block of broader investigations, and was motivated by existing literature highlighting that internal aspects of companies are particularly relevant to address in ecodesign integration (Boks, 2006; Murillo-Luna et al., 2011; Dekoninck et al., 2016).

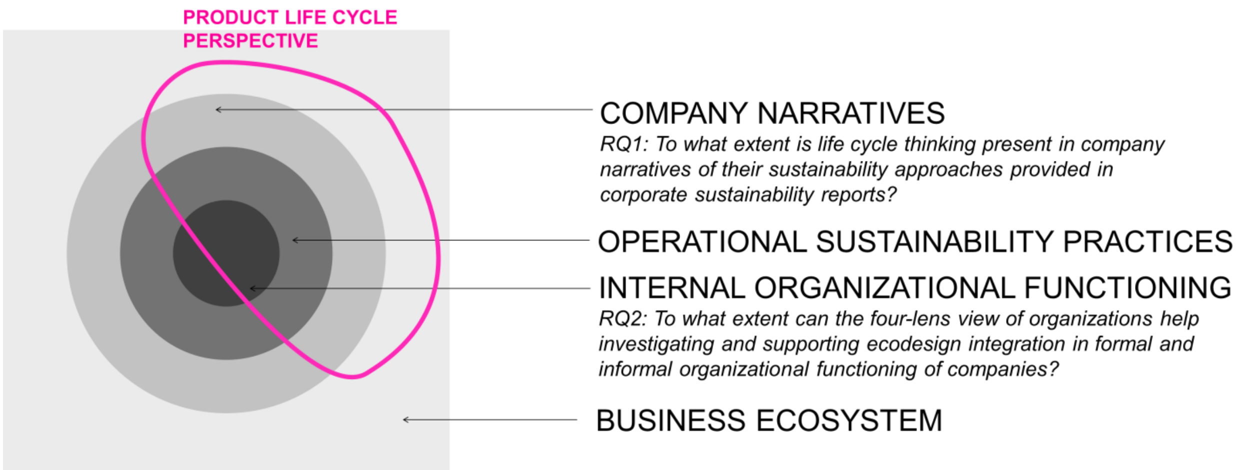


Figure 3. Research delimitation in this PhD project.

2 Research approach

Chapter 2 provides (i) an understanding of the research paradigm and (ii) a general overview of the research design adopted in this PhD project.

2.1 Research paradigm

In every research project, it is important for the researcher to reflect on her/his assumptions about knowledge creation and how knowledge relates to reality, in other words to make explicit the research paradigm. For example, positivists posit that reality is unique and can be approached objectively, while interpretivists consider that exchanges between the inquirer and the inquired are subjective, and hence plural realities may coexist since they are the resultant of specific interpretations (Krauss, 2005). From a third perspective, realists consider that multiple interpretations coexist of a single reality which does not depend on the one who is thinking it (Krauss, 2005).

Anchored in the field of business sustainability, this PhD project is *per se* positioned at the frontier between organizational science and environmental science. Although, as outlined in **Chapter 1**, multiple interpretations of sustainability coexist in academic literature and in practitioner approaches, the definition adopted in this project, namely that of ecological sustainability, positions this PhD work on a positivist stance as a start. Indeed, it implies that the endeavor of environmental scientists is to make ecological sustainability tangible so that unsustainability thresholds can be calculated and targets established on different levels. On the other hand, the role of companies in improving the environmental sustainability performance of their products' LCs is acknowledged as the result of a convention which has made LCT a dominant approach among scholars and policy makers (although not all academic work on sustainability make reference to LCT (Sala et al., 2013)). Furthermore, the second research question focusing on organizations beyond their formal aspects (i.e. processes, goals, systems, written rules) and towards a stronger embracement of their informal functioning leads the project towards the other end of the spectrum, where much is opened to individual interpretations. Overall, in this project, the need for our societies to transition towards sustainability, and for companies to contribute to achieving such transitions, is acknowledged as an objectively defined purpose. Yet, the present aim is to uncover companies' interpretations of sustainability in their context and study their organizational functioning beyond functionalist views where individuals would respond in deterministic ways (Rex and Baumann, 2008). Hence, this project leans towards an interpretive approach, which is actually called for in academic literature on LC approaches in companies (Rex and Baumann, 2008).

Additionally, it is important to reflect on the positioning of this PhD project within the spheres of qualitative and quantitative research. The main difference between quantitative and qualitative research designs is the type of assumptions they have about how knowledge is created (Trochim, 2006). Embedded in the first track of the project is the idea to uncover the extent to which LCT shapes sustainability approaches among companies, hence hypothesizing that companies' behaviors can be aggregated at the scale of e.g. sectors or regions, and announcing for a quantitative research approach. Yet, even if there was an interest in this project in building industry overviews of sustainability approaches, the underlying reason for doing so was the highlighted need for increasing our understanding of companies' appraisal and prioritization of their sustainability challenges. Thus, a balance between quantitative measures, which allowed a mapping of trends, and a qualitative approach, which enabled collecting details of companies' rationales was sought in the first track of this PhD project. In the second track of the project, the aim was to "*become more experienced with the phenomenon*" of interest as the intention was to take a deeper dive into the reality of organizational functioning, outlining the importance of the context and searching for details rather than aiming for immediate generalizability (Trochim, 2006). In these perspectives, the second track relied on a qualitative research design.

2.2 Research design

Figure 4 provides a general overview of the research design adopted in this PhD project, and positions the appended articles along the research design. From the formulation of two research questions defining the two main tracks around which the project was articulated, the research activities within each track were organized into background steps and main research steps, whose combination enabled answering the research questions, discussing the results, as well as highlighting theoretical contributions and practical recommendations.

In the first track, the background steps consisted of (i) gaining sufficient insights of CS reporting as a corporate practice (**background 1**) and (ii) building an overview of existing academic studies which built on analyses of CS reports (**background 2**). The main research steps consisted of four studies exploring different aspects of LCT presence in CS reports (**empirical studies 1-4**). In the second track, the background steps consisted of (i) providing a description of the four-lens view of organizations as a conceptual framework (**background 3**), and (ii) reviewing existing applicative studies of the framework in order to gain a deeper understanding of its relevance for investigating and supporting organizational studies in general, and ecodesign integration specifically (**background 4**). The main research steps were articulated around exploring (i) the relevance of using the four-lens view as a conceptual framework to investigate ecodesign integration in companies, i.e. focusing on the "*investigating*" part of **RQ2** (**conceptual study 1** and **empirical study 5**), and (ii) the practical value of the four-lens view as a framework to support ecodesign integration activities in companies, i.e. focusing on the "*supporting*" part of **RQ2** (**conceptual study 2** and **empirical study 6**). Specific methodological aspects for each research step embedded in this project are described in the related sections (see Table 1).

Quality of research design is important to consider in any research project and is typically appraised in the form of validity and reliability. Validity refers to "*the precision in which the findings accurately reflect the data*" (Noble and Smith, 2015, p.34). Reliability refers to "*the consistency of the analytical procedures, including accounting for personal and research method biases that may have influenced the findings*" (Noble and Smith, 2015, p.34). In the different research activities embedded in this PhD project, validity was enhanced by (i) using a combination of deductive approaches, based on existing conceptual frameworks (**conceptual studies 1-2** and **empirical studies 5-6**) or conceptual frameworks derived from existing knowledge (**empirical studies 1-4**), and inductive approaches (**conceptual study 1**, **empirical studies 1-6**); (ii) using multiple data sources (**conceptual studies 1 and 2** based on literature, and **empirical studies 5 and 6** based on empirical data); and (iii) giving participants involved the opportunity to comment on the results (**empirical study 5**). Reliability was enhanced by (i) ensuring transparency of the data and research process (**conceptual studies 1-2** and **empirical studies 1-6,** through quotes and transparency of research process); and (ii) using researcher triangulation (**empirical studies 1, 3-6**, yet to be completed for **empirical study 2** before submission of the related **Article II** to a scientific journal). Transcripts of **empirical studies 5 and 6** are remained undisclosed due to confidentiality agreements with the involved case companies.

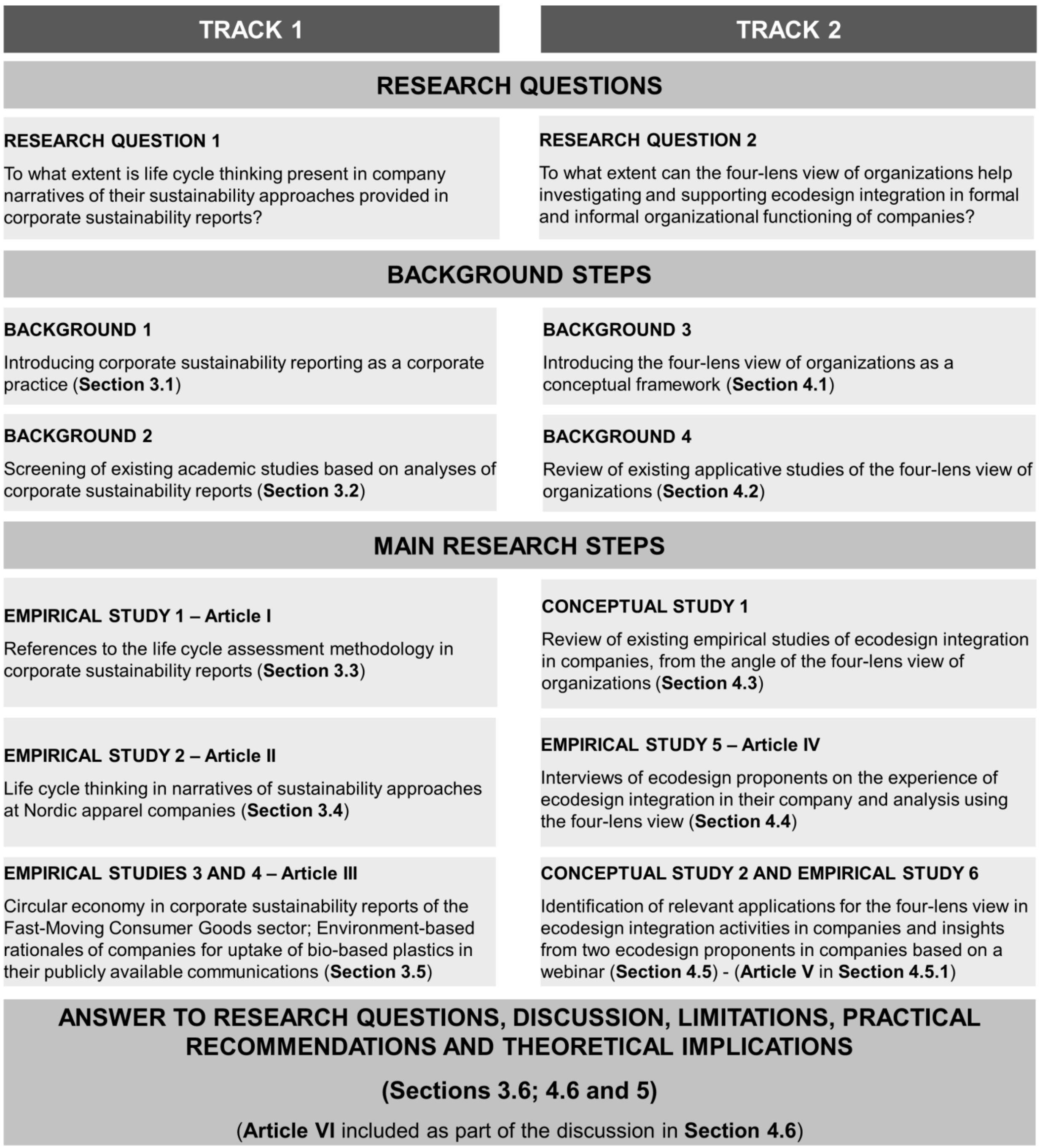


Figure 4. Overview of research design.

Table 1. Research steps and related methodological sections in this thesis. CS = Corporate Sustainability; FMCG = Fast-Moving Consumer Goods. Background 1 and 3 are not included in the table because they did not require specific methodological steps.

Research steps	Related methodological sections
Research question 1	
Background 2	Section 3.2.1
Empirical study 1	Section 3.3.1
Empirical study 2	Section 3.4.1
Empirical study 3	Section 3.5.1.1
Empirical study 4	Section 3.5.2.1
Research question 2	
Background 4	Section 4.2.1
Conceptual study 1	Section 4.3.1
Empirical study 5	Section 4.4.1
Conceptual study 2 and empirical study 6	Section 4.5.2

3 Life cycle thinking in companies' narratives of their sustainability approaches provided in corporate sustainability reports (RQ1)

In **Chapter 3**, I present the different research steps conducted during my PhD project in order to address **RQ1**: "*To what extent is life cycle thinking present in company narratives of their sustainability approaches provided in corporate sustainability reports?"* The structure of **Chapter 3** is illustrated in Figure 5.

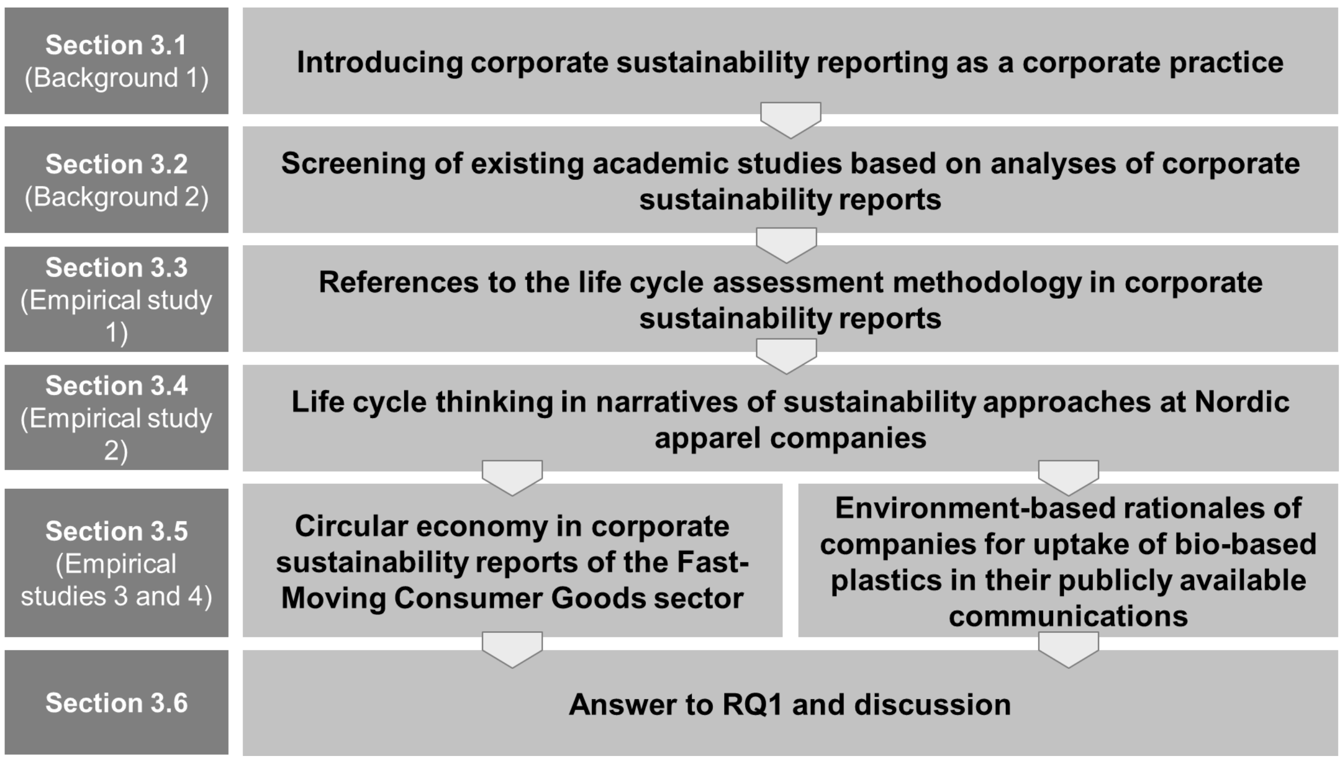


Figure 5. Structure of Chapter 3.

In **Section 3.1**, I describe CS reporting as a corporate practice, based on the knowledge I gained from readings throughout this PhD project (**background 1**). I particularly highlight insights on companies' motivations to release CS reports, factors influencing the process of producing CS reports, and views of external users of CS reports and scholars on CS reporting. This section particularly aims to elicit the *"purpose of [the] document, the context in which it was produced, and the intended audience",* which are critical aspects to consider before analyzing documents (Bowen, 2009, p.38). In **Section 3.2**, I describe the literature screening conducted to identify the purposes for which earlier scholars have analyzed CS reports, and especially the extent to which CS reports have been analyzed to explore sustainability approaches of companies from a product LC perspective (**background 2**). In **Sections 3.3 to 3.5**, I present the empirical studies which contributed to answering **RQ1**. In **Section 3.3**, I describe **empirical study 1** in which references in CS reports to the LCA methodology, as one way to operationalize LCT, were investigated (**Article I**). In **Section 3.4**, I present **empirical study 2**, in which the extent to which Nordic apparel companies rely on LCT in their sustainability approaches as narrated in their CS reports was investigated (**Article II**). In **Section 3.5**, I describe two additional studies which provided relevant insights to answer RQ1: **empirical study 3**, in which the uptake of the concept of Circular Economy (CE) by companies in the Fast-Moving Consumer Goods (FMCG) sector as described in their CS reports was explored (**Article III**); and **empirical study 4** which investigated how the uptake of bio-based plastics in industry was motivated from an environmental perspective by companies based on their publicly available communications. **Empirical study 4** was based and expands the co-supervised work of a master student's final project (Jonas, 2018). Finally, in **Section 3.6**, I summarize the findings of these different research steps and discuss the latter in the perspective of **RQ1**.

3.1 Introducing corporate sustainability reporting as a corporate practice (background 1)

3.1.1 Companies' motivations for corporate sustainability reporting

The stakeholder theory, signaling theory, legitimacy theory, and to a some extent the institutional theory (explained hereafter), have been utilized to explain the adoption of CS reporting from an external perspective by earlier scholars, as reported in the review of literature conducted by Hahn and Kühnen (2013). From the stakeholder theory perspective, companies are considered to engage in CS reporting practices in order to answer the concerns of influential stakeholders impacting their business (Hahn and Kühnen, 2013). From the signaling theory perspective, companies would engage in CS reporting practices to correct an information asymmetry by proactively and credibly delivering insights on their sustainability performance (Hahn and Kühnen, 2013). Both these theory are related to the legitimacy theory, according to which companies need to keep their social license to operate (i.e. acceptance by the society) to be able to survive. In such light, CS reporting helps addressing the legitimacy gap created by increasing sustainability concerns among stakeholders through demonstrating the company's engagement (Hrasky, 2011). From the institutional theory perspective, companies would tend to engage in CS reporting because of normative (i.e. expectations from stakeholders), coercive (i.e. regulations) or mimetic (i.e. influence from peers) pressures (Searcy and Buslovich, 2014). Extending the perspective of legitimacy theory from a corporate communication perspective, Hooghiemstra (2000) suggested that CS reporting is used by companies as an impression management tool to improve corporate reputation.

Empirical studies reported that companies' perceived motivations for CS reporting are based on a combination of internal and external motives, which are compiled in Table 2, and whose balance varies from one company to the other (Adams and Frost, 2008; Husillos et al., 2011; Pérez-Lopez et al., 2015). In a recent survey, to which mostly large European companies from various sectors responded, Lozano et al. (2016) found that before their first CS report release, companies had strong internal drivers and among their objectives to assess their sustainability efforts, improve their sustainability performance, foster stakeholder dialogue and change towards CS, and raise employees' awareness, whereas subsequent releases were related to both internal and external drivers.

Other studies focused on uncovering the rationales of companies which chose not to release CS reports. In their survey of UK companies, Solomon and Lewis (2002) found that a reluctance to provide sensitive information and a lack of regulatory pressures were disincentives for CS reporting. In their study of Australian companies, Stubbs et al. (2013) found that a lack of external stakeholder pressures or the availability of more efficient ways to address them (than CS reporting), no perceived benefits from producing CS reports and a compliance culture discarding the need for broader reporting (especially at mining companies) were mentioned as reasons against CS reporting.

Table 2. Overview of internal and external motivations of companies for corporate sustainability reporting found in earlier empirical studies, adapted from Pérez-Lopez et al. (2015).

Internal motivations	**Sources**
Initiate sustainability work	Hedberg and von Malmborg (2003)
Foster change towards sustainability	Lozano et al. (2016)
Improve risk management	Pérez-Lopez et al. (2015)
Identify strategic opportunities	Pérez-Lopez et al. (2015)
Improve operational performance (inform resource allocation decisions and cost reduction strategies)	Pérez-Lopez et al. (2015)
Improve processes and collaboration across functions	Hedberg and von Malmborg (2003); Pérez-Lopez et al. (2015)
Build legitimacy for sustainability work	Hedberg and von Malmborg (2003)
Increase awareness of sustainability	Pérez-Lopez et al. (2015); Lozano et al. (2016)
Motivate employees (celebrate progress, and bring visibility of employee activities)	Searcy and Buslovich (2014); Pérez-Lopez et al. (2015)
Enhanced ability to track progress against specific targets	Searcy and Buslovich (2014); Pérez-Lopez et al. (2015); Lozano et al. (2016)
Innovation and learning	Hedberg and von Malmborg (2003); Pérez-Lopez et al. (2015)
Internal management tool	Adams and McNicholas (2007)
External motivations	
Demonstrate compliance with local regulations and public norms	Solomon and Lewis (2002); Searcy and Buslovich (2014); Pérez-Lopez et al. (2015) ; Lozano et al. (2016)
Provide transparency to a range of stakeholders (with increasing concerns)	Hedberg and von Malmborg (2003); Searcy and Buslovich (2014); Dobbs et al. (2016); Husillos et al. (2011); Pérez-Lopez et al. (2015); Lozano et al. (2016)
Foster a stakeholder dialogue	Lozano et al. (2016)
Competitors' CS reporting practices (benchmark)	Husillos et al. (2011); Searcy and Buslovich (2014)
Reputational benefits and credibility	Solomon and Lewis (2002); Adams and McNicholas (2007); Pérez-Lopez et al. (2015); Lozano et al. (2016)
Ability to communicate efforts	Searcy and Buslovich (2014); Pérez-Lopez et al. (2015); Lozano et al. (2016)
License to operate, legitimacy	Hedberg and von Malmborg (2003); Pérez-Lopez et al. (2015)

3.1.2 Corporate sustainability reporting process

There has been relatively little research focusing on the development of CS reports in companies (Searcy and Buslovich, 2014). In order to decide on the content of CS reports, companies were found to rely:

- on standards and reporting guidelines (Adams and McNicholas, 2007; Searcy and Buslovich, 2014);
- on the conduction of internal evaluation based on internal dialogue or formalized in a materiality analysis (Searcy and Buslovich, 2014);

- on benchmarking other reports (Adams and McNicholas, 2007);
- on mapping stakeholders and gathering their requests (Hedberg and von Malmborg, 2003; Searcy and Buslovich, 2014);
- on taking into account opinions of experts, such as stock exchange analysts and thematic business associations (Husillos et al., 2011).

The involvement of stakeholders was found to vary among companies (Searcy and Buslovich, 2014; Lozano et al., 2016). Managers' individual proactivity and perceptions were reported to shape the reporting process, and the extent and quality of reporting (Adams, 2002; Adams and McNicholas, 2007; Husillos et al., 2011). The data collection and writing of CS reports were found in majority handled internally (Searcy and Buslovich, 2014) and led by sustainability departments (Searcy and Buslovich, 2014; Lozano et al., 2016). In their study of a large Swedish retailer, Frostenson and Helin (2017) found that low involvement of top management in the CS reporting process opened up for individuals' preferences and opinions about what how the CS report should look like.

Adams and Frost (2008) observed different attitudes related to CS reporting, with on the one hand, companies primarily concerned with the internal process and developing the appropriate culture, and on the other hand, companies primarily focusing on reporting as a means of communication to external stakeholders. In their study of Dutch companies, Thijssen et al. (2016) revealed that the internal organization for CS reporting varied a lot from one company to another in terms of degree of formality of the process (group of enthusiast people versus formalized organizational structure), and of integration of sustainability in the day-to-day activities (emergent versus formulated strategy). According to the authors' typology of reporters, improvisers have an informal reporting process and no integration of sustainability in their day-to-day activities and sustainability reporting is "one of the very few instances in which the company's sustainability management is made explicit" (Thijssen et al., 2016). On the other extreme, performers have a formal reporting process and high integration of sustainability in their daily activities. Thijssen et al. (2016) further reported that based on the sole observation of CS reports, it was difficult to differentiate between different profiles of reporters.

A number of challenges associated with developing CS reports were reported in literature, including:

- a lack of experience and knowledge (Adam McNicholas, 2007; Lozano et al., 2016);
- difficulty to obtain top management commitment (Lozano et al., 2016);
- difficulties of data collection due to coordinating the collection of information from multiple parts of the company (or even value chain);
- lack of resources (Searcy and Buslovich, 2014; Lozano et al., 2016),
- tight timelines, difficulties related to what to communicate, e.g. finding an appropriate balance between positive and negative news, making sure that the report is "digestible" and readable, keeping the report concise while fitting information addressing all stakeholders' needs, and complying with external guidelines (Searcy and Buslovich, 2014; Lozano et al., 2016).

CS reporting has been increasingly standardized in industry. The Global Reporting Initiative framework, driven by the World Business Council for Sustainable Development, is considered most influential in the industry with visibility in press and professional/trade publications and policy debates

(Brown et al., 2009; KPMG, 2015; Siew, 2015). Other approaches have been developed, for instance, the integrated reporting framework driven by the International Integrated Reporting Council (IIRC) seeks to bring closer business and sustainability perspectives and measures in organizations (Stacchezzini et al., 2016) and the North American initiative by Sustainability Accounting Standards Board (SASB) with a focus on disclosure of “financially material information” for an audience of investors (SASB, 2018). Other approaches address specific environmental sustainability issues, e.g. the Carbon Disclosure Project (CDP) provides a framework and platform for disclosures related to climate change and water use, on top of standalone CS reports produced by companies (CDP, 2018).

3.1.3 Insights from external users of corporate sustainability reporting

The actual use of CS reports by stakeholders has been understudied and thus remains unclear (Fifka, 2012; Searcy and Buslovich, 2014). External rating agencies and investors use CS reports as part of a broader set of data sources in order to assess and rank companies’ CS performance, e.g. the Dow Jones Sustainability Index (DJSI) (Herzig and Schaltegger, 2006; Brown et al., 2009; Searcy and Elkhawas, 2012). In their study of online requests of CS reports, Rowbotton and Lymer (2009) found that standalone CS reports attracted a limited number of requests, with a preference of investors and other financially-oriented bodies for annual reports. A rather low interest from mainstream investing institutions, apart from the socially responsible investment community, for non-financial performance data was reported by Brown et al. (2009). Despite standardization efforts, the large content diversity in CS reports of companies adopting the GRI guidelines was reported by scholars (Guthrie and Farneti, 2008; Roca and Searcy, 2012; Boiral and Henri, 2017; Zsóka and Vajkai, 2018), which is likely to diminish their comparability and utilization for benchmarking and rankings of companies (Langer, 2006). Brown et al. (2009) reported a low use of CS reports by NGOs and consumer associations among other civil society organizations, related to a lack of information usefulness because of e.g. low level of details, low focus on performance, lack of insights on the plans behind the numbers, and too excessive and unfocused information. Bradford et al. (2017) found a disconnection between issues discussed by companies in their CS reports and topics of concern among consumers.

Bartels et al. (2008) reported the results of a survey of GRI reports' readers, with more than 2000 respondents belonging mostly to businesses, consultancy, the civil society and academia. The survey revealed that CS reports were used to understand the company’s approach to sustainability by more than 60% of the respondents. The survey provided further indications of what the readers would expect to find in "good reports":

- a link between sustainability strategy and overall business strategy,
- commitment to sustainability, sustainability impact of the organization (direct and indirect),
- actions taken to address sustainability issues,
- innovative thinking,
- and translation of sustainability into (local) business.

In a survey conducted in the South African context (54 respondents including investment funds, environmental NGOs, and environmental reporting researchers), Kamala et al. (2016) found similar expectations from CS reports’ users:

- disclosure of both negative and positive aspects in a balanced manner,
- identification and description of key relevant issues (significant aspects),
- specificity and accurate information,
- provision of future-oriented information,
- identification and addressing of key stakeholders and their concerns,
- demonstration of integration of environmental issues into core business processes,
- and comparison of quantitative outputs/impacts against best practice /industry standards.

3.1.4 Views of corporate sustainability reporting among scholars

The extent to which CS reporting represents actual CS practices and substantive changes at companies has been in the center of an academic debate (Kolk, 2003). Burrit and Schaltegger (2010) classified the two main attitudes of scholars towards CS accounting (including CS reporting) under the "critical path" and the "managerial path". The critical path negates the ability of CS accounting to effectively address sustainability issues, while the managerial path sees the potential of CS accounting as a basis for a problem solving exercise, namely to support the transition of businesses towards sustainability (Burritt and Schaltegger, 2010). This dichotomy has also been summarized by Larrinaga-Gonzales and Bebbington (2001) who distinguished the "organizational change" from the "institutional appropriation" position:

"The first suggests that organizations can and do change in substantive ways when they respond to the environmental agenda and that environmental accounting is part of the process of enabling these organizational changes. In contrast, the second position posits that organizations will not change in response to environmental demands. Rather, they will change the environmental agenda itself in order to ensure that organizational activities can carry on as before." (Larrinaga-Gonzales and Bebbington, 2001, in abstract)

In the critical path, CS reporting has been recurrently criticized by scholars for different reasons. Several scholars argued that companies tend to use CS reporting in a symbolic approach, rather than a substantive approach (Hopwood, 2009; Tregigda et al., 2014; Stacchezzini et al., 2016; Deegan, 2017). According to this critique, companies make use of CS reporting to shape their corporate image but do not contribute with any actual change or initiatives. Further, companies were found to avoid communicating negative information (Boiral, 2013), and to increase their reporting of environmental information favorable to their corporate image in case of prosecution for environmental breach (Deegan and Rankin, 1996).

Another aspect often questioned by scholars is the ability of companies to use CS reporting as a real analytical exercise, to truly explore the relationships between their activities and Earth's eco-systems and seek to develop sustainable approaches, as opposed to falling into an "evaluatory trap" of using a ready-made set of disclosure items to be filled in with figures (Dumay et al., 2010). Among other critiques are also a lack of self-criticism in disclosures, e.g. no explicit tradeoffs, assumptions and uncertainties, and the absence of a discussion in the perspective of eco-systems' carrying capacities (Fonseca et al., 2014; Bjørn et al., 2017). Herzig and Schaltegger (2006) discussed the impact of external drivers related to awards and ratings on the mindset of managers responsible for CS reporting in firms. They argued that managers would then tend to adopt an outside-in perspective which consists in *“[structuring] the company’s sustainability reporting on the basis of the criteria applied by rating agencies, ranking schemes, and published guidelines”* (p. 316), to the detriment of an “inside-out” perspective in which an analysis of the company’s situation comes first.

On the other hand, scholars have reported that CS reporting was considered by companies as a means for organizational change in favor of sustainability (Husillos et al., 2011; Lozano et al., 2016). Lozano et al. (2016, p.180) highlighted that *“sustainability reporting and organizational change management for sustainability have reciprocal reinforcing relationships, where sustainability reporting provides a starting point for planning organizational change for sustainability and organizational change for sustainability improves the reporting process”*. Yet, the respondents to their survey in majority answered that CS reporting had only facilitated minor changes in some part of the company (Lozano et al., 2016). In their study of Swedish companies, Hedberg and von Malmborg (2003) found that using the GRI guidelines was a means for companies to initiate proactive sustainability work by enabling them to learn about themselves, and about what they had done so far, by fostering communication and collaboration between departments, and by legitimating sustainability efforts in the organization. Searcy and Buslovich (2014) found that companies used CS reports to monitor progress towards goals. Pérez-Lopez et al. (2015) argued that at internally-driven companies, CS reporting strengthened sustainability management practices by increasing internal awareness and providing useful measures for strategy evaluation; while at both internally and externally-driven companies, CS reporting could shift from a measurement tool to a strategic management tool. Adams and McNicholas (2007) found that the process of CS reporting had been a learning process for senior management and the team in charge of the development of the report, and had led the case company where they conducted action research to include sustainability in their Key Performance Indicators (KPIs) and strategic planning process. Adams and Frost (2008) found that reporting data externally had fostered the developments of data collection systems, and the integration of sustainability performance data into decision-making, risk management and performance measurement. On the other hand, in their study of a large Swedish retailer, Frostenson and Helin (2017) found that the potential managerial function of CS reporting to control and improve sustainability was not currently leveraged.

As introduced in **Chapter 1**, in complement to the managerial and critical path of CS reporting research, here an alternative way is suggested to appraise CS reports, based on Perrini’s and Mikler’s (2007) views that CS reports:

- *“represent […] the culmination of the efforts of teams of people qualified in, and tasked with, the presentation of information that casts their firm in the best possible light” (Mikler, 2007)*;
- *“reveal what firms […] perceive as constituting ‘the best possible light’. What do they see as most convincing and brand-enhancing for their readerships? What do they think will inspire confidence? What do they think will convince readers that they are a firm committed to environmental concerns and acting on them?”*
- document *“the activities a firm believes are most important to communicate for the period it covers”* (*Mikler, 2007);*

- and give an *“overall comprehension of what practitioners consider efficient and appropriate socially responsible behavior”* (Perrini, 2005).

From these perspectives, CS reports can be considered as “entry points” on companies’ understanding of what their sustainability work should look like. Hence, they allow identifying the extent to which different aspects are considered by companies to belong to the ideal sustainability agenda, and the other way round, absence of certain aspects in CS reports may reveal a lack on emphasis on the latter in the business community.

3.1.5 Summary

The above sections have shed light on the different facets of CS reporting as a corporate practice which are summarized in Figure 6. Companies release CS reports following a mix of internal (e.g. initiating a change at the company) and external motivations (e.g. complying with regulations). The reporting process depends on a variety of factors, ranging from the ways companies determine what to include in reporting, over who is involved in the reporting process, and to how the reporting process is organized in the company. Expectations from external users of reports are numerous and include (i) comparability and perspectives, (ii) conciseness, balance and precision, (iii) overview and analysis of critical issues, (iv) information about concrete plans to address issues, (v) reporting of performance, and (vi) innovative thinking about and commitment to sustainability. Academic views on CS reporting are divided, with on the one hand the “critical path” which heavily criticizes CS reporting, questioning the extent to which it genuinely addresses sustainability issues and presents substantive actions from companies, and on the other hand, the “managerial path” which considers CS reporting to provide the needed basis for taking decision and designing solutions. An alternative way of looking at CS reports considers them as “entry points” on companies’ understanding of how their sustainability work should be best presented.

3.2 Screening of existing academic studies based on analyses of corporate sustainability reports (background 2)

As a second background step, I built an overview of empirical studies in existing literature which built on *analyses of the content of CS reports*, with a focus on the purpose(s) for which such studies were conducted. Additionally, I explored the extent to which a product LC perspective had been taken in such studies.

Research on CS reporting and accounting has been thriving in academia and has focused on a variety of topics such as (i) identifying explanations of, or motivations for, social and environmental reporting, (ii) potential role of accounting in creating positive social and/or environmental change, and (iii) critiques of traditional accounting in terms of its appropriateness for advancing social and environmental issues (Fifka, 2012; Deegan, 2017). Several reviews in the field of CS reporting were conducted earlier. For instance, in his review of empirical studies in CS reporting research, Fifka (2012) analyzed the methodological approaches adopted by scholars, i.e. method of data collection (e.g. content analysis, survey, interviews), media analyzed (standalone reports, websites) and sample selection. He found that content analysis of standalone reports and homepages for broad non-industry specific samples was dominant in academia, although interviews and surveys were found as increasing data collection methods (Fifka, 2012).

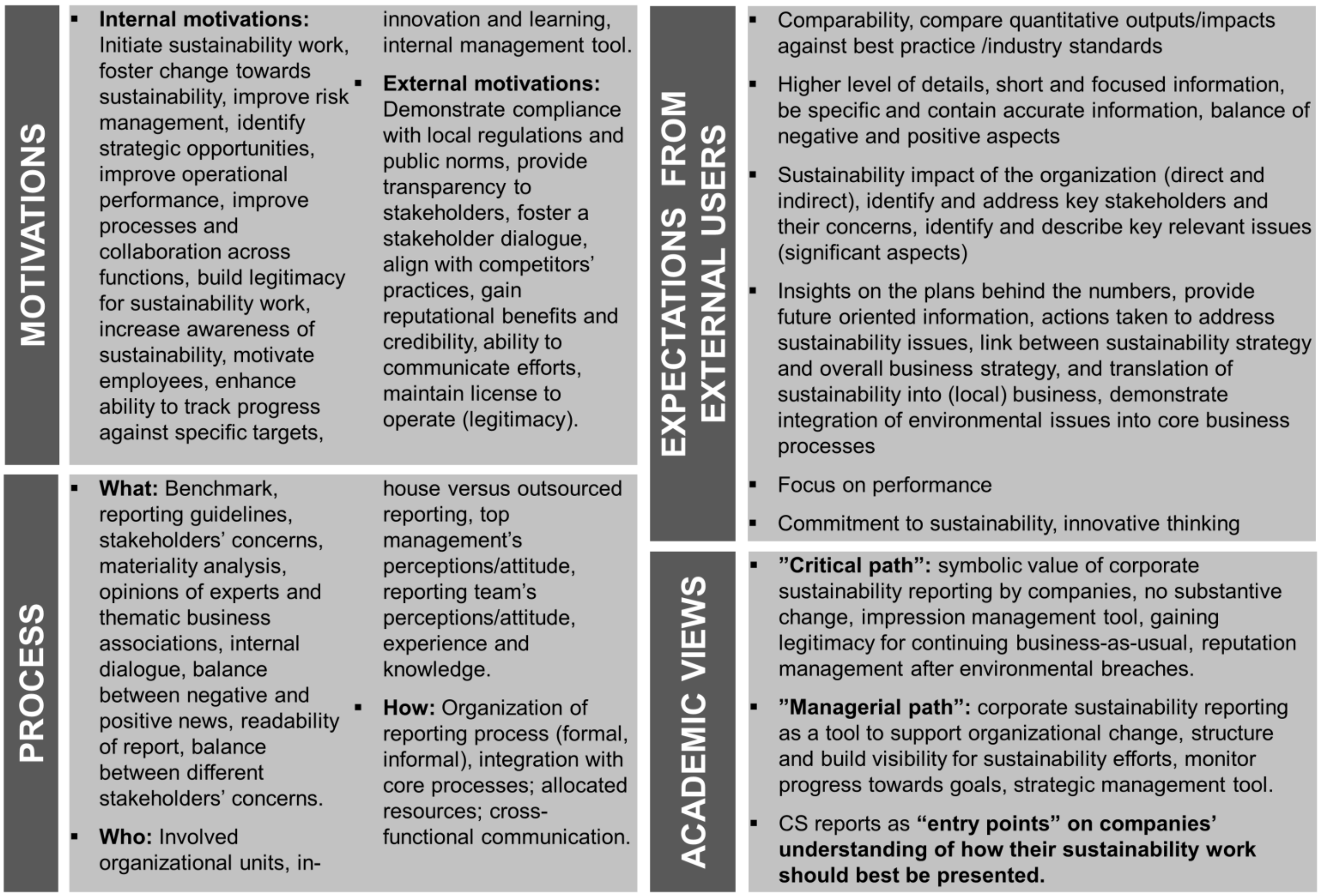


Figure 6. Summary of corporate sustainability (CS) reporting as a corporate practice, including motivations, process, expectations from external users and academic views.

Other scholars conducted reviews within the scope of journals specialized in the accounting discipline. For example, Deegan (2017) provided a review of CS reporting research published in the journal *Critical Perspectives of Accounting* over the past twenty-five years with a focus on the topics addressed (e.g. descriptions and/or evaluations of social and environmental reporting practice). Mata et al. (2018) reviewed the articles on environmental accounting published between 2006 and 2015 in twenty accounting journals and identified the aims and results obtained, methodologies adopted, data sources, industrial sectors, and countries involved. They found that most articles adopted an empirical approach (as opposed to a conceptual approach), and aimed to analyze the environmental information disclosed by companies in their annual, sustainability or environmental, reports using content analysis, and to test theories (predominantly legitimacy and stakeholder theories) explaining practices of environmental reporting (Mata et al., 2018). Other reviews have focused on the determinants of CS reporting adoption in industry (Hahn and Kühnen, 2013; Fifka, 2013; Braam et al., 2016). Yet, to the best of my knowledge, no earlier review had specially focused on the pool of empirical studies which built on *analyses of the content of CS reports*.

3.2.1 Methodology

The methodological approach is summarized in Figure 7. In order to identify empirical studies building on analyses of the content of CS reports, I conducted a literature search in the Scopus database, with a last update in July 2018. The objective with the literature search was to identify all journal articles published within the period 2000-2017 and based on an analysis of the content of CS reports. Studies investigating sustainability reports published by universities or local authorities were excluded. The search string was built on two building blocks respectively representing the topic of CS reporting and the analysis of the reports' content. The list of keywords associated to each building block is displayed in Table A1 in the Appendices of this thesis.

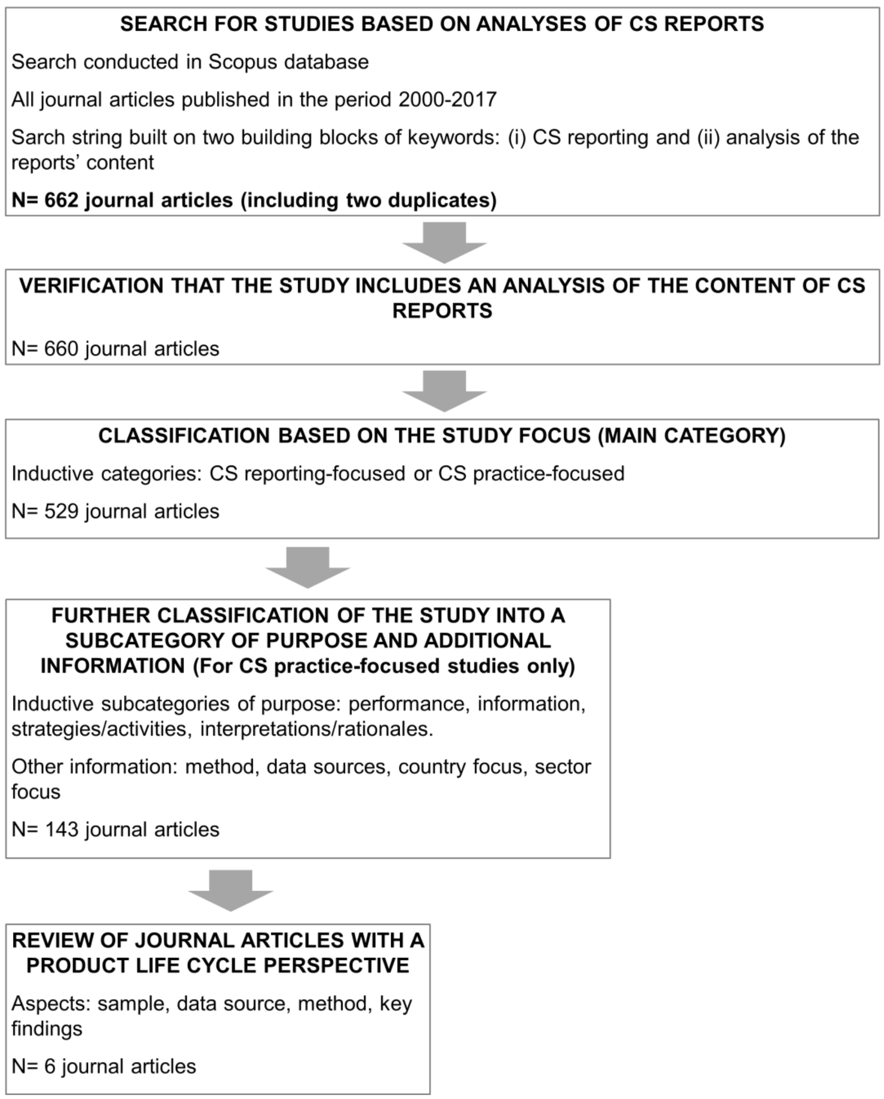


Figure 7. Methodological approach for the literature screening conducted in background 2.

The search resulted in 662 journal articles. Two duplicates were found in the list, and hence removed. The list of sources was exported to Microsoft Excel in order to perform a screening of titles and abstracts. As graphically displayed in Figure 7, the following steps were taken: 1) reading of title and abstract, and verification that the articles include an analysis of the content of CS reports (resulting in the exclusion of 131 articles, hence the final sample includes 529 journal articles); 3) classification based on the study focus (main category); 4) further classification of the study into a sub-category (for one main category); 5) association with keywords providing more details about the purpose or method of the study; and 6) review of journal articles found to focus on CS practice from a LC perspective. The categories used to classify the sample of studies inductively emerged from the data analysis and are presented in **Section 3.2.2**.

3.2.2 Results

3.2.2.1 Corporate sustainability reporting versus corporate sustainability practice-focused studies

When screening the list of articles, it became rapidly evident that some primarily focused on CS reporting in itself, while others aimed at gaining knowledge of CS practices of companies through analyses of their CS reports. Such distinction was also observed by Fifka (2012) who found that scholars had either focused on CS reporting practices directly, or used CS reporting *as "a proxy for measuring other indicators, e.g., social and environmental performance"*. Hence, the first level of classification categorizes articles under CS reporting-focused and CS practice-focused studies. Examples of the two types of focuses are displayed in Table 3 with extracts from the screened abstracts. The number of CS reporting-focused and CS practice-focused articles has been increasing over time, showing a growing interest for the topic in the research community (Figure 8).

As visible in Figure 9, the pool of articles focusing on CS reporting constitutes the majority of articles based on an analysis of CS reports (73%). Within the CS reporting-focused articles, a diversity of purposes for analyzing CS reports could be observed. Sub-categories within CS reporting-focused articles were not systematically created because my primary interest was in CS practice-focused articles; yet some examples are mentioned hereafter. A subset of articles were found to aim at investigating the content (e.g. type of information, presence of themes) and extent (e.g. in terms of number of indicators, or volume of words or sentences) of CS disclosures in reports. In some cases, compliance with specific reporting guidelines was assessed, as a way to define level of reporting or disclosures in CS reports. A large subset of articles attempted to assess the quality of CS disclosures, while others focused on their credibility or readability. Another set of scholars specifically investigated companies' discourse in CS reports from a rhetoric, impression management or business legitimation perspectives, aiming at unearthing greenwashing practices in companies' communications. In some cases, the impact of a new regulation, introduction of new reporting guidelines, or occurrence of sustainability scandals was investigated through exploring companies' disclosure practices, or discourse in CS reports before and after the event. Another set of articles aimed at investigating either the influence of different parameters (e.g. industrial sector, company size, company ownership) on CS reporting practices (e.g. extent or quality), or correlations between CS reporting practices and other corporate variables such as corporate financial performance or stock value. The second group of articles (CS practice-focused) is introduced in detail in **Section 3.2.2.2**. One study (Thijssen et al., 2016) was found to make a link between CS practice and CS reporting by studying the extent to which CS practice is reflected in CS reporting.

Table 3. Examples of stated purpose (extracted from screened abstracts) for corporate sustainability (CS) reporting-focused and corporate sustainability practice-focused studies.

Focus	Extract from abstracts
CS reporting	"This study examines environmental reporting amongst the top 100 forest and paper companies. The scale of environmental report publication is investigated, and the breadth and depth of reporting on the key industry issues of forest management and fiber procurement examined." (Sinclair and Walton, 2003) "This study compared the sustainability reports of leading Indian public and private sector companies. Reports were analyzed based on GRI guidelines toward their reporting on sustainability. A numerical score from 0 to 3 was assigned for each of the 84 performance indicators (9, 30, and 45 indicators for economic, environment, and social dimensions, respectively) of the GRI 2011 guidelines based on inclusiveness of sustainability report." (Yadava and Sinha, 2016) "Graph use in annual reports is well documented, and research into photographs is gaining momentum, but less is known about their use in sustainability reports. This research analyses graph and photograph use in sustainability reports of more and less sustainability-driven companies. It aims to determine whether use of imagery differs between these groups in a way reflective of different legitimation tactics." (Hrasky, 2012)
CS practice	"The research developed a framework of dynamic capabilities for corporate sustainability and used the approach of content analysis to verify the framework based on the CSR reports of UK leading companies." (Wu et al., 2013) "Sustainability is widely recognized as one of the most important challenges facing the world today. Companies publish sustainability reports that present their efforts and achievements in meeting sustainability goals and targets. In this paper, text mining is used to identify sustainability trends and practices in the process industries." (Liew et al., 2014) "Increasingly, many major U.S. agri-food firms are joining their European counterparts in incorporating sustainability initiatives into their business operations. This paper provides a content analysis of the sustainability initiatives reported by select U.S. agri-food firms throughout the supply chain in their corporate social responsibility (CSR) reports." (Ross et al., 2015) "This paper aims to identify the association between a firm's strategy and its sustainability aspects, represented by Global Reporting Initiative indicators as a proxy" (Hourneaux et al., 2017) "This paper examines current implementation status of corporate sustainability activities (CSA) in the mining industry. Specifically, it proposes and applies a multi-dimensional framework to analyze the implementation of CSA from three different angles: 1. the types of CSA from philanthropic to entrepreneurial activities, 2. the issues addressed (e.g., health, safety, environment) and 3. the step of the value chain concerned, i.e., supply, production or product-related sustainability activities." (Fuisz-Kehrbach , 2015)

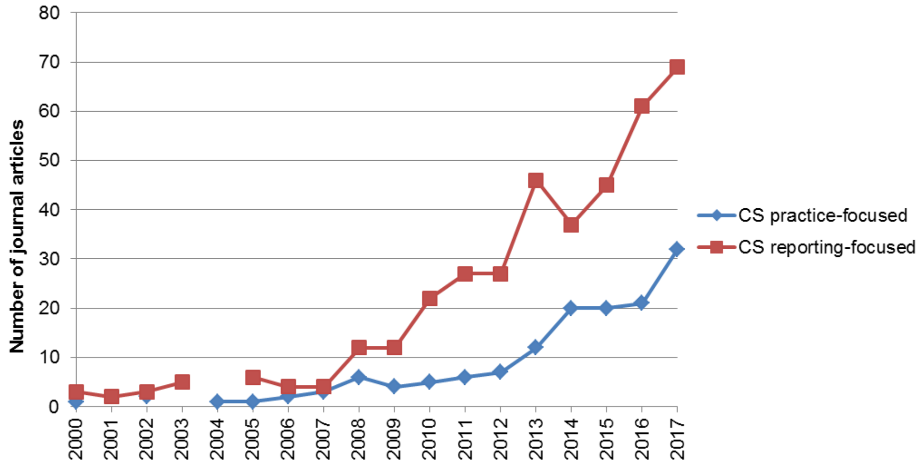


Figure 8. Temporal evolution of journal articles based on analyses of corporate sustainability (CS) reports, with focus on CS reporting (in red) and CS practice (in blue).

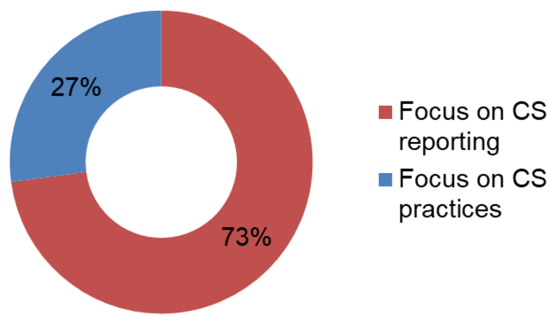


Figure 9. Distribution of journal articles based on analyses of corporate sustainability (CS) reports depending on their focus (N=529).

Within the full sample, some articles have targeted specific industrial sectors (see Figure 10), with the most represented being the mining, bank & finance, oil & gas, forestry & paper, and automotive sectors. In their review, Mata et al. (2018) found high representation of sensitive environmental industrial sectors such as mining, chemicals, oil, paper and electricity sectors. In the present screening, high presence was also found for sensitive environmental industrial sectors (mining, oil & gas, forestry & paper, automotive, energy), but also for the bank & finance sector. Some articles have targeted specific industrial sectors and/or specific countries (See Figure 10), with the most represented countries being Australia, the US, Malaysia, Spain, India and the UK (see Figure 11). The dominance of the US, Australia and the UK aligns with the findings of Mata et al. (2018). Fifka (2012) had also noted the importance of Malaysia among Asian countries.

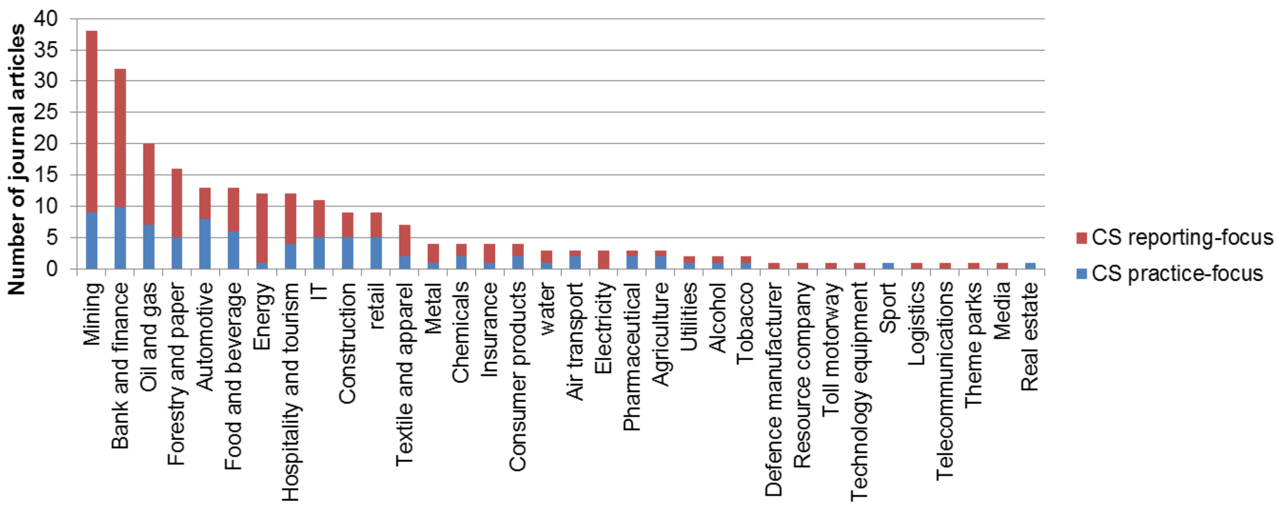


Figure 10. For each sector, number of journal articles which indicates that sector as in focus. Note that not all Corporate Sustainability (CS) practice-focused studies were undertaken with a specific sector in focus.

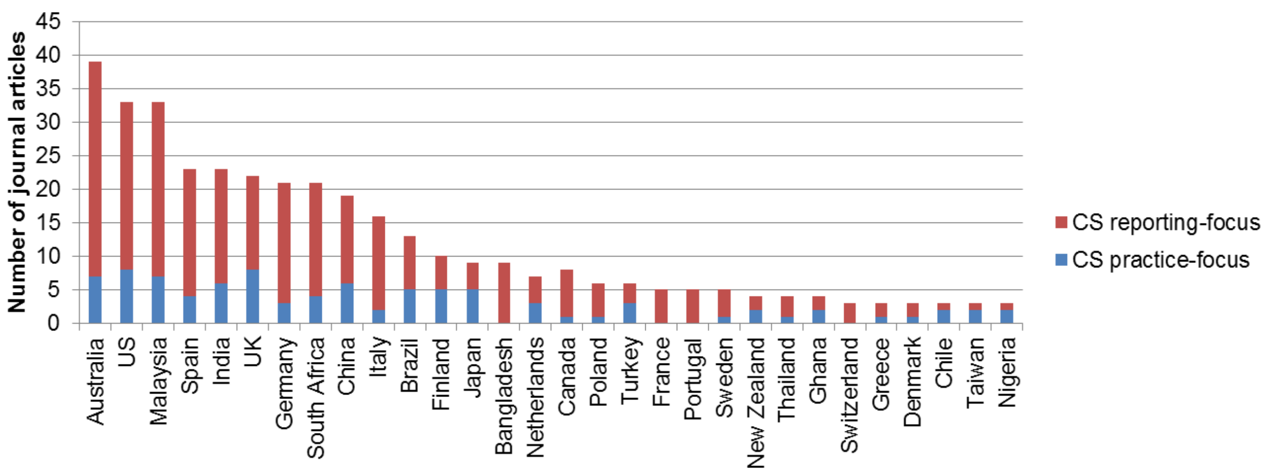


Figure 11. For each country, number of journal articles which indicates that country as in focus. Note that not all Corporate Sustainability (CS) practice-focused studies were undertaken with a specific country in focus. Countries with one or two journal articles are not represented.

3.2.2.2 Corporate sustainability practice-focused studies

Considering my interest in CS reports as a layer of sustainability approaches, the remainder of the section is dedicated to a finer analysis of CS practice-focused articles identified in the literature screening. The CS practice-focused articles were further classified into four sub-categories of purposes (see Figure 12): (i) to score sustainability activities or performance (sub-category 1, performance); (ii) to collect sustainability data from the company (e.g. water or energy consumption) (sub-category 2, information); (iii) to learn from the company's interpretations, meanings and rationales related to sustainability (sub-category 3, interpretations/rationales), and (iv) to learn from the company's sustainability strategies and activities (sub-category 4, strategies/activities).

In articles following the “performance” purpose (sub-category 1), scholars assumed that CS reporting constituted a meaningful proxy of CS practices and developed methods in order to quantify the degree of proactivity of sustainability activities (Chen et al., 2016) or the sustainability performance in order to e.g. rank companies (Frank et al., 2016); provide investors with a benchmark; study correlations with other parameters, e.g. company financial performance (Loucks et al., 2004; Hernández-Perlines and Rung-Hoch, 2017) or environmental performance (Albino et al., 2012); and evaluate the sustainability performance of a sector (Mäkelä, 2017).

Only few articles mentioned a use of CS reports for extracting environmental data related to different business activities (sub-category 2), e.g. to collect data for performing a LCA (e.g. Northey et al., 2013).

Within the articles aiming at learning about companies’ interpretations and rationales related to sustainability (sub-category 3), in most cases an analysis of discourse was used to unearth e.g. how companies define or mean a specific concept, e.g. eco-efficiency (Koskela and Vehmas, 2012), climate change (Metaxas and Tsavdaridou, 2017), corporate citizenship (Shinkle and Spencer) (2012); CSR and sustainability (Landrum and Ohsowski, 2018; Gatti and Seele, 2014; Huang and Zhu, 2017). On the other hand, they included analyses of how companies exposed their corporate motivations for their environmental engagements and commitments (Yusoff et al., 2006); how companies argued for their social license to operate (Bice, 2014); how companies linked their brand image and CSR (Gill and Broderick, 2014); how companies mapped their stakeholders (Ihlen, 2008); how companies defined their sustainability agenda (Onn and Woodley, 2014); what factors were expressed by companies as drivers of their efforts to develop greener products (Mikler, 2007). Sánchez-Hernández et al. (2017) explored CS reports to study whether water was considered a relevant sustainability issues by companies.

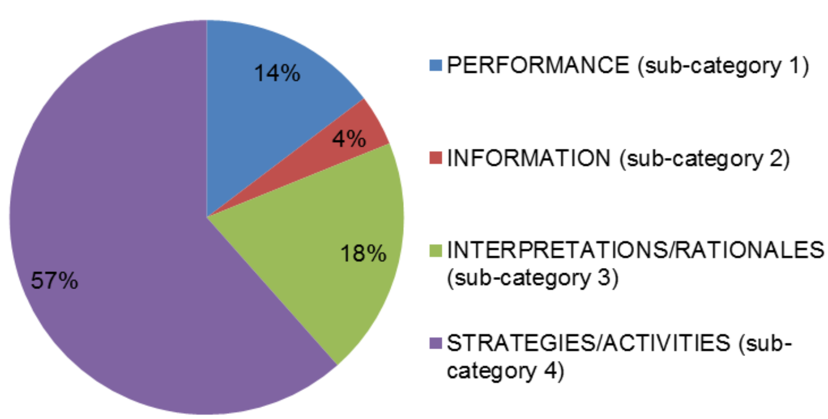


Figure 12. Distribution of sub-categories of purpose within corporate sustainability practice-focused studies (N=143).

Within the articles aiming at learning from the companies' CS strategies and activities (sub-category 4), some targeted specific aspects of CS (e.g. climate change, human resources management, waste management, collaborations, green product development), while others aimed at unearthing CS practices in general within one or several sectors. Palmer and Flanagan (2016) used CS reports to analyze companies' CS goals.

CS practice-focused articles from sub-categories 3 and 4 were mostly based on the sole analysis of CS reports (71% for sub-category 3; and 61% for sub-category 4), while the remaining studies used a combination of data sources, e.g. interviews, survey or analysis of other communication tools such as websites or presence in media. Only six studies (5%) used algorithmic methods (e.g. center resonance analysis).

Within CS practice-focused articles from sub-categories 3 and 4 relying only on CS reports as a data source, the abstracts were found not to contain information about their authors' consideration of the link between the content of CS reports and CS practice at the reporting companies; hence CS reports being introduced as an "obvious" data source to inquire CS practice of companies. Exceptions are the articles by Hourneaux et al. (2017) who stated that they would use CS reporting indicators as a "*proxy for sustainability aspects*" at companies; by Thijssen et al. (2016) who specifically investigated the extent to which CS practice as observed in companies were reflected in CS reports; and by Nunes and Bennett (2010) who stated that "*there might be a gap between what companies say they do in their environmental reports and what they actually do*". In several articles, CS reports were used as a data source to build an overview of existing practices in industry, without focusing on individual companies (e.g. Yu and Chen, 2014; Jung and Ha-Brookshire, 2017; Barrena-Martínez et al., 2017).

3.2.2.3 Corporate sustainability practice-focused studies dealing with a product life cycle perspective

Within CS practice-focused studies, six articles (ca. 4% of the total number of studies in this category) were found to address a product LC perspective, as identified in the screening (i.e. based on titles and abstracts). The corresponding articles were reviewed and details are given in Table A2 in the Appendices.

As shown in Table 4, these studies typically reviewed CS reports against one to four dimensions:

(i) environmental/sustainability aspect,
(ii) environmental/sustainability aspect locations or LC stages,
(iii) environmental/sustainability management practices
(iv) and environmental/sustainability operational practices.

Here, management practices and operational practices were defined similarly to in Pigosso et al. (2013, p. 163); management practices are "*practices involved in the management of the product development and related processes*" and do not depend on the type of products developed; operational practices are "*practices related to technical product design specifications*".

Table 4. Dimensions included in corporate sustainability practice-focused studies with a product life cycle perspective. EOL = End of Life; GHG = Greenhouse gases; CSR = Corporate Social Responsibility; EPR = Extended Producer Responsibility.

Study	Environmental/sustainability aspects	Environmental/sustainability locations or life cycle stages	Environmental/sustainability management practices	Environmental/sustainability operational practices	Other focus or details
Dangelico and Pontrandolfo (2010)	X	X		X	Aspects: material, energy and pollution/toxic waste Life cycle stage: before product usage, during product usage, after product usage Operational practices: e.g. packaging in bio-degradable materials, reduction of product weight, Eco-efficient production processes
Nunes and Bennett (2010)		X		X	Locations: buildings, design, suppliers, manufacturing, reverse logistics Operational practices: e.g. increased fuel efficiency, technologies to support fuel diversification, development of clean-energy vehicles, aluminum-based lightweight design, collection and recycling of end-of-life parts, working with dealers and parts distributors
Comas-Martí and Seifert (2013)	X	X	X		Aspects: e.g. materials, chemicals, GHG Locations: e.g. materials extraction, distribution, use Management practices: quantitative evidence, supplier capability building, external collaboration
Fuisz-Kehrbach (2015)	X	X	X		Aspects: health, safety, environment Location: supply, production, product-related Management practices: philanthropic activities, CSR activities, corporate sustainability activities and entrepreneurial activities
Hickle (2017)			X	X	Management practices: preferred policy approach for EPR, specific goal for EOL management of products, quantitative assessment of products or materials managed, design for environment considerations incorporated into the company's product design Operational practices: EOL product collection program such as collection at retail locations.
Sihvonen and Partanen (2017)			X	X	Operational practices: longevity, reuse, repair, remanufacturing Management practices: environmental quantitative targets for products

Dangelico and Pontrandolfo (2010) developed a Green Option Matrix to characterize green products and practices along different dimensions, including which environmental aspect is addressed (e.g. material or energy) and which stage of the LC is affected, and analyzed green products and related practices for a set of 142 companies belonging to the DJSI. They found in almost all sectors practices such as size and weight reduction of products, packaging, and materials, and improving energy efficiency of processes or products, and that the Consumer Goods sector had the highest level of diversification of green products and practices in their matrix (Dangelico and Pontrandolfo, 2010).

Nunes and Bennett (2010) investigated green operations initiatives in world three largest companies in the automotive industry relatively to green buildings, green supply chain, eco-design, green manufacturing and reverse logistics. Initiatives from the construction of their manufacturing plants to the end-of-life of products were found at the three companies, and product design was found to be considered important by companies for tackling environmental issues because it enabled influencing the whole life of the product (Nunes and Bennett, 2010).

Comas-Martí and Seifert (2013) developed a conceptual framework for the quantitative assessment of the comprehensiveness of firms' environmental strategies, in terms of environmental aspect types (e.g. energy consumption, material use), environmental aspect locations (i.e. LC stages) and environmental management practices, and applied it to a sample of 12 companies belonging to 6 different sectors. They found that companies remained mainly firm oriented, with the raw material (tier 2 suppliers), use and disposal phase being less covered by sustainability practices, and that attention to the supply chain was greater in sectors where stakeholder pressure was higher for supply chain issues (Comas-Martí and Seifert, 2013). In terms of environmental aspect types, they found that all companies emphasized greenhouse gas (GHG) emissions and to a lower extent other aspects.

Fuisz-Kehrbach (2015) investigated the implementation of corporate sustainability activities within sixteen mining companies in terms of activity type, aspect addressed and location in the value chain, and found that systematic management practices of environmental aspects at mining operations, while a lesser presence of upstream supply and downstream product-related activities.

Hickle (2017) examined how “extended producer responsibility” (EPR) as an environmental policy approach, and more broadly, product management strategies were characterized at a set of 121 companies, listed in Newsweek Green Ranking of the largest publically traded global companies and subject to EPR regulations. Sectors covered included electronics and electrical equipment, textiles, automotive, packaging, pharmaceuticals and household hazardous waste. He found that more than half of the companies indicated that Design for Environment (i.e. ecodesign) practices were in focus when developing products, e.g. design for recycling, energy efficiency, reduction in packaging, meaning that there was a focus on pollution prevention, as an intra-company activity; but that there was a lesser emphasis on inter-company activities, such as managing products at the End of Life (EOL) (Hickle, 2017).

Sihvonen and Partanen (2017) examined the extent to which 43 companies in the Information and Communication Technology sector reported quantitative environmental targets for products, and found positive correlation between presence of quantitative environmental targets for products and awareness of LCT, especially considering the durability of products, and remanufacture.

In these six articles, their authors' consideration of the link between the content of CS reports and CS practice at the reporting companies was also kept relatively implicit. Comas-Martí and Seifert (2013, p. 342) argued that CS reports can be considered to be the *most direct "expression of companies' perceptions and strategies in terms of corporate sustainability"* building on Perrini's (2005) argument. For Hickle (2017, p.117), CS reports provide the opportunity to study "*how EPR is positioned within the broader CSR agenda*" (i.e. in industry at large as opposed to for a limited sample of companies), but "*publically available documents may not reflect a particular company's stance on an EPR policy measure in a particular jurisdiction*" (p. 120). Sihvonen and Partanen (2017, p. 770) argued that *"content analysis using sustainability reporting is emerging as a meaningful research method to assess companies' practices with the increase of more standardized reporting frameworks"*, and built on the argument that "*sustainability report disclosures support planning or managing internal business processes moving forward*" (positioned on the managerial path of CS reporting literature*).* Fuisz-Kehrbach (2015, p.109) highlighted, in the limitations of the study, that *"the underlying rationale of this study is that one can make inference from sustainability reports on actual corporate sustainability activities. Consequently, those activities are neglected that are not reported though perhaps conducted. Furthermore, no independent check has been made to assure that alleged CSA (Corporate Sustainability Activities) have been actually accomplished."*

3.2.3 Conclusions

All in all, although a large majority of studies based on analyzing the content of CS reports specifically focused on appraising reporting practices (e.g. the extent, form, quality, completeness, credibility and compliance with existing guidelines), another set of studies was found to explore companies' sustainability approaches in terms of performance, interpretations/rationales, and strategies/activities based on their CS reports. Within CS practice-focused articles, some used CS reports as part of a more diverse set of data sources, e.g. including websites, surveys or interviews, but most relied on CS reports only. A limited number of articles have focused on exploring companies' sustainability approaches from a product LC perspective. They investigated the extent to which companies addressed different environmental aspects, through different environmental management and operational practices, related to different LC stages. The extent to which LCT is present in companies' narratives of their product environmental sustainability approaches remains to be investigated further.

3.3 References to the life cycle assessment methodology in corporate sustainability reports (empirical study 1)

As a way to operationalize LCT and inform companies' environmental sustainability strategies, a variety of LC-based indicators covering different environmental impacts, e.g. carbon footprint and water footprint, have been developed (Laurent and Owsianiak, 2017). The Life Cycle Assessment (LCA) methodology provides a comprehensive account of potential environmental impacts, by covering all relevant environmental issues associated with the LC of an assessed product or service system (ISO, 2006). Through intensive harmonization and standardization efforts, the LCA methodology has evolved into a robust methodology (Finnveden et al., 2009; Goedkoop et al., 2015).

The use of the LCA methodology has been promoted in various policy-making and other industry initiatives (Sonnemann et al., 2018). Numerous expert networks and industry initiatives drive the LCT agenda (Bjørn et al., 2013; ACLCA, 2017; The Sustainability Consortium, 2017). At a European level, LCA has been listed as one of the tools within the EU "Better regulation toolbox" and is the methodological basis for the development and testing of the LCA-based Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF) for application in industry (EC, 2015; 2018b; 2018c).

An increasing utilization of LCA in industry has been suggested (e.g. Goedkoop et al., 2015; Finkbeiner, 2016). In the late 1990s, Frankl and Rubik (2000) surveyed Italian, Swedish, German and Swiss companies for their adoption of LCA and found adoption of up to 40-45% among the largest companies, as well as indications that an increasing use of the methodology was planned in more than half of the surveyed companies. Based on the 2012 International Corporate Sustainability Barometer which collected insights from CSR managers from 468 companies located across the world (e.g. Germany, UK, South Korea, Japan, US, Australia) ranking among the largest in their home countries, Crutzen (2014) reported that on average nearly 40% of companies applied eco-balance or LCA, although how these methodologies were defined in the survey is unclear in the reference.

Only few studies have explored the topic of LCA in the context of CS reporting (Pflieger et al., 2005; Kaenzig et al., 2011), and only one was found to investigate the presence of the LCA methodology in companies' narratives, with a focus on twenty multinational companies considered as sustainability frontrunners and belonging to diverse sectors (Nygren and Antikainen, 2010). Yet, the presence of the LCA methodology in companies' narratives of their sustainability efforts remained to be explored on a broader scale. Hence, **empirical study 1** aimed at (i) evaluating the extent to which references to the LCA methodology were made in CS reports released in the past two decades, and (ii) exploring companies' use of the methodology based on their narratives in CS reports.

This empirical study was structured in two sub-studies (1A and 1B). **Empirical study 1A** consisted of evaluating the extent to which references to the LCA methodology were made in CS reports released in the past two decades. **Empirical study 1B** consisted of exploring companies' narratives of their use of the LCA methodology for a sample of CS reports mentioning LCA (as identified in **empirical study 1A**). **Empirical study 1A** is presented in detail in **Article I**. **Empirical study 1B** is not yet in the form of a draft manuscript (Stewart et al., in preparation). Hence, it was not included as an appended article in this thesis; yet additional methods and results are presented in the Appendices (**Section 7.2**). In **Sections 3.3.1** and **3.3.2**, I provide a summary of the methodological approach and results, respectively, for **empirical studies 1A and 1B**.

3.3.1 Methodology

The methodological approaches for **empirical studies 1A and 1B** are summarized in Figure 13. For **empirical study 1A**, CS reports referring to the LCA methodology were identified by performing searches of LCA-related terms ("life cycle assessment", "life cycle analysis" and other spellings) in the Corporate Register (CR) database using the embedded search function (CR, 2018b). The CR database is the largest online database of CS reports (CR, n.d.), previously used by other scholars for similar purposes (Hrasky, 2011; Roca and Searcy, 2012; Bjørn et al., 2017). It includes any type of sustainability reports in Latin-script, e.g. integrated report, sustainability and environmental reports (CR, n.d.). The worldwide coverage of reporting companies is evaluated by the database developers to be more than 90% (CR, n.d.). Information about the CS reports containing LCA-related terms was collected, including report name, publishing company name, sector of the publishing company, country where the company's headquarter is located and report publication year. Global, sectoral and regional trends of LCA presence were derived from the mapping. The LCA presence in CS reports of a given category, e.g. a sector in a given year or a country in a given year, was defined as the ratio of LCA-mentioning CS reports in a category to the total number of CS reports in that category. Further details about the methodology are given in **Article I.**

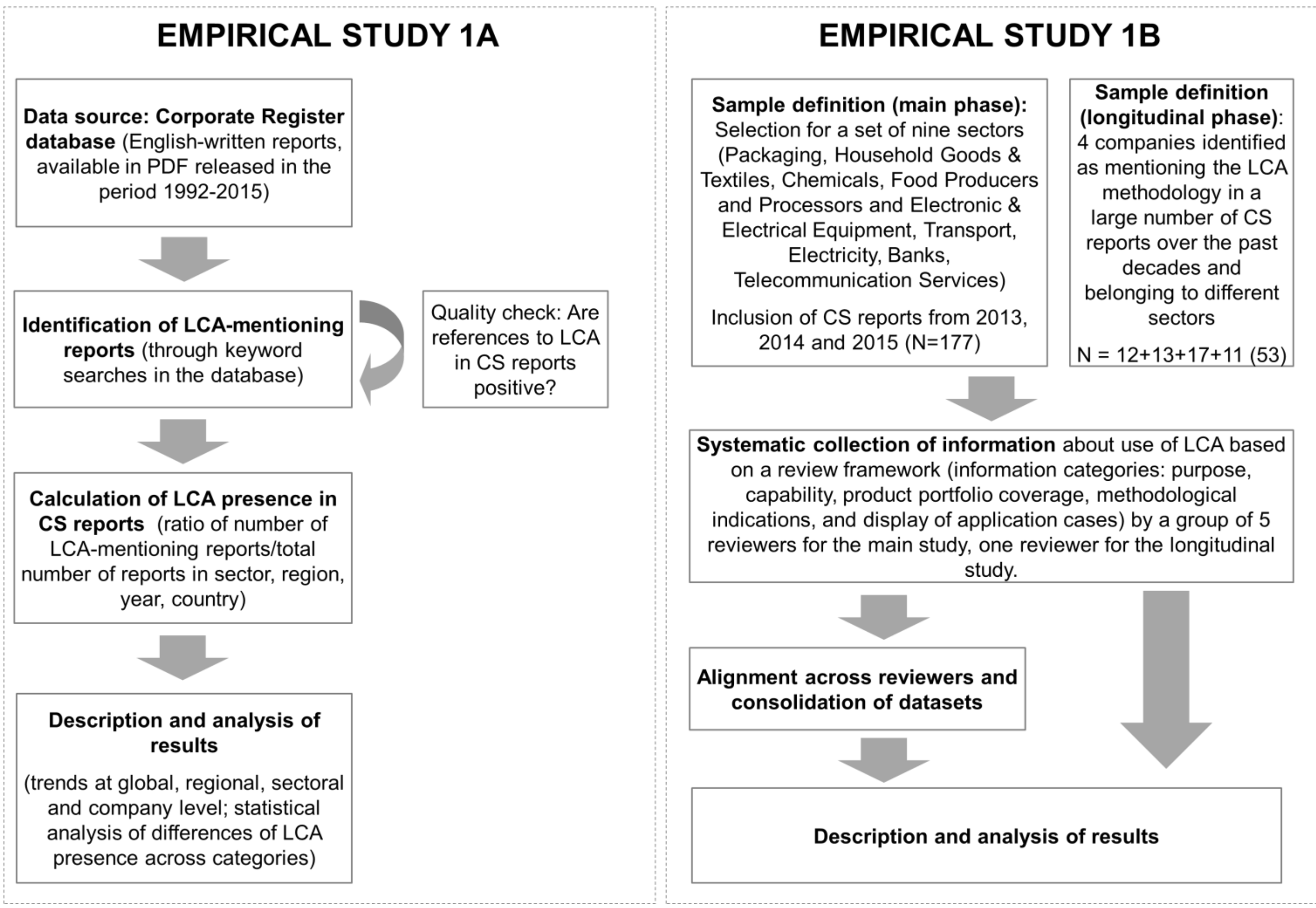


Figure 13. Overview of methodology for empirical study 1, adapted from **Article I**. CS = Corporate Sustainability; LCA = Life Cycle Assessment.

In this thesis, I took the results presented in **Article I** one step further, by adding "environmental product declaration" (EPD) in the list of keywords used in the search. Indeed, a reference to an EPD constitutes an indirect reference to the LCA methodology (even if the company might not explicitly mention the term LCA in its report), as EPDs involve the conduction of LCAs (EPD, 2018). Based on this second search, I was able to evaluate the extent to which specific countries or sectors would present higher LCA-presence in CS reporting if the reference to EPD was taken into account.

In **empirical study 1B**, for the *main phase*, a set of nine sectors were selected (Packaging, Household Goods & Textiles, Chemicals, Food Producers and Processors, Electronic & Electrical Equipment, Transport, Electricity, Banks, Telecommunication Services) with the objective to (i) cover manufacturing and service, business-to-business and business-to-consumer companies and (ii) represent different levels of presence of LCA in CS reports (from the findings of the **empirical study 1A**). The latest CS reports were selected (2013, 2014, and 2015). The sample included 177 CS reports (see Table A3). In order to systematically analyze CS reports, a review framework was developed including the following elements: purpose, capability, product portfolio coverage, methodological indications, and display of application cases (detailed in Table A4). The *longitudinal phase* consisted of the analysis of CS reports released over the past two decades of 4 companies which were identified as mentioning the LCA methodology in their CS reports in a large number of years and belonging to different sectors (see Table A6). Elements similar to the *main phase* were in focus in this second analysis.

3.3.2 Results

3.3.2.1 Empirical study 1A: Mapping of references to the life cycle assessment methodology in corporate sustainability reports

The results of **empirical study 1A** are described in detail in **Article I**. The mapping of references to the LCA methodology in CS reports revealed several key findings. First, the absolute number of LCA-mentioning CS reports has greatly increased over time (in parallel with increasing number of CS reports released each year), although LCA presence in CS reports (i.e. ratio of LCA-mentioning reports over total number of reports) has decreased over time and now stabilized below 5%. There are geographical and sectoral variations in LCA presence in CS reports. Europe and North America were observed to lead in terms of LCA presence in CS reports, with the Nordic region having especially high LCA presence over the aggregated period. From a sectoral perspective, the Container & Packaging and Personal & Household Goods sectors were found to lead in terms of LCA presence in CS reports in the most recent period (2011-2015), together with the Chemicals, Industrial Metals and Forestry & Paper sectors. LCA presence was found weaker in CS reports of service companies, in comparison with manufacturing companies. Sectors with high LCA presence in CS reports were observed not to correlate with sectors where indirect environmental impacts (i.e. in the supply chain) are large. Finally, LCA presence in CS reports was found irregular across years for a same company, which could only limitedly be explained by irregularities of reporting across years. This means that companies do not report about LCA continuously over time. From this perspective, presence of LCA in CS reports is not a straightforward proxy for use of LCA in industry, since the company may well continue LCA practices without reporting it.

The inclusion of “environmental product declaration” in the list of keywords led to add 430 CS reports to the number of LCA-mentioning CS reports previously identified (accounting for possible duplicates when several keywords are referred to in CS reports). As shown in Figure 14, a large number of these CS reports belong to the Construction & Materials, Forestry & Paper, Personal & Household Goods, Electronic & Electrical Equipment and Industrial Machinery sectors; and were mainly released by Swedish, US, Finnish and Italian companies. Figure A1, Table A5 and Figure A2 in Appendix (p. 151-

153) show how LCA presence in CS reports is affected by the inclusion of EPD in the list of keywords respectively, in terms of global temporal trend, sectoral trends in the periods 2006-2010 and 2011-2015 and at a country level. When including EPD, global LCA presence in CS reports was found to stabilize ca. 5% (Figure A1). The Construction & Materials, Forestry & Paper, Industrial Machinery and Technology Hardware & Equipment sectors were found with notably higher LCA presence when including EPD (Table A4). Country-level LCA presence were observed notably higher for Sweden, Finland, Norway, Denmark, Belgium and Italy when including EPD (Figure A2).

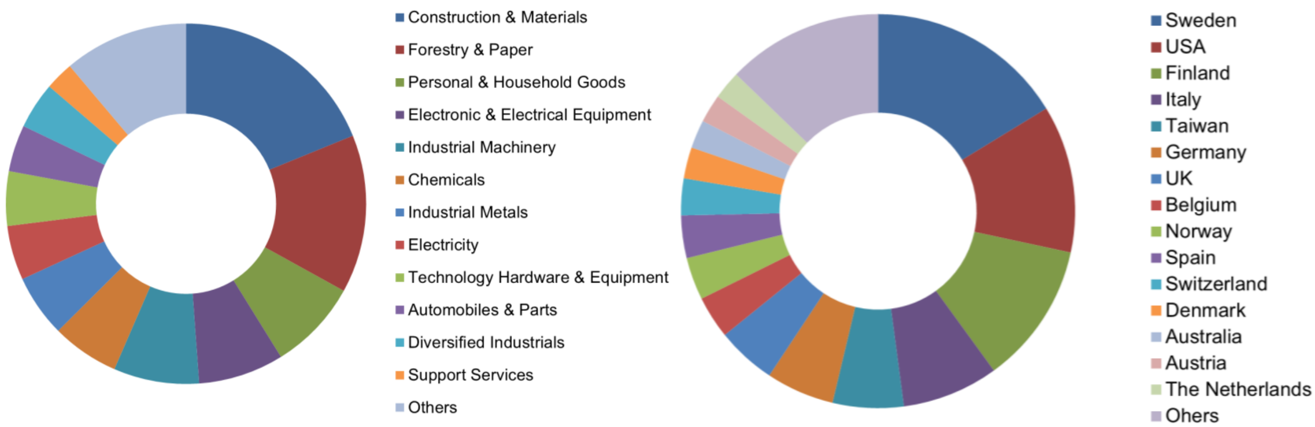


Figure 14. Sectoral and country distribution of added corporate sustainability reports when including the keyword "environmental product declaration".

3.3.2.2 Empirical study 1B: Insights on life cycle assessment use in industry from corporate sustainability reports

The review of CS reports conducted in the *main study* revealed various aspects of LCA use in industry as far as described by the companies themselves. In 31 CS reports, no information about LCA use could be retrieved; hence percentages in the following paragraph are expressed for a total of 146 CS reports. 89% of the CS reports mentioned current use of LCA by the company, while 11% mention a planned implementation of LCA.

Related to the purpose of doing LCAs, CS reports indicated most frequently application of LCA for ecodesign (55%), i.e. to guide the development of environmentally more compatible goods, services or processes at companies. There were also frequent mentions of using the LCA methodology for marketing purposes (33%), i.e. to promote the environmental superiority of a given products (See Figure A3).

In most cases, it was found that LCA studies were conducted on the companies' products, while, only in a few cases, companies indicated their participation in LCA initiatives of their industry branch or reference to LCA studies conducted by others on similar products, as an illustration for their own business. It was rather difficult to understand from the narratives of companies the extent of product portfolio coverage (found unclear in 32% of CS reports). Nevertheless, when indicated by companies, it was most frequently found that companies conducted LCAs for ad-hoc products (22% - i.e. with no specified reason behind the choice) or on a selection of products (22% - e.g. families of products,

products of a certain line, products with high impacts, product covering a certain revenue share, and less precisely defined “representative products” or “major products”) (See Figure A4). The systematic conduction of LCA studies for every product at the company was indicated in 15% of CS reports, either for support in product development or for marketing purposes. In 4% of the cases (5 reports), the use of LCA was indicated at an organizational-level, i.e. not applied on goods or services but covering the whole organization, but in these cases there were few details on how the LCA methodology was applied by the company.

With regards to the presence of LCA capabilities, there was also a majority of unclear indication in CS reports (50%). Yet, most often CS reports indicated the presence of in-house capabilities (35%), associated in some cases to the use of an in-house LCA tool, while others indicated a provision of LCA studies by universities or consultancies (15%).

In around one-fifth of the CS reports, companies displayed one or several LCA application case(s), in most cases comparing different products and with results shown in a table or a graph. The EOL stage was only accounted for in a minority of cases, and in nearly all application examples, only climate change was considered. In few cases only, other impact categories were included such as acidification or eutrophication (See Figure A5).

The *longitudinal* study of four companies’ LCA-mentioning CS reports over the period 1995-2015 provided indications of different trajectories of LCA uptake by companies based on their narratives over time (See Table A6). For instance, at Amcor (Australian packaging company), the LCA methodology was first mentioned in relation with the introduction of LCT in regulation on packaging in Australia. The company started its LCA practice by producing ad-hoc studies for large customers. Then it step-by-step integrated LCA as part of the innovation process and as a competitive edge for its business with the systematic coverage of products in an in-house tool. More recently, the company is running external initiatives (e.g. participation in seminars) to promote the use of LCA in the packaging industry at large. The CS reports also indicated an evolution from LCA capabilities concentrated in one department to the involvement of sales, marketing, technical groups and business group heads and for whom LCA tools were made available. At Knoll (US furniture company), the first reference to the LCA methodology was associated with a critique of the methodology because of its lack of systematization and high cost. Yet, the company expressed its willingness to make LCA a mainstream activity for practitioners. Initially part of a partnership to create an open LCA tool for the industry, Knoll then internalized the capability (GaBi software) and trained selected employees. From a mainly internal utilization of LCA for ecodesign, the company more recently focused on the marketing benefits of LCA with the goal to cover all product families with EPDs. Among the four case companies, three have regularly displayed LCA application cases in their CS reports and two of them used to cover different environmental impact categories, but in the recent years, they came to only focus on climate change. The third case company only focused on climate change in the display of its LCA results from the earliest CS reports on.

3.4 Life cycle thinking in Nordic apparel companies' narratives of their sustainability approaches (empirical study 2)

In **Section 3.4**, I introduce **empirical study 2** which took a complementary approach to **empirical study 1**. In **empirical study 2**, a specific economic sector and region were chosen to conduct an analysis of the presence of LCT in companies' narratives of their sustainability approaches. The focus on a single industry and region allowed for certain homogeneity in the institutional and cultural background (Gallego-Alvarez and Ortas, 2017; Ferri, 2016). In this study, the focus was not set on a particular LC methodology but on the presence of specific LCT elements in companies' narratives (described hereafter).

The study was performed for the Nordic apparel industry. Nordic countries were among the countries where LCA presence in CS reports was found highest in **empirical study 1A**. Belonging to the Personal and Household Goods sector, among the sectors where LCA presence in CS reports was found highest in **empirical study 1A**, the apparel industry is a particularly environmentally-damaging area of consumption. Although the Nordic region remains a minor player globally, it is an important exporter of clothes (Nordic Council of Minister, 2015). In the recent past, the clothing industry has attracted the attention from the Nordic Council of Ministers who has stated an ambition to "lead the way in sustainable design, consumption and production" (Nordic Council of Minister, 2015). This industry has been at the core of several initiatives, e.g. the Nordic prime ministers' green growth project on reducing textile waste and the LAUNCH Nordic project on developing sustainable materials focusing on clothes in 2014 (Nordic Council of Minister, 2015). These different aspects led to consider the Nordic apparel industry as a relevant candidate to perform **empirical study 2**.

Ranked as the fourth most environmentally-damaging area of consumption in the EU-27, the apparel (or clothing) industry drives various environmental problems ranging from the intense use of water and pesticides for cotton production, to pressure on water systems through the release of chemicals in wet treatments and garment care (EEA, 2014). The sector was estimated to account for 2-10% of LC environmental impacts caused by the EU-27 consumption, depending on the impact considered (EEA, 2014). World-wide clothing sales have doubled in the past fifteen years and demand for clothes rapidly grows in developing countries (The Ellen MacArthur Foundation (EMF), 2017). Faster wardrobe renewal is associated with increasing underutilization of garments and intensified disposal practices (Kozlowski et al., 2012, EMF, 2017). Clothing is a key economic sector with an estimated global apparel and footwear revenue of €1.5 trillion in 2016 and associated 60 million jobs along the value chain (Global Fashion Agenda and Boston Consulting Group and, 2017). Clothes are omnipresent in our daily lives and fulfill various human needs ranging from basic protection to identity building and expression (EMF, 2017; Roos et al., 2017). Transitioning towards sustainable clothing systems is thus a key challenge to be addressed in the coming decades.

There are indications that practitioners in the clothing sector use LCT in the form of LC-based assessments (van der Velden et al., 2014). Textiles were one of the pilot product categories for the development of the LCA-based Product Environmental Footprint guidance, and a LC perspective is strongly anchored in the metrics developed by the Sustainable Apparel Coalition initiative joined by the major apparel companies across the world (Kozlowski et al., 2015; Roos et al., 2017). Yet, the extent to which apparel companies build on LCT to develop their sustainability strategies remains unclear. Hence, the **empirical study 2** aimed to explore the extent to which LCT is present in apparel companies' narratives of sustainability approaches as described in their CS reports. In **Sections 3.4.1** and **3.4.2**, I provide a summary of the methodological approach and results.

3.4.1 Methodology

The methodological approach is summarized in Figure 15 and described in details in **Article II**. The analysis of LCT in CS reports was framed around four elements which are (i) product LC system, (ii) hotspots in the product LC, (iii) tradeoffs in the product LC and across environmental problems, and (iv) product environmental sustainability budget (See definition in Table 5). In the conceptual introduction of LCT detailed in **Article II**, these elements were singled out as key aspects associated with LCT and four research questions were formulated with these elements at their core.

- Q1: To what extent is the product LC system addressed in Nordic apparel companies' narratives of their sustainability approaches?
- Q2: To what extent are hotspots in the product LC addressed in Nordic apparel companies' narratives of their sustainability approaches?
- Q3: To what extent are tradeoffs between different options in the product LC system addressed in Nordic apparel companies' narratives of their sustainability approaches?
- Q4: To what extent is the idea of product environmental budget addressed in Nordic apparel companies' narratives of their sustainability approaches?

Table 5. Life cycle thinking elements.

LC analytical element	Definition
Product life cycle system	All processes required in order to deliver the function of a product, from raw materials to final disposal, and which contribute the total environmental sustainability impact of the product.
Hotspots in the product life cycle	Processes in the product life cycle system which significantly contribute to the system's environmental sustainability impacts and which should be addressed in priority.
Tradeoffs in the product life cycle or across environmental problems	Shift of environmental sustainability impact from one life cycle stage to another or from one environmental issue to another, revealed when comparing alternative options.
Product environmental sustainability budget	Account for Earth's ecosystems' source and sink limited capacities in the evaluation of the product system's environmental sustainability performance, i.e. assessment against absolute threshold.

All companies in the apparel sector and with headquarters in a Nordic country (i.e. Denmark, Sweden, Norway, Iceland and Finland) which released an English-written CS report in 2016 were identified using the CR database in August 2017, and included in the sample. The resulting 15 companies are shown in Table 1 in **Article II** (and can be seen in Table 6 in the thesis).

To answer the four research questions, the content of CS reports was systematically reviewed using content analysis which is a common method to analyze textual data in business studies (Kohlbacher, 2006; Duriau et al., 2007). To analyze CS reports, a combination of deductive and inductive approaches was used which was particularly suited for the explorative nature of the study (Hsieh and

Shannon, 2005). The deductive approach relates to the use of an initial set of categories for each element, which are detailed in **Article II**. For each CS report, based on a thorough reading of the full report, so-called “meaning units” associated with each element were identified in CS reports. Meaning units are defined as “words, sentences or paragraphs containing aspects related to each other through their content and context” (Graneheim and Lundman, 2004). These meaning units were organized under the deductive categories, or under additional categories inductively added based on data found in CS reports. As part of the element product LC system, a mapping was conducted of environmental sustainability operational practices affecting the different LC stages as reported by companies (inductive approach).

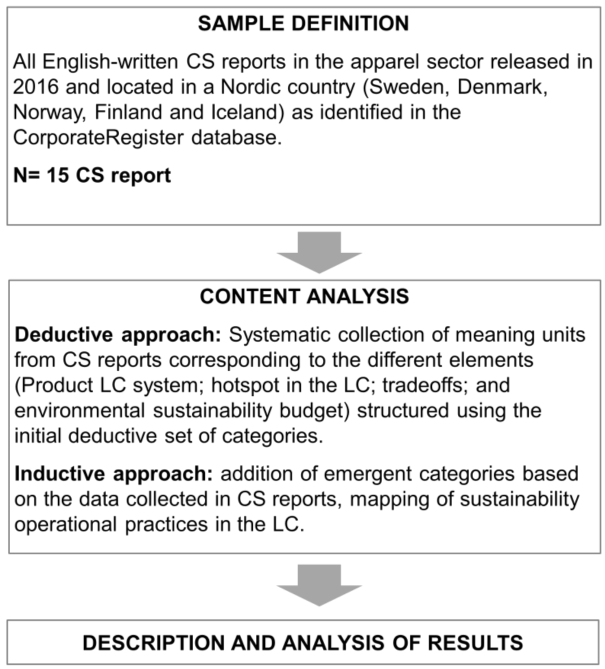


Figure 15. Overview of methodology for empirical study 2. CS = Corporate Sustainability; LC = Life Cycle.

3.4.2 Results

The results from the content analysis are shown in Table 6 and described in detail in **Article II**. Here I present a summary of the main findings. Among the four elements in focus, the idea of product LC system was found present in almost all CS reports, with some limitations in smaller companies. Some companies presented a graphical representation of their product LC system (S1), and more than half were found to express that the product LC system was in consideration in their sustainability strategy (S3). More than half of the companies expressed their willingness to address environmental sustainability challenges throughout their product’s LC or value chain. Yet, among the LC stages, upstream stages (raw material, fabric and garment production) were mostly focused on, and the use and disposal stages were more limitedly addressed by companies in their environmental sustainability operational practices (S4). In the use stage, for most companies, the only reported operational practice was the use of care labels on garment and care instructions in shops and online. Details about sustainability operational practices reported by the reviewed companies are shown in Table A2 of **Article II**.

Table 6. Results from the content analysis of empirical study 2, adapted from **Article II**. LC = Life Cycle. Categories marked with an asterisk were inductively derived from the CS reports. Note, that for the coverage of LC stages, cells are colored in dark grey, if the company reports operational practice(s) related to this LC stage; and light-grey, if the practice related to the LC stage is reported as under consideration at the company.

	(Company size[1])	Large	Large	Large	Medium	Large	Large	Large	Large	Medium	Small	Large	Small	Medium	Large	Large
	(Company type[2])	SAR	SAR	SAR	BM	SAR	SAR	BM	SAR	BM	BM	SAR	PBO	BM	PBO	BM
	Categories	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
S1	Graphical representation of the product LC	■			■		■		■						■	■
S2	Explicit definition of the product LC				■											
S3	Consideration of product LC in the sustainability strategy of the company	■	■	■	■	■	■	■	■							■
S4	LC stage coverage in sustainability operational practices:															
	Raw material	■	■	■	■	■	■	■	■	■	■	■		■		■
	Fabric production and processing	■	■	■	■	■	■	■	■	■	■	■	■	■		■
	Garment production	■	■	■	■	■	■	■	■	■	■	■	■	■	▒	■
	Transportation	■	■		■	■	■		■	■	■	■	■	■		■
	Packaging	■		■	■	■			■	■	■					■
	Stores/Offices	■	■	■	■	■	■		■	■	■	■	■	■		■
	Use		■	■	■	■	■	■	■		■	■				■
	End of life	■	■	■	▒	■	■		■	▒						■
S5	Possibility to influence product LC impacts through design*	■	■		■	■	■	■	■	■		■				■
H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach				■	░	■	■	■							
H2	Highlight hotspot processes relatively to other processes in product LC				■	■	■	■	■							■
H3	Quantify contributions to environmental impacts throughout the LC				■		■		■							
H4	Highlight processes particularly impacting in general*	■		■	■	■	■	■	■	■		■				■
T1	Practice of identifying possible tradeoffs in the LC to guide the environmental sustainability approach															
T2	Highlight possible tradeoffs associated with alternative solutions for products	■	■			■	■			■						■

T3	Quantify tradeoffs between different options															
T4	Multiple environmental problems referred to*															
T5	Use of multi-environmental impacts LC-based assessment tools*															
B1	Practice of assessing absolute impact of products to guide the environmental sustainability approach															
B2	Highlight ecological limits in relation with products															
B3	Quantify absolute impact of products															
B4	Reference to ecological limits on a general level*															

[1]Large= more than 250 employees, Medium=between 50 and 250 employees, Small=fewer than 50 employees

[2] Company type according to Fernandez-Stark et al. (2011): BM = Brand marketer, i.e. firm which owns the brand name but not manufacturing with products are sold at a variety of retail outlets; SAR = Specialty apparel retailer, i.e. retailer which develops proprietary label brands that commonly include the stores' name; PBO = production for brand owners.

Analysis of environmental sustainability hotspots in the product LC system was limitedly found, together with few references to potential tradeoffs in the LC or across environmental problems, and very few references to ecological limits. Although most companies mentioned particularly impacting processes in their business in general (H4), the analysis of environmental sustainability hotspots in the value chain or product LC was mentioned as a step towards designing environmental sustainability strategies at four companies only (H1). At these companies the use of various LC-based methodologies was mentioned as a way to build an understanding of LC impacts and guide companies into their sustainability approaches (e.g. LCA, water footprint, Higg Index, and Environmental Profit and Loss, see Table S3 in Supplementary Information of **Article II** for a definition of the last two methods). Processes typically singled out as hotspots in the product LC were the production and wash of garments. However, more in-depth discussion about the contribution of different production processes was usually lacking, e.g. spinning, weaving, dyeing and finishing of garments are particularly impacting processes which were not elaborated upon by companies. The identification of potential tradeoffs was not described as a common practice to guide product environmental sustainability work in the reviewed CS reports, although scattered examples of tradeoffs were referred to by nearly half of the companies (T2). Ecological limits were part of a minority of companies' narratives and kept at a general level (B4).

Overall, a rather high attention among Nordic apparel companies to the LC of their products was found in their CS reports. On the other side, only few companies were observed to i) provide detailed insights on the critical elements in the current apparel product system; ii) explicitly indicated that they lacked influence on hotspot processes as of today; or iii) discussed the advantages and drawbacks of alternative options (e.g. production processes or selection of fibers).

3.5 Additional studies (empirical studies 3 and 4)

In **Section 3.5**, I present two additional studies which provided relevant insights to answer **RQ1**. In **empirical study 3**, the uptake of the concept of Circular Economy (CE) by companies in the fast-moving consumer goods (FMCG) sector was explored as described in their CS reports (**Article III**). In **empirical study 4**, rationales from an environmental perspective put forth in public communications by companies adopting bio-based plastics in their material portfolio were analyzed. **Empirical study 4** was based and expands the co-supervised work of a master student's final project (Jonas, 2018).

3.5.1 Circular economy in corporate sustainability reports of the Fast-Moving Consumer Goods sector (empirical study 3)

In the context of increasing challenges related to resource scarcity and depletion of non-renewable resources, the concept of CE provides a central vision for our societies to move away from a linear model. There is no unified definition of CE (Kirchher et al., 2017); yet CE has been defined as "an emergent framing around waste and resource management that aims to offer an alternative to prevalent linear take-make-dispose practices by promoting the notion of waste and resource cycling" (Blomsma and Brennan, 2017). The principles behind the CE concept are not new; yet the momentum recently created, among others by the Ellen Mac Arthur Foundation (EMF), turned the concept into a business approach and brought CE on the agenda of decision-makers (Sauvé et al., 2016). In the broader debate around resource and waste, and in the sustainability literature, the value of CE is its core focus on optimizing value extraction through "extending resource life" and "reducing value loss and destruction" (Blomsma and Brennan, 2017), and on maintaining material quality, i.e. delaying its downgrading to lower quality applications (Korhonen et al., 2018; Webster, 2013). CE provides a vision and strategies to shift from linear economies towards circular systems (Bocken et al., 2016). However, not all CE strategies would systematically lead towards increased environmental performance across the LC. For instance, one way to operationalize CE is to adopt the cradle-to-cradle principles. Niero et al. (2016) found that higher score in the Cradle-to-Cradle certification program did not necessarily means higher environmental performance as assessed by an LCA. Haupt and Zschokke (2017) similarly warned that circular options are not always environmentally preferable from a LC perspective. From these perspectives, LCT and CE are seen as complementary concepts to inform sustainability strategies (Niero et al., 2016).

Businesses have been regarded as key stakeholders to facilitate the development of the CE and have recently shown increasing interest in the business approach (Lewandowski, 2016; Linder and Williamder, 2017). Among other economic sectors, the FMCG industry is particularly relevant for application of the CE. This sector is characterized by high throughput volumes, frequent purchases and large physical volumes available at relatively low prices (EMF, 2013). FMCGs currently account for 35% of material inputs into the economy, a significant part of total consumer spending on tangible goods, and 75% of municipal solid waste (EMF, 2012). Within the FMCG sector, food, beverages, textiles, and packaging represent 80 % of the total market by value (EMF, 2013). Investigations of the uptake of the CE concept in industry are limited in existing academic literature and no study has focused on the uptake of CE in the FMCG sector. In this perspective, **empirical study 3** aimed to explore how the recently highly promoted concept of CE appeared in FMCG companies' sustainability agenda as reported in their CS reports. Building on existing academic knowledge of CE (detailed in **Article III**), three research questions were formulated to guide the analysis of CS reports: 1) How is companies' uptake of CE in their CS reports? ; 2) How do companies link CE and sustainability in their

CS reports? ; 3) Which CE practices do companies present in their CS reports? In **Sections 3.5.1.1** and **3.5.1.2**, I provide a summary of the methodology and results of **empirical study 3**.

3.5.1.1 Methodology

The sample of companies to be included in this study was systematically built using the CR database (CR, 2018b). In January 2017, all sustainability reports of companies (i.e. excluding other organizations) listed in the database released until 2016 and mentioning at least once the term “circular economy” were identified. A total of 630 CS reports were retrieved, among which those published in 2016 were selected (representing more than half of all CS reports mentioning “circular economy”) by companies in the FMCG sector, i.e. Food & Beverage, Household Goods & Textiles, Packaging, and Personal Care & Household Products sectors. The final sample contains 46 CS reports released by 46 companies. The methodological approach used to conduct the study is graphically displayed in Figure 16 and presented in detail in **Article III**.

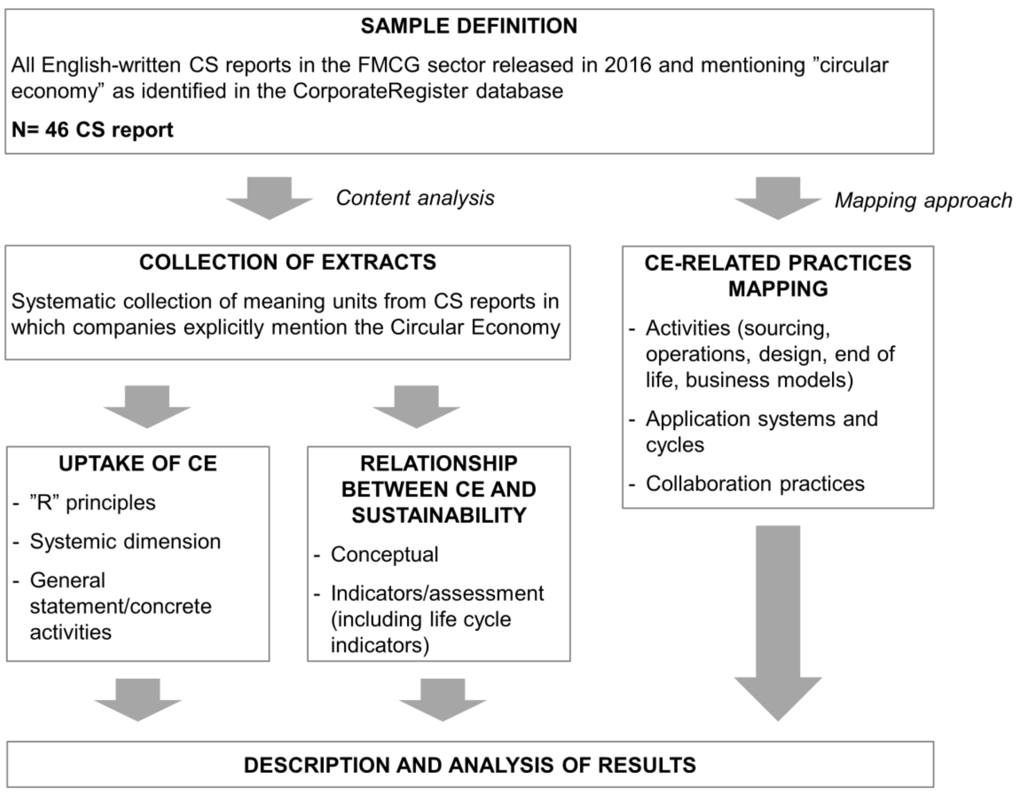


Figure 16. Overview of methodology for empirical study 3, adapted from **Article III**. CE= Circular Economy, CS= Corporate Sustainability, FMCG = Fast Moving Consumer Goods.

3.5.1.2 Results

The results showed that the concept of CE has started appearing in CS strategies of FMCG companies as visible from their CS reports, although a clear-cut definition of the CE concept was rarely provided. The concept of CE seemed mainly associated with the idea of recycling and to a lesser extent with the ideas of reusing, reducing, and recovering. It was found that the CE concept was discussed from a systemic perspective, i.e. associated with broader changes in our current production and consumption systems, only in a minority of reports. Notably, the role of consumers, business models and material quality was little emphasized.

Although CE was often associated with tackling environmental challenges, the linkage between CE and sustainability remained unclear in companies' narratives, and with no evaluation of the contribution of CE practices or strategies to the sustainability performance of the company. Notably, no company observed the potential existence of trade-offs between CE and sustainability, therefore suggesting that CE inherently would contribute to the sustainability agenda. It was observed that most companies mentioned footprint methodologies (LCA, carbon footprint or water footprint), although with no link to CE in most cases (with three exceptions).

With regard to the CE-related practices retrieved from CS reports, the focus was mainly on sourcing (use of recycled or renewable materials) and production (energy and material efficiency in production) practices. Almost half of the companies were found to engage in supporting recycling and resource recovery infrastructure through recycling campaign or initiatives with suppliers. Activities addressing circular product design and circular business models were reported to a lesser extent, except for design for reduce resource consumption (e.g. through lightweight) and design for resource recovery (e.g. through designing recyclable products). Most companies described some collaboration practices in the context of the CE; interestingly, most partners were business and very little emphasis was put on collaborating with consumers.

These observations provided indications on the uptake of CE by the FMCG industry. Webster (2013) warned that a "casual interpretation" of CE can lead practitioners to view it as a mere refreshing of recycling schemes and reverse supply chains, rather than a true systemic change. The findings of this study indicated a possible tendency for such "casual interpretation" in the narratives of FMCG companies on CE, both revealed in the strong association with the idea of recycling and the lack of CE-related practices beyond sourcing and production practices. Thus, there is a need for pushing companies towards a more systemic approach of the concept, including envisioning new business models, gaining deeper understanding of consumer behaviors, and taking a new perspective upon material quality. Our findings further revealed a potential uptake of CE as a *vision* by companies, with no explicit linkage with the sustainability performance of their business, and especially no emphasis on the possible tradeoffs between CE and sustainability. Here also, the findings provided an empirical basis to call for an increased attention on possible unwanted consequences of the uptake of CE by the industry and to take a LC perspective to uncover possible burden shifting.

3.5.2 Environment-based rationales of companies for uptake of bio-based plastics in their publicly available communications (empirical study 4)

Finite oil resources create a variety of challenges for our current fossil-dependent societies. Omnipresent in our production systems and used for a variety of applications, plastic is one of the key materials derived from oil resources, accounting for the use of 4-6% of extracted oil globally (Hottle et al., 2013; Spierling et al., 2018; Plastics Europe, 2018). The use of renewable feedstocks to produce plastics has been explored for many years and it has more recently gained priority in the agenda of policy-makers, e.g. in the EU through the bioeconomy policy and the recent strategy on plastics (EC, 2012; 2018d). Bio-based plastics are derived from renewable resources, typically from vegetal sources with an annual crop, and may or may not be biodegradable (Spierling et al., 2018). The definition of biodegradability for bio-based plastics remains vague and time to degrade, level of degradation, and conditions for degradation may vary a lot from one bio-based plastic to another. The share of bio-based plastics in industry remains very small as of today (2% of annual consumption of plastics in 2016) but is expected to grow in the future (Aeschelmann and Carus, 2017).

The environmental performance of bio-based plastics has been investigated from a LC perspective in several studies which have provided contrasting results (Hottle et al., 2013). There is no firm evidence for a superior environmental sustainability performance of bio-based plastics as compared with petroleum-based plastics (Hottle et al., 2013). Existing LCA studies have mainly focused on global warming potential and the use of non-renewable resources (Hottle et al., 2013). Disregarding other environmental problems may lead to overlooking potential tradeoffs between them; for instance, bio-based plastics may be associated with increased eutrophication, or impact on water quality (Hottle et al., 2013). Bio-based plastics can be derived from a variety of feedstocks and can be disposed in various ways (recycling, industrial composting, incineration, landfilling) which greatly influence their overall environmental performance (Hottle et al., 2013). Agricultural practices to produce the feedstocks may be more or less energy, pesticides and fertilizer demanding. If bio-based plastics are landfilled which is the case in areas where no other waste management infrastructures are available, it may result in methane emissions which would increase the climate impact associated with bio-based plastics (Hottle et al., 2013). Hence, the specific type of bio-based plastics, associated supply chain and End-of-Life (EOL) scenarios will impact greatly their environmental performance and ability to outperform conventional plastics. Spierling et al. (2018) ran a scenario of substitution of fossil-based plastics by bio-based plastics, based on existing knowledge on plastic demand and feasible technical substitution factors, and found that this could result in large savings of GHG emissions. However, the calculation was based on cradle-to-gate LCA studies and thus did not reflect the effect of EOL scenarios (Spierling et al., 2018). Hottle et al. (2013) found that LCA studies including the EOL stage found much higher global warming potential associated with bio-based plastics that studies which did not include it.

Few academic studies have explored the uptake of bio-based plastics by companies hitherto. They have mainly focused on identifying the business drivers of companies adopting bio-based plastics, e.g. risks of finite resources, cost, differentiation opportunity, or policy pressure (Bos-Brouwers, 2010; Iles and Martin, 2013; Aquilani et al., 2018). De Vargas Mores et al. (2018) found that the ongoing debate on climate change and a growing global demand for products from renewable sources had played in favor of adoption of bio-based plastics at a petro-chemical Brazilian company. Nevertheless, little is known about companies' understanding of the extent to which bio-based plastics may support their environmental sustainability efforts. Hence, the purpose of this study was to systematically explore the rationales of companies about incorporating bio-based plastics in their material portfolio from an environmental sustainability perspective. In **Sections 3.5.2.1** and **3.5.2.2**, I provide a summary of the methodology and results of **empirical study 4**.

3.5.2.1 Methodology

This study was part of a master student's (Tim Jonas) final project, conducted under the supervision of Monia Niero, Ólafur Ögmundarson, Niki Bey and mine. I summarized the methodological steps relevant for the present thesis in Figure 17.

Companies dealing with bio-based plastics (both producers which produce bio-based plastics and converters which include bio-based plastics in the final goods they produce), and providing publicly available information about their use of bio-based plastics were identified based on Google searches. All in all 81 companies were included (69% producers and 31% converters). Companies were mainly located in Europe and converters mainly belonged to the consumer goods or packaging sectors. 68% of the companies were found to display information about bio-based plastics on their websites only.

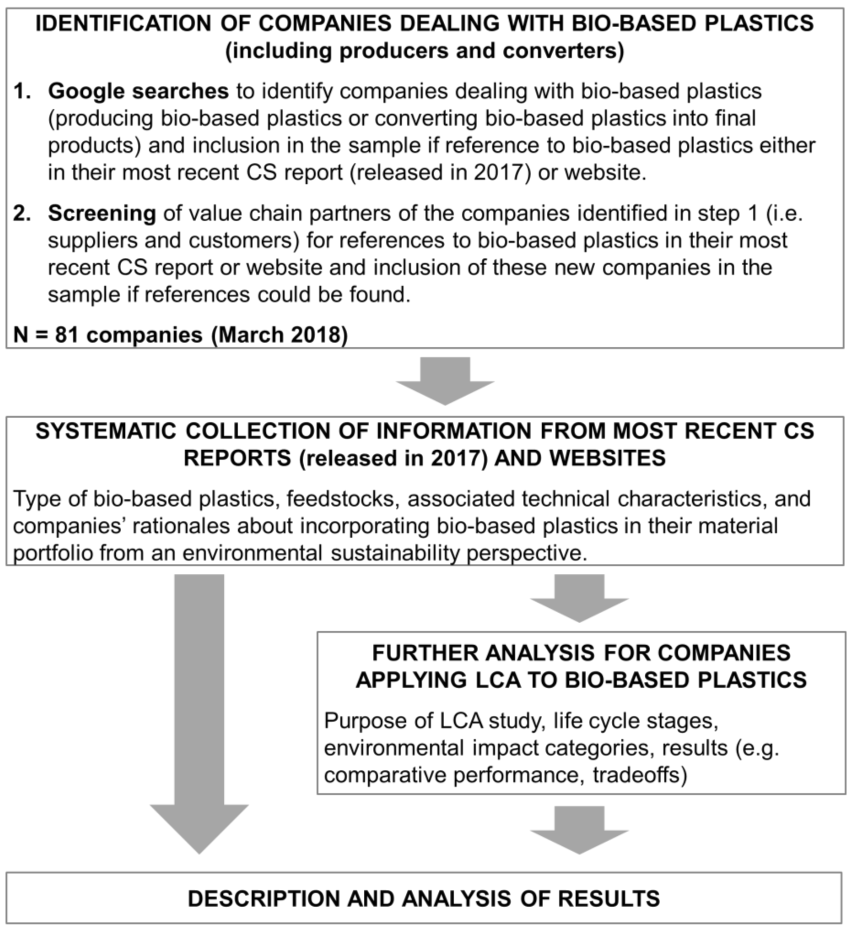


Figure 17. Overview of methodology for empirical study 4. CS = Corporate Sustainability; LCA = Life Cycle Assessment.

For each company, the type of bio-based plastics, feedstocks and associated technical characteristics were recorded from the publicly available communications of these companies, i.e. both websites and most recent CS reports (released in 2017). Further, companies' rationales about incorporating bio-based plastics in their material portfolio from an environmental sustainability perspective were mapped combining deductive and inductive approaches. An initial set of rationales was derived from existing literature and used for the deductive analysis of communications. Rationales which emerged from the analysis were inductively added to the initial framework.

For the purpose of the present thesis, I took the study one step further and explored the extent to which companies used LCA to analyze and document the environmental sustainability performance of bio-based plastics or products made of bio-based plastics. For the companies mentioning LCA (as identified by Tim Jonas), I investigated whether they actually mentioned LCA in relation with bio-based plastics and whether they displayed the LCA results in their CS reports or on their website. For those companies displaying LCA results, I reviewed the purpose of conducting an LCA, the LC stages and environmental impact categories taken into account and the conclusions drawn by companies based on the results. The sources of LCA applications to bio-based plastics found in publicly available communications of the corresponding companies are displayed in Table A7 in the Appendices of this thesis.

3.5.2.2 Results

Within the sample, 72% of the companies indicated the type of bio-plastics they used (mostly Polylactic Acid (PLA) – 21%) and 62% indicated the associated feedstock (mostly sugar cane - 25%, and corn - 21%) (See Figure A6). 52% of the companies indicated that the bio-plastics they produce or use are biodegradable (which aligns with the fact that the most frequently mentioned bio-based plastics is PLA which is biodegradable under certain conditions); 48% of the companies indicated that they are compostable; and 17% indicated that they are recyclable (See Figure A7). The results further revealed a strong faith in companies' communications in the environmental superiority of bio-based plastics. Most frequently mentioned drivers for using bio-based plastics were the lower dependence on oil (51%), that bio-based plastics were more sustainable (30%), and the increased demand for environment-friendly products (24%). 61% of the companies associated bio-based plastics with a lower climate change impact; 41% of the companies expect bio-based plastics to reduce their corporate environmental footprint; and 25% of the companies associate bio-based plastics with reduced energy use in production (See Figures A9 and A10).

22% of companies in the sample (18 companies), with all being producers but one, claimed to conduct LCA on their bio-based plastics and 4% (3 companies) mentioned LCA studies performed by other institutes. For 20% of the sample (16 companies), LCA results for their bio-based plastics could actually be found either accessible from their website or in reports found by direct searches in Google engine (scientific article published by the company and report published by an industry association).

LCA studies were used by companies in order (i) to deliver environmental information about their materials (Evonik, Futaruma); (ii) to compare their bio-based plastics and other plastic types, e.g. recycled plastics (NatureWorks) or conventional plastics (API, BioAmber, Braskem, Dupont, Plantic, Tate & Lyle, Total Corbion, Toray, Arkema); to compare their bio-based plastics with other material in specific applications, e.g. packaging (Earthsoul, NatureWorks, Synbra); or to compare different bio-based routes to produce plastics (Reverdia).

With regards to the LC coverage, for all companies but two the raw material and production stages were indicated as covered, while the use and disposal phases were only included by four companies. For only three companies, information about the EOL scenarios taken into account was provided. In terms of environmental impact categories, for all companies, climate impact was included, together in several cases with energy use, fossil energy use or abiotic resource depletion. A broader range of impact categories was covered by five companies only, including e.g. acidification, eutrophication and/or toxicity impacts. Coverage of LC stages and environmental impact categories across LCA studies displayed by companies are shown in Figure 18.

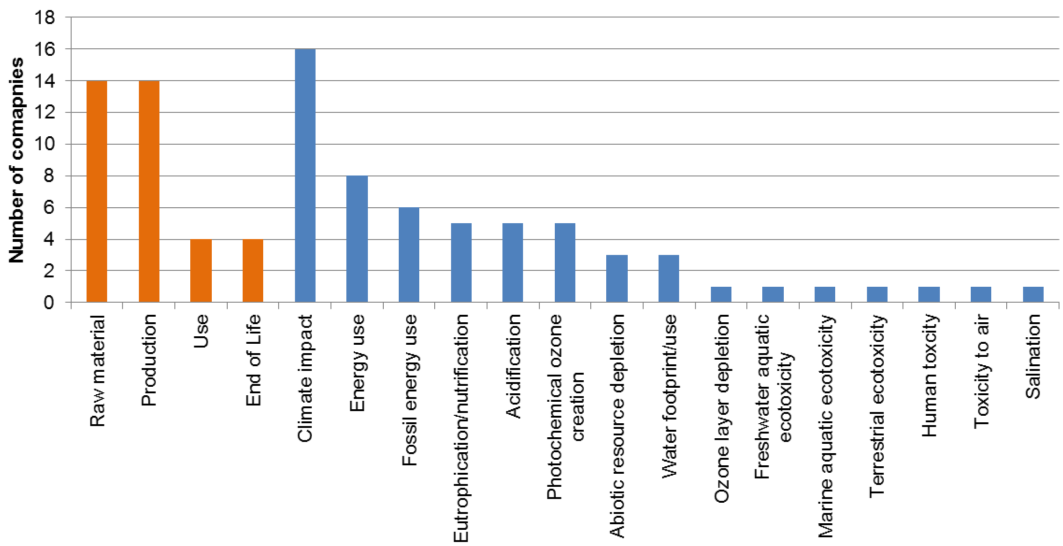


Figure 18. Distribution of life cycle stages (orange bars) and environmental impact categories (blue bars) among companies displaying Life Cycle Assessment results for bio-based plastics (N = 16).

Most LCA studies comparing bio-based plastics with conventional plastics typically concluded that the former showed a better climate performance. Nonetheless, the cradle-to-gate study by E4tech and LCAworks (2013) for Braskem's biobased PE resin revealed that the bio-based plastic performed better than the conventional plastic for climate change, fossil energy use, while it performed worse for acidification, eutrophication and photochemical ozone formation. Furthermore, the LCA studies by NatureWorks revealed that the better performance of bio-based plastics in terms of climate change is not as straightforward when a cradle-to-grave perspective is taken and would require future technology developments for the bio-based plastic to outperform other options (NatureWorks, 2018).

Overall, a dominant focus on climate change was found among companies to justify the adoption of bio-based plastics and a lack of discussion around the possible higher impact from bio-based plastics with regards to other impact categories. On the other hand, documented environmental claims delivered by bio-based plastics producers were in most cases performed as cradle-to-gate assessments. Hence there is a lack of perspectives in corporate communications on the impact of bio-based plastics disposal and little reflections on current waste management systems versus disposal properties of bio-based plastics. This either reveals a misunderstanding or a lack of interest from companies in the criticality of EOL scenarios to determine the environmental performance of bio-based plastics. These findings reveal a need for companies to expand their assessment of bio-based plastics beyond the climate impact and to consider actual disposal practices of bio-based plastics in their narratives and assessments. From the perspective of bio-based plastics producers, Vink et al. (2010) argued that cradle-to-polymer factory gate assessments among bio-based plastics producers are performed because the variety of applications and EOL routes for bio-based plastics which induce high complexity and uncertainty in cradle-to-grave assessments. Yet, attention to the EOL of bio-based plastics could be especially relevant for converters to address since they determine bio-based plastics application and are closer to consumers.

3.6 Answer to research question 1 and discussion

In **Section 3.6**, the results from the above mentioned research steps are combined in order to answer **RQ1**: "*To what extent is life cycle thinking present in company narratives of their sustainability approaches provided in corporate sustainability reports?"* From the systematic literature screening of earlier empirical studies based on analyses of CS reports, a limited number of articles were found to explore sustainability approaches from a product LC perspective. They investigated the extent to which companies in different sectors and countries addressed different environmental aspects (e.g. material, energy and pollution/toxic waste), through different environmental management practices (e.g. design for environment considerations incorporated into the company's product design, quantitative environmental targets for products) and operational practices (e.g. packaging in bio-degradable materials, reduction of product weight, eco-efficient production), related to different LC stages (e.g. before product usage, during product usage, after product usage). Yet, the extent to which LCT is present in companies' narratives of their sustainability approaches provided in CS reports remained to be investigated further.

In order to address this, I presented four empirical studies, which together contribute to building a picture of LCT presence in companies' narratives in the form of CS reports (and website communications for **empirical study 4**). In **empirical study 1**, references to the LCA methodology in CS reports were mapped and analyzed for the past two decades (**empirical study 1A**). Additionally, for a sample of CS reports that made reference to the LCA methodology, the insights they delivered on LCA use at the corresponding companies were analyzed (**empirical study 1B**). In **empirical study 2**, presence of LCT elements, namely the product LC system, hotspots in the product LC, tradeoffs in the product LC and across environmental problems, and product environmental sustainability budget were investigated in CS reports of the Nordic apparel industry. In **empirical study 3**, the adoption of the concept of CE by FMCG companies was reviewed in their CS reports. In **empirical study 4**, rationales from an environmental perspective of companies adopting bio-based plastics in their material portfolio were analyzed. These two last studies provided complementary views to answer **RQ1**, respectively because of the need expressed by earlier scholars to assess the environmental performance of CE strategies from a LC perspective, and because of the unclear environmental performance of bio-based plastics from a LC perspective.

Overall, the presence of LCT in companies' narratives was detected in these four empirical studies through three indicators:

(i) reference to LC-based methodologies (e.g LCA, footprints and EPDs);
(ii) extent to which environmental sustainability operational practices addressed the different LC stages in the product LC system;
(iii) and presence of LCT elements in the forms of product LC system, hotspots, tradeoffs and product environmental sustainability budget.

Figure 19 provides an overview of the answer to **RQ1**, where the findings from each empirical study are shown against these three indicators.

Presence of LCT in companies' narratives provided in their CS reports

	References to LC-based methodologies	LC coverage by sustainability operational practices	Presence of LCT elements in (product LC system, hotspots, tradeoffs, budget)
EMPIRICAL STUDY 1 References to the LCA methodology in CS reports	▪ References to the LCA methodology (including EPD) in ca. 5% of English-written CS reports published in 2015 ▪ Sectoral and geographical variations ▪ LCA used for ecodesign and marketing		▪ High focus on climate change in LCAs ▪ EOL and use stage less often included than raw materials and production in LCAs ▪ Earlier CS reports found to display LCA application cases covering more environmental problems
EMPIRICAL STUDY 2 LCT elements in narratives of sustainability approaches at Nordic apparel companies	▪ References to LC-based methodologies in one-third of the sample: LCA, EP&L, Higg Index, EIM, Made-by scoring model, carbon footprint, water footprint	▪ Focus of environmnetal sustainability operational practices on the sourcing stages (raw material, fabric production and processing, garment production) and some initiatives or intention to address the EOL stage ▪ Low emphasis on the use stage	▪ Idea of product LC system present in most CS reports ▪ Limited presence of idea of hotspots in LC ▪ Very limited presence of the ideas of tradeoffs and product environmental budget
EMPIRICAL STUDY 3 CE in sustainability agenda of FMCG companies	▪ In most CS reports, references to LCA, carbon footprint or water footprint, but in most cases not in relation with CE	▪ Focus of CE-related operational practices on sourcing and production stages, with some initiatives to influence the EOL stage ▪ Low emphasis on the use stage	▪ No emphasis on potential burden shifting across the LC potentially induced by CE-related initiatives
EMPIRICAL STUDY 4 Environment-based rationales for uptake of bio-based plastics	▪ Among the companies identified as dealing with bio-based plastics, 26% were found to refer to LCA applied to bio-based plastics		▪ High focus on climate change, lack of discussion of possible higher impact from bio-based plastics for other environmental problems ▪ Cradle-to-gate LCAs, lack of perspectives on the impact of bio-based plastics EOL

Figure 19. Graphical overview of the answer to research question 1. LCT= Life Cycle Thinking; CS= Corporate Sustainability; EPD= Environmental Product Declaration; LCA= Life cycle assessment; EOL= End-Of-Life; EP&L= Environmental Profit & Loss; EIM= Environmental Impact Measurement; FMCG= Fast-Moving Consumer Goods; CE= Circular Economy.

3.6.1 Product life cycle system in corporate sustainability reports

In **Study 2**, the idea of product LC system was found present in the narratives of Nordic apparel companies, with some limitations in smaller companies. It was found in several forms; graphical representations of the product LC; indications that the product LC is in focus in the sustainability approach at the company; and indications that LC environmental impacts can be addressed through product development. This explicit presence of the product LC system corroborates claims from earlier studies according to which the product LC has become a common frame for companies to explore and address their environmental impacts (Heiskanen, 2001; Pennington et al., 2007). Yet, a particularly high focus on the product LC could be specific to the apparel industry due to the intense use of outsourced production in this sector, or to the Nordic region where LCA uptake in industry is high as found in **empirical study 1A**.

The presence of a product LC perspective was further revealed through an investigation of environmental sustainability operational practices in the different LC stages. **Empirical study 2** revealed a focus on the sourcing stages (raw materials, fabric production and processing, and garment production), with some initiatives or intentions – found at the largest companies, to influence the EOL stage. **Empirical study 3** showed a focus on sourcing and operations stages, also with some initiatives to influence the EOL stage. The use stage was found in both studies only limitedly addressed. Using a volumetric approach (i.e. measuring the amount of disclosure on different topics, which differs from the approach taken in **empirical studies 2 and 3**, which else relied on a mapping of operational practices), Comas-Martí and Seifert (2013) analyzed the LC coverage of disclosures in CS reports from six different sectors (computer & electronic hardware, retail, building material, clothing, food producers and automotive), and found that the firm-level (i.e. production or own operations stage of the LC) dominated in terms of disclosure volumes to the detriment of other LC stages. References to the use and EOL stages were found largely absent from CS reports, with some exceptions for the computer & electronic hardware and the automotive sectors, whose products are energy-intensive in the use stage and subject to extended producers policies at the EOL of products (Comas-Martí and Seifert, 2013). Hickle (2017) found that Design for Environment (or ecodesign) practices were in focus when developing products, e.g. design for recycling, energy efficiency, reduction in packaging, and some but less emphasis on managing products at the EOL through reverse logistics.

3.6.2 References to the life cycle assessment methodology and other life cycle-based methods in corporate sustainability reports

Empirical study 1A showed that the LCA methodology in itself had a rather weak presence in CS reporting in industry, with a decreasing trend revealing that LCA has dropped on the CS reporting agenda in the period 1999-2007, which has now stabilized ca. 5% (including EPD as an indicator of LCA methodology). This relative absence of LCA in CS reports may reflect that the companies do not work with LCA for various reasons such as their cost, complexity or unreliability (Schaltegger, 1997; Cooper and Fava, 2006). The low LCA presence may also be explained by the fact that some LCA results are unfavorable to the business activities (Berkhout, 1996), not peer reviewed (Jensen et al., 1997) or deemed unsuited for the audience of CS reports (Goedkoop et al., 2015; Testa et al., 2016). Omitting references to LCA in CS reporting due to unfavorable results could be motivated by the company's use of CS reporting to legitimize its business and manage its sustainability reputation (Hooghiemstra, 2000; Hahn and Kühnen, 2013). Single life-cycle impact indicators, like carbon footprint or water footprint, may be preferred over more complex LCA results, because they are simpler to communicate (Weidema et al., 2008; Molina-Murillo and Smith, 2009).

In **empirical study 2**, one-third of companies referred to their use of multi-environmental aspects LC tools (e.g. Higg Index, EP&L, EIM Jeanologia, and LCA). In **empirical study 3**, most companies were found to mention LCA and footprint methodologies (carbon footprint or water footprint) in their CS reports. In **empirical study 4**, around one-fourth of companies were found to refer to their use of LCA in relation to bio-based plastics in their publicly available communications. **Empirical studies 2 and 3** provided a more granulated picture of LC-based tools referred to by companies in CS reports, based on their inductive approach, and revealed higher presence of LC-based methodologies in the samples they covered than **empirical study 1A**, although they are not representative of industry at large. **Empirical study 4** included both CS reports and companies' websites as data sources, and information about LCA applied to bio-based products were mainly found on companies' websites. This could indicate that companies display more information on their LCA use on their website than in their CS reports, although the sample included in **empirical study 4** is not representative of industry at large.

Empirical study 1B showed that companies mentioning the LCA methodology in their CS reports referred to the use of the methodology to support their ecodesign and marketing practices at a product level. LCAs were found mostly conducted internally on a selection of products (e.g. product family). In their review of public communications of twenty sustainability forerunners, Nygren and Antikainen (2010) similarly found that internally, LCAs were used to support ecodesign practices, and externally to support the creation of EPDs or eco-labels. In their study, Frankl and Rubik (2000) had found on the contrary that companies surveyed in the late 1990s had low marketing purpose and were making use of LCA in a retrospective manner, i.e. for informative purposes, rather than for prospective purposes, e.g. ecodesign of products. **Empirical study 1B** provided indications that the LCA methodology is also used from a prospective perspective.

The longitudinal phase of **empirical study 1B** indicated different trajectories of LCA adoption by companies with emphasis on e.g. external use for communication, internal use as an innovation competency, or external use for normative approaches in the sector. This latter emphasis was specially found in Nygren and Antikainen's (2010) sample, as reviewed companies were found involved in research activities around LCA, which might be explained by their identified forerunner role. Based on case study research at four companies in different sectors (manufacturer of bio-fuels, manufacturer of stainless steel tanks, manufacturer of paints and building designer), Häkkinen et al. (2013) found LCA use ranging from studying the environmental performance of alternative design options and giving information to end-users, over provision of LCA information upward to the supply chain and to LCA research. In their study of two companies from the pulp & paper industry, Rex and

Baumann (2007) found that organizational aspects of LCA adoption differed at the two companies in two main ways. First, at the paper and pulp producing company SCA, LCA capability was centralized in the environmental department, whereas at another company of the same sector, Stora Enso, LCA was used in different points of the organization. Second, at SCA the use of LCA was mostly as a formal requirement in product development processes, while at Stora Enso LCA studies were standalone, comparisons of processes and of different products. Examples of such differences could only be partly captured in **empirical study 1B** when CS reports contained indications of product portfolio coverage, or systematic use of LCA in product development.

LCA application cases observed in **empirical study 1B** and LCA applied to bio-based plastics observed in **empirical study 4** showed that (i) in terms of LC coverage, the EOL stage was least included, and (ii) in terms of environmental impact categories, most cases included only climate change or energy use. The longitudinal phase of **empirical study 1B** indicated that the focus on climate change in LCA applications shown in CS reports might be a recent trend, with earlier CS reports displaying LCA applications covering more environmental impact categories. In **empirical study 1B**, the use stage was found covered in more than half of applications, whereas in **empirical study 4**, it was covered only by one-fourth of companies applying LCA to bio-based plastics. The difference could be due to the companies found to refer to LCA in **empirical study 4** being bio-based plastics producers, with limited visibility of final applications for bio-based plastics.

3.6.3 Analytical use of life cycle thinking in narratives provided in corporate sustainability reports

In **empirical study 2**, analytical elements of LCT, namely hotspots in the product LC, tradeoffs in the product LC or across environmental problems, and product environmental sustainability budget related to ecological limits were found only limitedly elaborated upon in Nordic apparel companies' narratives of their sustainability approaches. In **empirical study 2**, less than one-third of the sample mentioned analysis of hotspots in the product LC as a way to guide their environmental sustainability approaches, and tradeoffs and ecological limits were not mentioned as taken into account when designing environmental sustainability approaches. **Empirical study 3** revealed that CE was often associated with tackling environmental sustainability challenges by FMCG companies. Yet, the linkage between CE and sustainability remained unclear in companies' narratives, and in particular burden-shifting across the LC potentially induced by CE-related initiatives was not discussed. **Empirical study 4** showed a dominant focus on climate change to justify the adoption of bio-based plastics with a lack of discussion around the possible higher impact from bio-based plastics for other environmental impact categories. It further revealed that documented environmental claims were in most cases performed as cradle-to-gate assessments, hence, with a lack of perspectives on the impact of bio-based plastics EOL, and little reflections on current waste management systems versus disposal properties of bio-based plastics. These different findings indicate a lack of use of LCT from an analytical perspective in narratives provided in CS reports included in the samples.

This echoes critics of CS reporting made in the critical path of CS reporting research: a lack of reflection on the relationships between companies' activities and Earth's eco-systems (Dumay et al., 2010; Milne and Gray, 2013), and a lack of self-criticism in disclosures with low focus on tradeoffs, assumptions and uncertainties (Fonseca et al., 2014). Higgins and Coffey (2016) found that narratives provided by companies in their CS reports are mainly in the form of an “argument”, i.e. written by companies to demonstrate that they are taking actions to address their sustainability challenges, as opposed to be in the form of a “dialogue”, opening up for discussion with stakeholders. Such attitudes from companies may reflect motivations behind CS reporting such as the use of CS reports by investors and external agencies to rate and rank companies according to their CS practices (Burrit and Schaltegger, 2010), and the use of CS reports by companies as communication tools to strengthen their “license to operate” and shape their reputation (Hooghiemstra, 2000; Hahn and Kühnen, 2013). Higher analytical content on hotspots, tradeoffs, and environmental sustainability budgets could be considered detrimental to “best presenting” the sustainability efforts of the company (Mikler, 2007).

Yet, building further on analytical aspects of LCT in CS narratives, through explicitly discussing hotspots in the product LC, tradeoffs in the product LC and across environmental problems and ecological limits, would create the basis for a dialogue with stakeholders on how to improve the sustainability performance of the business, which is one key purpose of LCT (Thabrew et al. 2009; Fullana i Palmer et al., 2011). From the perspective of investors and ranking agencies, it would demonstrate a better understanding of environmental sustainability challenges associated with products, and possibly denote higher competitiveness and business resilience. Expectations from external users of CS reports reported in **Section 3.1.3**, such as providing an overview and analysis of critical issues, together with information about concrete plans to address these issues, would benefit from higher presence of analytical elements of LCT in companies’ narratives of their sustainability approaches.

3.6.4 Understanding the presence of life cycle thinking in corporate sustainability reports from the perspective of corporate sustainability reporting as a corporate practice

Earlier academic studies revealed that the process of producing CS reports influenced their final form. From an internal perspective, managers’ individual proactivity and perceptions were reported to shape the reporting process, and the extent and quality of reporting (Adams, 2002; Adams and McNicholas, 2007; Husillos et al., 2011), and low involvement of top management in the CS reporting process was found to open up for individuals’ preferences and opinions about how the CS report should look like (Frostenson and Helin, 2017). Hence, the human factor behind the extents of LCT presence in companies’ narratives of their environmental sustainability work in their CS reports would be highly relevant to study in future work.

The 2015 update of the ISO 14001 standard for environmental management systems has set a higher focus on LCT and ecodesign “*for identifying and assessing the environmental aspects in relation to products”*, including *“indirect environmental aspects that are beyond the direct control of the organization”* (Lewandowksa and Matuszak-Flejszman, 2014, in abstract). Lewandowksa and Matuszak-Flejszman (2014) argued that this revision is an opportunity for an increased focus on ecodesign among companies, considering the current popularity of the ISO 14001 standard in industry. An increasing focus on the product perspective and LCT in environmental management systems could drive higher focus on the product LC perspective in CS reporting as well.

From an external perspective, requirements from policy-makers, investors and external agencies influence the CS reporting process. These different actors could drive higher focus of companies on building their narratives of sustainability approaches on LCT from an analytical perspective. For example, in the EU, the sustainable finance action plan launched in 2018 requires companies to strengthen their non-financial information disclosures. A strong LC focus could be anchored in such initiatives to complement the current focus on applicability of the EU eco-label framework for financial products (EC, 2018e).

Considering the traction of the GRI, strengthening the presence of LC analytical elements in their reporting guidelines (GRI, 2013) would be another meaningful entry point. A LC perspective is already embedded in environmental disclosures covering e.g. material used (recycled sources), products retrieved at their EOL, indirect GHG emissions, and supplier assessments (GRI, 2013). Similar observations can be made for the recently launched GRI Standards replacing the GRI 4 guidelines as of July 2018 (GRI, 2018). However, the focus on analytical elements of LCT (hotspots, tradeoffs and budget) could be strengthened. Materiality analysis as defined in the GRI 4 guidelines could in theory provide the ground for companies to highlight environmental sustainability hotspots in their activities. However, previous studies on the application of materiality analysis by companies found that they seemed to reflect business continuity issues rather than environmental issues, and did not allow representing the relative magnitude of importance and impacts (Jones et al., 2016; Zsóka and Vajkai, 2018). In **empirical study 2**, it was found that the materiality analyses displayed by a subset of companies limitedly referred to environmental sustainability hotspots in the product LC.

“Experts”, such as stock exchange analysts and thematic business associations, in forums where companies learn and discuss how to approach CS reporting, were highlighted as influencers of CS reporting practices, and could also be a means to increasing analytical and reflective narratives based on LCT in CS reporting (Husillos et al., 2011).

Finally, availability of adequate methodological support for companies to analytically build on LCT in their CS reports remains to be investigated. Ongoing guidance development for the application of LCA at an organizational-level, and for the conduction of hotspot analysis may be opportunities for an increased presence of LCT in CS reporting (Barthel et al., 2017; EC, 2018c). The category sustainability profiles developed by the Sustainability Consortium based on LCA studies and dialogue with researchers, experts and stakeholders, which contain information about the environmental and social hotspots for a variety of product categories could also be a tool used by companies (Dooley and Johnson, 2015).

3.6.5 Presence of life cycle thinking in corporate sustainability reports and life cycle thinking in corporate sustainability practice

In earlier academic studies, the extent to which CS reporting matches with actual CS practices was found to vary from one company to the other. On the one hand, CS reporting was seen as a means of communication to external stakeholders, and could be associated with the “improviser” profile defined by Thijssen et al. (2016), i.e. informal reporting process and no integration of sustainability in day-to-day activities. On the other hand, CS reporting was found to occur in parallel of internal processes of developing the appropriate culture, and could be associated with the “performers” profile defined by

Thijssen et al. (2016), i.e. formal reporting process and high integration of sustainability in their daily activities. In practice, analyses of CS reports were found not to help differentiating between different profiles of reporters (Thijssen et al., 2016). Hence, presence of LCT in CS practice cannot be directly inferred from presence of LCT in companies' narratives of their sustainability approaches.

Moreover, LCT may be present in various departments of an organization, with no overarching strategy linking all these practices at a more strategic level, as found by Holgaard et al. (2007) in their study of a Danish company. In their study of a multinational company, Nilsson-Lindén et al. (2018a) arrived to the same conclusion of a lack of comprehensive overview of LC-based activities in the company, where LC-based aspects were discussed in separate forums. Analyses of LCT presence in companies' overall environmental sustainability strategy for their products as presented in their CS reports helps investigating the presence of LCT from an overarching perspective. Yet, combining interviews or field studies and analysis of CS reports would be a good way to grasp whether LCT is present in companies both on an overarching and on a more granulated level.

Specifically, the extent to which LCT is on the radar of (i) senior management and (ii) employees in different departments in the organization would be relevant to explore further, and compare with company narratives in CS reports. In the context of **RQ2**, empirical insights from ecodesign proponents in Danish and Norwegian manufacturing companies were collected and provided evidence of LCT presence in ecodesign proponents' descriptions (described in **Section 4.4**). For instance, at Company C, the conduction of LCA studies on the company's products had initially received weak attention in the internal organization, but was recently regarded with interest by senior management for use in the company's external communication; whereas at Company D, senior management was described not to focus much on LCA results in review meetings of product development processes. At Company A, an interviewed project manager demonstrated his understanding of the product LC, although he did not know what an LCA was, while at Company G, two product developers evoked the LCA methodology in their descriptions of ecodesign integration in their company. At Company E, the LCA methodology was not referred to in the company's CS report; yet one interviewed employee from the EHS department indicated that there had been internal requests for doing LCAs, that a LC-based mapping of the resources used by the company had been developed by consultants, and she further emphasized the necessity of identifying hotspots in the company's value chain. In their study of LCA adoption in companies of the pulp and paper sector, Rex and Baumann (2007) found that patterns highly depended on the human factor, i.e. on individual perceptions and preferences of those introducing the LCA methodology in their organizations. The insights collected as part of **RQ2** corroborate the findings by Rex and Baumann (2007) and further suggest that the focus on LCT among employees in core functions (i.e. beyond ecodesign or sustainability-oriented functions) may also depend on human factors.

Although earlier studies found that the potential managerial function of CS reporting for CS practices was limitedly leveraged (Lozano et al., 2016; Frostenson and Helin, 2017), internal function of CS reporting were identified such as:

(i) initiating proactive sustainability work at companies, fostering communication and collaboration between departments and legitimating sustainability efforts in the organization (Hedberg and von Malmborg, 2003);
(ii) monitoring progress towards goals (Searcy and Buslovich, 2014);
(iii) increasing internal awareness and providing useful measures for strategy evaluation (Pérez-Lopez et al., 2015);
(iv) triggering a learning process for senior management and the team in charge of the development of the report (Adams and McNicholas, 2007);
(v) developing data collection systems and the integration of sustainability performance data into decision-making, risk management and performance measurement (Adams and Frost, 2008).

Considering these internal functions of CS reports, strengthening the presence of LCT in narratives presented in CS reports could strengthen LCT use in the organizational functioning.

3.6.6 Limitations and suggested areas for future work

Analysis approach

The presence of LCT in companies' narratives was detected through three indicators, namely (i) references to LC-based methodologies (e.g. LCA, footprints and EPDs), (ii) extent to which environmental sustainability operational practices addressed the different LC stages in the product LC system, and (iii) presence of LCT elements in the forms of product LC system, hotspots, tradeoffs. However, these indicators can be refined. For instance, one important observation from the studies is that LC-based methodologies can be found under various terminologies which may depend on the sector addressed (e.g. methodologies specific to the apparel sector such as the Higg Index). Hence, a refined analysis of references to LC-based methodologies in CS reports could be conducted, after compiling these different LC-based methodologies coexisting in industry. Furthermore, the analyses of CS reports was done with a focus on the content, more than on the form and *"flavor"* in which narratives were provided, with an exception for **empirical study 2.** Indeed, in the analysis of LCT elements in Nordic apparel CS reports, more nuances in which the different elements were present in narratives could be captured (e.g. graphical display of the product LC or definition in text). However, less factual analyses, for instance at the discourse-level or of graphical content, could be the focus of future work.

Subjectivity and lack of access to context

The use of corporate documents and their interpretation for research purpose is subject to biases due to the subjectivity of the researcher, and the lack of access to the context in which the documents were produced (Bowen, 2009). In order to minimize the biases related to the researcher's subjectivity, measures were applied such as researcher triangulation, transparent reporting of data, and the use of existing conceptual framework or conceptual framework derived from existing knowledge to guide analyses. Moreover, CS reports being stable data sources, repeatability of the research process is possible (Bowen, 2009). Regarding the second potential source of biases (related to the lack of context), data triangulation would have been necessary to address the issue, such as direct contact with the companies releasing CS reports. However, this bias is particularly critical to answer research questions using documents as a data source, since they were created independently from the research agenda (Bowen, 2009). It is less critical in this thesis, since the research question set a direct focus on CS reports as the objects under investigation. The research steps under **RQ1** must be regarded as revealing the presence of LCT in CS reports, as interpreted by a reader of these reports who had no other contact with the companies producing these reports.

Yet, future work could be based on conducting interviews of employees responsible for CS reporting in companies, in order to triangulate the interpretations of LCT presence stemming from analyses of CS reports. This is particularly critical in order to better understand the role of LCT in companies' narratives about their sustainability approaches, and refine the set of identified levers (i.e. reporting guidelines, policy-making, investors, external ranking agencies and method development) to drive higher focus on analytical aspects related to the product LC (e.g. hotspots, tradeoffs, and budget) in companies' narratives.

Exploratory nature of the studies

Apart from **empirical study 1A**, the other studies conducted as part of **RQ1** were exploratory studies. Especially, **empirical study 2,** which aimed at exploring the presence of LCT elements in companies' narratives of their environmental sustainability approaches, should be replicated within other sectors and countries, as it only provided insights in the context of the Nordic apparel industry.

The research methods used to analyze CS reports in the studies conducted throughout this PhD project (apart from **empirical study 1A**) can be qualified as semi-quantitative. Indeed, they involved interpretation throughout the analysis and inductive aspects, where analysis elements emerged from the data. In this perspective, thorough reading of full or part of the CS reports was required, hence restricting the feasible size for the samples. In order to fully leverage the benefit of using document analysis and considering the amounts of CS reports released each year, an area for future work would be to explore the possibility to automatize the analysis of CS reports, although nuances within narratives would not be grasped in such setting.

Exploring other channels of companies' narratives

Not a direct limitation because **RQ1** specifically targeted companies' narratives provided in CS reports, the presence of LCT in other channels of companies' narratives could be relevant to explore in future work. The study of corporate websites could be particularly interesting. In **empirical study 4**, which included both CS reports and companies' websites, one observation was that information about the companies' use of bio-based plastics was more often available on the websites than in CS reports. Although corporate websites do not have the same function as CS reports, they could provide richer insights on companies' niche practices. Another possible channel could be corporate press releases, as was undertaken by Bocken et al. (2017) with the aim to detect the presence of CE-related terms.

4 Four-lens view of organizations to investigate and support ecodesign integration in companies' formal and informal organizational functioning (RQ2)

In **Chapter 4**, I present the different research steps conducted during my PhD project in order to address **RQ2**: "*To what extent can the four-lens view of organizations help investigating and supporting ecodesign integration in formal and informal organizational functioning of companies?"* The four-lens view of organizations was introduced in **Chapter 1** as a good candidate conceptual framework to support the investigation of and practically support ecodesign integration in companies' formal and informal organizational functioning identified as a research gap. The structure of **Chapter 4** is illustrated in Figure 20.

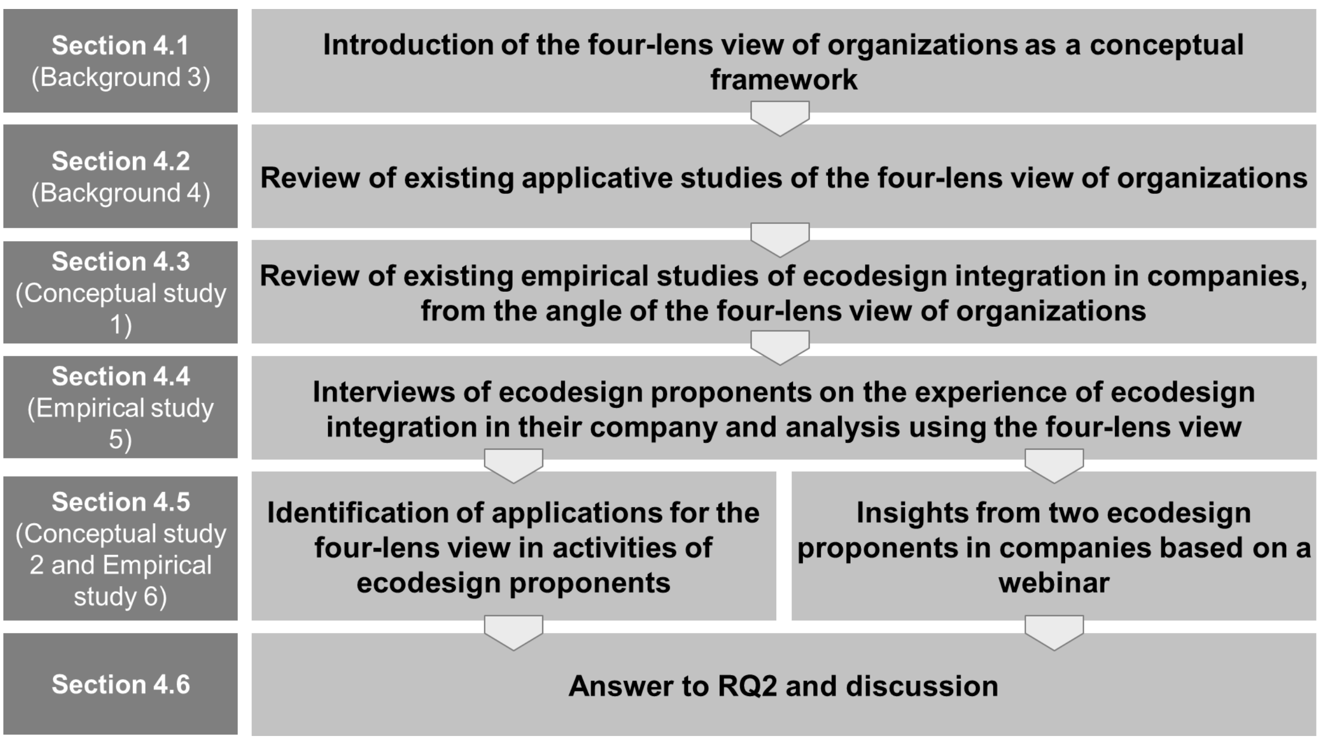


Figure 20. Structure of Chapter 4.

In **Section 4.1**, I introduce the details of the four-lens view of organizations as developed by Bolman and Deal (2008) (**background 1**). In **Section 4.2**, I present the review of existing empirical studies in academic literature applying the four-lens view of organizations in diverse organizational contexts. This literature review was conducted in order to further my understanding of the framework, and gather insights on the application of the framework in investigations of organizational phenomena (**background 2**). **Sections 4.3 to 4.5** have in focus ecodesign integration in internal organizational functioning from the perspective of the four-lens view of organizations, and represent the three main research steps taken to answer **RQ2**. **Sections 4.3 and 4.4** address the analytical part of **RQ2**, related to "*investigating ecodesign integration*", whereas **Section 4.5** addresses the practical part of

RQ2, related to "*supporting ecodesign integration*". In **Section 4.3**, I present a review, from the angle of the four-lens view of organizations, of existing academic studies empirically exploring the phenomenon of ecodesign integration in companies from an internal organizational perspective (**conceptual study 1**). My focus was on investigating the extent to which measures in favor of ecodesign integration earlier identified by scholars covered the different lenses of organizations. In **Section 4.4**, I present the analysis of exploratory case studies conducted at seven companies, in which ecodesign proponents were interviewed about the ecodesign experience at their company (**Article IV**). The analysis was conducted with a specific focus on uncovering the extent to which the four lenses of organizations were found useful to support ecodesign integration (**empirical study 5**). In **Section 4.5**, I present three concrete applications of the four-lens view of organizations to support activities of ecodesign integration in companies, which I derived from the applications of the framework identified in **Section 4.2** and relevant knowledge of ecodesign integration in companies. Further, I contrast these three practical applications with initial insights from ecodesign proponents in industry (**conceptual study 2 and empirical study 6**). Finally, in **Section 4.6**, I summarize the findings of these different research steps and discuss the latter in the perspective of **RQ2**.

4.1 Introducing the four-lens view of organizations as a conceptual framework (background 3)

The original aim of the four-lens view of organizations developed by Bolman and Deal's (2008) is to pragmatically support the work of managers, leaders and change agents (i.e. instigators of changes) in organizations by bringing together different groups of management theories providing complementary views of what organizations are and how they function. Each lens of organizations is built on specific management theories, and corresponds to a specific perspective of organizations. As introduced in **Chapter 1**, organizations are viewed on the one hand as *formal* structures designed to fulfill a given mission, applying specific procedures, systems, and roles corresponding to the "structural lens". On the other hand, firms are *informal* communities where employees have needs, aspirations, preferences and fears ("human lens"), personal or group agendas with possibly conflicting objectives ("political lens"), as well as a shared understanding of "how things work around here" (e.g. habits and routines) ("symbolic lens").

The structural lens builds among others on Taylor's (1911) scientific management theory, Weber's (1947) bureaucratic management theory, and Mintzberg's (1979) work on organizational structures. The human lens is derived among others from the Theory Y (as opposed to Theory X) developed by McGregor (1960), and the work of Argyris (1964) on the relationships between organizations and individuals. The political lens is anchored among others in the works of Kotter (1985) and Pfeffer (1981) about political skills of managers. The symbolic lens draws among others from the work of Schein (1992) on organizational culture. The structural lens emphasizes division and coordination of work and embraces well defined rules, policies and goals; the human lens focuses on the relationships between employees and the organization, and pays specific attention to individual needs; the political lens views organizations as arenas where interest groups compete for power and resources; and the symbolic lens focuses on creating meaning in a chaotic and ambiguous environment (Bolman and Deal, 1991).

The original purpose of the four-lens view is to invite managers, leaders and change agents in organizations to expand their views of their organization and situations by using these different lenses, in order to gain a deeper understanding of hotspots or challenges, a better overview of available levers, and ultimately to develop more effective approaches. Concretely, such reframing can be done by alternatively using an architect's, catalyst's, advocate's or prophet's perspective corresponding to different metaphors of organizations. Through the structural lens, the *architect* views the organization as a *machine or a factory* and design targets, organizational units, processes and coordination mechanisms. Through the human lens, the *catalyst* views the organization as *a family* and aims at embracing employees' needs, fears and aspirations and supporting them in their tasks. Through the political lens, the *advocate* views the organization as a *jungle* and aims at building coalitions, gaining power and negotiating agendas. Through the symbolic lens, the *prophet* views the organization as a *temple* and focuses on fostering sense-making, challenging common beliefs and inspiring the group. Figure 21 displays the four-lens view of organizations as a conceptual framework, which includes for each lens (i) the corresponding metaphor of organization, (ii) the perspective adopted by managers, leaders or change agents, (iii) the summary of underlying basic assumptions about organizations, and (iv) examples of courses of action, adapted from the work by Bolman and Deal (1991; 2008).

Bolman and Deal (2008) have suggested various applications for the four-lens view framework. First, it may be used to understand the role of diverse organizational processes. For instance, *decision-making* may be regarded as a "*rational sequence to produce the right decision*" (architect's perspective), an "*open process to produce commitment*" (catalyst's perspective), an "*opportunity to gain or exercise power*" (advocate's perspective) or a "*ritual to confirm values and provide opportunities for bonding*" (prophet's perspective). Similarly, *meetings* can be seen as "*formal occasions for making decisions*", "*informal occasions for involvement and sharing feelings*", "*competitive occasions to win points*" or "*sacred occasions to celebrate and transform the culture*" (Bolman and Deal, 2008, p. 314-315). Second, the four-lens view may be used to explore *lens preferences* among managers, leaders and change agents. Bolman and Deal developed a *leadership orientation instrument* (LOI) operationalizing each lens into a set of activities or attitudes, and used it to test leaders or managers' lenses preferences, and relate the use of different lenses to effectiveness variables. Third, the four-lens view may be used in the context of change management, in order to enrich the change agent's understanding of the change process from the different perspectives. For example, the four-lens view may be used to investigate and address *barriers to change*. From the structural lens, a change can be associated with a loss of direction, clarity and stability, and thus requires communicating, realigning and renegotiating formal patterns and policies (Bolman and Deal, 2008, p.379). From the human lens, a change may be associated with anxiety and uncertainty, and thus requires training and psychological support (Bolman and Deal, 2008, p.379). From the political lens, a change may be associated with disempowerment and conflicts between winners and losers, and thus requires creating arenas where issues can be negotiated and new coalitions formed (Bolman and Deal, 2008, p.379). From the symbolic lens, a change may be associated with a loss of meaning and purpose, and thus requires creating transition rituals, mourning the past and celebrating the future (Bolman and Deal, 2008, p.379).

LENS	STRUCTURAL	HUMAN	POLITICAL	SYMBOLIC
METAPHOR OF ORGANIZATION	FACTORY OR MACHINE	FAMILY	JUNGLE	TEMPLE
PERSPECTIVE	ARCHITECT	CATALYST	ADVOCATE	PROPHET
SUMMARY OF BASIC ASSUMPTIONS	❑ The organization exists to achieve established goals and objectives. ❑ What matters is that tasks are clearly and rationally divided, defined by procedures and coordinated so that work gets done.	❑ People and organizations need each other: organizations need ideas, energy, and talent; people need careers, and opportunities. ❑ What matters is to align people's needs and aspirations with the organization's goals.	❑ The organization is an arena where individuals and interest groups fight over resources to advance their agendas. ❑ What matters is to gain power, create strong alliances and manage to secure resources and priority in agendas.	❑ Organizations are chaotic, uncertain and ambiguous places, where much is open to interpretation. ❑ What matters is to create meaning and to understand deeply anchored aspects ruling in the organization.
EXAMPLES OF COURSES OF ACTION	❑ Reorganize, implement or clarify policies and procedures ❑ Develop new information, budgeting, or control systems ❑ Add new organizational units ❑ Plan processes	❑ Processes of participation and involvement (e.g. task forces, open meetings) ❑ Train, coach ❑ Empower ❑ Address individual needs, personal aspirations	❑ Bargain ❑ Negotiate ❑ Build alliances ❑ Network with other key players ❑ Anticipate conflicts	❑ Create or revitalize ceremonies and rituals ❑ Work to develop or restate the institution's vision ❑ Use heroes, stories, symbols ❑ Energize, inspire

Icons from left to right: Architect by Augusto Zamperlini from Noun Project; Family by Luis Prado from Noun Project; Lawyer asking question by Gan Khoon Lay from Noun Project; Hero by Andrew J. Young from Noun Project.

Figure 21. Conceptual framework around the four-lens view of organizations, adapted from **Article IV**. It includes for each lens (i) the corresponding metaphor of organization, (ii) the perspective adopted by managers, leaders, or change agents, (iii) the summary of underlying basic assumptions about organizations, and (iv) examples of associated courses of action, elaborated based on the work by Bolman and Deal (1991; 2008).

From these perspectives, the four-lens view of organizations was regarded as a good candidate conceptual framework to explore internal organizational functioning in the context of ecodesign integration, considering its structured approach of formal and informal aspects of organizations. Other similar models built on different views of organizations exist in literature, and some scholars have suggested that the four-lens view can be complemented with other lenses of organizations (Othman et al., 2010; Yi, 2011; McClellan, 2011). An example of a similar model of organizational understanding is Morgan's set of metaphors of organizations: the machine, the organism, the brain, the culture, the political system, the psychic prison, the flux and transformation, and the instrument of domination (Palmer and Dunford, 1996; Örtenblad et al., 2016). A tentative addition of complementary lenses to the four-lens view was suggested by McClellan (2011) who defined the "open systems" lens and the "complex adaptive systems" lens. The basic assumptions behind the open systems lens are that "*organizations are webs of interconnected, interdependent entities in which changes in one part of the system have unintended impacts on other parts*", thus "*understanding the relationships within the system and beyond is essential to managing it*" and "*problems are a result of poor systemic relationships as opposed to just bad processes, procedures and structures*" (McClellan, 2011, p.647). The basic assumptions behind the complex adaptive systems lens are that "*organizations are 'living' organisms capable of self-generating creativity in which complexity and chaos delimit comprehension*", and thus "*management involves participating in/disturbing the system and creating boundaries*" (McClellan, 2011, p.647). The four lenses of organizations included in Bolman and Deal's (2008) framework seemed particularly suited for our investigation of ecodesign integration into formal and informal aspects of internal organizational functioning. Indeed, the structural lens represents formal aspects of organizations which were claimed to be over-emphasized in existing sustainability and ecodesign integration literature. By combining this perspective of organizations with the three others granulating the informal aspects of organizations under the human, political and symbolic lenses, the four-lens view of organizations enables addressing the call for an increased focus on informal aspects of organizations in the ecodesign integration literature (Boks, 2006; Verhulst and Boks, 2012a; 2012b; Brones et al., 2015; Skelton et al., 2016). Hence, the four-lens view of organizations was kept as a candidate conceptual framework to guide **RQ2**.

4.2 Review of existing applicative studies of the four-lens view of organizations (background 4)

4.2.1 Methodology

In order to explore existing applicative studies of the four-lens view of organizations, a literature search was conducted in the Scopus database, with a last update in August 2018. The objective was to identify all English-written journal and conference articles published until 2017, presenting empirical studies in organizational research and using the four-lens view of organizations as a main conceptual framework. The search was based on references to "Bolman and Deal" (and other spellings) in title, keywords and abstracts. The initial search returned 70 English-written journal and conference articles published between 1991 and 2017. Based on the abstracts (and complementary screening of the article when the abstract was not conclusive), purely conceptual studies, non-organizational studies, and studies which did not use the four-lens view as their main conceptual framework were excluded. This led to exclude 27 sources. Two articles which had been identified in an earlier non-systematized search for references and did not appear in the systematized search were added, because considered relevant for the context of this study. The resulting sample contains 45 sources, displayed in Table A8.

4.2.2 Results

4.2.2.1 Application sectors

Applicative studies have focused primarily on educational organizations (64%), to some extent on libraries (18%) and in some cases on healthcare organizations (9%). Only two studies applied the framework in an industrial corporation context (Bolman and Deal, 1991; Sjøback and Knutstad, 2017).

4.2.2.2 Research methods

Insights about the research method used in each applicative study are provided in Table A8. The four-lens view has mainly been applied as a conceptual framework to guide researchers in their investigations. On the one hand, the four-lens view was used *directly* to collect empirical data, in a few cases as a framework for guiding interviews (Schneiderman, 2005; Tan et al., 2015) and in many cases, operationalized in a survey instrument (e.g. Scott et al., 1999; St. Onge et al., 2012; McGowan et al., 2017). On the other hand, the four-lens view was used *indirectly*, i.e. as a deductive framework to conduct content analysis of empirical material but with no influence on the data collection step (e.g. Bolman and Deal, 1991; Lieff and Albert, 2010; Swan-Sein et al., 2012).

In some studies, the four-lens view was *directly* used by practitioners spontaneously or prompted by the researchers (Israel and Kasper, 2005; Janz and Hall, 2013; Sjøback and Knutstad, 2017), with some cases where the researcher was also the practitioner (e.g. Sowell, 2014; Keller, 2015; Thammasitboon et al., 2017).

4.2.2.3 Application contexts

Applicative studies can be classified into three categories corresponding to their focus area: (i) change management (29%), (ii) analysis of organizational processes, roles or situations (18%), and (iii) lens preferences of leaders and managers (53%).

Change management

In the first group of studies, the four-lens view was used to interpret challenges associated with an investigated change, as well as to design solutions to address the challenges. It was applied for example in the context of innovation in higher education (Hulpiau and Waeytens, 2001), implementation of a participatory management approach in a hospital (Bernardes et al., 2015), an academic reform in pharmacy (Bajis et al., 2018), the introduction of a new curriculum in a university (Drake et al., 2014) and a library merger (Molaro, 2014). Kaae et al. (2011) explored how leadership styles of pharmacy owners influenced the implementation of a pharmacy service and found that leaders combining an architect's and catalyst's approaches were associated with success factors such as alignment of values, leader's ownership for the service and addressing of individual perceptions. Building on the four-lens view, Swan-Sein et al. (2012) reviewed the agenda topics of meetings concerning the implementation and sustaining of an advisory dean program over a period of 5 years. They found that structural aspects were particularly prominent at the introduction of the program, human aspects were emphasized after some experience with the program, while the political and symbolic frames had been only limitedly emphasized throughout the years (Swan-Sein et al., 2012). They further indicated the usefulness of such analysis to uncover challenges and improvement areas (e.g. the need to symbolically compensate for potential negative connotation due to high student-to-faculty ratio, and the light shed on actual time allocation and delegating practices from the political lens) and suggested to use the framework in a context of continuous improvement (Swan-Sein et al., 2012). Sowell (2014) found that libraries had been good at using the structural and human lens in their planning of changes, but that the political and symbolic lenses were increasingly important to use "*as libraries seek to work through the issues of changing long-held cultural values and power structures*" (p. 224).

In this first group of studies, the four-lens view was mainly used as a framework to analyze ongoing organizational change, as opposed to a framework used to plan change. Exceptions are the studies by Mason et al. (2014) and Thammasitboon et al. (2017), and to some extent the study by Haviland (2014). Mason et al. (2014, p.2) reported how their project team, mandated to support an increased presence of women among faculty staff at a given university, relied on the four-lens view in order to "*understand [the] organization*" and "*ensure that the set of proposed interventions [were] designed to positively impact the university at the structural, human resource, political, and symbolic levels*". Thammasitboon et al. (2017) documented their strategies as practitioners to enable medical educators' scholarly development which, as they described, were anchored in and embracing the four lenses of organizations. Haviland (2014) built on the four-lens view to identify measures from literature and exemplary institutions expected to help program leaders in their implementation of program assessment practices, although the author indicated that the extent to which these measures would guarantee implementation effectiveness remained to be investigated.

Analysis of organizational processes, roles or situations

In the second group of studies, the four-lens view was used to analyze current processes, roles, or organizational situations. Schneiderman (2005) and Fleming-May and Douglass (2014) used the four-lens view as a conceptual framework to explore the role of nurses and librarians, respectively, and the challenges they experienced in their organizations. Within this group of studies, two documented a direct use of the four-lens view by practitioners (Janz and Hall, 2013; Sjøback and Knutstad, 2017). Janz and Hall (2013) conducted action research at the Information Technology department of a university where they taught the different lenses of organizations to employees, and encouraged them to examine real work issues through the different lenses of organizations. They found that, on the long term, the four-lens view had become a common language for the leadership team to address organizational issues (Janz and Hall, 2013). In the context of an outsourcing process at a Norwegian manufacturing company, Sjøback and Knutstad (2017) organized workshops in which participants from the supplier's and buyer's side were encouraged to use the four-lens view to analyze key decisions that were made in the outsourcing process; they concluded that the four-lens view increased the understanding among stakeholders and improved their decision-making abilities. In her own reflections as a practitioner about challenges experienced in international schools, Keller (2015, p.911) suggested to analyze general issues from the four lenses of organizations in order to "*generate comprehensive strategies*".

In the first and second groups of studies, scholars underlined that the framework enabled a rich understanding of organizational processes, roles and changes and allowed the investigation of success factors, challenges and solutions in diverse organizational phenomena (e.g. Swan-Sein et al., 2012; Janz and Hall, 2013; Sowell, 2014; Keller, 2015; Bajis et al., 2018; Sjøback and Knutstad, 2017). Kaae et al. (2011) emphasized that the four-lens view of organizations was a useful framework to link leaders' actions and the rationales behind their actions. Thammasitboon et al. (2017) highlighted flexibility as a strength of the framework. Bernardes et al. (2015) contended that using the four lenses of organizations was necessary to successfully implement the studied organizational change. On the other hand, difficulties related to performing analyses based on the four-lens view of organizations were expressed by Bajis et al. (2018), who attempted to sort out the factors impacting the studied change into each lens of organizations, and found initial overlaps.

Lens preferences of leaders and managers

In the third group of studies, the four-lens view was used to explore the use of lenses by managers and leaders in organizations. Table A9 displays the overview of studies belonging to this group, for cases where more than ten leaders or managers were involved. Most studies built on the Leadership Orientation Instrument (LOI) developed by Bolman and Deal (1991), e.g. Scott (1999), Sasnett and Ross (2007), Phillips and Baron (2013), McGowan et al. (2017). In fewer studies, scholars developed other types or questionnaire surveys (St Onge et al., 2012; Yi et al., 2011). For instance, St. Onge et al. (2012) analyzed the preferred strategies used by academic pharmacy deans to solve typical dilemmas, e.g. "dealing with a faculty member with poor teaching evaluations", and found that they mostly used the structural, human and symbolic frames and that they often showed one favorite lens regardless of the dilemma.

This group of studies also contains research based on critical incidents, i.e. narratives written by managers or leaders asked to share some of their leadership experiences (Bolman and Deal, 1991; McArdle, 2013), or on interviews (with or without framing questions around the four lenses of organizations, e.g. respectively Tan et al. (2015) and Frydén et al. (2015)). For instance, Bolman and Deal (1991) studied the extent to which managers in academic institutions used different lenses in their approaches based on analyses of critical incident reports, and found that the structural lens was particularly prominent among managers and the symbolic lens, particularly absent. In their study of medical education program directors' own perceptions of their role in terms of tasks and functions, Frydén et al. (2015) found that the latter mostly emphasized structural and human functions.

A cross-comparison of applicative studies in the third group, as shown in Table 7, reveals a dominance of the architect's and catalyst's perspectives among different groups of leaders and managers, and indicates that managers tend to use one or two lenses, although the definition of what "using a lens" means in practice varied from one study to the other. For example, in Phillips and Baron (2013), a lens was considered as used if its composite score in the LOI was superior or equal to 80% of the maximum score, whereas in Yi (2009), a lens was considered as used if the answer corresponding to that lens was selected by the respondent in the questionnaire survey used in this study (different from the LOI).

A subset of studies explored the influence of various variables, e.g. gender, position, geography, sector and seniority, on lens use (Bolman and Deal, 1991; Thompson, 2000; Sasnett and Ross, 2007; Alsmadi and Mahasneh, 2011; Yi, 2011). McArdle (2013) investigated the influence of a leader's lens use on his/her subordinates' frame use but did not find strong correlations. Another subset of studies investigated the influence of lens use on managerial and leadership effectiveness measured with different variables as described in Table A9 in the Appendices, e.g. leadership skillset in the study by Thompson (2000); ranking of leaders' effectiveness as compared with all leaders the respondent knows about (e.g. "ranked in the bottom 20% of all leaders the subject has known") in the study by Phillips and Baron (2013); and lecturer's commitment towards the university in the study by Othman et al. (2010). These studies provided some evidence of positive correlations between various effectiveness variables and the number of lenses used by managers or leaders (Thompson, 2000; Sasnett and Ross, 2007; Phillips and Baron, 2013; McGowan et al., 2017). However, whether specific lenses are individually correlated with effectiveness variables remains inconclusive across studies (See Table A9 in the Appendices).

Table 7. Retrieved results from applicative studies of the four-lens view focusing on lens preferences among leaders and managers (Type 3) for (i) number of used lenses, (ii) used lenses, (iii) primary/preferred leadership lens, and (iv) average lens score. LOI = Leadership Orientation Instrument; CI/CA = Critical Incident and Content Analysis; OS = Other Survey. Note that the definitions of a lens being used or preferred vary from one study to another. These definitions are provided in Table A9 in the Appendices for the corresponding studies. For the study of Bolman and Deal (1991) and St. Onge et al. (2012), note that the scores are approximate because they could only be read on graphs.

Study	Bolman and Deal (1991); qualitative study; sample 1	Bolman and Deal (1991); qualitative study; sample 2	Bolman and Deal (1991); qualitative study; sample 3	Bolman and Deal (1991); quantitative study; sample 1	Bolman and Deal (1991); quantitative study; sample 2	Bolman and Deal (1991); quantitative study; sample 3	Bolman and Deal (1991); quantitative study; sample 4	Scott 1999 (self)	Scott 1999	Shee et al. (2002)	Sasnett and Ross (2007)	Yi (2009)	Othman et al. (2010)	Othman et al. (2010)	Alsmadi and Mahasneh (2011)	Yi (2011)	St Onge et al. (2012) Scenario 1	St Onge et al. (2012) Scenario 2	St Onge et al. (2012) Scenario 3	Phillips and Baron (2013)	McGowan et al. (2017)
	CI/CA	*CI/CA*	*CI/CA*	*LOI*	*LOI*	*LOI*	*LOI*	*LOI*	*LOI*	*LOI*	*LOI*	*OS*	*LOI*	*LOI*	*LOI*	*OS*	*OS*	*OS*	*OS*	*LOI*	*LOI*
rated by self/others?	*self*	*self*	*self*	*others*	*others*	*others*	*others*	*self*	*others*	*self*	*self*	*self*	*self*	*others*	*others*	*self*	*self*	*self*	*self*	*others*	*self*
N(leaders)=	*145*	*53*	*220*	*90*	*145*	*140*	*229*	*13*	*13*	*206*	*64*	*455*	*76*	*76*	*na*	*455*	*25*	*25*	*25*	*133*	*43*
N(others)=				*na*	*na*	*na*	*na*		*100*					*841*	*657*					*226*	
NUMBER OF USED LENSES																					
No lens										19%	13%									41%	16%
One lens	24%	16%	26%							29%	28%	17%				18%				15%	49%
Two lenses	50%	58%	55%							23%	27%	39%				30%				11%	23%
Three lenses	20%	19%	13%							13%	13%										7%
Multiple lenses (3 or 4)												*44%*				*52%*				*34%*	
Four lenses	6%	6%	5%							17%	20%										5%
USED LENS																					
Structural lens	67%	58%	62%							52%	63%	10%				75%	36%	40%	28%		47%
Human lens	59%	86%	98%							70%	75%	96%				81%	34%	42%	22%		60%
Political lens	71%	50%	21%							30%	27%	52%				13%	20%	28%	10%		9%
Symbolic lens	17%	11%	17%							28%	36%	69%				69%	34%	40%	18%		19%
PRIMARY/PREFERRED LEADERSHIP LENS																					
Structural lens																				33%	26%
Human lens																				47%	65%
Political lens																				11%	0%
Symbolic lens																				10%	5%
AVERAGE SCORE (LIKERT SCALE 1-5)																					
Structural lens				4,05	4,05	4,20	4,25	>3,6	3,75	3,89			4,25	3,84	3,45						
Human lens				4,10	4,20	3,70	4,20	4,09	3,54	4,18			4,39	3,88	3,68						
Political lens				3,90	4,00	3,70	4,00	>3,6	3,64	3,62			4,18	3,80	3,75						
Symbolic lens				3,90	3,80	3,25	4,15	>3,6	3,41	3,61			4,19	3,79	3,41						

Studies where several respondents were asked to rate the leadership of a given leader, e.g. combined self and colleagues' ratings (Scott, 1999; Othman et al., 2010; Tan et al., 2015), or ratings by two profiles of colleagues (Alsmadi and Mahasneh, 2011) found discrepancies in their answers. McArdle (2013) found discrepancies between perception of multi-lens use collected in a questionnaire survey, and actual traces of multi-lens use in managers' narratives about their most critical leadership challenge, which the authors suggested was due to a deeper level of reflection in narratives than through a Likert scale response (i.e. on a 5-step scale from fully disagree to fully agree).

4.2.3 Conclusions

Although, the four-lens view of organizations was designed with no limitation to specific organizational contexts, until now it has been documented in literature as applied in a limited number of sectors, mainly educational institutions and libraries, and very seldom in industry, for which only two studies were found. The first applications of the framework by its developers took in focus educational institutions, which could explain this silo of studies on educational institutions. The four-lens view has mainly been applied as a conceptual framework to guide researchers in their investigations, but it was also tested and found to be a relevant framework for direct use by practitioners in a limited number of studies.

Existing applicative studies have used the framework to investigate (i) change management, (ii) organizational processes, roles and situations, and (iii) lens preferences among managers and leaders. Overall, their findings indicate that *embracing multiple lenses* proves fruitful, e.g. to understand the dimensions of and facilitate an organizational change, to interpret challenges and success factors, to manage and to lead teams. Moreover, managers and leaders were found to generally use one or two lenses for their approaches, with a dominance of the structural and human lens.

This review of existing applicative studies provided relevant insights on how the four-lens view of organizations could be used to investigate and support ecodesign integration in companies. The initial intent of using the framework was to explore internal organizational functioning in the context of ecodesign integration, by using the structured approach of formal and informal aspects of organizations that it suggests. Applicative studies showed that this can be done from the perspective of organizational change, processes, roles and situations in general, and that the framework enabled the identification of blind spots, i.e. important areas which needed more attention, and provided evidence on the need for combining the different lenses of organization.

Furthermore, the review of applicative studies revealed a relatively dominant use of the framework by scholars to detect lens preferences among managers and leaders in organizations. Within internal stakeholders in companies driving the ecodesign integration agenda are "ecodesign proponents" who include people working with environmental management as part of their jobs, e.g. sustainability managers or Environmental, Health and Safety specialists, *and* people working in core-business roles who seek to drive the sustainability agenda based on their personal interest (Walker, 2007). Ecodesign proponents have been identified as key drivers of ecodesign integration in their organizations (Bey et al., 2013; Cantor et al., 2013; Opoku and Fortune, 2011; Taylor et al., 2012) and are expected to act as leaders and change agents in their organization (Dunphy et al., 2007; Holton et al., 2010; Visser and Crane, 2010; Opoku and Fortune, 2011; Walker, 2007; Taylor et al., 2012; Skelton et al., 2016; Sroufe, 2017). Identifying ecodesign proponents' lens preferences is thus another possible direction for using the four-lens view in the context of ecodesign integration in companies.

4.3 Review of existing empirical studies of ecodesign integration in companies, from the angle of the four-lens view of organizations (conceptual study 1)

After eliciting the four-lens view of organizations framework and gaining knowledge on its application in earlier organizational studies, the three next research steps were conducted in order to answer **RQ2** based on conceptual and empirical insights. Through **conceptual study 1**, presented in **Section 4.3**, my aim was to explore the extent to which the different lenses of organizations could be identified in earlier empirical studies of ecodesign integration, based on the measures in favor of ecodesign integration they suggested. Additionally, this review of literature enabled building an initial list of measures in favor of ecodesign integration corresponding to the four lenses of organizations.

4.3.1 Methodology

A literature search was conducted in the Scopus database, with a last update in May 2018. The objective was to identify all journal articles published within the period 2000-2017, which focused on empirically studying the phenomenon of *ecodesign integration in companies* from the perspective of internal organizational functioning (consistent with **RQ1**). The focus was set on (i) studies at least partly based on interviews or field methods, because they were expected to provide the necessary depth and flexibility to address internal organizational functioning; and (ii) studies primarily investigating existing practice at the companies from an organizational perspective. Hence, studies describing interventions in companies (typically introduction of a given ecodesign tool or procedure) and studies focusing on ecodesign operational practices were excluded. The search string was built using four building blocks representing the four different concepts embedded in the planned search: “ecodesign”, “integration”, “company context” and “qualitative studies”. The list of keywords associated with each building block is displayed in Table A10.

The sample was built in four steps. First the search in Scopus database using the search string derived from Table A10 was conducted. The search returned 351 journal articles. Second, a first filtering phase consisting of screening the title and abstract of each article in the list was conducted, in order to exclude the articles which would not fall under the scope of the study. This filtering phase resulted in a list of 73 included articles. Third, a screening of the shortlisted articles allowed further excluding articles which would not fall under the scope of the study. This second filtering phase resulted in 28 included journal articles. Fourth, journal articles which had been identified as part of earlier literature searches (not systematized to the extent of that of **conceptual study 1**) and were relevant for the context of this study were added. The doctoral work of Pigosso (2011), which among key contributions provided a list of ecodesign management practices incorporated in a maturity management model aimed at supporting companies in their ecodesign integration efforts, was included. The final sample includes 40 sources (i.e. 39 journal articles and one doctoral thesis), which can be seen in Table A11.

The analysis consisted in mapping the different lenses of organizations for each source included in the sample, based on the recommendations and best practices indicated by scholars in these sources. Best practices were defined as practices observed at the investigated companies and highlighted by scholars because they acted in favor of ecodesign integration. Recommendations were defined as explicitly formulated guidance for strengthening ecodesign integration in companies. However, the nuance between both was not in focus in the review, since the primary goal was to map the *courses of action* identified by scholars corresponding to the different lenses of organizations. Hence, recommendations and best practices will be referred to hereafter with one same term, namely "*measures*".

Measures were primarily identified in the discussion or conclusion section of each source, and secondarily in the results section if the discussion or conclusion did not provide a good overview of measures. The list of measures was elaborated iteratively. In the first step, each measure was noted down in an initial table, with specific efforts for capturing nuances and specificities. In the second step, measures were consolidated under broader categories. In order to collect measures under each lens of organizations, I proceeded to infer from each measure the basic underlying assumptions of what an organization is, as displayed in Figure 21, behind that measure. For example, if one measure showed a primary interest in people's needs in the organization, that measure would be classified under the human lens; if one measure primarily referred to job division and coordination, that measure would be classified under the structural lens. This also means that a number of measures were not included in the mapping, when they were found not to refer to a specific lens of organizations. For example, "exploration, experimentation, double-loop learning, creativity, and entrepreneurship" (Alblas et al., 2014) or "improving two-way communication between operational and strategic levels" (Dekoninck et al., 2016) were identified as measures in favor of ecodesign integration, but could not be seen to correspond to a particular lens, and were thus discarded in the context of the present mapping. This is because operationalization of such measures could take multiple forms. The first one could imply measures such as creating organizational structure facilitating experimentation (which would have been classified under the architect's perspective) or allocating resources for experimentation (which would have been classified under the advocate's perspective). The second one could imply measures such as improving data sharing processes between departments (which would have been classified under the architect's perspective), or creating an informal forum where operational levels can share their ideas around sustainability with higher levels of organizations (which would have been classified under the prophet's perspective). Hence, the mapping only included the measures which were *granulated enough* to fall under a lens.

4.3.2 Results

4.3.2.1 Brief description of journal articles included in the review (N=39)

Among the 39 journal articles included in the review, the majority was based on case study research, building on interviews at a set of one to twelve case companies – in most articles, one or two. In seven articles, the authors conducted action research at one or two case companies. For these, as well as two other articles based on interviews, the empirical data collection spanned a number of years rather than occurring at a single point in time, hence providing longitudinal studies. In three articles, both a large-scale survey and interviews were combined. Two articles were written by company practitioners based on their own experience.

Half of the studies were based on large companies, and to a lower extent on a mix of smaller and larger companies. Geography-wise, the studies were in majority conducted at European companies, with most frequent countries being Sweden and the United Kingdom. Sector-wise, most frequently represented industrial sectors were furniture, electronics, automotive and consumer goods; yet, all studies combined, a broad range of industry sectors was covered (chemical, electrical appliances, packaging, paper, bank, mining, construction, energy, telecommunication, industrial goods and technologies, etc.).

The studies were published in a wide range of scientific journals - the Journal of Cleaner Production being the most represented (14 studies). More than half of the reviewed articles were published in sustainability-related journals (e.g. Journal of Cleaner Production, Organization & Environment, Business Strategy and the Environment).

In around half of the reviewed articles, case companies were selected for their relatively high level of “maturity” with sustainability, while four studies purposefully included both beginner and forerunner companies. Such selection was based on companies being recognized for their proactivity through external ranking, awards, publicly available information about companies’ activities, or known presence of at least one employee with formal responsibilities for supporting ecodesign. In the remaining studies, no specific indication was given about the selection of cases with regards to the “maturity” of ecodesign integration.

4.3.2.2 Mapping of lenses

Table 8 shows for each source the number of retrieved measures anchored in the different lenses of organizations. The structural lens was found to dominate in the reviewed studies as found in nearly all sources. The human and political lenses appeared relatively present, in more than half of the sample. The symbolic lens was found in seven studies only of the 40 analyzed.

Table 8. Mapping of lenses of organizations across ecodesign integration studies resulting from conceptual study 1. Numbers in cells represent the number of measures that could be extracted as pertaining to each lens (see Table A12 for the details of measures per source).

LENS	Simon et al., 2000	Handfield et al., 2001	Magnusson and Johansson, 2001	Ritzen and Beskow, 2001	Sherwin and Bhamra, 2001	Tingström et al., 2006	Johannsson and Magnusson, 2006	Boks, 2006	Donnelly et al., 2006	Johannson et al., 2007	Stubbs and Cocklin, 2008	Sandström and Tingström, 2008	Kivimaa, 2008	White, 2009	Dangelico and Pujari, 2010	Hallstedt et al., 2010	Petala et al., 2010	Zhu and Liu, 2010	Arnold and Hockerts, 2011	Pigosso, 2011
STRUCTURAL	4	5	3	4	2	7	1	5	9	1	2	5	8	6	4	7	3	8	8	13
HUMAN	1	2	0	1	1	3	0	2	1	0	0	3	2	2	0	2	1	2	0	1
POLITICAL	0	1	0	2	0	0	0	1	2	0	0	1	0	1	0	3	1	2	2	3
SYMBOLIC	0	2	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0

LENS	Verhulst and Boks, 2012a	Bey et al., 2013	Chipps and Wilson, 2013	Deutz et al., 2013	Hallstedt et al., 2013	Alblas et al., 2014	Brones et al., 2014	Neto et al., 2014	Poulikidou et al., 2014	Verhulst and Boks, 2014	Björkdal and Linder, 2015	Domingo et al., 2015	Høgevold et al., 2015	Bonou et al., 2016	Dekoninck et al., 2016	Skelton et al., 2016	Alange et al., 2017	Brones et al., 2017	Küçüksayraç, 2017	Prendeville et al, 2017
STRUCTURAL	1	4	1	1	5	5	4	0	4	2	3	4	2	9	0	2	5	5	2	4
HUMAN	5	0	0	0	1	0	0	1	1	9	0	1	3	5	1	2	2	5	0	0
POLITICAL	2	1	1	0	1	0	0	0	1	5	2	3	1	2	2	1	0	5	1	0
SYMBOLIC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	4	2	0	0

4.3.2.3 Measures corresponding to the four lenses of organizations

Table 9 displays the list of measures identified in the four lenses of organizations, and the number of sources in which each could be identified (Table A12 displays the full mapping, i.e. granulated at the source level).

Structural lens (architect's perspective)

From the architect's perspective, measures pertaining to: (i) designing ecodesign guidelines and tools to support decision-making, (ii) integrating ecodesign in the existing product development processes, (iii) setting targets at organizational and/or product level, (iv) using environmental criteria among design criteria, and (v) allocating responsibilities in the organizational structure were found to stand out as most frequent measures.

Both as an alternative and a complement of allocating responsibilities in the organizational structure depending on the source, some scholars indicated the need to create new jobs or organizational units to support ecodesign practice in the organization (e.g. environmental product developer (Ritzén and Beskow, 2001)). The integration of ecodesign in performance measurement systems (e.g. in project, in function and managers' KPIs (Bonou et al., 2016), in monitoring systems of the product development activities (Hallstedt et al., 2010), or as an internal labeling system (Arnold and Hockert, 2010)) were also frequently highlighted. In one-fourth of the sources, scholars emphasized the need for either developing ecodesign strategies (e.g. Magnusson and Johannson, 2001; Kivimaa, 2008; Arnold and Hockerts, 2011; Pigosso, 2011; Alblas et al., 2014) or integrating sustainability in the business mission and strategy (e.g. Simon et al., 2000; Zhu and Liu, 2010; Hallstedt et al., 2010; Bonou et al., 2016; Prendeville et al., 2017). The translation of strategy/goals into lower levels of organizations, e.g. into targets for innovation projects, was also highlighted as a measure by several scholars (e.g. Boks, 2006; Hallstedt et al., 2010; Pigosso, 2011; White, 2009).

Some concerns about measures from an architect's perspective were found. Several scholars criticized the integration of environmental aspects in the form of design criteria (Sherwin and Bhamra, 2001; Deutz et al., 2013) or checkpoints in the development process (Handfield et al., 2001). For Sherwin and Bhamra (2001) and Handfield et al. (2001), such approach may symbolically influence designers in seeing ecodesign as an evaluative approach, rather than a support for generating new ideas, and, hence, decrease the interest for ecodesign among designers. For Deutz et al. (2013) integrating environmental aspects in the form of design criteria, rather than setting environmental objectives in the functional requirements for product development, drastically reduces the design space for developing radically improved solutions. Other scholars have discussed whether the use of a systematic ecodesign procedure in the development process would allow companies to develop more radical innovations. For instance, Kivimaa (2008) argued that a case-specific approach outside corporate procedures may be necessary for more radical innovation to emerge. Similarly, Magnusson and Johansson (2001) argued that in the case of ambitious environmental targets requiring new technology development, the linear and procedural view of product development may not hold or only lead to minor improvements.

Table 9. List of measures in favor of ecodesign integration in the four-lens view of organizations, as identified in conceptual study 1, and number of sources from which they were retrieved (N=40). KPI = Key Performance Indicator.

LENS/PERSPECTIVE	Number of sources mentioning it
STRUCTURAL / ARCHITECT'S	**38**
Design ecodesign guidelines and develop/internalize decision-support tools	19
Integrate ecodesign procedures in processes related to product development	16
Set ecodesign target at different levels (e.g. corporate, products, innovation projects)	16
Include ecodesign in design criteria	13
Assign responsibilities for ecodesign (e.g. added in job descriptions of product designers) at different organizational levels	12
Integrate ecodesign into the business mission/strategy	11
Integrate ecodesign criteria in performance measurement systems (e.g. KPIs, internal labeling)	10
Design ecodesign strategies	10
Create dedicated organizational units and jobs for ecodesign visible in the organigram	9
Establish system for ecodesign information collection	8
Implement environmental management system/standards	6
Integrate ecodesign aspects in the fuzzy front end/early stages of development	6
Translate corporate strategy into action plan for specific business units/functions	6
Compose project teams with all relevant functions to address ecodesign (e.g. environmental specialists)	5
Design ecodesign policies	5
Establish ecodesign expertise/knowledge sharing process and platform (e.g. for lessons learned, successes, avenues for future investigation)	4
Integrate ecodesign in portfolio management	4
Set project processes allowing for development of radical innovation	3
Define scope of ecodesign, make it measurable, tangible	3
Acquire in-house expertise on ecodesign	2

HUMAN / CATALYST'S	26
Provide tailored training for employees (e.g. in their context, adapted to their daily tasks)	20
Use co-creation/participative approach (e.g. to include criteria in project tool)	8
Provide empowering tools (e.g. adapted to the nature of jobs and skills)	4
Support teams with environmental experts/expertise	3
Address differences between individual sensitivities/needs/emotions	2
Give room for experimentation, autonomy	2
Involve and support people who have personal aspirations for ecodesign	3
Provide appreciation and support	2
Raise awareness or motivation with employee newsletters, podcasts, site events, trips	2
Translate ecodesign concepts in easy to understand terms	2
Use success stories to raise motivation	2
Understand what motivate employees or leads them to resistance (e.g. through workshops)	2
Collaboration with Human Resources department	1
Explain/inform employees about ecodesign (e.g. “why”, “how”, “when”, “who”)	1
Give responsibility and support for initiative taken	1
Make it easy to find information about ecodesign	1
One-to-one encounters	1
Reassure employees	1
Stimulate and support individual employees to share ideas	1
Use nudging techniques, i.e. leading without inducing guilt or being prescriptive	1
POLITICAL / ADVOCATE'S	**25**
Have top management explicitly express ecodesign as a priority/commit for ecodesign (e.g. involvement in decision-making, public statements, responsibility for ecodesign goals)	16
Allocate resources/budget	7

Foster the development of ambassador(s) for ecodesign in the organization	5
Use success stories to create buy-in	3
Build awareness among key decision-makers	2
Communicate risk and benefits to the organization	2
Demonstrate value of ecodesign for different functions and the company	2
Find employees who will be able to influence others	2
Understand resource availability and target low-hanging fruit	2
Allow ecodesign champions to network in the organization	1
Align and adapt ecodesign communication to different departments (e.g. different language/terminology)	1
Enable access to resources for ecodesign initiatives	1
Identify and leverage existing competencies in the company	1
Manage the gap between expectations and capabilities	1
Seek for interactions compatible with each group's priorities and agendas	1
CULTURAL / PROPHET'S	**7**
Celebrate ecodesign successes and heroes (e.g. awards)	2
Adapt tools to the company's way of working	2
Efforts of environmental teams to be accepted as core members of the product development community	2
Use or creation of rituals (e.g. create regular events around products)	2
Storytelling about the founder's choice, communicating how it fits with the way of working	1
Value testing and failures	1
Develop common heuristic rules	1
Change perceived mission of the company, make sustainability part of the DNA	1
Identify and break the poor history of ecodesign at the company	1
Negotiate/translate meanings with product development teams	1
Provide inspiration on ecodesign to the organization	1

Human lens (catalyst's perspective)

The catalyst's perspective was primarily present through various measures related to the training of human resources: practical training on ecodesign tools and guidelines (Handfield et al., 2001), training adapted to each function (Ritzén and Beskow, 2001; Petala et al., 2010; Domingo et al., 2015), training of senior managers (Zhu and Liu, 2010), appropriate training (Hallstedt et al., 2010); training to support conceptual understanding (Neto et al., 2014; Bonou et al., 2016), awareness-building training (Poulikidou et al., 2014; Domingo et al., 2015), training to stimulate creativity (Brones et al., 2017). Contextualized training and education were indicated to drive commitment, comfort with the topic and motivation among employees (Ritzén and Beskow, 2001; Tingström et al., 2006; Domingo et al., 2015). The use of participative approaches or co-creation with internal stakeholders was recommended in nearly one-fourth of the sources (e.g. Sandström and Tingström, 2008; Skelton et al., 2016; Bonou et al., 2016). The topic of "ecodesign tool" had both a structural facet, e.g. in Hallstedt et al. (2010) where it was recommended that an ecodesign toolset should be established by senior management in the organization, and a human facet, e.g. in Sherwin and Bhamra (2001) and Handfield et al. (2001) who recommended to account for the nature of jobs and skills of users of ecodesign tools. Although other measures were relatively scattered in the reviewed articles (i.e. only mentioned in a few sources), they revealed some importance on motivating, explaining, empowering, supporting, understanding the feelings of, stimulating, and reassuring humans resources in the context of ecodesign integration.

Political lens (advocate's perspective)

From an advocate's perspective, little less than half of the sources emphasized the need for top or senior management to explicitly show their commitment for ecodesign, through involvement in decision-making process (Bonou et al., 2016), public statements (Boks, 2006), insisting for ecodesign uptake (Petala et al., 2010), and their responsibility-taking for sustainability goals (Björkdahl et al., 2015). Allocating resources and budget (e.g. Handfield et al., 2001; Pigosso, 2011) and having ecodesign champions act as ambassadors, across levels and horizontally in the organization, were mentioned in a subset of studies (Bey et al., 2013; Chipps and Wilson, 2013; Verhulst and Boks, 2014; Dekoninck et al., 2016). Other measures were more scattered in the sample. Among others, various measures were noted such as the need to build awareness among key decision makers (Zhu and Liu, 2010; Domingo et al., 2015), understand priorities of and agendas of different groups (Brones et al., 2017), adapt to the perspectives of different organizational functions (Verhulst and Boks, 2012a), foster networking (White, 2009; Verhulst and Boks, 2014) and understand who the influencers are in the organization (Brones et al., 2017).

Symbolic lens (prophet's perspective)

Fewer measures from the prophet's perspective were identified, and also found scattered in the sample. Among others, measures focused on, the creation or use of rituals for ecodesign (Skelton et al., 2016; Alänge et al., 2016), the celebration of ecodesign successes and heroes (Handfield et al., 2001; Donnelly et al., 2006), the negotiation of meanings between the environmental and product development communities in organizations, the strive for environment specialists to be accepted as core members of product development communities (Skelton et al., 2016), and the anchoring of sustainability in the company's "DNA" (White, 2009). The adaptation of tools to the company's way of working revealed a third facet (besides the structural and human facets) of the topic of "ecodesign tool" (Verhulst and Boks, 2014; Brones et al., 2017).

4.3.2.4 Cross-lens effects

Along with the review process and not initially planned, a number of indications of *cross-lens effects,* or interactions between the different lenses, emerged from the data as displayed in Table 10. These interactions were identified when a specific measure corresponding to a lens of organizations as *per* the mapping above, was indicated in the source as positively influencing a factor at the core of another lens of organizations. In Table 10, the rows correspond to the measures from the different perspectives of organizations (e.g. setting clear goals/formal targets from the architect's perspective), and the columns correspond to the factors at the core of the lenses of organizations (e.g. motivation, for the human lens).

Measures corresponding to an architect's perspective, e.g. integration of ecodesign in the company processes, definition of strategies and targets, or team composition were indicated by scholars to drive factors at the core of other lenses of organizations, such as:

- higher motivation among employees (Petala et al., 2010; Arnold and Hockerts, 2011), more familiarity with ecodesign practices (Poulikidou et al. 2014), and more understanding and acceptance of ecodesign practices (Poulikidou et al. 2014) (human factors);
- higher priority for ecodesign in agendas both of product development teams and senior management (Johansson and Magnusson, 2006; Petala et al., 2010), even in the case that the business case cannot be proven yet (Hallstedt et al., 2010), increased networking opportunities (Johansson and Magnusson, 2006) (political factors);
- a change in the corporate culture (Simon et al., 2000; Donnelly et al., 2006; Björkdahl and Linder, 2015) and mentalities (Arnold and Hockerts, 2011), and greater understanding of each other's roles (Johansson and Magnusson, 2006) (symbolic factors).

These findings indicate a certain reliance on the ability of measures from an architect's perspective to enhance factors at the core of the human (e.g. in terms of employee motivation and participation), political (e.g. in terms of priority in agenda) and symbolic (e.g. in terms of a change of culture and mindset) lenses.

From a contrary perspective, concerns expressed about the insufficiency of architects' measures to enable ecodesign integration in companies were identified. Kivimaa argued that the sole use of codified practices, e.g. LCA, does not guarantee a common understanding within the organization and emphasized the role of people-based approaches, e.g. training in environmental issues (Kivimaa 2008). Skelton et al. (2016) concluded that the use of boundary objects for ecodesign integration, e.g. environmental improvement targets, which can be associated with an architect's perspective, *"only establish specific instances where the environmental specialists can communicate around ecodesign and increase the engineers' level of awareness"* (p. 54). They further found that the use of boundary objects was not sufficient to integrate brokers, i.e. people working in functions supporting ecodesign integration, inside the product development community; neither to change the behavior of the product development community (Skelton et al., 2016).

Table 10. Indications of cross-lens effects, as identified in conceptual study 1. KPI = Key Performance Indicator.

		STRUCTURAL FACTORS			HUMAN FACTORS						POLITICAL FACTORS				SYMBOLIC FACTORS		
	INFLUENCES (rows influence columns)	Procedure in product development processes	Targets	KPIs	Motivation	Commitment	Feeling of constraints	Participation	Awareness	Adoption	Priority in agendas	Continuity on agendas	Resource allocation	Networking	Mindsets/mentalities	Cross-function understanding	Culture
ARCHITECT'S MEASURES	Setting clear goals/formal targets				X				X		X						
	Establishing processes, integrating ecodesign procedure in existing processes							X		X							
	Including environmental criteria in product development briefs						X				X						
	Dedicated organizational unit																X
	Project composition										X			X		X	X
	Internal labeling scheme										X				X		
	Setting strategy/policy										X						X
	Setting ecodesign KPIs, integrating ecodesign in performance measurement system				X	X						X	X		X		
CATALYST'S MEASURES	Training employees														X	X	
	Empowering employees																X
	Involving employees, co-creation	X	X	X													X
POLITICAL MEASURES	Have top management express priority and commitment for ecodesign				X												X

Arguing that nowadays managerial approaches tend to place less emphasis on command and control mechanisms (architect's perspective) to the benefit of increasing team autonomy, Brones et al. (2017) highlighted the need for "soft" mechanisms to lead the organization towards green innovation practices, e.g. fostering employees' engagement.

In these lines, there were indications in the sources of the use of participative approaches or co-creation with internal stakeholders enhancing structural factors, such as the integration of ecodesign into existing procedures (Skelton et al., 2016), targets design (Sandström and Tingström, 2008), and key performance indicators (Bonou et al., 2016). Catalyst's measures were further indicated to foster symbolic factors, such as employee training and empowerment enhancing a change of mindsets and mentalities in the organization (Tingström et al., 2006; Zhu and Liu, 2010; Poulikidou et al., 2014), and a change or strengthening of the organizational culture for sustainability (Verhulst and Boks, 2012a; Chipps and Wilson, 2013; Alänge et al., 2016). From an advocate's perspective, top management commitment was indicated to enhance employee motivation for ecodesign – human factor (Petala et al., 2010), and the corporate culture for ecodesign - symbolic factor (Høgevold et al., 2015). Furthermore, demonstrating the value of ecodesign through pilot project was indicated as a way to motivate teams (human factors) (Verhulst and Boks, 2014)

4.3.3 Conclusions

Overall, measures from the architect's perspective, together with employee training (from the catalyst's perspective) and having top management explicitly express ecodesign as a priority (from an advocate's perspective) were found to dominate in the reviewed sources. Moreover, it was found that measures from the architect's perspective were considered to drive alignment with the other perspectives by several scholars. On the other hand, the need to use other lenses was emphasized by several scholars and a variety of measures from the catalyst's, advocate's and prophet's (to a limited extent) perspectives could be found in the sample, yet rather scattered across studies. Indications were found of catalyst's measures enhancing structural and symbolic factors, and advocate's measures enhancing human and symbolic factors. The mapping of literature using the four-lens view of organizations as a deductive framework provided initial evidence of the need for measures from the different lenses of organizations to support ecodesign integration in companies. Additionally, the literature review catered indications of interactions between lenses, whose elicitation was not initially planned in the analysis.

4.4 Interviews of ecodesign proponents on the experience of ecodesign integration in their company and analysis using the four-lens view of organizations (empirical study 5)

The next step in answering **RQ2** consisted of conducting exploratory case studies at a set of companies to further the understanding of the four-lens view in the context of ecodesign integration.

4.4.1 Methodology

The methodology of **empirical study 5** can be found in **Article IV,** and is summarized in Figure 22 and the present section**.** Exploratory case studies were used in order to explore the extent to which the four lenses of organizations are needed to support ecodesign integration in companies. The empirical basis consisted of a set of fifteen interviews in seven case companies in the Danish and Norwegian manufacturing sector (covering various sectors) with in-house product development. The included case companies were large organizations, with all but one (which is family owned) listed in the DJSI. From this perspective, the set of cases presented characteristics of homogenous sampling and characteristics of variation sampling (Miles and Huberman, 1994).

Lasting between 60 and 90 minutes, Faheem Ali (co-tutelle PhD student) and I conducted the fifteen interviews between June 2016 and February 2017. The details about the interviewees' profiles are displayed in Table 11. The set of interviewees included two types of ecodesign proponents. The first type included employees working in sustainability-related functions, e.g. sustainability managers or Environment, Health and Safety specialists, and the second type included employees involved in product development with some interest in pushing the ecodesign agenda in their company.

Table 11. Interviewed case companies in empirical study 5, sectors of activity, number of interviews conducted and interviewees' job area (**Article IV**). EHS = Environment, Health and Safety; R&D = Research and Development.

Company	Sector	Number of interviews	Interviewees' job area
Company A	Medicare	2	A1: EHS A2: EHS
Company B	Biotechnologies	1*	B1: Sustainability
Company C	Renewable energy	2	C1: EHS C2: EHS
Company D	Construction	2	D1: Regulation (incl. environment) D2: Sourcing and technologies
Company E	Consumer products	2	E1: EHS E2: Corporate Responsibility
Company F	Consumer products	2	F1: Communication F2: Sourcing
Company G	Consumer products	4	G1: R&D G2: R&D G3: R&D G4: Marketing

* Information about ecodesign activities collected at a university lecture given the same year by another sustainability expert of the same company was also included in the analysis.

Interviews were semi-structured and designed to gain knowledge of ecodesign integration at the case companies. The initial focus set for the interviews was on (i) investigating how ecodesign has been and is being integrated in the organization and (ii) exploring internal (across departments) and external (in the business ecosystem, e.g. with suppliers and customers) interactions around ecodesign at the company. Here, the interview transcripts were used to explore the presence of the different lenses of organizations in ecodesign proponents' elaborations about ecodesign integration at their company. Hence the four-lens view was used as a deductive framework to conduct the interview analysis and not as a framework to guide the data collection. A similar analysis approach was undertaken in earlier applicative studies of the four-lens view of organizations (e.g. Farrell, 2003; Lieff and Albert, 2010; Frydén et al., 2015).

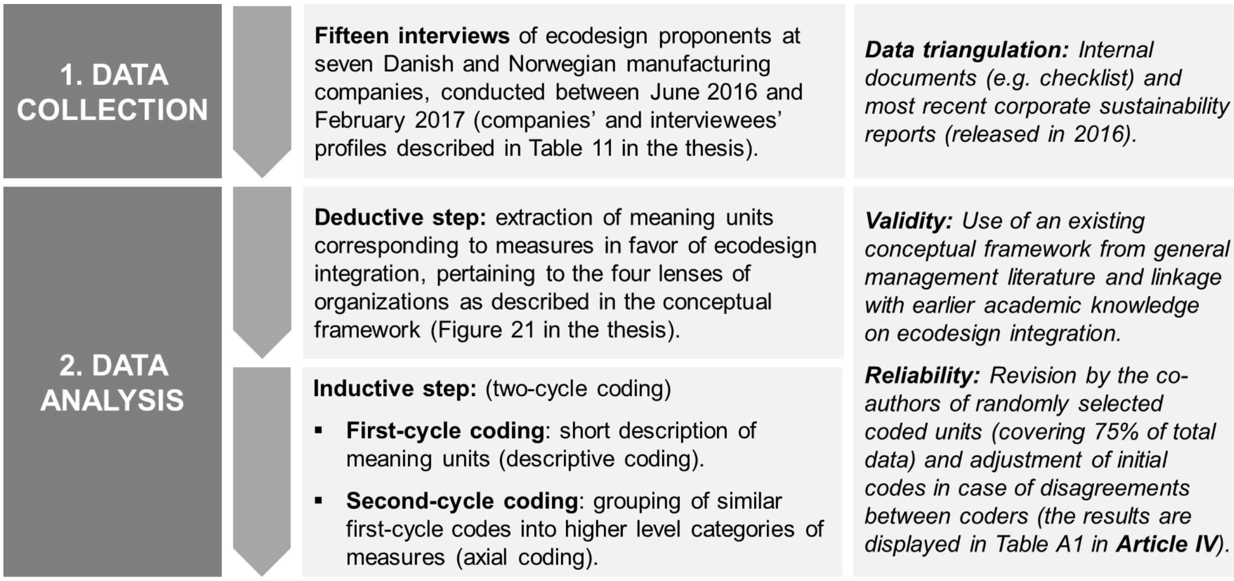


Figure 22. Overview of methodology for empirical study 5, adapted from **Article IV**.

The use of internal documents provided by the case companies (e.g., stage gate model used by the company in product development projects, ecodesign checklist and ecodesign tool) and their most recent corporate sustainability report (released in 2016) enabled some extents of data triangulation. CS reports were particularly suited to grasp the overall sustainability context at each case company and to elicit companies' sustainability vision, drivers (e.g., presence of a market for ecodesigned products), strategy (e.g., reducing the LC environmental impacts of products) and targets (e.g., reducing GHG emissions in the product portfolio, reaching a certain percentage of recycled material in packaging and phasing out substances of concern), in relation to the architect's perspective. Yet, other organizational aspects associated with sustainability integration were not searched for in CS reports, which were earlier documented to provide poor inputs on this level (Thijssen et al., 2016).

To explore the presence of the different lenses in descriptions of ecodesign integration approaches, each interview transcript was analyzed using a deductive-inductive content analysis method (Hsieh and Shannon, 2005). The deductive step consisted of identifying extracts describing measures stemming from the different lenses of organizations. In the inductive step, measures were organized into higher-level categories of measures. The most challenging part of the analysis was the deductive step consisting of associating measures for ecodesign integration to an underlying lens of organizations. To conduct such exercise, similarly to the approach taken in **conceptual study 1**, each extracted measure was boiled down to the basic assumptions of what an organization is, implicitly present in the interviewee's explanation, as displayed in Figure 21. The resulting measures can be seen in Table 12. To explore cross-lens effects, instances where lenses could be found to interact with each other were analyzed. More details about the analysis approach can be found in **Article IV**.

4.4.2 Results

4.4.2.1 Lens presence

The results from the mapping of measures in the four-lens view are displayed in Table 12. The architect's perspective was found particularly present in the measures mentioned by ecodesign proponents (35%-71% of total meaning units at the case companies), followed by the advocate's perspective (13%-33%), with the catalyst's perspective (0%-26%) and the prophet's perspective relatively less represented (0%-21%), see Table A2 in **Article IV**. However, the formal integration of ecodesign aspects in the company's activities was one of the focuses of the interviews, and hence could have biased to some extent the perceptions of interviewees towards the relevance and need for measures from the architect's perspective.

Details about measures in each lens and related quotes can be found in **Article IV** and in **Section 4.4.2.2** where interactions between lenses are addressed. Here, I highlight the most frequently mentioned measures across case companies:

- From the architect's perspective: "integrate ecodesign procedure in product development process", "acquire/develop tools for decision-making", "design strategy related to products" and "set direction/target/goals"
- From the catalyst's perspective: "support/chaperon initiatives"
- From the advocate's perspective: "align with business/stakeholders' agenda", and "negotiate for prioritization"
- From the prophet's perspective: "manage beliefs/truths in the company"

No contradicting opinions on the measures across case companies were found, except for the measure "set directions/goals/targets". It was mentioned as a non-taken measure at Company A and Company C. At Company A, the reported foremost priority of the company is to provide solutions to people who need medical support in their daily life, and environment-friendly solutions are weakly driven by the market. Hence, improving the environmental performance of new product generations was considered as a nice-to-have but could not be set as a must in projects. At Company C, the interviewees indicated that material and energy efficiency gains from one generation of products to the other were inherently driven by the business, and thus no target was defined from an ecodesign perspective. At Company D, one interviewee also highlighted the idea that energy efficiency was core to the business activity, but that targets regarding material recyclability should be developed. Another interviewee at Company D indicated that there was a lack of direction or focus from top management when it comes to taking decisions in favor of material sustainability, which she explained by a lack of pull from the construction market for "green stamped" products. This showed that the company context factored in regarding setting goals for ecodesign.

At the respondent level, the number of lenses identified in elaborations of ecodesign proponents varied, from one lens to all four. For around half of interviewees, three lenses were identified, in most cases the architect's, the advocate's and either the prophet's or the catalyst's. The interviewees in sustainability functions were found to mention measures pertaining to at least three perspectives, and more than half of them on all the four perspectives of organizations. On the other hand, more than half of the interviewees in core activity functions indicated measures from three different perspectives, and the others from one or two.

Table 12. Results from the second-cycle coding for empirical study 5 (**Article IV**). For each lens, mentioned measures in favor of ecodesign integration were mapped against the case companies. H = indicated as happening at least to some extent in the organization; N = indicated as lacking and needed; KPI = Key Performance Indicator; No = number of.

MEASURES	**Company A**	**Company B**	**Company C**	**Company D**	**Company E**	**Company F**	**Company G**	**No companies**
Architect's perspective								
Integrate ecodesign procedure in product development process	H	H	H	H	N	N	N	7
Acquire/develop tools for decision-making	H	H	H	H	H		H	6
Design strategy related to products		H	H	N	N		N	5
Set directions/goals/targets		H		N	N	N	N	5
Develop guidelines related to product development					H	H		2
Formally define "sustainability" (e.g. standard, criteria)				H		N		2
Translate strategy into action plan for specific business units/functions					H		N	2
Translate corporate targets into targets for individual innovation projects		N						1
Create sustainability roles				H				1
Set up new KPIs					H			1
Use a process with more experimental approach							H	1
Catalyst's perspective								
Support/chaperon initiatives	H		H	H	H			4
Increase comfort of people to work with the topic of ecodesign		N	H		H			3
Build individual awareness of impact of decisions	H			N				2
Leverage people's aspirations	H		H					2
Participative approach to adapt the product development process		H	H					2
Frame ecodesign challenges in familiar terms			H					1
Give autonomy					H			1
Trigger people/"plant seeds"	H							1
Advocate's perspective								
Align with business/stakeholders' agenda	H	H	H		H	H	N	6
Negotiate prioritization of ecodesign in agendas	N			H	H		N	4
Emphasize criticality/emergency for business	N			H	H			3
Target efforts/"pick battles"	H	H					H	3
Ally with/get support from relevant people in the company	N					H		2
Have answers to all technical questions			H	H				2
Leverage network in the company			H		H			2

Secure present resource allocation for long term/more prospective objectives	N						N	2
Leverage existing umbrella projects			H					1
Prophet’s perspective								
Manage beliefs/”truths” in the company	H		H	H			N	4
Change perceived vision/mission of the company				N			N	2
Leverage "typical ways of doing"	H			H				2
Preach in the company	H			H				2
Provide inspiration from outside						H	H	2

4.4.2.2 Cross-lens effect

Advocate’s, catalyst’s or prophet’s measures in the absence of structural factors

In several cases, measures from an advocate’s, catalyst’s or prophet’s perspective seemed to be developed in the absence of structural factors at the company. For instance, Interviewee F1 reported that so far the inclusion of environmental criteria in product development had been “mostly about convincing the right people” (advocate’s perspective). At Company E, both interviewees indicated the absence of procedures for ecodesign in innovation processes, and reported that their work was much about supporting and chaperoning managers which were eager to act, and that their approach should not give the impression to “dictate” managers (catalyst’s perspective). Interviewee D2 reported that, she recurrently sought to bring-in the focus on sustainability aspects in her presentations to senior managers (prophet’s perspective), in a context where no specific direction or target came from a top-down perspective for product development.

However, in case companies were structural factors were lacking, the need for measures from an architect’s perspective was expressed with different intensity. For examples, Interviewees F1, G1 and G2 emphasized the necessity to have ecodesign as part of the organizational structure and processes. Interviewee E1 indicated that in order to take things one step further, more centralized guidelines would be necessary. Interviewee D2 indicated that more formally tying the use of LCA models to the product development stage gate model would help increase attention on ecodesign aspects.

Architect’s measures enhancing political and symbolic factors

Measures pertaining to the architect’s perspective were considered or expected in several instances to facilitate factors associated with other lenses. For example, formally incorporating sustainability in the organizational system was expected to provide the official scene for prioritizing time and resources on searching environment-friendly solutions at Company G (political factor). Having corporate environmental targets was indicated to raise sustainability up in agendas throughout the organization at Company B (political factor). Interviewee E2 indicated that the establishment of a sustainability strategy had been a facilitator to bargain sustainability implementation with managers (political factor). Adding an ecodesign procedure to the product development process at Company A seemed to have made it “normal” for project teams to look at environmental criteria throughout the project which may be interpreted as the influence of an architect’s measure on a factor belonging to the symbolic lens.

Prophet’s measures enhancing structural and political factors

Some instances were noted where from a prophet’s perspective, interviewees indicated methods which “worked best” at their companies and how the latter were actually leveraged in structural and political factors. Numbers and graphs were indicated as the normal way to display information at Company A, and in that sense integrating LCA in the product development process fitted well with the scientific culture of the company as indicated by Interviewee A1. At Company D, concrete experiments are in the DNA of the organization, hence demonstrating the urgency for the company to integrate CE principles through a pilot study was found relevant. Hence, relying on some elements anchored in the organizational culture (prophet’s perspective) may strengthen factors at the core of the structural and political lenses.

Advocate’s, catalyst’s and prophet’s measures enhancing structural factors

A set of instances was found where advocate’s, catalyst’s and prophet’s measures seemed to enhance structural factors. From the catalyst’s perspective, for example the use of participatory approaches to design how to add ecodesign procedures to the current product development process together with product development teams was observed (Company B; Company C). The influence of employees’ own aspirations for ecodesign on the actual efforts deployed in developing solutions in projects, even if environmental assessments were formally part of the process, was also noted, and thus the importance to intensively support those who are eager (Company A). From the advocate’s perspective, it was observed for instance a need to secure resources for more prospective projects in order to complement what can be done in common product development projects (Company A), and the idea that setting up new performance indicators is not enough to have people prioritize them (Company E). It was also noted how taking an advocate’s perspective and putting efforts on those product development projects with a promising business case allows getting the marketing department onboard, and thus complement the structural factor according to which an LCA has to be conducted for each product development project (Company B). Finally the prophet’s perspective was associated for example with fighting misconceptions about who has the ability to influence product environmental performance in product development projects, and thus an important lever to encourage project teams to actually design environment-friendly solutions, and to actually build on LCAs conducted for each project as a decision-support tool, rather than a mere documentation exercise (Company A).

4.4.3 Conclusions

All in all, the analysis of ecodesign proponents’ elaborations on ecodesign integration in their companies revealed the presence of the architect’s, catalyst’s, advocate’s and prophet’s perspectives in mentioned measures to support ecodesign integration, with some emphasis on the architect’s and advocate’s perspective. The analysis further provided indications of cross-lens effects. First, advocate’s, catalyst’s and prophet’s measures seemed to develop or be needed in the absence of structural factors at the company. Second, measures from the architect’s perspective seemed considered or expected to provide an official scene for prioritizing ecodesign in the organization, hence facilitating political factors, and for acting on symbolic factors such as the "normality" of conducting ecodesign procedures. Third, it was found that prophet's measures could enhance structural and political factors, by building on symbolic factors such as the company's tendency to rely on concrete examples or on its engineering culture for numbers. Fourth, measures stemming from the catalyst's, advocate's, and prophet's perspectives were found needed to enhance structural factors.

Hence, these exploratory case studies brought further evidence on the meaningfulness of embracing different perspectives of organizations in ecodesign integration efforts in companies. The empirical analysis complemented the results from the literature review through (i) additional measures pertaining to each lens of organizations (displayed in Table A13), and (ii) additional indications of interactions between lenses (shown in Table 13). Measures from the architect's perspective identified in the empirical data matched measures identified in the literature review, whereas for the other three perspectives, measures identified in the empirical data and in the literature data were complementary. Measures from the catalyst's, advocate's and prophet's perspective identified in the literature review were found relatively scattered, hence, unconsolidated, which can be seen in accordance with these extra measures emerging from the empirical data for these lenses.

Table 13. Update of Table 11 with cross-lens interactions from conceptual study 1 indicated with "L" (literature), from empirical study 5 indicated with "I" (interviews) and from both indicated with "B". KPI = Key Performance Indicator.

		STRUCTURAL FACTORS			HUMAN FACTORS						POLITICAL FACTORS					SYMBOLIC FACTORS			
	INFLUENCES (rows influence columns)	Procedure in product development processes	Targets	KPIs	Motivation	Commitment	Feeling of constraints	Participation	Awareness	Adoption	Priority in agendas	Criticality	Continuity on agendas	Resource allocation	Networking	Mindsets/mentalities	Cross-function understanding	Culture	"Normal ways of doing"
ARCHITECT'S MEASURES	Setting clear goals/formal targets				L				L		B			I					
	Establishing processes, integrating ecodesign procedure in existing processes							L		L									I
	Including environmental criteria in product development briefs						L				L								
	Dedicated organizational unit																	L	
	Project composition										L				L		L	L	
	Internal labeling scheme										L					L			
	Setting strategy/policy										B			I				L	

	Setting ecodesign KPIs, integrating ecodesign in performance measurement system				L	L							L	L		L			
CATALYST'S MEASURES	Training employees															L	L		
	Empowering employees																	L	
	Involving employees, co-creation	B	L	L														L	
	Particularly supporting employees that are personally eager for ecodesign	I																	
ADVOCATE'S MEASURES	Having top management express priority and commitment for ecodesign				L													L	
	Bargaining for KPI priority			I															
	Having influencing people speak up for environmentally superior options	I																	
	Picking battle, targetting project with high potential	I																	
	Securing resources for prospective/long term developments	I																	
PROPHET'S MEASURES	Relying on the company's way of demonstrating things											I							
	Relying on the company's engineering culture for numbers	I																	
	Changing misconceptions about who influences product environmental performance	I																	

When it comes to indications of interactions between lenses, insights from the literature review hinted towards an influence of architect’s measures on factors at the core of the other three lenses, of catalyst’s measures on structural and symbolic factors, and of advocate’s measures on human and symbolic factors. In the empirical data, similar interactions were found between architect’s measures and political and symbolic factors. However, no influence of architect’s measures on human factors such as motivation or awareness was documented. Most indications of interactions found in the empirical data related to advocate’s, catalyst’s and prophet’s measures enhancing structural factors, such as procedure in product development processes and KPIs. This focus may have been driven by the data collection approach, as interview questions started with the formal aspects of ecodesign integration in companies, i.e. measures corresponding to the architect’s perspective, and continued with discussing the challenges of ecodesign integration.

4.5 Identification of relevant applications for the four-lens view in ecodesign integration activities in companies and insights from two ecodesign proponents in companies based on a webinar (conceptual study 2 and empirical study 6)

In **Sections 4.3 and 4.4**, the four-lens view of organizations was used as an *analytical* framework to investigate ecodesign integration in companies, and more precisely to explore the extent to which the different lenses of organizations are needed to support ecodesign integration. The literature review and exploratory case studies brought initial evidence on the need for embracing different perspectives of organizations in ecodesign integration efforts in industry. Additionally, measures anchored in the four lenses of organizations and interactions between lenses were compiled from literature and empirical insights. In the light of this analysis, and building on earlier studies which exemplified the practical use of the four-lens view by practitioners, exploring practical application(s) of the four-lens view in ecodesign integration activities in companies was identified as a relevant next step.

Hence, **Section 4.5** provides initial reflections on ecodesign integration activities which could be enhanced by the four-lens view of organizations translated in the ecodesign integration context. Many ecodesign tools and procedures have been developed in academia and their application in industry has been recurrently reported as scarce (Pigosso et al., 2013). From this perspective, initially exploring potential application(s) is considered critical before any further development of a tool. This was done through (i) a conceptual exploration of application(s) departing from the review of existing applicative studies of the framework (**Section 4.2)** which is presented in **Section 4.5.1**; and (ii) the collection of initial feedback from two ecodesign proponents which are presented in **Section 4.5.2**.

4.5.1 Applications of the four-lens view of organizations in ecodesign integration activities (conceptual study 2)

As described in detail in **Section 4.2**, earlier research applied the four-lens view of organizations in contexts of change management, analysis of organizational processes, roles and situations, and to detect lens preferences among scholars. In the next three subsections, I build on these applications of the four-lens view and conceptually explore potential similar applications in the context of ecodesign integration in companies.

4.5.1.1 Continuous improvement

The four-lens view of organizations was used by scholars in a context of change management, yet mainly as a conceptual framework to guide the interpretation of factors influencing the change process. Scholars have typically concluded that a multi-lens approach was necessary to successfully implement change. On the other hand, other scholars have used the framework as guidance to plan change (Thammasitboon et al., 2017), advocated its use as a tool for supporting planned change (Haviland, 2014) or to support continuous improvement (Swan-Sein et al., 2012).

Ecodesign integration has been conceptualized in earlier research as an organizational change (Le Pochat et al., 2007; Dunphy et al., 2007; Bertels et al., 2010; Verhulst and Boks, 2012a; 2012b; Millar et al., 2012; Brones and Monteiro de Carvalho, 2015; Brones et al., 2017; Sroufe, 2017). Initially stemming from the field of quality management, continuous improvement has been taken up by change management scholars as a way to support organizational changes, in complement of dramatic and discontinuous changes typically introduced by top management (Choi, 1995). Continuous improvement consists in a continuous series of feedback loops guiding managers in the identification of issues, actions and monitoring of improvement of processes (Gemechu et al. 2015). In the field of sustainability/ecodesign integration in companies, various scholars have suggested continuous improvement as an approach (e.g. Dewulf and Duflou, 2004; Ammenberg and Sundin, 2005; Donnelly et al., 2006; Remmen et al., 2007; Asif et al., 2011; Pigosso et al., 2013; Gemechu et al., 2015).

Continuous improvement is typically operationalized in the Plan-Do-Check-Act (PDCA) cycle, also called Deming wheel, which provides a "meta-routine" in organizations (Sokovic et al., 2010; Asif et al., 2011). In the "PLAN" stage, managers are expected to recognize an opportunity and plan the change; in the "DO" stage, companies are encouraged to develop and implement solutions; in the "CHECK" phase, companies are supposed to review the test, analyze the results and identify the learnings; and in the "ACT" stage, companies will take action based on the previous learnings (Johnson, 2002). As shown in Table 14, PDCA cycles were earlier recommended to support continuous improvement in the context of ecodesign/sustainability implementation (Dewulf and Duflou, 2004; Ammenberg and Sundin, 2005; Donnelly et al., 2006; Remmen et al., 2007; Asif et al., 2011; Pigosso et al., 2013). Moreover, the PDCA is the core approach used in the ISO 14001 standard for environmental management system broadly used in industry, and whose recent update includes aspects of ecodesign (ISO, 2015; Lewandowksa and Matuszak-Flejszman, 2014). From this perspective, the use of the four-lens view as part of PDCA cycles of ecodesign integration in companies was identified as a potential application.

Table 14. Examples of Plan-Do-Check-Act (PDCA) cycles proposed in the sustainability/ecodesign integration literature.

PDCA cycles	PLAN	DO	CHECK	ACT
Dewulf and Duflou (2004)	Selection of environmental performance indicators based on company policy and legislation Setting of long-term targets	Supply of adequate support (tools, training, procedures)	Analysis of company performance	Start of a new cycle
Ammenberg and Sundin (2005)	Identification of environmental impacts/aspects Review of Design for the Environment organization and capabilities Review of the product development process Market investigation Definition of roles, responsibilities and authorities for product development	Development of environmentally compatible products with competitive price, performance and quality standards	Audit and evaluations	Revision of existing procedures and products aiming at continual improvement

	Establishment of policies, objectives and targets Establishment of procedures for staff involved in product development and other product-related activities			
Donnelly et al. (2006)	Environmental aspects Legal and other requirements Objectives and targets Environmental management program	Structure and responsibilities Training, awareness and competence Communication Environmental management system documentation, document control and records Operational control Emergency preparedness and response	Monitoring and measurements Non-conformance, corrective and preventive actions Environmental management system audit	Management review
Life cycle management (Remmen et al., 2007; Gemechu et al., 2015)	Set policies - set goals and determine the ambition level Organize – get engagement and participation Survey – overview of where the organization is and wants to be Set goals – select areas where the efforts will be directed, determine goals and make an action plan	Make environmental and social improvements – put the plan into action Report – document the efforts and their results	Evaluate and revise – evaluate the experience and revise policies and organizational structures as needed Measure effectiveness of solutions Collect feedback and criticism	Top management review Take it to the next level: set up new goals and actions, more detailed studies
Key questions to evaluate the extent of integration of corporate sustainability (Asif et al., 2011)	Stakeholder dialogue process Setting values and objectives Securing top management commitment	Integration (strategic, tactical and operational in procedures, manuals, measurement) Developing competencies and knowledge	Evaluation (competencies, reviews, resources, communication, reporting, feedback medium)	Learning and innovation (previous experience, knowledge repositories, strategic focus on learning how to be sustainable)
Ecodesign maturity model (Pigosso et al., 2013)	Diagnosis of the current maturity profile on ecodesign Proposition of ecodesign practices and improvement projects Portfolio management of improvement projects Planning of the	Implementation of the improvement projects (people change management)	Assessment of the results (performance indicators)	Start of a new cycle

	improvement projects for ecodesign implementation (scope, responsible, risk, resources)			
ISO 14001 (ISO, 2015)	Identify environmental aspects Establish environmental objectives and processes in accordance with organization environmental policy Plan actions to reach environmental objectives (task, responsibility, resource, timeline)	Allocate resources Develop competences Raise awareness Communicate Implement, control and maintain processes	Monitor and measure progress against the environmental policy and report the results	Monitor Internal audit Management reviews Corrective actions Continual improvement

From Table 14, one can observe that PDCA cycles suggested in the ecodesign/sustainability integration literature so far are relatively strongly anchored in the architect's perspective of organizations. There are aspects of a catalyst's perspective when it comes to developing competencies, raising awareness, getting engagement and participation, people change management and of an advocate's perspective when it comes to securing top management commitment, allocating resources and managing the portfolio of improvement projects. Yet, these aspects seem mainly meant to support architects' measures agreed on in the PLAN stage, as visible from Table 14. The integration of the four-lens view in PDCA cycles could thus bring the other perspectives of organizations in greater focus, as suggested in Figure 23.

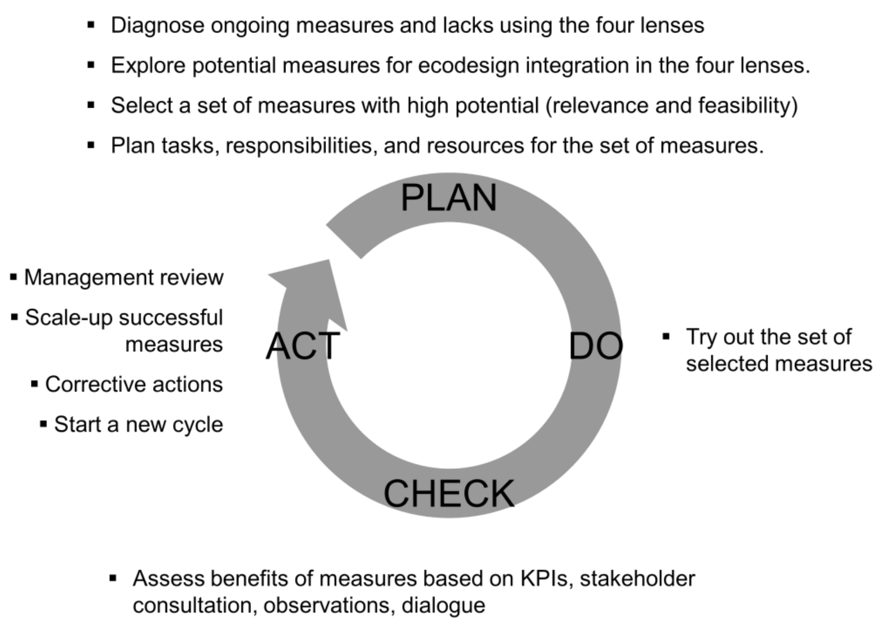


Figure 23. Suggested application of the four-lens view to review, select, and implement four-lens measures in favor of ecodesign integration within Plan-Do-Check-Act cycles. KPI = Key performance indicators.

4.5.1.2 Problem solving

The four-lens view of organizations has been used by scholars as a framework to analyze organizational processes, roles and situations. More specifically, Janz and Hall (2013) and Sjøback and Knutstad (2017) tested the direct use of the four-lens view by practitioners to analyze a current process or experienced challenges, and concluded that such exercise proved fruitful for practitioners to uncover improvement areas and solutions.

Recent research provided evidence that ecodesign and sustainability integration in companies does not only rely on the implementation of planned strategies (which has yet often been assumed in sustainability research), but also happens as an emergent practice (van der Heijden et al., 2012; Neugebauer et al., 2016; Nilsson-Lindén et al., 2018b). Van der Heijden et al. (2012) emphasized that in organizational changes for sustainability, planned implementation efforts happen in parallel of "emergent, unpredictable aspects of change" which greatly depend on how change agents interpret and make sense of sustainability for their organization. Building on the literature on strategy making, Neugebauer et al. (2016) hypothesized that planned strategy making will be a preferred mode for salient (where "salient" means highly visible among stakeholders and requiring immediate action) and non-wicked problems (where a "wicked problem" is a problem that cannot be fully understood and for which there is no obvious solution), and that emergent strategy making will be a preferred mode for non-salient and wicked problems. In their study of LC promoters, Nilsson-Lindén et al. (2018b) found that emergent strategies for LCM derived from situational adaptation and tailored responses developed by LC promoters, and that LC promoters developed knowledge from their "*numerous, and organizationally dispersed creative problem-solving practices"* (p.11). Problems typically addressed by LC promoters were found to be, for instance, related to creating interest for LCT in the company, gaining a mandate to do LC work in the company, and building the legitimacy for LC efforts (Nilsson-Lindén et al., 2018b).

Identifying challenges and barriers of ecodesign integration has been a focus in many earlier empirical studies (e.g. Verhulst and Boks, 2012a; Bey et al., 2013; Alblas et al., 2013; Poulikidou et al., 2014; Dekoninck et al., 2016; Rossi et al., 2016). As one of the initial steps of this PhD project (**Article V**), I undertook the exercise of classifying internal barriers of ecodesign integration (and other sustainability approaches) into the four-lens view of organizations, as shown in Table 15 (see also **Section 2.2** in **Article IV**).

A deeper understanding of the four-lens view as a conceptual framework and the review of its use in earlier academic studies have led me to consider its usefulness to interpret challenges related to ecodesign integration in a complementary way. Beyond classifying barriers or inhibiting factors against the four lenses of organizations, the four-lens view could help interpret practical challenges alternatively using the different lenses of organizations, as shown with three examples in Table 16. Such approach would allow going beyond generic formulation of barriers of ecodesign integration as an overall phenomenon, by focusing the discussion on concrete challenges experienced in companies, and tracing these back to a set of inhibiting factors which needs to be addressed and reflects the complexity of organizational functioning.

Table 15. Review of barriers to the implementation of sustainability approaches in the four-lens view of organizations, adapted from **Article V**.

Barriers from the structural lens	Barriers from the human lens
• Difficulty to scope, prioritize and set goals, lack of strategy • Lack of goal translation to a functional or department basis • Difficulty to define relevant sustainability performance metrics or perform reporting • Issues concerning information filtering, flows and timing to support decision making • Lack of function integration or cooperation • Lack of clear responsibility distribution • Difficulties related to decision making processes • Non-adapted performance measurement and incentive systems • Locked-in situation based on capital and technology investments	• Lack of awareness • Lack of interest and commitment • Lack of employee/management involvement • Lack of empowerment • Lack of support from middle and top management • Lack of skills and knowledge • Difficulties linked to learning process • Fear to lose creativity or flexibility • Fear of work overload • Discomfort / uncertainty about topic • Difficulty to find sustainability ambassadors with necessary set of skills
Barriers from the political lens	**Barriers from the symbolic lens**
• Difficulty to elaborate the business case, conflict and difficulty to manage trade-offs • Low priority on agenda, short term priority • Lack of continuity due to changing agenda • Lack of alignment with other projects • Power of resisting versus promoting groups • Lack of financial resources • Lack of time and human resources • Lack of local empowerment (department, business unit, subsidiary)	• Skepticism regarding potential benefits • Lack of entrepreneurial spirit and room for out-of-the-box thinking • It is not the company's responsibility • Sustainability is a distraction • Language barriers • Sustainability is "not invented here" • Sustainability inputs are constraints or criticism

From this perspective, the use of the four-lens view of organizations as a framework for problem solving by ecodesign proponents in companies seemed particularly interesting to consider. Either used in task forces or as a reflection tool at an individual level, the four-lens view could be used to interpret identified typical problematic situations or challenges experienced in the organization, and develop tailored solutions.

Table 16. Examples of ecodesign integration challenges and possible interpretations using the four-lens view of organizations.

Example of problems	Architect's perspective	Catalyst's perspective	Advocate's perspective	Prophet's perspective
Why is there a lack of ownership for sustainability aspects in project teams?	Responsibilities are not allocated clearly and sustainability aspects are not included in performance measurement	Most project members have only a vague understanding of what sustainability means for the company, and thus are quite	Project teams have other priorities and sustainability will not help them get a promotion. Moreover, it could mean going against their current practices and hence	In most project managers' mind, sustainability is associated with higher cost and a premium. Hence ecodesign is only relevant for those

	systems.	uncomfortable with the topic. They avoid the topic.	threaten their current agendas. They cannot see the value of it.	project managers dealing with product lines for green markets.
Why isn't the new ecodesign checklist introduced in the product development process (e.g. stage gate model) more proactively used by project teams?	It is not a mandatory part of the process and it will not stop the process from moving forward.	The ecodesign checklist is written in a jargon that project teams do not know at all, and they were not consulted about it. It is just one more requirements that will add more stress to their work.	Top management does not look at it in review meetings. There is no time to allocate on it. It would require a lot more resources to do something about it. It was introduced at the same time as an update of another project document, which is higher priority for project teams and already requires adaptation efforts.	It is believed that the ecodesign checklist is a matter for the environmental teams. Why should project teams look into it?
Why is there a lack of communication around ecodesign aspects in the organization?	There is a lack of horizontal and vertical communication procedures.	People who need to communicate do not know each other.	Priority for ecodesign varies a lot from one department to another which delays exchanges of information.	Different languages and visions coexist in the organization and prevent people from being able to communicate efficiently

4.5.1.3 Training

The four-lens view of organizations has been used by scholars to uncover different lens use among managers and leaders. Studies have shown varying lens preferences, by surveying managers and leaders on the approaches they reckon using (e.g. McGowan et al., 2017), their approaches as perceived by their subordinates or colleagues (e.g. Phillips and Baron, 2013), their interpretation of their role and tasks in the organization (Lieff and Albert, 2010; Frydén et al., 2015) and the ways they would face various dilemmas (St. Onge et al., 2012). Moreover, a cross-comparison of empirical studies showed a dominance of the architect's and catalyst's perspectives among different groups of leaders and managers, and that they would tend to use one or two lenses. Lastly, there was some evidence that multi-lens use was correlated with higher effectiveness as a manager or leader.

Ecodesign proponents, defined as internal stakeholders in companies driving the ecodesign integration agenda to different extents, include people working with environmental or sustainability aspects as part of their jobs, e.g. sustainability managers or Environmental, Health and Safety specialists. Employees in sustainability-related functions may have as part of their job to support goods and services sustainability efforts (Longsworth et al., 2012). With the update of the ISO 14001 environmental management standard with stronger emphasis on LCT and product environmental performance (ISO, 2015), more focus on ecodesign is expected to grow in environmental management functions (Lewandowksa and Matuszak-Flejszman, 2014; Boucher et al., 2018).

Employees in sustainability-related functions are organized under a variety of functional areas (e.g. legal, marketing, EHS), and come from various backgrounds (e.g. engineering, law, business, policy-making), as illustrated in Table 17.

Table 17. Illustration of profiles of employees in sustainability-related functions (Longsworth et al., 2012; Wolf, 2013; Osagie et al., 2016; 2016; Boucher et al., 2018; Nilsson-Lindén et al., 2018b). HR = Human Resources; CSR = Corporate Social Responsibility; LCA = Life Cycle Assessment; LCM = Life Cycle Management; R&D = Research and Development; EHS = Environment Health and Safety.

Examples of titles of sustainability-oriented jobs	**Examples of reporting line/affiliation in organization for sustainability functions**	**Examples of former job experience (for sustainability leaders only)**	**Example of educations (for sustainability leaders only)**
▪ Environment, quality, health and safety manager ▪ Environment, health and safety manager ▪ Manager CSR & Quality ▪ Environmental manager ▪ LCA specialist ▪ Sustainability specialist ▪ Sustainability officer ▪ Corporate Responsibility Officer ▪ Senior Advisor and Strategist Sustainability ▪ Sustainability manager ▪ Sustainability Manager, Engagement, & Learning ▪ Manager CSR ▪ Manager CSR and Sustainable Development ▪ Manager Global Sustainable Development ▪ Business Developer Sustainability ▪ Coordinator Corporate Responsibility ▪ Director Sustainability ▪ Director Corporate Responsibility ▪ LCM project manager ▪ Director Corporate Communication and CSR ▪ Manager Portfolio & Innovation ▪ Manager compliance ▪ Program Manager CSR ▪ Manager HR Director Sourcing and Sustainability	▪ Direction (CEO) ▪ R&D or Innovation ▪ Strategy ▪ Quality ▪ Health, Safety and Environment ▪ Legal/Regulatory affairs ▪ Human Resources ▪ Finance ▪ Business services ▪ External Affairs ▪ Operations ▪ Sustainability ▪ Environmental management ▪ Technology ▪ Sustainability and communications	▪ Environment ▪ EHS ▪ Products/operations ▪ Law ▪ Marketing & Communications ▪ Public affairs ▪ Finance ▪ Corporate ethics ▪ Non-profit	▪ Environmental engineering ▪ Chemical engineering ▪ Mechanical engineering ▪ Business administration ▪ EHS ▪ Engineering management ▪ Environmental management ▪ Public policy

Not all employees in sustainability-related functions take a similar role of change agent in their organizations. In their empirical study of environmental managers of seven French and Swiss companies, Boucher et al. (2018) documented one type of environmental managers, the "norm-driven environmental managers", who mainly focus on ensuring compliance with standards and compliance, as opposed to the "innovation-driven environmental managers" who seek to implement change outside of any normative framework. Similarly, Nilsson-Lindén et al. (2018b) found that LCA practitioners were engaging to varying extents in promotional activities of LCT in their organizations.

Ecodesign proponents are not solely located in sustainability dedicated functions, but also include employees working in core activities with personal interest in pushing the ecodesign agenda in the organization (Walker, 2007). In the interview study conducted in this PhD project, this second type of ecodesign proponents was found among sourcing and product development departments.

Considering these different aspects, one could expect high heterogeneity in lens use across ecodesign proponents in industry. At one end of the spectrum, a so-called "ecodesign champion" defined as "*very knowledgeable, inspirational and motivated about environmental issues" and "usually in middle management linking top management and designers*" (Boks, 2006, p.1353) could have multiple lenses in focus; whereas at the other end of the spectrum, a new-on-the-job junior employee recruited in the environmental management team could have more limited views of the organization.

It is also meaningful to draw a parallel between the four lenses of organizations and earlier research conducted by Visser and Crane (2010), whose approach revealed differences in how sustainability managers make sense of their role in companies, and developed a typology of sustainability managers including "experts", "facilitators", "catalysts" (different definition than in the four-lens view) or "activists" (see Table 18). Using this typology of sustainability managers, it could be expected that "experts" would primarily rely on the structural lens, "facilitators" on the human lens, "activists" on the symbolic lens and "catalysts" (in Visser and Crane's terms) on the structural and political lenses. From the interview studies, the number of lenses identified in each interview varied from one lens to all four, which could reveal different lens use among ecodesign proponents. However, this result must be interpreted with caution as it was not the aim of the interviews to detect lens use among ecodesign proponents.

Table 18. Typology of sustainability managers from Visser and Crane (2010).

EXPERTS Engage with projects or systems, give expert input, focus on technical excellence, seek uniqueness through specialization, and derive pride from their problem solving abilities.	**FACILITATORS** Focus on transferring knowledge and skills, people development, creating opportunities for staff, changing the attitudes or perceptions of individuals, and paying attention to team building.
CATALYSTS Initiate change, give strategic direction, influence leadership, track organizational performance, and have a big-picture perspective.	**ACTIVISTS** Aware of broader social and environmental issues, feel part of the community, make a contribution to poverty eradication, fight for a just cause, and leave a legacy of improved conditions in society.

From these perspectives, different lens use among ecodesign proponents could be driven by different backgrounds, job positions, ambitions, experience with the job and sense-making of the job. Hence, using the four-lens view of organizations, translated into the ecodesign integration context, at an ecodesign proponent level was identified as relevant. Practically, the framework could be included as part of training sessions of ecodesign proponents. Uncovering lens preferences among ecodesign proponents could lead to (i) supporting the development of multi-lens use at an individual level, or (ii) identifying complementarities/synergies within the ecodesign proponing team, as suggested by Sasnett and Clay (2008).

4.5.1.4 Summary of applications of the four-lens view identified as relevant for ecodesign integration activities in companies

Overall, the conceptual exploration presented in the above sections, led to hypothesize three applications of the four-lens view of organizations in ecodesign integration activities in companies, namely (i) continuous improvement, (ii) problem solving, and (iii) training. These are summarized in Table 19. These different applications are either of an active or reflective type, and either of a planned or an ad-hoc type. Application in continuous improvement would be *active* because the expected outcome is a set of measures taken to support ecodesign integration from a continuous improvement perspective, and *planned* as a regular activity in the company. Application in problem solving would be *active* because the framework would provide concrete solutions to address problems, and *ad-hoc* because taken up when problems arise. Application in training would be *reflective* because providing insights on what can be done rather than directly resulting in actions, and *planned* as a regular activity in the company (e.g. on-boarding).

Table 19. Identified ecodesign integration activities where the four-lens view of organizations could be used as a tool.

	Continuous improvement	**Problem solving**	**Training**
Why?	Ecodesign integration is a change process and continuous improvement is a common framework to support cycles of incremental improvement in companies.	Emergent strategies play a key role in ecodesign integration in companies. Ecodesign proponents face various challenging situations for which they must develop solutions.	Ecodesign proponents have varied profiles and thus are expected to exhibit different lens preferences. A multi-lens approach may bring new perspectives for their efforts to integrate ecodesign in their organization.
How?	Integration of the four-lens view in Plan-Do-Check-Act cycles	Use of the four-lens view at an individual level or in task forces to interpret and solve identified challenges.	Use of the four-lens view in training sessions to uncover lens preferences among ecodesign proponents and discuss the value of using various lenses.
Type of application	Active Planned	Active Ad-hoc	Reflective Planned

4.5.2 Initial insights from ecodesign proponents in industry (empirical study 6)

In order to gather initial insights from ecodesign proponents in industry about the potential application of the four-lens view in their activities, a one-hour webinar was organized to which ecodesign proponents belonging to an LCA and ecodesign network of Danish companies were invited. Two participants were able to attend. The first participant (Participant 1) was an EHS specialist at a Danish company from the energy sector (ecodesign proponent of type I); the second participant (Participant 2) was a project manager at a Danish company from the construction sector (ecodesign proponent of type II). From the research team, Faheem Ali, Niki Bey and myself were present during the webinar. The presence of several researchers enabled some extent of researcher triangulation.

The webinar had the double aim to (i) present the four-lens view of organizations as a conceptual framework and its relevance in the context of ecodesign integration in companies building on the exploratory case studies presented in **Section 4.4**, and (ii) allow for an interactive session about potential applications of the four-lens view in activities of ecodesign proponents in industry. The presentation included the introduction of initial operationalizing elements of the four-lens view in the ecodesign integration context. These include:

- A four-lens ecodesign integration questionnaire allowing diagnosing the extent to which the different lenses of organizations are being used in the current approach of integrating ecodesign at a given company. This questionnaire consists of 16 items representing the different lenses of organizations to be rated on a Likert-scale by ecodesign proponents. This questionnaire was adapted from the Leadership Orientation Instrument developed by Bolman and Deal (1991), retrieved from Thompson (2000), in the following ways: shortened (16 questions instead of 32), keywords from the four-lens view of organizations were used for each question and adapted to the ecodesign integration context based on literature and empirical insights from this PhD project. It was tested by an EHS manager from a multinational organization whose feedback served to the final iteration of the questionnaire. The questionnaire is available at this link: https://goo.gl/forms/DNg4OFP8ezjewzlv1 and in the Appendices (Figure A10).
- The four lists of measures in favor of ecodesign integration initially derived from the literature review presented in **Section 4.3**, and updated with the results of exploratory case studies presented in **Section 4.4** which are a graphical representation of Table A13 (see Figure A11 in the Appendices).

In the interactive session, the two participants were encouraged to answer the question *"Can you see the four-lens view being used as a tool in your activities in relation to ecodesign integration?"* Participant 1 indicated that she could recognize the different lenses in approaches taken at her company to some degree, although she could feel that the architect's perspective remains dominant through structured procedures and processes which can be traced back in the history of the company. Yet, she highlighted that in the most recent period, more emphasis is set on the catalyst's (in terms of ownership, behaviors and engagement) and prophet's (in terms of focus on the values) perspective. For Participant 1, there were some correlations between the catalyst's and prophet's perspective, in the sense that in order to energize teams, teams should first be able to participate and share their perspective on the matter. In terms of practical applications, Participant 1 evoked the possibility to use the four-lens view beyond ecodesign integration, as an analytical tool to review the set of sustainability improvement tasks proposed in the whole organization for a given fiscal year compiled in their central action plan registry, in order to assess the extent to which the different lenses of organizations are represented there. Further, Participant 1 suggested that the four-lens view could be relevant to use in the context of recruiting or hiring resources to join the ecodesign teams, as a matrix to map competencies, understand how individuals bring in the different lenses in their daily work and/or help define training needs.

Participant 2 indicated that she saw some similarities between the four lenses of organizations and the values of her company which promote both a structured approach and bottom-up initiatives. She further explained that her company is currently in the process of defining sustainability targets and objectives (from an architect's perspective), and that it coexists with local bottom-up projects aiming to explore ecodesign possibilities for specific products and markets (which can be interpreted as individual autonomy from a catalyst's perspective). The value of using the four-lens view to support ecodesign integration was not clear *per se* for Participant 2, who suggested its application in a pilot development project with ecodesign aspects, in order to evaluate the extent to which it may help support such project.

These initial insights from practitioners can be directly related to the three applications hypothesized in **Section 4.5.1**, as the four-lens view was suggested as a tool to assess the focus of existing continuous improvement projects, and as a matrix to support the recruitment (and definition of training needed) of ecodesign proponents. When it comes to using the four-lens view in problem solving, drawing from concrete examples of projects with ecodesign aspects would help evaluating the relevance and could be the focus of future investigations. These are only initial insights on concrete applications of the four-lens view in ecodesign integration activities at companies and future work is required to (i) refine hypothesized applications scenarios based on practitioners' views, and (ii) empirically test application scenarios.

4.6 Answer to research question 2 and discussion

In **Section 4.6**, the results from the above presented research steps are combined to answer **RQ2**: "*To what extent can the four-lens view of organizations help investigating and supporting ecodesign integration in formal and informal organizational functioning of companies?"* The four-lens view of organizations was initially identified as a framework suitable to investigate and support ecodesign integration in companies by embracing both formal and informal aspects of organizations, respectively captured by the structural lens on one side, and the human, political and symbolic lenses on the other side. The review of existing applicative studies of the four-lens view of organizations in academic literature revealed that the framework had rarely been applied in industry, although in other organizational settings (mainly educational institutions), it was found useful as (i) a conceptual framework to guide researchers in their investigations, and (ii) as a relevant framework for direct use by practitioners in a limited number of studies.

4.6.1 Using the four-lens view of organizations as a conceptual framework to investigate ecodesign integration in companies

Conceptual study 1 (review of existing empirical studies of ecodesign integration in companies) and **empirical study 5** (interviews of ecodesign proponents) allowed addressing the analytical part of **RQ2**, related to *investigating* ecodesign integration in formal and informal organizational functioning of companies. In **conceptual study 1**, measures in favor of ecodesign integration indicated in the reviewed studies were mapped against the four lenses of organizations. For each lens, a set of measures was identified, although more measures were found to pertain to the structural lens and to the human lens. In terms of lens presence, nearly all sources were found with measures from the structural lens; more than half of the sample, with measures of the human and political lenses; and only a limited number of studies were mapped for the symbolic lens. In terms of frequency in the reviewed sources, dominance was found for measures from an architect's perspective (e.g. designing ecodesign tools for decision-making and integrating ecodesign procedures in product development processes), for training (from the catalyst's perspective) and for having top management express explicit priority and commitment for ecodesign (from the advocate's perspective). The dominance of the architect's perspective in existing ecodesign integration literature corroborates the statements of different scholars who argued that very often solutions proposed are methods or systems, rather than a deeper understanding of the organizations (Harris and Crane, 2002; Boks, 2006; Verhulst and Boks, 2012a; Dekoninck et al., 2016). In the general management literature, architect's and catalyst's approaches were found dominant among managers and in change management approaches (Swan-Sein, 2012; Sowell, 2014). Here, the advocate's perspective was also found relatively present, which can be interpreted as the result of prominent challenges for ecodesign integration related to resource allocation, tradeoffs management and low priority on senior management agenda (Dewulf and Duflou, 2004; Alblas et al., 2914; Poulikidou et al., 2014; Dekonink et al., 2016; Schulte and Hallstedt, 2017).

A number of measures from the architect's perspective were reported to positively influence human (e.g. motivation and involvement), political (e.g. priority in agenda, resource allocation and networking) and symbolic (e.g. mindsets) factors. On the other hand, the need to use other lenses was emphasized by several scholars (Kivimaa, 2008; Verhulst and Boks, 2012a; Skelton et al., 2016; Brones et al., 2017) and a variety of measures from the catalyst's (other than training), advocate's and prophet's (to a limited extent) perspectives could be found in the sample, yet rather scattered across studies. Measures from the catalyst's perspective were indicated to positively influence structural and symbolic factors; and measures from the advocate's perspective were indicated to positively influence human and symbolic factors.

In **empirical study 5**, the exploratory case studies conducted at seven Nordic manufacturing companies analyzed in the perspective of the four-lens view of organizations enabled furthering the understanding of ecodesign integration in companies with a focus on formal and informal aspects. The measures mentioned by ecodesign proponents in these companies were found to cover the different perspectives of organizations, with some emphasis on the architect's and advocate's perspective. The dominance of the architect's and advocate's perspectives matches the findings from **conceptual study 1**. Higher focus on the advocate's perspective, than on the catalyst's perspective, could be related to ecodesign proponents expressing their struggle for gaining priority in agenda for ecodesign. At a measure-level, measures from the architect's perspective identified in **empirical study 5** aligned with measures identified in **conceptual study 1**, whereas from the other three perspectives, a set of new measures were identified in the empirical data. This strengthens the need for consolidation efforts of measures from a catalyst's, advocate's, prophet's perspectives.

Moreover, the analysis in **empirical study 5** provided further indications of interactions between lenses:

(i) Advocate’s, catalyst’s and prophet’s measures seemed to develop or be needed in the absence of structural factors at the company. However, in case companies were structural factors were lacking, the need for measures from an architect’s perspective was expressed with different intensity, from a necessity to a way to reach higher steps of ecodesign integration.

(ii) Measures from the architect’s perspective seemed considered or expected to provide an official scene for prioritizing ecodesign in the organization, hence enhancing political factors, and for acting on symbolic factors such as the “normality” of conducting ecodesign procedures.

(iii) It was found that measures from the prophet’s perspective could enhance structural and political factors, by building on symbolic elements such as the company’s tendency to rely on concrete pilots or its engineering culture.

(iv) Measures stemming from the catalyst’s, advocate’s, and prophet’s perspectives were needed to enhance structural factors, such as ecodesign procedures in the product development process and ecodesign KPIs.

These findings confirm the need for embracing both formal and informal aspects of organizations (Boks, 2006; Verhulst and Boks, 2012a; Skelton et al., 2016; Brones et al., 2017), and align with general management studies that argued for using a multi-lens approach in order to uncover challenges and success factors of diverse organizational changes and processes (e.g. Bernardes et al., 2015; Swan-Sein et al., 2012; Janz and Hall, 2013; Sowell, 2014; Keller, 2015; Bajis et al., 2018; Sjøback and Knutstad, 2017). From these different perspectives, it can be concluded that the four-lens view of organizations applied to the ecodesign integration context enables extending existing ecodesign integration frameworks in literature by expanding primarily architectural focuses to other perspectives of organizations (Pigosso et al., 2013) and by granulating the “soft factors” around the human, political and symbolic lenses of organization (Boks, 2006; Brones and Monteiro de Carvalho, 2015). The framework was found relevant (i) as a way to structure measures in favor of ecodesign integration and reveal lens dominance, and (ii) because it allowed eliciting cross-lens effects which provided evidence of lens complementarity in ecodesign integration efforts.

Using the framework as a conceptual tool to analyze current focus of measures on different aspects of internal organizational functioning, **conceptual study 1** and **empirical study 3** showed that the symbolic lens was particularly underemphasized. Existing applicative studies of the four-lens view similarly reported low use of the symbolic lens by managers and leaders. The complexity of defining and addressing organizational culture could be a reason for such low emphasis, as measures from an architect’s perspective (e.g. setting goals, defining processes), the catalyst’s perspective (mostly employee training) and the advocates perspective (e.g. having top management demonstrate commitment, emphasizing criticality) could be seen as more tangible.

From **conceptual study 1** and **empirical study 5**, the structural lens was found relatively dominant and measures from an architect’s perspective considered relatively important to facilitate ecodesign integration in companies, although with different intensities across case companies in **empirical study 5**. However, these findings should be put in contrast with earlier studies which emphasized that the balance of formal and informal measures may depend on the company context. Kivimaa (2008) similarly argued that the balance between process-based and people-based means of integration may depend on the company's specific context. Brones et al. (2017) argued that the balance between top-down (mainly architect's measures) and bottom-up integration efforts should be tailored to the company context.

Several empirical studies of ecodesign integration took a specific focus on eliciting differences between companies. For example, Verhulst and Boks (2012b) studied the trajectories of eight medium and large Belgian and Dutch companies in their efforts to integrate sustainable criteria in product development. They found for example (i) an opportunity-driven company where little focus was set on planning processes (emphasis on the advocate's perspective); (ii) a company where employee empowerment was fundamental and the change seen to rely on human behavior (emphasis on the catalyst's perspective); and (iii) a company where a rational process led to implementing procedures (emphasis on the architect's perspective) (Verhuslt and Boks, 2012b). Van der Heijden et al. (2010) analyzed the experience of eighteen companies with CSR. They were able to classify these companies based on their pragmatic or systematic strategies. Pragmatic strategies relied on short discussions of what to do, conduction of small targeted projects and later formalization in frameworks, reusable for other projects (emphasis on the advocate's or catalyst's perspectives and later, on the architect's perspective), whereas systematic strategies relied on long discussion about how to go about the topic, creation of organizational structures and formalization in reports and systems (emphasis on the architect's perspective) (van der Heijden et al., 2010). Alänge et al. (2016) compared the approach of integrating sustainability in product development at two Swedish companies, IKEA and SCA. They found that IKEA primarily relied on success stories, projects, education and the founder's vision (emphasis on the prophet's, advocate's and catalyst's perspectives), whereas SCA relied on a structured and documented approach building on procedures and processes (emphasis on the architect's perspective). The authors explained such difference due to different organizational cultures and management systems at the two companies (Alänge et al., 2016).

The relevance of *measures* within each lens was found to depend on the company context in **empirical study 5**. The company persona characteristics developed by Faheem Ali in his PhD project (**Article VI**) could be particularly relevant to integrate with the four-lens view. For instance, case companies where the *market conditions* were not in favor of ecodesigned products, where the *strategic focus of the company* was strongly anchored on specific aspects crowding out ecodesign aspects, or where *functional goals in DfS* were indirect goals resulting from companies' business-as-usual activities, the measure "setting objective/goals/targets" (architect's perspective) was not highlighted as a measure with applicability by ecodesign proponents in the respective case companies. The measure "involve people who have personal aspirations for ecodesign, target people who "burn for it"" (catalyst's perspective) was highlighted at case companies where ecodesign integration was department driven (by the EHS department), rather than top management-driven; the *DfS chaperoning* characteristic thus possibly having an influence on the highlighting of this measure. Hence, future work should specifically explore the extent to which different company contexts leads to differentiated emphasis on (i) the lenses of organizations, and (ii) measures within each lens of organizations.

Both in **conceptual study 1** and **empirical study 5**, the approach taken was mainly to separate different measures in favor of ecodesign integration according to the different lenses of organizations, based on their basic underlying assumptions of what an organization is. An alternative approach could consist of deciphering the different facets of a given measure according to the different lenses of organizations (see example for the topic of ecodesign tool in **Section 4.3.2.3**). This would be similar to Bolman and Deal's (2008) proposal to uncover the meaning of various organizational processes using the different lenses, e.g. meetings (see **Section 4.1**). Another example of such measures in the context of ecodesign integration could be the use of networks, as proposed by Nilsson-Lindén et al. (2018a), which could (i) from the symbolic lens, enhance the creation of shared meanings; (ii) from the human lens, motivate ecodesign proponents, allow them to share their own ideas and grow based on others' ideas; (iii) from the political lens, create an interest group with possibly higher weight among other organizational agendas; and (iv) from the structural lens, create a visibility for the topic in the organization's organigram. Furthermore, the four-lens-view could alternatively be used to granulate measures of the type "exploration, experimentation, double-loop learning, creativity, and entrepreneurship" (Alblas et al., 2014) or "improving two-way communication between operational and strategic levels" (Dekoninck et al., 2016) into different perspectives of organizations. The first one could require the combination of creating organizational structure facilitating experimentation (architect's perspective) and developing creativity skills among employees (catalyst's perspective). The second one could require the combination of data sharing processes between departments (architect's perspective), and creating an informal forum where operational levels can share ideas with higher levels (prophet's perspective).

4.6.1.1 Limitations and suggested areas for future work for the first part of RQ2

Limitations of the research design developed to answer the first part of **RQ2** and areas for future work could be identified as threefold. First, **conceptual study 1** solely included empirical studies of ecodesign (and similar concepts, e.g. green product innovation, design for environment) integration. Thus, purely conceptual studies on the one hand, and studies focusing on integration of other sustainability-related concepts on the other hand, were excluded. Expanding the review in these two directions would be relevant areas for future work. The review of conceptual studies (with no direct connection to empirical data) could add additional perspectives on the extent to which the four lenses of organizations are anchored in ecodesign integration scholars' schemes to support ecodesign integration in companies. Moreover, including empirical studies focusing on the integration of sustainability-related approaches in organizations beyond ecodesign (e.g. environmental management, sustainability strategies, CE, green supply chain management) would be relevant in order (i) to evaluate the extent to which the four lenses are being used in such a broader literature field, and (ii) to further populate the list of measures anchored in the four lenses of organizations based on insights from these other fields, especially relevant for the under-emphasized symbolic lens.

Second, the research design of **empirical study 5** was exploratory *per se*, and in the specific context of large Nordic manufacturing companies with recognized efforts towards sustainability. Employee empowerment and flat organizational structures which are characteristics of Nordic companies (Ali et al., 2016) could have influenced our findings, and more specifically the relative importance of the catalyst's, advocate's and prophet's perspectives in ecodesign integration efforts. Hence, the use of different perspectives in ecodesign integration efforts and relations between perspectives should be investigated in broader samples of companies, including different contexts.

Third, in the investigation of ecodesign integration in **empirical study 5**, the four-lens view of organizations was used indirectly, in the sense that the framework was not used to structure the data collection, but to interpret the data once generated. This approach has been used by various scholars either to conduct interviews (e.g. Farrell, 2003; Lieff and Albert, 2010; Frydén et al., 2015), analyze critical incidents written by managers about their leadership challenges (Bolman and Deal, 1991; McArdle, 2013), or to analyze documents (Swan-Sein et al., 2012). Yet, using the four-lens view as a framework for data collection about ecodesign integration in companies would be particularly suited to address broader samples of case companies. This could be done using a survey instrument similar to the Leadership Orientation Instrument (LOI) introduced by Bolman and Deal (1991), and since then used by various scholars (e.g. Sasnett and Ross, 2007; Othman et al., 2010; Phillips and Baron, 2013; McGowan et al., 2017). The questionnaire developed in **Section 4.5.2** is a first attempt to adapt the LOI to the context of ecodesign integration and should be refined. However, a purely quantitative setting based on Likert scale response might not be representative of lens use in ecodesign integration efforts (McArdle, 2013). One advantage of the LOI is the possibility it gives to study correlations between multi-lens use of managers or leaders and their effectiveness as managers or leaders. A similar approach could be undertaken in the context of ecodesign integration in order to evaluate the effect of measures and combinations of measures from different lenses on the effectiveness of ecodesign integration in companies. However, defining the effectiveness variable might be more difficult in the context of ecodesign. Moreover, specific company contextual factors are likely to factor in, and thus should be used a control variables.

4.6.2 Using the four-lens view of organizations to practically support ecodesign integration activities in companies

Conceptual studies 1-2 and **empirical studies 5-6** provided insights to answer the "practical" part of **RQ2**, relating to "supporting ecodesign integration in companies' formal and informal organizational functioning". From **conceptual study 1** and **empirical study 5**, measures corresponding to the different lenses of organizations were listed and compiled in four sheets, which can be used by practitioners as inspiration for improving ecodesign integration in their companies. Furthermore, **conceptual study 2** led to hypothesize three applications of the four-lens view in ecodesign integration activities, building on applications in other organizational contexts identified in **background 4**.

The first hypothesized application is as part of a continuous improvement approach, and relates to ecodesign integration being interpreted as an organizational change (Verhulst and Boks, 2012a; Pigosso et al., 2013; Brones et al., 2017). The second hypothesized application pertains to supporting problem solving, i.e. to interpret and respond to identified challenges in a specific project or related to ecodesign integration in general. This application was identified as relevant because emergent strategies to answer challenges play a key role in ecodesign integration in companies (Nilsson-Lindén et al., 2018b). Third, the review of applicative studies revealed a relatively dominant use of the framework by scholars to detect lens preferences among managers and leaders in organizations. Ecodesign proponents are expected to act as leaders and change agents in their organization (Dunphy et al., 2007; Holton et al., 2010; Visser and Crane, 2010; Opoku and Fortune, 2011; Walker, 2007; Taylor, 2012; Skelton et al., 2016; Sroufe, 2017). Considering the diversity of backgrounds, job positions, ambitions, experiences with the job and sense-making of the job, different lens use among ecodesign proponents can be expected. Hence, training ecodesign proponents on the value of multi-lens approaches could bring new perspectives in their efforts to integrate ecodesign in their organizations. **Empirical study 6** provided initial insights from ecodesign proponents on applications of the four-lens view in ecodesign integration activities, which strengthened the hypotheses from **conceptual study 2,** regarding continuous improvement and training. An additional application was evoked in relation to the recruitment of resources in ecodesign teams.

Related to the use of the four-lens view by practitioners, important aspects to consider, as raised by Palmer and Dunford (1996), are (i) the cognitive ability of practitioners to use several lenses, and (ii) the constraints and circumstances causing possible lens dominance within an organization. Regarding the first aspect, our dialogue with two ecodesign proponents about the four lenses of organizations did not primarily yield into incomprehension of specific lenses, and of their relevance to address the organizational context. Yet, using the four-lens view requires critical reflection from practitioners which is not necessarily a natural exercise (Gray, 2007). Hence, the practical use of the four-lens view by practitioners might require external facilitation to help practitioners grasp what the different lenses actually mean, and trigger them into using them to look at their organization's current approaches and challenges in different ways (Gray, 2007).

The second issue, related to constraints and circumstances causing possible lens dominance within an organization, may be higher when using the four-lens view as an ecodesign proponent than as a typical manager in an organization. Indeed, managers have a direct mandate to manage their teams; hence learning about the four-lens view can have direct effect on their management style. In the case of ecodesign proponents, they may be managers, but ecodesign integration encompasses areas that they are not directly mandated to manage. Hence, learning about the four-lens view would enable ecodesign proponents to understand what might be missing as of today in the organization, but their influence on the current approach would remain more limited (Harris and Crane, 2002). For instance, an ecodesign proponent may acknowledge the need to integrate sustainability in the technology strategy of the company or to have top management demonstrate its commitment to ecodesign more explicitly, but he or she does not have the direct influence on the matters. From this perspective, exploring the extent and how using the four-lens view as an ecodesign proponent may lead to actual changes in the organization is relevant to address.

4.6.2.1 Limitations and suggested areas for future work for the second part of RQ2

Limitations of the research design developed to answer the second part of **RQ2** and areas for future work were identified as fourfold. First, measures listed in the four lenses, and more specifically measures under the human, political and symbolic lenses, require further testing as they were identified as relatively scattered in existing knowledge from **conceptual study 1** and from the results of **empirical study 5**.

Second, measures listed in the four lenses require to be further operationalized, e.g. in the form of guidelines, examples or tools in order to facilitate the concrete taking of the measures by companies. For example, for the measure “understand what motivate employees or leads them to resistance”, using a user-oriented design tool such as journey mapping (to get in-depth knowledge about employees’ experience with ecodesign) could be a way to operationalize that measure (Liedtka, 2014).

Third, the four-lens lists of measures provide, as of now, a relatively flat support for ecodesign integration in companies, in the sense that all measures are presented on the same level of importance. Such a display is relevant to drive reflections among practitioners about what is done today, what is not and could be relevant, and what is not feasible or relevant. However, it has a limited prescriptive orientation which is an area for future research, either with a maturity perspective, i.e. determining which measures should come first in a company’s ecodesign integration journey (Pigosso et al., 2013), and/or from a Company Persona perspective, i.e. determining which measures would fit a given company context. A general overview of how the four-lens view and Company Persona (**Article VI**) could be integrated to develop tailored measures for ecodesign integration in specific company contexts is shown in Figure 24. These considerations also relate to the fourth limitation mentioned in **Section 4.6.1.1**, about the need to better understand the effect of multi-lens measures on effectiveness of ecodesign integration in companies.

Fourth, the empirical insights collected as part of this PhD project on the relevance of the three hypothesized applications of the four-lens view of organizations in ecodesign integration activities are thin as of now. Future work could consist of (i) organizing another focus group in the same line as the webinar described in **Section 4.5.2**, but involving a broader set of participants, in order to expand initial hypotheses on how the four-lens view could be used in ecodesign proponents’ activities; and (ii) empirically testing in an action research setting preferred application scenarios stemming from the focus group.

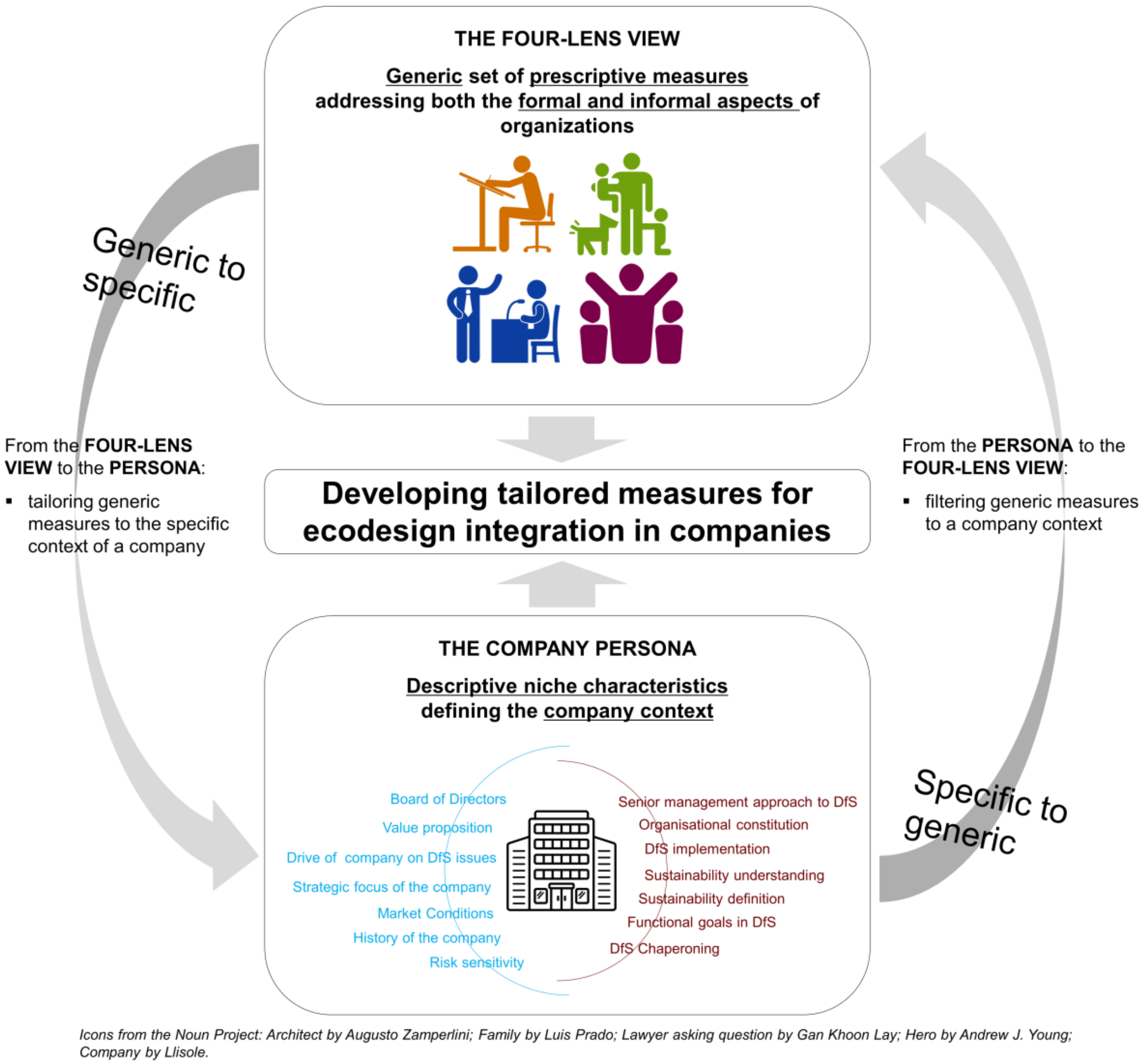
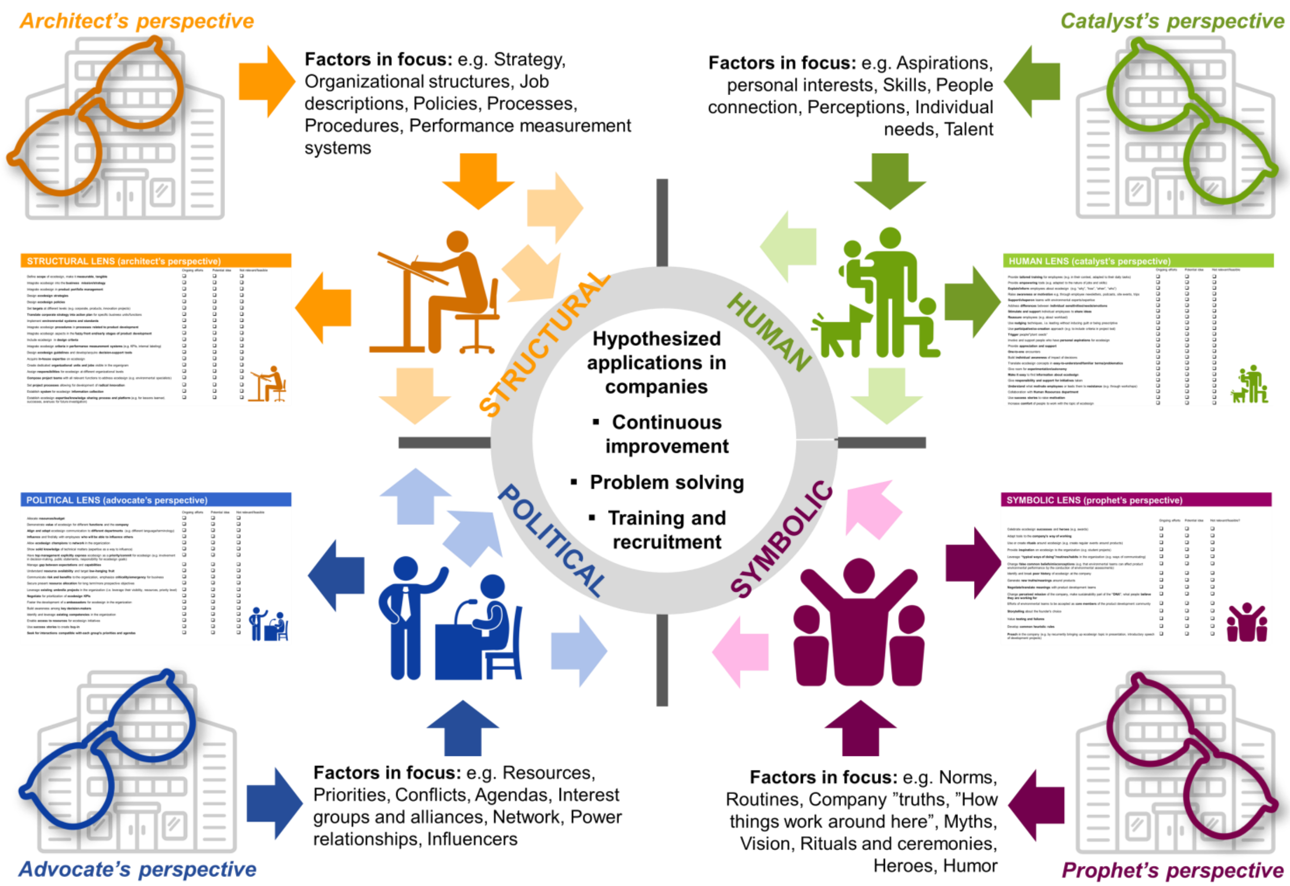


Figure 24. Suggested integration between the four-lens view of organizations framework and Company Personas. DfS = Design for Sustainability.

4.6.3 Graphical overview of answer to RQ2

Figure 25 shows the translation of the four-lens view of organizations in the context of ecodesign integration in companies, building on the results from the research steps in the second track of this PhD project. For each lens, it shows the corresponding perspective, which factors are in focus, and the list of measures that can be taken from this perspective as identified in literature and empirical data (the measures are not readable in Figure 25 but are reported in full-size in Figure A11 in the Appendices). Light color arrows show where indications of interactions between lenses were found in literature and empirical data (See Table 13). In the inner circle, the three hypothesized applications of the framework in ecodesign integration activities are reported.



Icons from the Noun Project: Architect by Augusto Zamperlini; Family by Luis Prado; Lawyer asking question by Gan Khoon Lay; Hero by Andrew J. Young; Glasses by Vladimir Belochkin; Company by Llisole.

Figure 25. Graphical overview of the answer to research question 2. Light color arrows represent cross-lens interactions identified in the literature and empirical data and are detailed in Table 13. Example on how to read the scheme: when using the structural lens, the focus is brought on specific elements such as the strategy, the organizational structures, the job descriptions, etc. which call for acting as an architect, pulling from the list of ecodesign integration measures compiled in the architect's sheet. The four-lens lists of measures in favor of ecodesign are not readable on this overview but they can be found in the Appendices (Figure A11).

5 Conclusions

In **Section 5.1**, I first provide an executive answer for each research question. In **Section 5.2**, I bring together both research questions and provide an outlook for future research. Finally, in **Section 5.3**, I highlight the contributions of this work to research and practice.

5.1 Executive answers to the research questions

In the context of increasing sustainability challenges and renewed attention to the role of companies in providing part of the solution to address them, this PhD project took an environmental sustainability and product LC perspective, and set out to contribute to closing two identified research gaps. On the one hand, this project took an "*outsider perspective*", by focusing on companies' narratives of their sustainability approaches provided in CS reports, and aimed at increasing knowledge about the extent to which LCT is present in such corporate documents (**RQ1**). On the other hand, this project took an *"insider perspective"*, by focusing on internal organizational functioning of companies, and aimed at testing the relevance of a conceptual framework from general management literature, namely the four-lens view of organizations, to investigate and support product sustainability approaches in companies' formal and informal organizational functioning (**RQ2**). **RQ1** corresponded to conducting a relatively narrow analysis for a broad set of companies, whereas **RQ2** corresponded to conducting a relatively broad analysis for a more limited set of companies. Figure 26 provides an overview of this PhD project, including its focus areas, main findings and opportunities for future research.

RQ1: To what extent is life cycle thinking present in company narratives of their sustainability approaches provided in corporate sustainability reports?

Four studies constituted the backbone of the answer to **RQ1**. All in all, the presence of LCT in companies' narratives provided in CS reports was explored using three different indicators: (i) references to LC-based methodologies; (ii) extent to which reported environmental sustainability operational practices covered the different LC stages in the product LC system; and (iii) presence of LCT elements in companies' narratives, including product LC system, hotspots in the product LC, tradeoffs in the product LC or across environmental problems, and product environmental sustainability budget (related to the idea of ecological limits). The main findings are threefold:

1. The idea of product LC system was found present in CS reports as a concept or through operational practices addressing the different LC stages.
2. The LCA methodology in itself was found with a rather weak presence in CS reports globally (ca. 5% of all reports released in 2015), with some sectoral and geographical variations; yet, in smaller and targeted samples of CS reports, presence of LC-based methodologies was found more frequent.
3. LCT was only limitedly used to critically analyze and reflect about environmental sustainability challenges associated with product LC systems.

Areas for future research include (i) exploring other LCT indicators and conducting discourse or graph-based analyses of CS reports content, (ii) triangulating interpretation of CS reports with the views of employees involved in the CS reporting process, and (iii) exploring the possibility to automatize CS reports analyses in order to investigate broader samples.

RQ2: To what extent can the four-lens view of organizations help investigating and supporting ecodesign integration in formal and informal organizational functioning of companies?

In order to answer **RQ2**, different research steps were undertaken to address the "investigating" and "supporting" parts of the research question. In relation to the first part, a literature study and an empirical study were combined and led to (i) mapping measures in favor of ecodesign integration according to the different lenses; and (ii) uncovering cross-lens effects, i.e. interactions between lenses. In relation to the second part, measures corresponding to the different lenses of organizations were listed and compiled in four sheets for inspiration among practitioners. Furthermore, the review of existing applicative studies of the framework, existing knowledge of ecodesign integration, and a webinar with practitioners were combined to hypothesize applications of the four-lens view in ecodesign integration activities of companies. The main findings are fourfold:

1. Measures from the structural lens were found to dominate in existing literature, together with training of employees which pertains to the human lens, and having top management explicitly express priority for ecodesign which pertains to the political lens, although multiple measures corresponding to all lenses could be found in existing literature.
2. Measures from the structural and political lenses were mentioned by ecodesign proponents at all case companies, and measures from the human and symbolic lenses at some.
3. Indications of cross-lens effects, i.e. indications that measures corresponding to a given lens enhance factors at the core of other lenses, were found in the literature and in the empirical data (e.g. "setting clear goals/formal targets" (structural lens) enhances "employees' motivation" (human lens), "prioritize ecodesign in agendas" (political lens) enhances "ecodesign KPIs" (structural lens), and "changing misconceptions about who influences product environmental performance" (symbolic lens) enhances "ecodesign procedures in the product development process" (structural lens)).
4. Three applications of the four-lens view in ecodesign integration activities were hypothesized: continuous improvement, problem solving and training or recruitment of employees.

Areas for future research include (i) building on other related bodies of literature to further identify potential measures from the different perspectives of organizations, (ii) investigating the use of and interactions between different lenses of organizations in broader samples of companies (with a focus on uncovering correlations between multi-lens use and ecodesign integration effectiveness, and on exploring the influence of contextual factors), (iii) operationalizing, testing and prioritizing measures to refine the four-lens framework for ecodesign integration, and (iv) testing the practical application of the four-lens view of organizations in ecodesign integration activities.

5.2 Cross-linking and outlook for future research

As shown in Figure 26, **RQ1** and **RQ2** focused on two different layers of sustainability approaches: companies' narratives captured in CS reports, and internal organizational functioning captured in interviews of practitioners, respectively. CS reports provide high-level, one-sided, senior management-approved, narratives of companies' sustainability efforts meant for public availability. They deliver insights on how companies understand their sustainability efforts should be best presented and, hence, contain concepts and reasoning lines considered critical by the companies' themselves for their official communications. Interviews provide in-depth insights of practitioners' individual perceptions of the phenomenon under observation in the broader context and reality of organizational functioning, and in close relation to their own work area. Together, the two tracks of the PhD project allowed "*getting closer to companies*"- to the companies' understanding of how to best present their sustainability efforts, and to the companies' internal organizational functioning, respectively. They had in common to anchor the discussion of sustainability approaches closely to companies' practice. Hence, this PhD research provides complementary insights on how to strengthen the integration of sustainability approaches in industry, from a product LC perspective. The first track identified the need for an increased use of LCT in companies' narratives for critical analyses and reflections about existing product LC systems, and the environmental sustainability challenges they are associated with. The second track provided evidence and structure around combining different perspectives of organizations in order to address ecodesign integration, with a broad horizon of what internal organizational functioning entails.

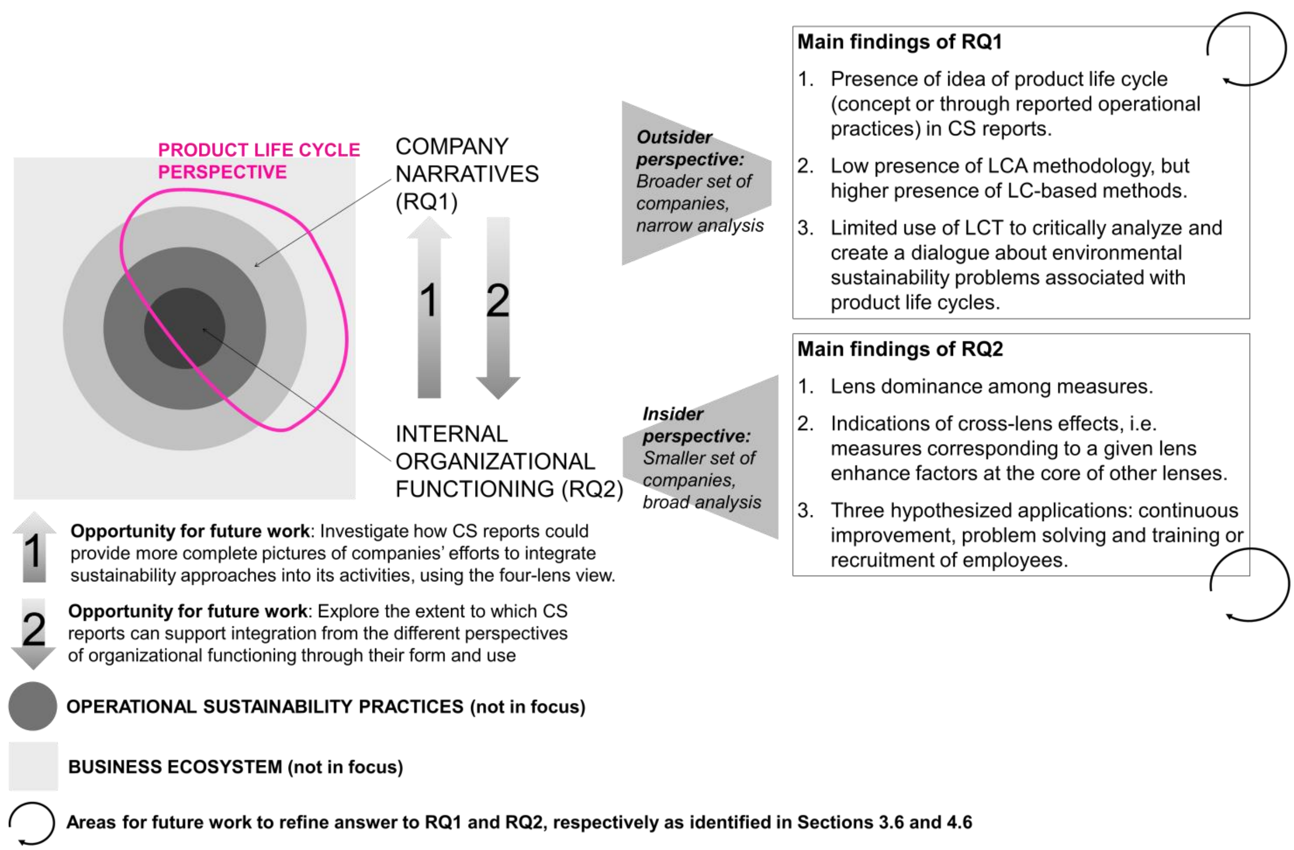


Figure 26. Graphical overview of answer to the research questions and outlook for future work. RQ = Research Question; LCA = Life Cycle Assessment; LCT = Life Cycle Thinking; CS = Corporate Sustainability.

These two tracks were conducted independently to a great extent, and their cross-linking is an opportunity for future research. On the one hand, it was observed from earlier literature that CS reports may fulfill a number of internal functions, such as (i) structuring data collection and monitoring progress towards goals (Adams and Frost, 2008), (ii) raising awareness and motivation among employees (Searcy and Buslovich, 2014), (iii) providing legitimacy for sustainability efforts in the company (Hedberg and von Malmborg, 2003), and (iv) celebrating progress (Searcy and Buslovich, 2014). A parallel can be drawn between these four internal functions of CS reports and the structural, human, political and symbolic lenses, respectively. From this perspective, future work could explore the extent to which CS reports fulfill these different functions, and how they may support integration from the different perspectives of organizational functioning through their form and use. The research by Thijssen et al. (2016) showed that companies' managerial and organizational sustainability practices were limitedly reflected in their CS reports. Future work could investigate the extent to which factors and measures from the structural, human, political and symbolic lenses of organizations are documented by companies in their CS reports, and how the link to internal organizational functioning could be made stronger in CS reports in order to deliver more complete pictures of companies' efforts to integrate sustainability approaches into their activities. These two opportunities for future research are indicated as "arrow 1" and "arrow 2" in Figure 26.

5.3 Theoretical and practical contributions

The research conducted in this PhD project has contributions both to research and practice, as summarized in this final section.

On a **theoretical level**, the contributions of this PhD project are:

(i) The provision of insights of the extent to which LCT is present in company narratives of their sustainability approaches provided in CS reports, using three different indicators. This contributes to answering the call for increasing the knowledge of businesses' conceptions of sustainability, as a critical step towards achieving sustainability transitions. The last indicator, consisting of presence of LCT elements which are the product LC system, hotspots in the product LC, tradeoffs in the product LC and across environmental problems, and product environmental sustainability budget, constitutes a conceptual framework which could be reused in future research of the presence of LCT in company narratives.

(ii) The introduction of the four-lens view of organizations as a conceptual framework from general management literature to structure the investigation of formal and informal aspects of organizations influencing ecodesign integration. This answers to a call in ecodesign integration literature for embracing both formal and informal aspects of organizational functioning. The framework enabled to build a consolidated view of existing knowledge of ecodesign integration, and shed light on the dominance of specific lenses over others. It further enabled eliciting interactions between different aspects of ecodesign integration in companies.

As side aspects of the core research areas in this project, the embedded research steps additionally contributed to the fields of CS reporting research and general management, (i) by providing an overview of the context in which scholars have scrutinized CS reports in existing literature, and (ii) by building an overview of existing applicative studies of the four-lens view of organizations, and demonstrating the relevance of applying the framework in a corporate context, which expands the scope of applicative fields currently documented in academia.

On a **practical level**, the contributions of this PhD project are:

(i) Evidence of LCT presence in company narratives in CS reports, and recommendations for CS reporting guidelines developers, policy-makers, companies, and the LCT research community to increase the use of LCT from an analytical perspective in company narratives.

(ii) The translation of the four-lens view of organizations into the ecodesign integration context, including a set of measures in favor of ecodesign integration anchored in the four lenses derived from literature and empirical insights, and suggestions for practical application in ecodesign integration activities. This translated framework can already be used by ecodesign proponents in industry for inspiration to improve ecodesign integration, although refined and more operationalized versions should be the object of future work.

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7 Appendices

7.1 Section 3.2 (background 2)

7.1.1 Supplementary methods

Table A1. Two building blocks and associated keywords used for the literature screening in background 2. Not all spelling variations used in the search string are included in the table. CSR = Corporate Social Responsibility; CR = Corporate Responsibility.

Corporate sustainability reporting	Analysis of reports (both sets of keywords were searched within a range of 5 words away from each other)	
CSR report	Analyze	Report
Citizenship report	Examine	Content
Corporate responsibility report	Explore	Document
Corporate social responsibility report	Investigate	Disclosure
CR report	Study	Text
Environmental report AND company	Review	
Sustainability report AND company	Assess	
	Evaluate	
	Scrutinize	

7.1.2 Supplementary results

Table A2. Information on purpose, sample, data sources, methods and key findings of corporate sustainability (CS) practice-focused studies with a product life cycle perspective.

Study	Purpose	Sample	Data source	Method	Key findings (in relation with product life cycle)
Dangelico and Pontrandolfo (2010)	Developing a Green Option Matrix (GOM) which characterizes green products and practices along different dimensions and analyze the different features of green products as well as related green practices for a set of companies.	The 142 companies listed in the Dow Jones Sustainability World Index (DJSWI) and belonging to the Technology, Consumer Goods, Industrial, and Basic Materials sectors.	Websites and CS reports	Development of a matrix to characterize green products (according to their focus, i.e. material, energy and pollution and the life cycle phase in which the environmental improvement is delivered) and analysis of the different features of green products for a set of case companies. Search for sections containing specific keywords, positioning of identified green products in the matrix, listing of examples under	In almost all sectors, practices such as size and weight reduction of products, packaging, and materials, also quite common are practices aimed at improving energy efficiency of processes or products The Consumer Goods sector is the sector with the highest levels of diversification of green products and practices.

				each cell of the matrix.	
Nunes and Bennett (2010)	Investigate green operations initiatives in the automotive industry.	World's major three companies in the automotive industry	Website and CS reports	Development of a conceptual framework for green operations based on existing literature structured around green buildings, eco-design, green supply chains, green manufacturing, reverse logistics and innovation. Content analysis against the conceptual framework (listing of examples under each pillar).	The results show that product design is considered important by companies for tackling environmental issues because it enables influencing the whole life cycle of the product. Product design initiatives include lightweight material, fuel efficiency and diversification, elimination or reduction of Volatile Organic Compounds and the "four substances of concern", and also intelligent systems to reduce traffic congestion. To address issues at the end of life (associated with stricter regulations), design for recycling and dismantling are the main approaches.
Comas-Martí and Seifert (2013)	Develop and test a conceptual framework for the quantitative assessment of the comprehensiveness of firms' environmental strategies, in terms of issue and life cycle coverage.	12 companies in 6 different sectors (automotive, construction material, food, clothing, technology hardware, general retailers) and identified as sustainability leaders in the SAM Sustainability Yearbook 2010.	CS reports	Development of the conceptual framework based on existing literature and structured in (i) the environmental inputs and outputs addressed, (ii) the firm versus supply chain orientation of environmental strategies, and (iii) the environmental management practices adopted by companies. Content analysis against the conceptual framework (categorization of disclosures according to the	Companies remain mainly firm oriented; the raw material (tier 2 suppliers), use and disposal phase are less covered by sustainability practices. Attention to the supply chain is greater in sectors where stakeholder pressure is higher for supply chain issues.

				framework and calculation of the relative presence of framework elements in percentage of disclosures)	
Fuisz-Kehrbach (2015)	Investigate the implementation of corporate sustainability activities (CSA) within mining companies	16 mining companies	CS reports	Analysis along three dimensions: 1. The types of CSA from philanthropic to entrepreneurial activities 2. the issues addressed (e.g., health, safety, environment) 3. the step of the value chain concerned: supply, production or product-related sustainability activities.	Systematic management of environmental aspects at mining operations. Lesser presence of upstream supply and downstream product-related activities.
Hickle (2017).	Examines how extended producer responsibility (EPR) as an environmental policy approach and, more broadly, product management strategies are characterized.	The 121 companies listed in Newsweek Green Ranking of the largest publically traded global companies and subject to EPR regulations. The sample includes sector such as electronics, pharmaceuticals, packaging, automobiles, textiles, household waste.	CS reports	Search for references to EPR and end-of-life (EOL) management strategies for discarded products. Specific themes: Statement of a preferred policy approach for EPR, Reference to a specific goal for EOL management of products, Quantitative assessment of products or materials managed, Reference to an EOL product collection program such as collection at retail locations, Design for environment considerations incorporated into the company's product design.	More than half of the companies indicated Design for the Environment practices in focus when developing products, e.g. design for recycling, energy efficiency, reduction in packaging, meaning that there is a focus on pollution prevention, as an intra-company activity. There is lesser emphasis on inter-company activities, such as managing products at the EOL.
Sihvonen and Partanen	Examine the extent to which companies	43 companies in the Information and	CS reports	Awareness of ecodesign	The results suggested that indicating

(2017)	report quantitative environmental targets for products, and what topics are in focus for their environmentally conscious practices related to products' reuse.	Communication Technology sector, mostly using the Gobal Reporting Initiative (GRI) guidelines in their reporting, and having responded to the Carbon Disclosure Project.	practices assessed based on occurrence of ecodesign terms in reports (e.g. Eco-design, Design for environment, product stewardship, green products, green devices, Circular economy, longevity, reuse, and repair). Mapping of environmental quantitative targets for products. Level of internal environmental performance quantified by the "percentage of products sold and their packaging materials that are reclaimed by category" (GRI item). Test of correlations between the different variables.	quantitative environmental targets for products is positively associated with awareness of life cycle thinking, especially considering the durability of products, and remanufacture. Quantitative environmental targets for products are not yet dominantly present but they are positively associated with internal environmental performance.

7.2 Section 3.3 (empirical study 1)

7.2.1 Supplementary methods

Table A3. Corporate sustainability reports included in empirical study 1B (Stewart et al., in preparation).

Company	Sector	Country	2013	2014	2015
ACOME	Chemicals	France			1
Air Products and Chemicals Inc	Chemicals	USA		1	1
Airbus SAS	Transport	France	1		
Alpine Electronics Inc	Electronic & Electrical Equipment	Japan		1	1
Alpro Comm VA	Food Producers & Processors	Belgium			1
Amway Corporation	Household Goods & Textiles	USA		1	
Annie's	Food Producers & Processors	USA		1	
Aptargroup Inc	Packaging	USA		1	1
Aquafil SpA	Household Goods & Textiles	Italy		1	1
Ardagh Group SA	Packaging	Luxembourg			1
Arizona Chemical	Chemicals	USA		1	1
Asics Corporation	Household Goods & Textiles	Japan			1
Ball Packaging Europe GmbH	Packaging	Switzerland			1
Banca Monte dei Paschi di Siena	Banks	Italy	1	1	

SpA					
Bang & Olufsen A/S	Electronic & Electrical Equipment	Denmark		1	1
Barilla G e R Fratelli SpA	Food Producers & Processors	Italy		1	
Bata	Household Goods & Textiles	Switzerland		1	
Bell Canada	Telecommunication Services	Canada		1	1
Billerud AB	Packaging	Sweden		1	1
BioMar AS	Food Producers & Processors	Norway		1	
Birla Carbon	Chemicals	USA		1	
Blackberry	Telecommunication Services	Canada	1		
Bord na Móna Energy Ltd	Electricity	Republic of Ireland (Eire)			1
Borregaard Industries Ltd	Chemicals	Norway			1
BSH Bosch und Siemens Hausgeräte GmbH	Household Goods & Textiles	Germany			1
Caixa Econa Federal	Banks	Brazil			1
Canon Europe Ltd	Electronic & Electrical Equipment	UK			1
Celestica Inc	Electronic & Electrical Equipment	Canada		1	
Charoen Pokphand Foods pcl	Food Producers & Processors	Thailand			1
Chicken of the Sea	Food Producers & Processors	USA		1	
Danske Bank A/S	Banks	Denmark			1
DSM NV	Chemicals	The Netherlands			1
Duni AB	Household Goods & Textiles	Sweden			1
Eastman Chemical Company	Chemicals	USA		1	1
Eco-Products	Household Goods & Textiles	USA		1	
Egetæpper A/S	Household Goods & Textiles	Denmark		1	
Elopak AS	Packaging	Norway		1	1
Epta SpA	Electronic & Electrical Equipment	Italy		1	1
ETAP NV	Electronic & Electrical Equipment	Belgium			1
FMC Corporation	Chemicals	USA			1
Gabriel A/S	Household Goods & Textiles	Denmark		1	1
Gildan Activewear Inc	Household Goods & Textiles	Canada			1
GNP Company	Food Producers & Processors	USA		1	
Gojo Industries Inc	Chemicals	USA		1	
Good Energy	Electricity	UK			1
Greif Inc	Packaging	USA		1	
Groupe Coopératif Maïsadour	Food Producers & Processors	France			1
GS Yuasa Corporation	Electronic & Electrical Equipment	Japan		1	
Hansgrohe AG	Household Goods & Textiles	Germany		1	
Haworth Inc	Household Goods & Textiles	USA		1	1
Herman Miller Inc	Household Goods & Textiles	USA		1	
Hexion Inc	Chemicals	USA			1
Huhtamäki Oyj	Packaging	Finland		1	1
Hydro Québec	Electricity	Canada	1	1	1
Ikea AB	Household Goods & Textiles	Sweden			1
International Flavors & Fragrances Inc	Chemicals	USA		1	
J&J Industries	Household Goods & Textiles	USA		1	
Jack Wolfskin Ausrstung fr Draussen GmbH & Co KG	Household Goods & Textiles	Germany		1	
Kamstrup AS	Electronic & Electrical Equipment	Denmark		1	1
Kendrion NV	Electronic & Electrical Equipment	The Netherlands		1	

Kering	Household Goods & Textiles	France			1
Kimball Office	Household Goods & Textiles	USA		1	
Knoll Inc	Household Goods & Textiles	USA			1
Kvadrat	Household Goods & Textiles	Denmark		1	1
Land O'Lakes Inc	Food Producers & Processors	USA		1	
Levi Strauss & Co	Household Goods & Textiles	USA		1	
Living Edge	Household Goods & Textiles	Australia		1	
Lodam Electronics AS	Electronic & Electrical Equipment	Denmark		1	1
MAUSER Holding	Packaging	Germany			1
Mondelez International Inc	Food Producers & Processors	USA			1
Mountain Equipment Co-operative	Household Goods & Textiles	Canada			1
National Office Furniture	Household Goods & Textiles	USA		1	
Naturex SA	Food Producers & Processors	France			1
Nefab AB	Packaging	Sweden		1	1
Neonlite Electronic & Lighting (HK) Limited	Electronic & Electrical Equipment	Hong Kong			1
Nestle Canada Inc	Food Producers & Processors	Canada		1	
Nestle UK Ltd	Food Producers & Processors	UK		1	
Network Rail	Transport	UK		1	
Newell Rubbermaid Inc	Household Goods & Textiles	USA		1	1
Nippon Sheet Glass Co Ltd	Chemicals	Japan	1	1	1
Nomacorc	Packaging	USA			1
Northwest Territories Power Corporation	Electricity	Canada	1		
Novus International Inc	Food Producers & Processors	USA			1
Nutiva	Food Producers & Processors	USA		1	
Oberthur Technologies SA	Electronic & Electrical Equipment	France		1	
ODLO Sports Group AG	Household Goods & Textiles	Switzerland		1	
OSRAM GmbH	Household Goods & Textiles	Germany		1	
Owens-Illinois Inc	Packaging	USA			1
Pacific Market International	Packaging	USA		1	
Palmberg Broeinrichtungen + Service GmbH	Household Goods & Textiles	Germany		1	
Prysmian SpA	Electronic & Electrical Equipment	Italy		1	
PTT Global Chemical Public Company Limited	Chemicals	Thailand		1	1
Quadra Chemicals Limited	Chemicals	Canada			1
Quorn Foods Ltd	Food Producers & Processors	UK		1	
Radici Partecipazioni SpA	Chemicals	Italy		1	
Renewable Energy Corporation ASA	Electronic & Electrical Equipment	Norway		1	
RONA Inc	Household Goods & Textiles	Canada		1	
Saft Groupe SA	Electronic & Electrical Equipment	France		1	1
Sanyo Denki Co Ltd	Electronic & Electrical Equipment	Japan		1	1
Scottish Leather Group Limited	Household Goods & Textiles	UK		1	1
Sdwolle GmbH & Co KG	Household Goods & Textiles	Germany		1	1
Sealed Air Corp	Packaging	USA		1	
Seur SA	Transport	Spain		1	
Seventh Generation Inc	Household Goods & Textiles	USA		1	
Shaw Industries Group Inc	Household Goods & Textiles	USA			1
Singapore Telecommunications Pte Ltd	Telecommunication Services	Singapore			1
Skretting Australia	Food Producers & Processors	Australia		1	1

Smit & zoon BV	Chemicals	The Netherlands			1
Société de transport de Montréal	Transport	Canada	1		
Solar Century Holdings Limited	Electricity	UK			1
SolarWorld AG	Electricity	Germany	1	1	
Solstad Offshore ASA	Transport	Norway			1
Sonoco Products Company	Packaging	USA			1
Sovena SA	Food Producers & Processors	Portugal		1	
Sprint Nextel Corporation	Telecommunication Services	USA	1		
Stanley Black & Decker Inc	Household Goods & Textiles	USA		1	
Sunshine Makers Inc	Household Goods & Textiles	USA		1	
Switcher SA	Household Goods & Textiles	Switzerland		1	1
Tata Chemicals Limited	Chemicals	India		1	1
TDK Corporation	Electronic & Electrical Equipment	Japan		1	
Technicolor	Household Goods & Textiles	France		1	1
Teknion Corporation	Household Goods & Textiles	Canada		1	
Tetra Pak Group	Packaging	Belgium		1	
Tetra Pak Sverige AB	Packaging	Sweden		1	
The Global Group	Household Goods & Textiles	Canada			1
The WhiteWave Foods Company	Food Producers & Processors	USA		1	
Thule Group AB	Household Goods & Textiles	Sweden		1	1
Toray Industries Inc	Chemicals	Japan			1
Toshiba Corporation Semiconductor & Storage Products Company	Electronic & Electrical Equipment	Japan			1
Toyo Ink MFG Co Ltd	Chemicals	Japan		1	1
Trina Solar	Electricity	People's Republic of China	1		
Universal Scientific Industrial Co Ltd	Electronic & Electrical Equipment	Taiwan		1	
Upsolar Global Co Ltd	Electricity	People's Republic of China		1	
USBancorp	Banks	USA	1		
Vinnolit GmbH & Co KG	Chemicals	Germany			1
Virgin Atlantic Airways Ltd	Transport	UK		1	
Vodafone Libertel NV	Telecommunication Services	The Netherlands	1		
VTech Holdings Limited	Electronic & Electrical Equipment	Hong Kong		1	
Whirlpool Corporation	Household Goods & Textiles	USA		1	
WL Gore & Associates GmbH	Household Goods & Textiles	USA		1	1
	Electronic & Electrical Equipment	Japan			
Total			**12**	**90**	**75**

Table A4. Categories constituting the review framework used to analyze reference to the LCA methodology in corporate sustainability reports in empirical study 1B (Stewart et al., in preparation). LCA = Life Cycle Assessment; LCIA = Life Cycle Impact Assessment.

Framework categories	**Definition**	**Subcategories**
Purpose	For what purpose is LCA used by the company?	Ecodesign, target-setting, informative, marketing, collaboration, normative for the industry, LCA research or development
Capability	Does the company have internal capability or does it conduct LCA externally?	LCA done for the company (in-house, externally), LCA done for others, reference to a tool
Product portfolio coverage	What products does the company apply LCA to?	nearly full coverage; selection; organization-level; ad-hoc
Methodological indications	Is there any indication regarding LCA methodological aspects?	
Display of application cases	Does the company refer to specific LCA application cases in the report?	Object of the LCA, functional unit, life cycle stage coverage, environmental impact categories, ISO standard, LCIA methodology, software, data quality, uncertainty, sensitivity, normalization, weighting display of results (table, figure)

7.2.2 Supplementary results

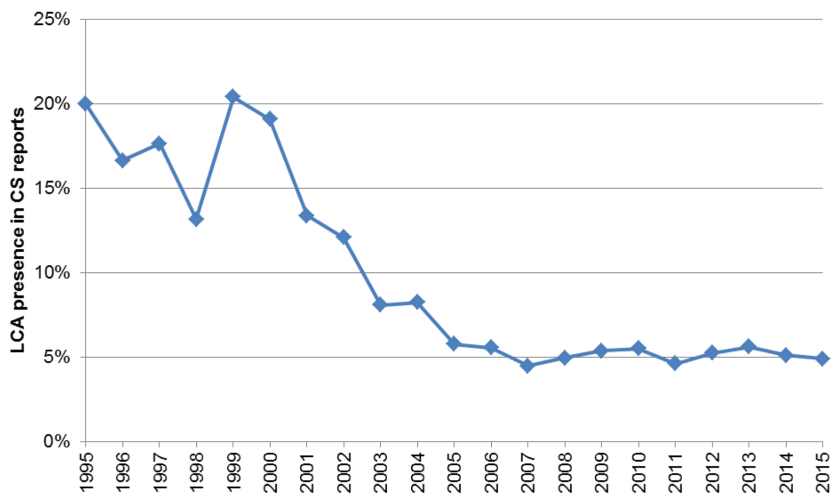


Figure A1. Evolution of Life Cycle Assessment (LCA) presence in corporate sustainability (CS) reports, including "Environmental Product Declaration" in the list of keywords.

Table A5. Life cycle Assessment (LCA) presence in corporate sustainability (CS) reports per sector for the periods 2006-2010 and 2011-2015, including and excluding “Environmental Product Declaration” in the list keywords.

Sector	**LCA presence (2006-2010) - "EPD" included**	**LCA presence (2006-2010) - "EPD" excluded**	**LCA presence (2011-2015) - "EPD" included**	**LCA presence (2011-2015) - "EPD" excluded**
Aerospace & Defense	5%	3%	7%	5%
Automobiles & Parts	15%	14%	6%	5%
Chemicals	6%	6%	11%	9%
Construction & Materials	8%	6%	11%	7%
Containers & Packaging	29%	29%	25%	24%
Diversified Industrials	6%	6%	6%	5%
Electricity	3%	2%	3%	2%
Electronic & Electrical Equipment	11%	9%	8%	6%
Finance	0.2%	0.1%	1%	1%
Food & Beverage	7%	7%	5%	5%
Forestry & Paper	10%	5%	13%	9%
Gas, Water & Multi-utilities	2%	2%	2%	1%
Health Care Equipment & Services	2%	2%	1%	1%
Industrial Machinery	11%	9%	9%	5%
Industrial Metals	7%	5%	12%	10%
Industrial Transportation	1%	1%	1%	1%
Insurance	0.3%	0.3%	0%	0%
Media	5%	5%	1%	1%
Mining	3%	3%	2%	1%
Oil & Gas	3%	3%	2%	2%
Personal & Household Goods	14%	13%	16%	14%
Pharmaceuticals & Biotechnology	3%	3%	3%	3%
Real Estate	2%	1%	3%	2%
Retail	2%	2%	2%	2%
Software & Computer Services	3%	3%	2%	2%
Support Services	4%	4%	4%	4%
Technology Hardware & Equipment	10%	9%	9%	6%
Telecommunications	2%	2%	2%	1%
Travel & Leisure	2%	2%	1%	1%

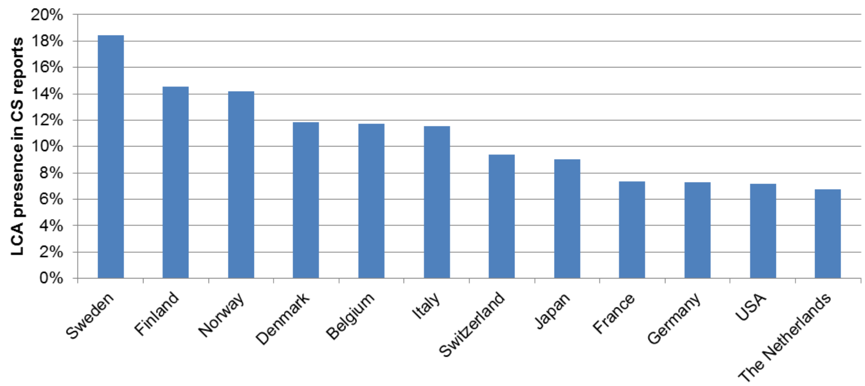


Figure A2. Top 12 countries with the highest Life Cycle Assessment (LCA) presence in corporate sustainability (CS) reports aggregated over the period 1995–2015, that is, the total number of corporate sustainability reports referring to LCA in a given country relative to the total number of corporate sustainability reports in that country over the whole period (including "Environmental Product Declaration" in the list keywords). A cutoff criterion of 500 CS reports per country and cumulated over the time period was applied to prevent possible biases caused by countries with high LCA presence in CS reporting on a limited number of total CS reports.

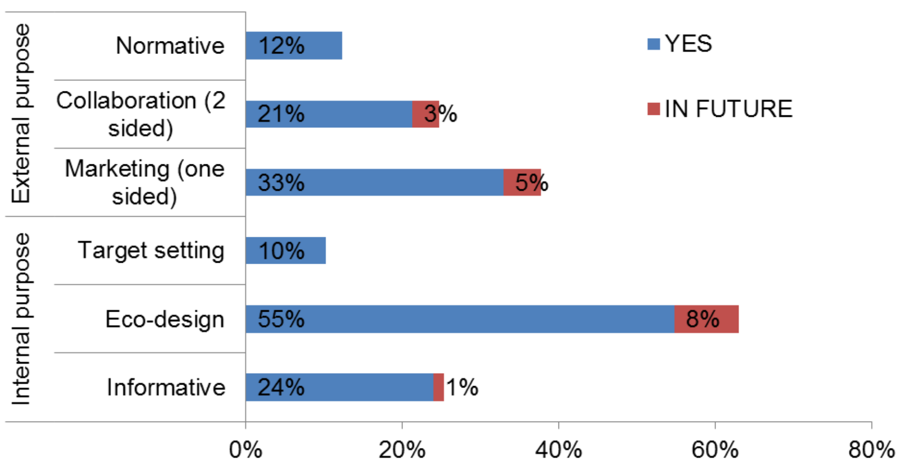


Figure A3: Frequency of Life Cycle Assessment purposes inferred from corporate sustainability reports (N=146) (Stewart et al., in preparation).

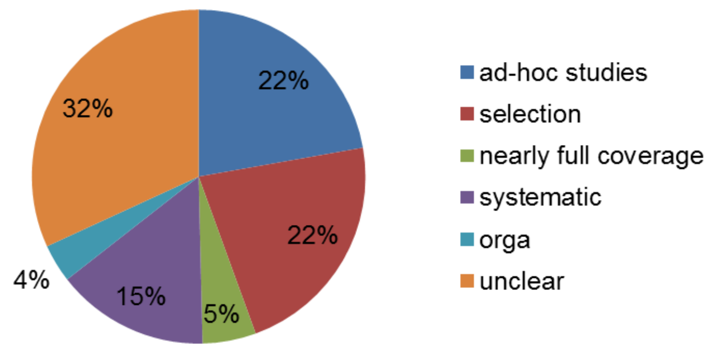


Figure A4: Distribution of product portfolio coverage inferred from corporate sustainability reports where Life Cycle Assessments were conducted specifically in the company context (N=135) (Stewart et al., in preparation). Orga = organizational.

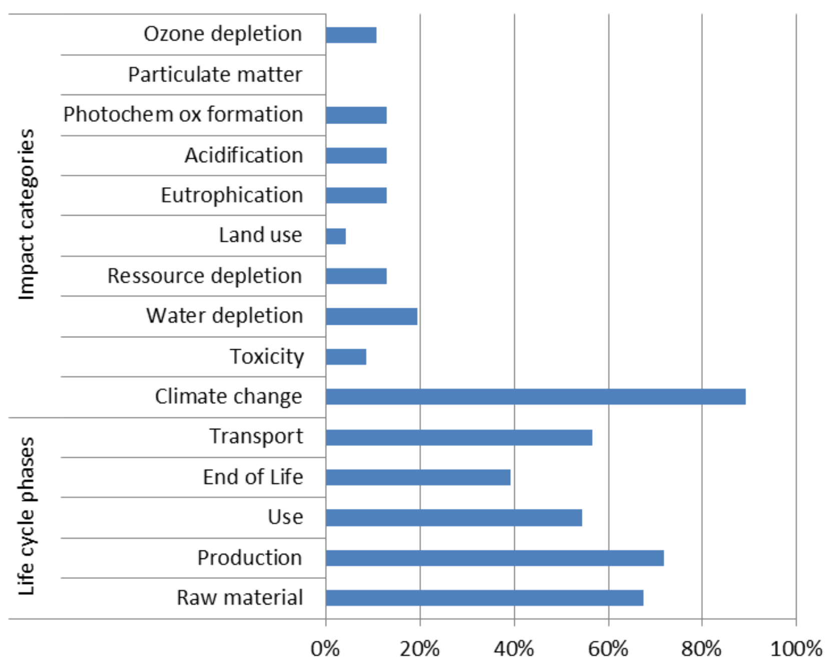


Figure A5: Life cycle phases and impact categories coverage in application cases presented in corporate sustainability reports (N=45) (Stewart et al., in preparation).

Table A6. Results for the longitudinal phase of empirical study 1B (Stewart et al., in preparation). CS = corporate sustainability; LCA = Life Cycle Assessment; EPD = Environmental Product Declaration; GHG = Greenhouse gases; LEED = Leadership in Energy and Environmental Design.

Aspect	**Amcor**	**Sanyo Denki**	**Rockwool**	**Knoll**
Country	Australia	Japan	Denmark	US
Sector	Packaging	Electronic and Electrical Equipment	Construction & Materials	Household Goods & Textiles
Number of CS reports	12	13	17	11
Start	Introduction of life cycle thinking in regulation on packaging in Australia.	An LCA working group is established, stated initial focus on energy but intention to expand LCA to other impact categories.		Initial opposition to LCA as long as it cannot be systematized and made cheap for practitioners but willingness to make LCA a mainstream activity.
Purposes	Ecodesign and collaboration with customers: from ad-hoc studies with large customers to integration in innovation processes as a competitive edge; later normative role in the packaging industry.	Early introduction of LCA in product development process, possibly marketing purpose (eco-label?) and strategic purpose (monitoring of environmentally superior products sales).	From informative purpose to marketing and collaboration with customers(around using EPDs), unclear whether ecodesign purpose.	From internal use on some products for ecodesign to more recently increased marketing purpose with goal of full coverage of product families with EPDs (push from LEED standard in the construction industry).
Product portfolio coverage	From ad-hoc studies on customers' demand to systematic coverage of products in an in-house tool.	From a restricted set of products to an increased coverage.	Increase in product coverage over time.	From use on some products to integration of an LCA tool into product development process.
Capabilities	From LCA capabilities concentrated in one department to the involvement of sales, marketing, technical groups and business group heads and a large group of users of the LCA tools available at the company.	Early working group on LCA and green procurement and training of employees on the LCA software	Externally-conducted LCAs.	From a partnership to develop an open LCA tool, to the integration of GaBi as an LCA tool and training of selected employees.
Evolution in the methodological aspects and display of application cases in CS reports	From LCA to carbon footprint/LCA services. Application cases communicated relatively regularly in CS reports; in the early years with multiple impact indicators (Human health, ecosystem quality and resources) and more recently only with climate change.	Application cases regularly communicated in CS reports, sole focus on climate change.	Application cases regularly communicated in CS reports; in the early years with four impact categories (GHG, acid rain, smog and eutrophication) and more recently only with climate change.	From cradle-to-gate to cradle-to-grave assessments From non-specific data to collection of specific data from suppliers and in the company's operations Few results displayed, sole focus on climate change.

7.3 Section 3.5.2 (empirical study 4)

7.3.1 Supplementary methods

Table A7. Sources of LCA applications to bio-based plastics found in publicly available communications of the corresponding companies.

Companies	Sources (all links accessed on 03-11-2018)
API	https://www.apiplastic.com/wp-content/uploads/2016/09/PIEGHEVOLE_BIO_PER-SITO-2016.pdf
Arkema	https://www.extremematerials-arkema.com/export/sites/technicalpolymers/.content/medias/downloads/article-reprints/rilsan-article-reprints/RilsanFamily_eco-profile_article.pdf
Bioamber	https://www.bio-amber.com/bioamber/fr/products (cannot be accessed anymore)
Braskem	https://www.braskem.com.br/life-cycle-assessment http://www.braskem.com.br/Portal/Principal/Arquivos/ModuloHTML/Documentos/1204/20131206-enviro-assessment-summary-report-final.pdf
Dupont	http://www2.dupont.com/Sorona_Consumer/en_US/assets/downloads/PS-1_Sorona_Environmental_Data.pdf
Earthsoul	http://www.earthsoulindia.com/lifecycle.html
Evonik	https://www.vestamid.com/sites/lists/re/documentshp/vestamid-terra-life-cycle-analysis-en.pdf
Futamura	http://www.futamuragroup.com/sustainability/life-cycle-assessment-(lca/ http://www.futamuragroup.com/sustainability/carbon-footprint/
Natureworks	https://www.natureworksllc.com/What-is-Ingeo/Why-it-Matters/Life-Cycle-Analysis/Cups_OVAM https://www.natureworksllc.com/What-is-Ingeo/Why-it-Matters/Life-Cycle-Analysis/Cups_PEA https://www.natureworksllc.com/What-is-Ingeo/Why-it-Matters/Life-Cycle-Analysis/Clamshells_rPET
Plantic	http://www.plantic.com.au/sustainability/eco-profiling/greenhouse-emissions.html
Reverdia	https://reverdia.com/wp-content/uploads/icb-9-Dec-Reverdia.pdf
Synbra	https://www.synbratechnology.com/biofoam/
Tate & Lyle	http://www.duponttateandlyle.com/sites/default/files/Susterra%20LCA.pdf http://www.duponttateandlyle.com/our_process
Toray	https://www.icca-chem.org/wp-content/uploads/2017/12/ICCA_Infosheets_Toray.pdf
Total Corbion	https://www.total-corbion.com/about-pla/sustainability/
Virent	http://www.virent.com/technology/sustainability/

7.3.2 Supplementary results

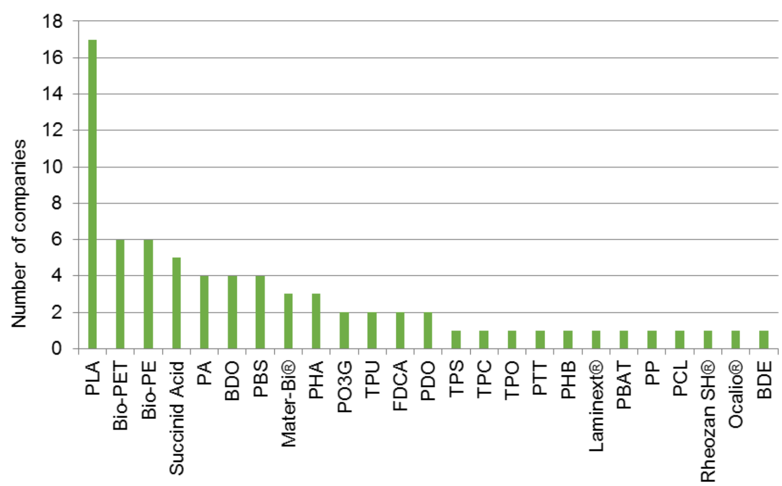


Figure A6. Types of bio-based plastics reported by the reviewed companies, based on Jonas (2018) (N=81).

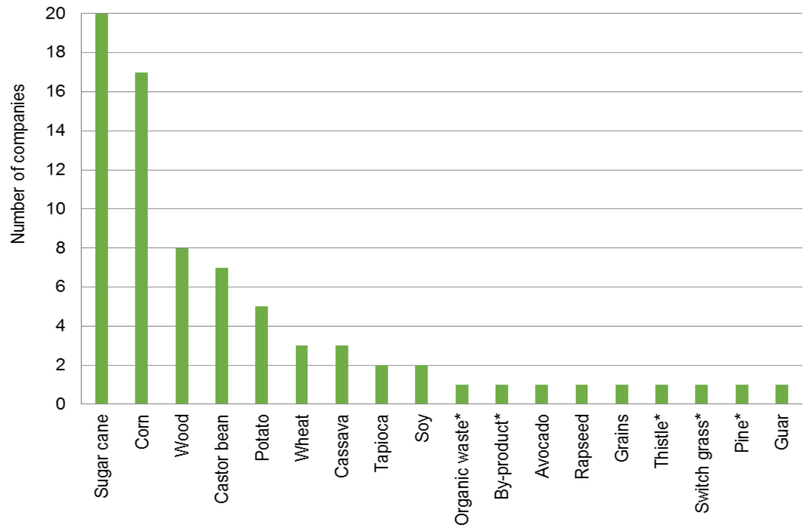


Figure A7. Types of feedstocks reported by the reviewed companies, based on Jonas (2018) (N=81).

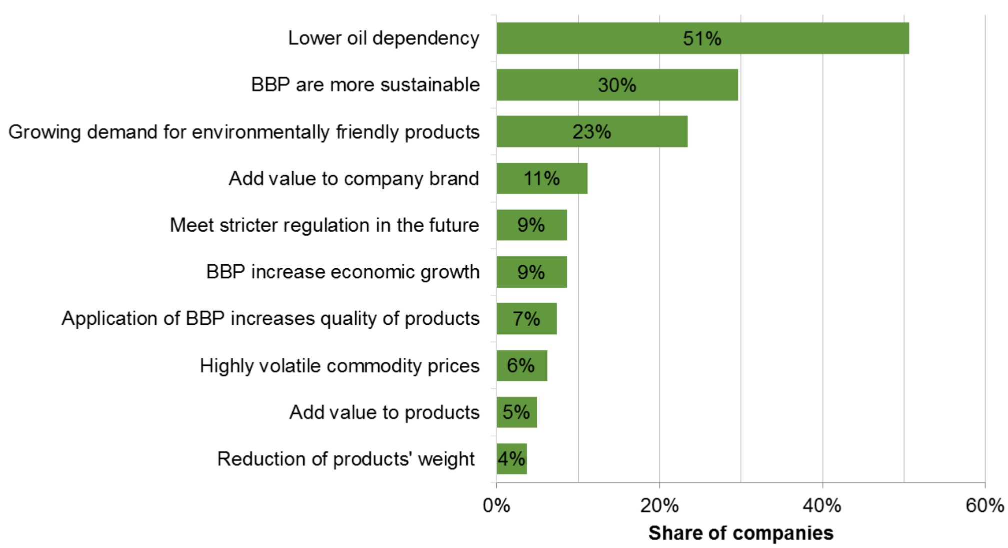


Figure A8. Drivers for adoption of bio-based plastics as identified in public communications of reviewed companies, based on Jonas (2018) (N=81). BBP = Bio-based plastics.

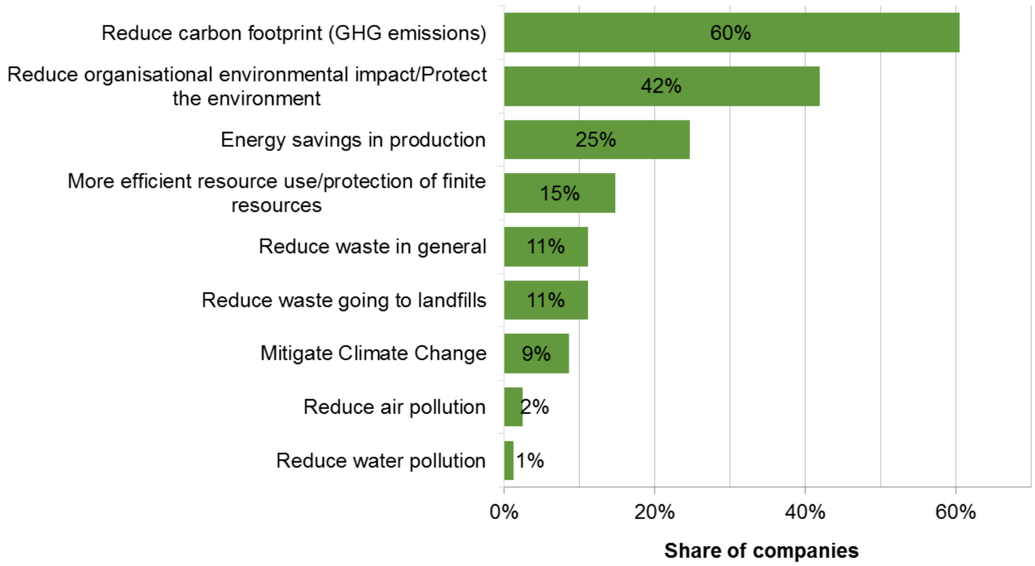


Figure A9. Environmental sustainability benefits claimed for bio-based plastics, as identified in public communications of reviewed companies, based on Jonas (2018) (N=81). GHG = Greenhouse gases.

7.4 Section 4.2 (background 4)

7.4.1 Supplementary methods

Table A8. List of sources included in the literature review of background 4, with authors, date, focus area (CM = change management; APRS = analysis of process, role or situation; LP = lens preferences), data collection method, framework user (researcher or practitioner), and indication of direct (i.e. influencing the data generation) or indirect use (i.e. to analyze the data) of the framework, sector of application and source type (J= journal, C = conference).

Authors	Date	Focus area	Data collection	Framework user	Direct or indirect use of framework	Sector	Source type
Hulpiau, V, Waeytens, K	2003	CM	document analysis	Researcher	indirect	Education	C
Carr, I., Williams, C.	2009	CM	survey	Researcher	direct	Education	J
Kaae, S., Søndergaard, B., Haugbølle, L.S., Traulsen, J.M.	2011	CM	field observation, interviews	Researcher	indirect	Pharmacy	J
Swan-Sein, A., Mellman, L., Balmer, D.F., Richards, B.F.	2012	CM	document	Researcher	indirect	Education	J
Drake, R., Crawford, J., Rohrbacher, C.	2014	CM	researchers' own experience	The researchers' experience as a practitioner	direct	Education	J
Haviland, D	2014	CM	document	Researcher	indirect	Education	J
Molaro, A.	2014	CM	unclear	researcher	unclear	Libraries	J

Sowell, S.	2014	CM	researchers' own experience	The researchers' experience as a practitioner	direct	Libraries	J
Bailey, M.B., Marchetti, C., Mason, S.P., Valentine, M.S., Dell, E.	2015	CM	action research	The researchers' experience as a practitioner	direct	Education	C
Bernardes, A., G. Cummings, G., Gabriel, C.S., (...), Gomes Maziero, V., Coleman-Miller, G.	2015	CM	action research, observation, interviews, document analysis	Researcher	indirect	Health	J
Mason, S., Marchetti, C., Crawford, K., (...), Clayton, L., Valentine, M.	2015	CM	action research	The researchers' experience as a practitioner	direct	Education	C
Bajis, D., Chaar, B., Basheti, I.A., Moles, R.	2017	CM	interviews and open-ended questions in a survey	Researcher	indirect	Education	J
Thammasitboon, S., Lee Ligon, B., Singhal, G., Schutze, G.E., Turner, T.L.	2017	CM	researchers' own experience	The researchers' experience as a practitioner	direct	Education	J
Guiles, H.J.	1995	APRS	survey	researcher	direct	Laboratory	J
Schneiderman, J.U.	2004	APRS	interview and observation	Researcher	unclear	Education	J
Schneiderman, J.U.	2005	APRS	interviews	Researcher	direct	Health	J
Albino, J.*	2013	APRS	n.a.	Researcher	indirect	Education	J
Janz, K., Honken, R.	2013	APRS	workshop/action research	Practitioner	direct	Education	C
Fleming-May, R.A., Douglass, K.	2014	APRS	researchers' own experience	Researcher	direct	Libraries	J
Keller, D.	2015	APRS	researchers' own experience	researcher as a practitioner	direct	Education	J
Sjøbakk, B., Knutstad, G.	2017	APRS	workshop	Practitioner	direct	Manufacturin g	C
Bolman, L.G., Deal, T.E.	1991	LP	survey and critical incidents	Researcher	direct in survey, indirect in critical incidents	Education and industry	J
Scott, D.K.	1999	LP	survey	Researcher	Direct	sport organization	J
Thompson, M.D.	2000	LP	survey	Researcher	Direct	Education	J
Shee, S.C., Ji, C.-H.C., Boyatt, E.	2002	LP	survey	Researcher	Direct	Education	J
Farrell, M.	2003	LP	interviews	Researcher	indirect	Health	J
Israel, M.S., Kasper, B.B.	2005	LP	case study	Practitioner	direct	Education	J
Davis, B.L.	2007	LP	researchers' own experience	researcher as a practitioner	direct	Education	J
Dennis, B.P.	2007	LP	researchers'	researcher as	direct	Education	J

			own experience	a practitioner			
Sasnett, B, Ross, T	2007	LP	survey	Researcher	Direct	Education	J
Slater, C.L., Garcia, J.M., Gorosave, G.L.	2008	LP	case study	Researcher	indirect	Education	J
Yi, Z	2009	LP	survey	Researcher	Direct	Libraries	J
Lieff, S.J., Albert, M.	2010	LP	interviews	Researcher	indirect	Education	J
Othman, N., Mujir, S.J.M., Ibrahim, M.S.	2010	LP	survey	Researcher	Direct	Education	J
Alsmadi, R., Mahasneh, R.	2011	LP	survey	Researcher	Direct	Education	J
Yi, Z	2011a	LP	survey	Researcher	Direct	Libraries	J
Yi, Z	2011b	LP	survey	Researcher	Direct	Libraries	J
St. Onge, E.L., Suda, K., Devaud, L., (...), Sacks, G., Bricker, J.D.	2012	LP	survey	Researcher	Direct	Education	J
McArdle, M.K.	2013	LP	survey and critical incidents	Researcher	direct in survey, indirect in critical incidents	Education	J
Phillips, R.S., Baron, M.A.	2013	LP	survey	Researcher	direct	Education	J
Yi, Z	2013a	LP	survey	Researcher	direct	Libraries	J
Yi, Z	2013b	LP	survey	Researcher	direct	Libraries	J
Frydén, H., Ponzer, S., Heikkilä, K., Kihlström, L., Nordquist, J.	2015	LP	interviews	Researcher	indirect	Education	J
Tan, M., Hee, T.F., Piaw, C.Y.	2015	LP	interviews, observations, document	Researcher	direct	Education	J
McGowan, E., Walsh, C., Stokes, E.	2017	LP	survey	Researcher	Direct	Health	J

*no version of the full article could be retrieved.

7.4.2 Supplementary results

Table A9. Review of academic studies investigating lens use among leaders/managers for a number of leaders/managers equal or superior to ten). LOI = Leadership Orientation Instrument, n.a. = non-applicable. Only two studies by Yi are included (Yi, 2009; 2011a) – the others (Yi, 2011b; 2013a; 2013b) were omitted because they all build on the same data set.

Study	Sample of leaders (N=number)	Measure of lens orientation/use	Measure of effectiveness variable (if applicable)	Findings: Lens orientation/use	Findings: Correlation with effectiveness variable
Bolman and Deal, 1991	Four samples: Senior managers from a multinational (N1=90) corporation; higher	LOI rated by colleagues (N= non-indicated)	Effectiveness as a manager and as a leader rated by colleagues	Sample 1: high score for structural lens Sample 2: high score for human and	Positive influence of structural lens on perceived

	education administrators (N2=145); school administrators in the US (N=140); school administrators in Singapore (N=229)			structural lenses Sample 3: high score for human and structural lenses Sample 4: high score for structural lens but all lenses have rather high score.	effectiveness as managers Positive influence of political and symbolic lenses on perceived effectiveness as leader.
Bolman and Deal, 1991	Three samples: Higher education administrators from colleges and universities (N1=145); principals and superintendents from school districts in the US (N2=53); school principals in Singapore (N3=220)	Critical incidents (narratives of their experiences) written by managers, content analysis Unclear how it is determined whether a manager use a given lens.	n.a.	Sample 1: The most used lenses are the structural and political lenses; most frequently, managers use two lenses. Sample 2: The most used lens is the human lens; most frequently, managers use two lenses. Sample 3: The most used lenses are the human and structural lenses; most frequently, managers use two lenses.	n.a
Scott, 1999	Leaders in intercollegiate athletic departments in the US (N=13)	LOI rated by self and coaches (N=100)	Effectiveness as manager and leader rated by coaches	Self-rated: highest score for human lens Rated by coach: highest score for structural lens, then political, human and symbolic.	Positive influence of structural and political lenses on perceived effectiveness as manager Positive influence of human and symbolic lenses on effectiveness as leader.
Thompson, 2000	Leaders in elementary, secondary schools, colleges and universities in the US (N=57)	LOI rated by subordinates (N=535) A lens is considered as "used" if the lens composite score is superior or equal to 80% of the maximum score.	Leadership skills (Quinn's competing value model), rated by subordinates	n.a.	Positive influence of number of lenses used on all leadership dimensions
Shee et al. (2002)	School leaders in the US (N=206)	LOI self-rated Unclear, but it seems that a manager is considered to use a given lens if the composite score is between 4 and 5.	n.a.	Highest score for human and structural lens; most frequently, managers use either 1 or 2 lenses.	n.a
Farrell	Network and hospital	Interviews of leaders	n.a.	Dominance of	n.a.

(2003)	administrators in Australia (N=15)	and content analysis		structural lens and human lens in managers approaches	
Sasnett and Ross (2007)	Health information program directors in the US (N=64)	LOI self-rated A lens is considered as used if its composite score is superior or equal to 80% (case 1) and 50% (case 2) of the maximum score *Note that in Table 7, percentages of used lenses are reported for case 1 definition.*	Self-rated effectiveness as manager and leader	Most used lenses are the human and structural lenses; most frequently, managers use one or two lenses (defined as in case 1)	Positive influence of structural, political and symbolic lens on self-rated effectiveness as manager. Positive influence of all lenses on self-rated effectiveness as leader. Some correlation between number of lenses used (case 2) and self-rated effectiveness as manager.
Yi (2009)	Academic library Directors in the US (N=455)	Survey on how directors address change management A lens is considered as used if the answer corresponding to that lens is selected by the respondent. There is an option for "other lens" which count as one lens when reporting the number of used lenses	n.a.	Most used lenses are the human and the symbolic lenses; most frequently, directors used a multi-lens approach (3 or 4 lenses) or 2 lenses.	n.a.
Lieff and Albert (2010)	Medical education leaders in Canada (N=16)	Interviews of leaders about their experiences, content analysis, focus on "identifying excerpts that described participants' various understandings of their organizational work", occurrence of themes to weigh the relative importance of the theme in the group of interviewees	n.a.	14 leaders used all lenses. The human lens was important by all participants, the symbolic and the political for 14 participants. The structural lens was expressed by most interviewees but with a lesser emphasis.	n.a.
Othman et al. (2010)	Academic department heads in	LOI rated by self and lecturers (N=841)	Self-perceived commitment of	Self-rated: Highest score for human	Positive influence of

	Malaysia (N=76)		lecturers towards the university.	lens, but all scores are >4 Rated by lecturers: highest score for human lens as well but all scores are between 3 and 4.	cultural lens on self-perceived commitment of lecturers towards the university. Negative influence of political lens on self-perceived commitment of lecturers towards the university.
Alsmadi and Mahasneh (2011)	School counselors in Jordan (N=non-indicated)	LOI rated by principals and teachers (N=657)	n.a.	Highest score for political and human lens (but all scores are very close) Scores given by principals were higher than those given by teachers.	n.a.
Yi (2011)	Academic library directors in the US (N=455)	Survey presenting different ways to view meetings A lens is considered as used if the answer corresponding to that lens is selected by the respondent. There is an option for “other lens” which count as one lens when reporting the number of used lenses	n.a.	Most frequently, directors used multiple lenses (three or four) Most used lenses are human, structural and symbolic.	n.a.
St Onge et al. (2012)	Deans of schools/colleges of pharmacy in the US (N=25)	Survey presenting a promotion case and three different scenarios which could affect the Dean’s decision. Different ways of dealing with the situations represent the different lenses. A lens is considered used if the respondent agreed to the action that corresponds to that lens.	n.a.	Dominance of structural, human and symbolic lenses, with little use of the political lens. Each Dean often presented a preference for the same lens regardless of the dilemmas.	n.a.
Phillips and Baron (2013)	Collegiate aviation program leaders in the US (N=133)	LOI rated by faculty and staff (N=226) A lens is considered	Leadership effectiveness rated by faculty and staff	Most managers have a primary leadership lens, in most cases the human or the	No influence of primary lens on perceived leadership

		as used if its composite score is superior or equal to 80% of the maximum score. A leader has a primary leadership lens if the composite score for that frame is superior or equal to 80% of the maximum score and is higher than for the all other lenses.		structural lenses. Most frequently, leaders use no lens or multiple lenses.	effectiveness Positive influence of the number of lenses used on perceived leadership effectiveness
Frydén et al. (2015)	Postgraduate program directors in Sweden (N=17)	Interviews of directors about their functions and content analysis.	n.a.	Directors most often emphasized functions anchored in the structural and human lenses.	n.a.
McGowan et al. (2017)	Physiotherapy managers in Ireland (N=43)	LOI self-rated A lens is considered as used if the frame composite score is superior or equal to 80% of the maximum score Unclear how preferred lenses are determined (likely: lens with highest score)	Self-rated effectiveness as manager and leader, or manager's self-confidence in their managerial and leadership skills	The human lens is the most used and the political lens is the least used. Most frequently, managers use one or two lenses. Most often preferred lens is the human lens, followed by the structural.	Positive influence of the number of lenses used by managers on the self-rating of effectiveness as manager and leader

7.5 Section 4.3 (conceptual study 1)

7.5.1 Supplementary methods

Table A10. Four building blocks and associated keywords used in conceptual study 1. Not all spelling variations used in the search string are included in the table.

Ecodesign	Integration	Company context	Qualitative empirical studies
Green/environmental/sustainable product development	Integrate	Company	Case study
Green/environmental/sustainable product innovation	Approach	Firm	Interview
Green/environmental/sustainable product design	Operationalize	Organization	Dialogue
Green/environmental/sustainable business model	Incorporate	Corporation	Meeting
Green/environmental/sustainable criteria in/into product	Apply	Enterprise	Call
Green/environmental/sustainability issues incorporated in/into product	Uptake		Consultation
Green/environmental/sustainability issues integrated in/into product	Implement		Conversation
Green/environmental/sustainability aspects in/into product	Adopt		Observation
Environmental/sustainability aspects in/into product			Action research
Green/sustainable design			Empirical
			Field work
			Field study
			Workshop

Environmentally conscious design
Environment friendly product design
Environment friendly product development
Design for the environment
Sustainability in product development
Sustainability in product innovation
Sustainability issues incorporated in product
Sustainability in product
Design for sustainability
Lifecycle design
Ecodesign
Ecofriendly design
Eco-innovation in product

Table A11. List of sources included in conceptual study 1, with authors, year, journal focus area (S = sustainability-related, O = other), concept, empirical data, number of case companies, geography, company size, activity sector(s) and case company "maturity". N.a = non available; SME = Small and Medium Enterprise; FMCG = Fast-Moving Consumer Goods.

Authors	Year	Journal focus	Concept	Empirical data	Number of case companies	Geography	Company size	Activity sector(s)	Case company "maturity"
Simon M., Poole S., Sweatman A., Evans S., Bhamra T., Mcaloone T.,	2000	S	ecodesign	interviews and action research	2	UK, USA, continental EU	n.a.	manufacturing companies	"good practice of ecodesign"
Handfield et al.	2001	O	design for environme nt	interviews	10	USA	mixed	automotive, furniture, computer, pharmaceutical, consumer products	best in class
Magnusso n and Johansson , 2001	2001	O	ecodesign	case study	1	Sweden	large	power and automation technologies	pro-active environmental management strategy and in-house product development
Ritzen and Beskow	2001	S	environme ntally conscious design	interviews	4	Sweden	large	manufacturing	best practice and starter
Sherwin and Bhamra	2001	O	ecodesign	case study/inter vention	1	UK	large	global manufacturer of electronic and electrical appliances	leading profile in ecodesign and environmental excellence.

Boks	2006	S	ecodesign	survey and interviews	na	Japan and South Korea	large	electronics	n.a
Donelly et al.	2006	S	ecodesign	practitioner experience	1	France	large	telecommunications	Proactive company
Johansson and Magnusson	2006	S	environmental considerations in product development projects	case study	1	Sweden	probably large	telecommunication	n.a
Tingström et al.	2006	S	Sustainability management in product development projects	case study	1	Sweden	large	power and automation technologies	n.a
Johansson et al.	2007	O	ecodesign	interviews	2	n.a.	unclear	electronics	n.a
Kivimaa	2008	S	environmental integration in company product development	interviews	4	Sweden and Finland	Large	packaging	sector chosen for certain maturity of environmental practices, nothing about the companies
Sandström G.O., Tingström J.,	2008	O	ecodesign, eco-innovation	case study	1	Sweden	large	power and automation technologies	n.a
Stubbs W., Cocklin C.,	2008	S	sustainability business model	case studies	2	Australia (and US)	large	bank and furniture	leaders
White P.,	2009	S	sustainable innovations that improve the environmental profile of products	practitioner experience	1	UK	large	FMCG	Proactive company

Dangelico and Pujari	2010	S	green product innovation	interviews	12	Italy and Canada	SMEs	varied (detergents, photovoltaic applications, glass tiles, wooden pallets, recycled rubber products, solar walls, etc.)	Proactive company (environmental awards or environmentally-specific patents)
Hallstedt et al.	2010	S	strategic sustainable development	interviews	6	Sweden and Norway	2 large and 2 SMEs	2 consulting companies, packaging, plastic manufacturer, lamp manufacturer, technology development for manufacturing companies	SMEs at the compliance stage and large companies at a more advanced stage
Petala et al.	2010	O	incorporation of sustainability in the new product development	workshop with industry and academia, study of briefs, interviews with project leaders	1	n.a.	unclear	FMCG	leader
Zhu Q., Liu Q.,	2010	O	ecodesign	case study	1	China	large	telecommunications	subsidiary of a leading company
Arnold and Hockert	2011	S	Sustainability innovation	case study/interviews/longitudinal	1	The Netherlands	large	electronics	Proactive company
Pigosso et al.	2011	T	ecodesign	Action research and interviews	3	Denmark and Brazil	large	manufacturing (other transport equipment, chemicals and chemical products, machinery and equipment)	Maturity assessment was one of the object of the case studies)
Verhulst and Boks	2012a	S	sustainable design criteria in business	interviews	8	Belgium and the Netherlands	large and medium	chemical industry, furniture, electronics, consumer goods, construction, lighting equipment and traffic signalisation	starters and experienced firms
Bey et al.	2013	O	sustainability strategies	survey and interviews	80	Denmark and US	large, medium, small	product developing and manufacturing companies	n.a.

Chipps R., Wilson J.,	2013	S	environmental design	case study/interviews	1	UK	large	point-of-purchase industry "'all communications, including marketing, advertising, and promotions that are designed to influence the shopper's purchasing decisions in-store'."	n.a.
Deutz et al.	2013	S	ecodesign	survey and interviews	9	UK	3 SMEs, 6 MNCs	electronic equipment, furniture, mining, aerospace, construction, electronics appliance, metallic pieces, heat exchangers, power generation and mechanical drives	n.a.
Hallstedt et al.	2013	S	strategic sustainable development	interviews	6	na	large	manufacturing	companies which "already do well"
Alblas et al.	2014	O	sustainability in new product development	interviews and workshop	6	The Netherlands	large	slurry equipment solutions, domestic appliances, flow technology, document systems, electrical components and systems, thermo-technology applications	purposely different maturity levels
Brones et al.	2014	S	ecodesign	interviews	1	Brazil	large	consumer goods	company recognized as proactive in the field (environmental policies and practices, strong commitment in sustainability, international rankings and prizes.)
Neto A.S., Jabbour C.J.C., Jabbour A.B.L.D.S.,	2014	O	eco-innovation	case studies	3	Brazil	n.a.	n.a.	n.a.
Poulikidou et al.	2014	S	design for environment	interviews	4	Sweden	unclear but probably large	manufacturer of produce road and rail vehicles and vehicle components	n.a.

Verhulst and Boks	2014	S	sustainable design	interviews/ case studies	8	Belgium and the Netherlands	large and medium	furniture, electronics, chemical and construction industry	relatively experienced with implementation of sustainability in product development
Björkdahl J., Linder M.,	2015	O	environmental innovation	case study (5 years)	1	Sweden	large	automotive (ball-bearing business)	n.a.
Dekoninck et al.	2016	S	ecodesign	interviews	9	Denmark, France, Brasil, Germany, UK	8 large and 1 small	Transport, chemicals, vehicles, textiles, electronics, electronical equipment	certain maturity
Domingo et al.	2015	O	ecodesign	action research	2	probably UK	SMEs	automotive, electro-domestic kitchen appliances	n.a.
Høgevold N.M., Svensson G., Padin C.,	2015	O	sustainable business model	case study	1	Norway	large	hotel chain in Scandinavia	Company known for certain maturity of sustainability implementation
Alänge S., Clancy G., Marmgren M.,	2016	S	sustainability in product development	interviews and action research	2	Sweden	large	furniture, paper	leaders
Bonou et al.	2016	S	ecodesign	action research	1	Denmark	Large	renewable energy technologies	n.a
Skelton et al.	2016	O	ecodesign	action research/interviews	2	Denmark	large	renewable energy, electronics	n.a.
Brones et al.	2017	S	ecodesign	action research	1	Brazil	large	cosmetics	company recognized as proactive in the field
Küçüksayraç Elif,	2017	O	design for sustainability	case studies	2	Turkey	large and small	promotional products, particularly pens made out of biodegradable plastics and bathroom products	best practice

Prendeville et al.	2017	S	ecodesign	action research (9 years)	1 (4 products)	UK	unclear	office furniture	evolution at one company over the years, and increasing maturity

7.5.2 Supplementary results

Table A12. Mapping, per source, of measures in favor of ecodesign integration in the four-lens view of organizations resulting from conceptual study 1. KPI = Key Performance Indicator.

LENS/PERSPECTIVE		Simon et al., 2000	Handfield et al., 2001	Magnusson and Johansson, 2001	Ritzen and Beskow, 2001	Sherwin and Bhamra, 2001	Tingström et al., 2006	Johannsson and Magnusson, 2006	Boks, 2006	Donelly et al., 2006	Johansson et al., 2007	Stubbs and Cocklin, 2008	Sandström and Tingström, 2008	Kivimaa, 2008	White, 2009	Dangelico and Pujari, 2010	Hallstedt et al., 2010	Petala et al., 2010	Zhu and Liu, 2010	Arnold and Hockerts, 2011	Pigosso, 2011 (thesis)	Verhulst and Boks, 2012a	Bey et al., 2013	Chipps and Wilson, 2013	Deutz et al., 2013	Hallstedt et al., 2013	Alblas et al., 2014	Brones et al., 2014	Neto et al., 2014	Poulikidou et al., 2014	Verhulst and Boks, 2014	Björkdal and Linder, 2015	Domingo et al., 2015	Høgevold et al., 2015	Bonou et al., 2016	Dekoninck et al., 2016	Skelton et al., 2016	Alänge et al., 2017	Brones et al., 2017	Küçüksayraç, 2017	Prendeville et al, 2017
STRUCTURAL / ARCHITECT'S	**38**	4	5	3	4	2	7	1	5	9	1	2	5	8	6	4	7	3	8	8	13	1	4	1	1	5	5	4	0	4	2	3	4	2	9	0	2	5	5	2	4
Design ecodesign guidelines and develop/internalize decision-support tools	19	X	X		X	X	X		X	X						X	X			X	X	X				X		X		X					X				X	X	X
Integrate ecodesign procedures in processes related to product development	16				X		X		X	X			X	X				X	X		X		X				X			X			X		X			X	X		
Set ecodesign target at different levels (e.g. corporate, products, innovation projects)	16	X	X	X			X			X			X		X	X	X	X	X	X	X						X								X		X				
Include ecodesign in design criteria	13						X		X				X	X					X	X	X					X		X		X			X		X						X
Assign responsibilities for ecodesign (e.g. added in job descriptions of product designers) at different organizational levels	12						X			X					X			X	X		X					X					X			X	X		X	X			
Integrate ecodesign into the business mission/strategy	11	X							X			X			X		X		X		X														X			X	X		X
Integrate ecodesign criteria in performance measurement systems (e.g. KPIs, internal labeling)	10	X	X									X			X		X			X	X		X									X			X						
Design ecodesign strategies	10			X										X		X	X			X	X						X					X	X		X						
Create dedicated organizational units and jobs for ecodesign visible in the organigram	9		X		X		X			X					X								X							X	X			X							
Establish system for ecodesign information collection	8				X		X						X	X					X		X						X											X			
Implement environmental management system/standards	6									X									X	X				X														X		X	
Integrate ecodesign aspects in the fuzzy front end/early stages of development	6					X				X															X	X		X							X						
Translate corporate strategy into action plan for specific business units/functions	6								X						X		X				X											X							X		
Compose project teams with all relevant functions to address ecodesign (e.g. environmental specialists)	5							X		X	X			X																			X								
Design ecodesign policies	5									X				X		X				X	X																				
Establish ecodesign expertise/knowledge sharing process and platform (e.g. for lessons learned, successes, avenues for future investigation)	4		X																	X	X					X															
Integrate ecodesign in portfolio management	4																				X							X											X		X
Set project processes allowing for development of radical innovation	3			X									X	X																											
Define scope of ecodesign, make it measurable, tangible	3																X						X				X														
Acquire in-house expertise on ecodesign	2													X					X																						
HUMAN / CATALYST'S	**26**	1	2	0	1	1	3	0	2	1	0	0	3	2	2	0	2	1	2	0	1	5	0	0	0	1	0	0	1	1	9	0	1	3	5	1	2	2	5	0	0
Provide tailored training for employees (e.g. in their context, adapted to their daily tasks)	20	X	X		X		X			X				X	X		X	X	X		X					X			X	X	X		X	X	X			X	X		
Use co-creation/participative approach (e.g. to include criteria in project tool)	8												X				X		X			X									X				X		X		X		
Provide empowering tools (e.g. adapted to the nature of jobs and skills)	4		X			X	X															X																			
Support teams with environmental experts/expertise	3						X							X																					X						
Address differences between individual sensitivities/needs/emotions	2								X																										X						
Give room for experimentation, autonomy	2																														X							X			
Involve and support people who have personal aspirations for ecodesign	3								X				X																		X										
Provide appreciation and support	2												X									X																			
Raise awareness or motivation with employee newsletters, podcasts, site events, trips	2														X																			X							
Translate ecodesign concepts in easy to understand terms	2																														X			X							
Use success stories to raise motivation	2																														X				X						
Understand what motivate employees or leads them to resistance (e.g. through workshops)	2																																			X			X		
Collaboration with Human Resources department	1																																						X		
Explain/inform employees about ecodesign (e.g. "why", "how", "when", "who")	1																					X																			
Give responsibility and support for initiative taken	1																														X										
Make it easy to find information about ecodesign	1																														X										
One-to-one encounters	1																																				X				
Reassure employees	1																					X																			
Stimulate and support individual employees to share ideas	1																														X										
Use nudging techniques, i.e. leading without inducing guilt or being prescriptive	1																																						X		
POLITICAL / ADVOCATE'S	**25**	0	1	0	2	0	0	0	1	2	0	0	1	0	1	0	3	1	2	2	3	2	1	1	0	1	0	0	0	1	5	2	3	1	2	2	1	0	5	1	0
Have top management explicitly express ecodesign as a priority/commit for ecodesign (e.g. involvement in decision-making, public statements, responsibility for ecodesign goals)	16				X				X	X			X				X	X	X	X	X					X					X	X		X	X	X			X		
Allocate resources/budget	7		X		X					X							X				X																		X	X	
Foster the development of ambassador(s) for ecodesign in the organization	5														X								X	X							X					X					
Use success stories to create buy-in	3																X					X													X						
Build awareness among key decision-makers	2																		X														X								
Communicate risk and benefits to the organization	2																				X									X											
Demonstrate value of ecodesign for different functions and the company	2																														X						X				
Find employees who will be able to influence others	2																			X																			X		
Understand ressource availability and target low-hanging fruit	2																																X						X		
Allow ecodesign champions to network in the organization	1																														X										
Align and adapt ecodesign communication to different departments (e.g. different language/terminology)	1																					X																			
Enable access to resources for ecodesign initiatives	1																														X										
Identify and leverage existing competencies in the company	1																															X									
Manage the gap between expectations and capabilities	1																																X								
Seek for interactions compatible with each group's priorities and agendas	1																																						X		
CULTURAL / PROPHET'S	**7**	0	2	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	4	2	0	0
Celebrate ecodesign successes and heroes (e.g. awards)	2		X							X																															
Adapt tools to the company's way of working	2																														X								X		
Efforts of environmental teams to be accepted as core members of the product development community	2									X																											X				
Use or creation of rituals (e.g. create regular events around products)	2																																				X	X			
Storytelling about the founder's choice	1																																					X			
Value testing and failures	1																																					X			
Develop common heuristic rules	1																																					X			
Change perceived mission of the company, make sustainability part of the DNA	1														X																										
Identify and break the poor history of ecodesign at the company	1		X																																						
Negotiate/translate meanings with product development teams	1																																				X				
Provide inspiration on ecodesign to the organization	1																																						X		

7.6 Section 4.4 (empirical study 5)

7.6.1 Supplementary results

Table A13. Updated four-lens list of measures based on data collected in interviews (update of Table 9 with data from Table 12); L = from literature, I = from interviews, KPI = Key Performance Indicator.

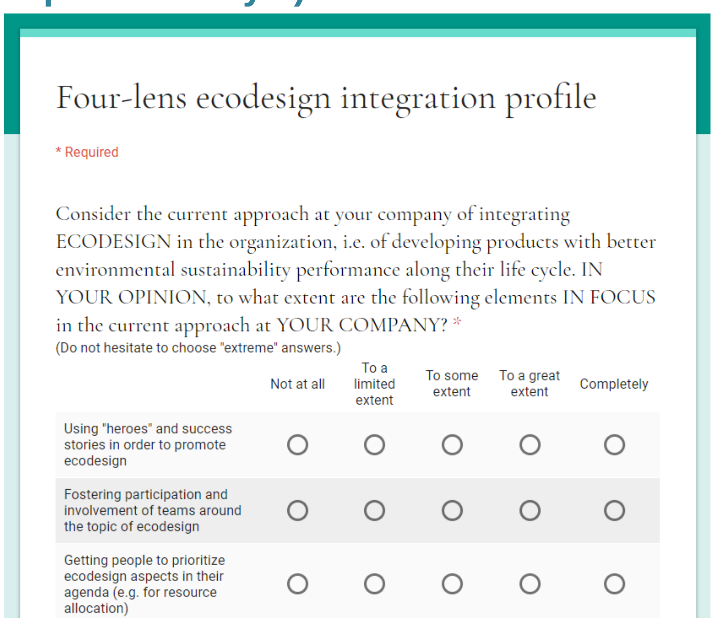
LENS/PERSPECTIVE	
STRUCTURAL / ARCHITECT'S	**Sources**
Design ecodesign guidelines and develop/internalize decision-support tools	L,I
Integrate ecodesign procedures in processes related to product development	L,I
Set ecodesign targets at different levels (e.g. corporate, products, innovation projects)	L,I
Include ecodesign in design criteria	L
Assign responsibilities for ecodesign (e.g. added in job descriptions of product designers) at different organizational levels	L
Integrate ecodesign into the business mission/strategy	L
Integrate ecodesign criteria in performance measurement systems (e.g. KPIs, internal labeling)	L,I
Design ecodesign strategies	L,I
Create dedicated organizational units and jobs for ecodesign visible in the organigram	L,I
Establish system for ecodesign information collection	L
Implement environmental management system/standards	L
Integrate ecodesign aspects in the fuzzy front end/early stages of development	L
Translate corporate strategy into action plan for specific business units/functions, Translate corporate targets into targets for individual innovation projects	L,I
Compose project teams with all relevant functions to address ecodesign (e.g. environmental specialists)	L
Design ecodesign policies	L
Establish ecodesign expertise/knowledge sharing process and platform (e.g. for lessons learned, successes, avenues for future investigation)	L
Integrate ecodesign in portfolio management	L
Set project processes allowing for development of radical innovation	L,I
Define scope of ecodesign, make it measurable, tangible	L,I

Acquire in-house expertise on ecodesign	L
HUMAN / CATALYST'S	**Sources**
Provide tailored training for employees (e.g. in their context, adapted to their daily tasks)	L
Use co-creation/participative approach (e.g. to include criteria in project tool)	L,I
Provide empowering tools (e.g. adapted to the nature of jobs and skills)	L
Support/chaperon teams with environmental experts/expertise	L,I
Address differences between individual sensitivities/needs/emotions	L
Give room for experimentation, autonomy	L,I
Involve and support people who have personal aspirations for ecodesign, target people “who burn for it”	L,I
Provide appreciation and support	L
Raise awareness or motivation with employee newsletters, podcasts, site events, trips	L
Translate ecodesign concepts in easy to understand terms, easy-to-understand/familiar terms/problematics	L, I
Use success stories to raise motivation	L
Understand what motivate employees or leads them to resistance (e.g. through workshops)	L
Collaboration with Human Resources department	L
Explain/inform employees about ecodesign (e.g. “why”, “how”, “when”, “who”)	L
Give responsibility and support for initiative taken	L
Make it easy to find information about ecodesign	L
One-to-one encounters	L
Reassure employees (e.g. about workload)	L, I
Stimulate and support individual employees to share ideas	L
Use nudging techniques, i.e. leading without inducing guilt or being prescriptive	L
Increase comfort of people to work with the topic of ecodesign	I
Build individual awareness of impact of decisions	I
Trigger people/”plant seeds”	I
POLITICAL / ADVOCATE'S	**Sources**

Have top management explicitly express ecodesign as a priority/commit for ecodesign (e.g. involvement in decision-making, public statements, responsibility for ecodesign goals)	L
Allocate resources/budget	L
Foster the development of ambassador(s) for ecodesign in the organization	L,I
Use success stories to create buy-in	L
Build awareness among key decision-makers	L
Communicate risk and benefits to the organization, emphasize criticality/emergency for business	L,I
Demonstrate value of ecodesign for different functions and the company	L
Influence and find/ally with employees who will be able to influence others	L,I
Understand resource availability and target low-hanging fruit	L,I
Allow ecodesign champions to network in the organization	L
Align and adapt ecodesign communication to different departments (e.g. different language/terminology)	L,I
Enable access to resources for ecodesign initiatives	L
Identify and leverage existing competencies in the company	L
Manage the gap between expectations and capabilities	L
Seek for interactions compatible with each group's priorities and agendas	L
Negotiate prioritization of ecodesign KPIs in agendas	I
Secure present resource allocation for long term/more prospective objectives	I
Leverage existing umbrella projects in the organization (i.e. leverage their visibility, resources, priority level)	I
Show solid knowledge of technical matters (expertise as a way to influence)	I
CULTURAL / PROPHET'S	**Sources**
Celebrate ecodesign successes and heroes (e.g. awards)	L
Adapt tools to the company's way of working	L
Efforts of environmental teams to be accepted as core members of the product development community	L
Use or creation of rituals (e.g. create regular events around products)	L
Storytelling about the founder's choice, communicating how it fits with the way of working	L

Value testing and failures	L
Develop common heuristic rules	L
Change perceived mission of the company, make sustainability part of the DNA, what people believe they are working for	L,I
Identify and break the poor history of ecodesign at the company	L
Negotiate/translate meanings with product development teams	L
Provide inspiration on ecodesign to the organization	L,I
Preach in the company (e.g. by recurrently bringing up ecodesign topic in presentation, introductory speech of development projects)	I
Generate new truths/meanings around products	I
Change false common beliefs/misconceptions (e.g. that environmental teams can affect product environmental performance by the conduction of environmental assessments)	I
Leverage “typical ways of doing”/routines/habits in the organization (e.g. ways of communicating)	I

7.7 Section 4.5 (empirical study 6)



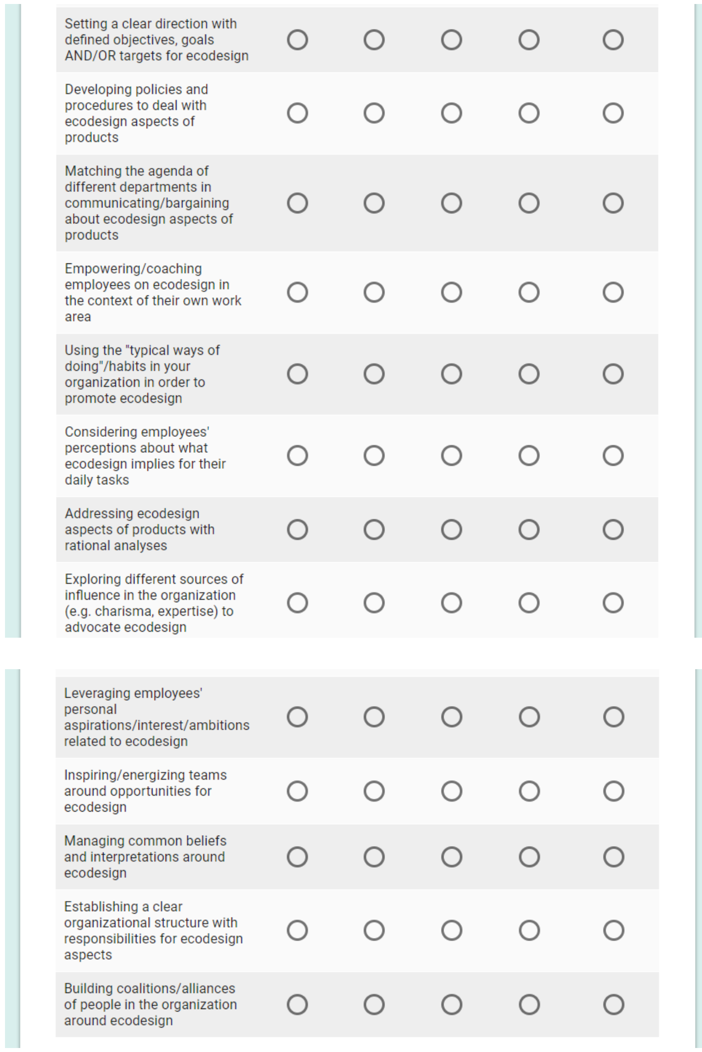
Four-lens ecodesign integration profile

* Required

Consider the current approach at your company of integrating ECODESIGN in the organization, i.e. of developing products with better environmental sustainability performance along their life cycle. IN YOUR OPINION, to what extent are the following elements IN FOCUS in the current approach at YOUR COMPANY? *

(Do not hesitate to choose "extreme" answers.)

	Not at all	To a limited extent	To some extent	To a great extent	Completely
Using "heroes" and success stories in order to promote ecodesign	○	○	○	○	○
Fostering participation and involvement of teams around the topic of ecodesign	○	○	○	○	○
Getting people to prioritize ecodesign aspects in their agenda (e.g. for resource allocation)	○	○	○	○	○



Setting a clear direction with defined objectives, goals AND/OR targets for ecodesign	○	○	○	○	○
Developing policies and procedures to deal with ecodesign aspects of products	○	○	○	○	○
Matching the agenda of different departments in communicating/bargaining about ecodesign aspects of products	○	○	○	○	○
Empowering/coaching employees on ecodesign in the context of their own work area	○	○	○	○	○
Using the "typical ways of doing"/habits in your organization in order to promote ecodesign	○	○	○	○	○
Considering employees' perceptions about what ecodesign implies for their daily tasks	○	○	○	○	○
Addressing ecodesign aspects of products with rational analyses	○	○	○	○	○
Exploring different sources of influence in the organization (e.g. charisma, expertise) to advocate ecodesign	○	○	○	○	○
Leveraging employees' personal aspirations/interest/ambitions related to ecodesign	○	○	○	○	○
Inspiring/energizing teams around opportunities for ecodesign	○	○	○	○	○
Managing common beliefs and interpretations around ecodesign	○	○	○	○	○
Establishing a clear organizational structure with responsibilities for ecodesign aspects	○	○	○	○	○
Building coalitions/alliances of people in the organization around ecodesign	○	○	○	○	○

Figure A10. Four-lens ecodesign integration questionnaire. Accessible at: https://goo.gl/forms/DNg4OFP8ezjewzlv1.

STRUCTURAL LENS (architect's perspective)

	Ongoing efforts	Potential idea	Not relevant/feasible
Define **scope** of ecodesign, make it **measurable**, **tangible**	❑	❑	❑
Integrate ecodesign into the **business mission/strategy**	❑	❑	❑
Integrate ecodesign in **product portfolio management**	❑	❑	❑
Design **ecodesign strategies**	❑	❑	❑
Design **ecodesign policies**	❑	❑	❑
Set **targets** at different levels (e.g. corporate, products, innovation projects)	❑	❑	❑
Translate corporate strategy into action plan for specific business units/functions	❑	❑	❑
Implement **environmental systems and standards**	❑	❑	❑
Integrate ecodesign **procedures** in **processes related to product development**	❑	❑	❑
Integrate ecodesign aspects in the **fuzzy front end/early stages of product development**	❑	❑	❑
Include ecodesign in **design criteria**	❑	❑	❑
Integrate ecodesign **criteria** in **performance measurement systems** (e.g. KPIs, internal labeling)	❑	❑	❑
Design **ecodesign guidelines** and develop/acquire **decision-support tools**	❑	❑	❑
Acquire **in-house expertise** on ecodesign	❑	❑	❑
Create dedicated **organizational units and jobs** visible in the organigram	❑	❑	❑
Assign **responsibilities** for ecodesign at different organizational levels	❑	❑	❑
Compose project teams with all relevant functions to address ecodesign (e.g. environmental specialists)	❑	❑	❑
Set **project processes** allowing for development of **radical innovation**	❑	❑	❑
Establish **system** for ecodesign **information collection**	❑	❑	❑
Establish ecodesign **expertise/knowledge sharing process and platform** (e.g. for lessons learned, successes, avenues for future investigation)	❑	❑	❑

HUMAN LENS (catalyst's perspective)

	Ongoing efforts	Potential idea	Not relevant/feasible
Provide **tailored training** for employees (e.g. in their context, adapted to their daily tasks)	❑	❑	❑
Provide **empowering** tools (e.g. adapted to the nature of jobs and skills)	❑	❑	❑
Explain/inform employees about ecodesign (e.g. "why", "how", "when", "who")	❑	❑	❑
Raise **awareness or motivation** e.g. through employee newsletters, podcasts, site events, trips	❑	❑	❑
Support/chaperon teams with environmental experts/expertise	❑	❑	❑
Address **differences** between **individual sensitivities/needs/emotions**	❑	❑	❑
Stimulate and support individual employees to **share ideas**	❑	❑	❑
Reassure employees (e.g. about workload)	❑	❑	❑
Use **nudging** techniques, i.e. leading without inducing guilt or being prescriptive	❑	❑	❑
Use **participative/co-creation** approach (e.g. to include criteria in project tool)	❑	❑	❑
Trigger people/"plant seeds"	❑	❑	❑
Involve and support people who have **personal aspirations** for ecodesign	❑	❑	❑
Provide **appreciation and support**	❑	❑	❑
One-to-one encounters	❑	❑	❑
Build **individual awareness** of impact of decisions	❑	❑	❑
Translate ecodesign concepts in **easy-to-understand/familiar terms/problematics**	❑	❑	❑
Give room for **experimentation/autonomy**	❑	❑	❑
Make it easy to find **information about ecodesign**	❑	❑	❑
Give **responsibility and support for initiatives** taken	❑	❑	❑
Understand what **motivate employees** or leads them to **resistance** (e.g. through workshops)	❑	❑	❑
Collaboration with **Human Resources department**	❑	❑	❑
Use **success stories** to raise **motivation**	❑	❑	❑
Increase **comfort** of people to work with the topic of ecodesign	❑	❑	❑

POLITICAL LENS (advocate's perspective)

	Ongoing efforts	Potential idea	Not relevant/feasible
Allocate **resources/budget**	❑	❑	❑
Demonstrate **value** of ecodesign for different **functions** and the **company**	❑	❑	❑
Align and adapt ecodesign communication to **different departments** (e.g. different language/terminology)	❑	❑	❑
Influence and find/ally with employees **who will be able to influence others**	❑	❑	❑
Allow **ecodesign champions** to **network** in the organization	❑	❑	❑
Show **solid knowledge** of technical matters (expertise as a way to influence)	❑	❑	❑
Have **top management explicitly express** ecodesign as a **priority/commit** for ecodesign (e.g. involvement in decision-making, public statements, responsibility for ecodesign goals)	❑	❑	❑
Manage **gap between expectations** and **capabilities**	❑	❑	❑
Understand **resource availability** and target **low-hanging fruit**	❑	❑	❑
Communicate **risk and benefits** to the organization, emphasize **criticality/emergency** for business	❑	❑	❑
Secure present **resource allocation** for long term/more prospective objectives	❑	❑	❑
Leverage **existing umbrella projects** in the organization (i.e. leverage their visibility, resources, priority level)	❑	❑	❑
Negotiate for prioritization of **ecodesign KPIs**	❑	❑	❑
Foster the development of a **ambassadors** for ecodesign in the organization	❑	❑	❑
Build awareness among **key decision-makers**	❑	❑	❑
Identify and leverage **existing competencies** in the organization	❑	❑	❑
Enable **access to resources** for ecodesign initiatives	❑	❑	❑
Use **success stories** to create **buy-in**	❑	❑	❑
Seek for interactions compatible with each group's priorities and agendas	❑	❑	❑

SYMBOLIC LENS (prophet's perspective)

	Ongoing efforts	Potential idea	Not relevant/feasible?
Celebrate ecodesign **successes** and **heroes** (e.g. awards)	❑	❑	❑
Adapt tools to the **company's way of working**	❑	❑	❑
Use or create **rituals** around ecodesign (e.g. create regular events around products)	❑	❑	❑
Provide **inspiration** on ecodesign to the organization (e.g. student projects)	❑	❑	❑
Leverage **"typical ways of doing"/routines/habits** in the organization (e.g. ways of communicating)	❑	❑	❑
Change **false common beliefs/misconceptions** (e.g. that environmental teams can affect product environmental performance by the conduction of environmental assessments)	❑	❑	❑
Identify and break **poor history** of ecodesign at the company	❑	❑	❑
Generate **new truths/meanings** around products	❑	❑	❑
Negotiate/translate meanings with product development teams	❑	❑	❑
Change **perceived mission** of the company, make sustainability part of the **"DNA"**, what people **believe they are working for**	❑	❑	❑
Efforts of environmental teams to be accepted as **core members** of the product development community	❑	❑	❑
Storytelling about the founder's choice	❑	❑	❑
Value **testing and failures**	❑	❑	❑
Develop **common heuristic rules**	❑	❑	❑
Preach in the company (e.g. by recurrently bringing up ecodesign topic in presentation, introductory speech of development projects)	❑	❑	❑

Figure A11. Four-lens lists of measures in favor of ecodesign integration in companies. KPI= Key Performance Indicator. *Icons from top to bottom: Architect by Augusto Zamperlini from Noun Project; Family by Luis Prado from Noun Project; Lawyer asking question by Gan Khoon Lay from Noun Project; Hero by Andrew J. Young from Noun Project.*

Article I

Life cycle assessment in corporate sustainability reporting: Global, regional, sectoral and company-level trends

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Life cycle assessment in corporate sustainability reporting: Global, regional, sectoral and company-level trends

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Abstract

Large companies now commonly release corporate sustainability (CS) reports, in which they describe their approach to handle sustainability challenges. To guide environmental sustainability efforts in industry, the Life Cycle Assessment (LCA) methodology has been recognized as an important tool by researchers and policy-makers. But to what extent has the LCA methodology been present in companies' narratives through their CS reports up to now? To answer this question we map references to the LCA methodology in CS reports over the past two decades at geographical, sectoral and company levels through keyword searching within an extensive database (ca. 45000 CS reports); analyze trends; and highlight challenges, opportunities, and recommendations to strengthen the presence of LCA in CS reports. The results show that LCA generally remains weakly present in CS reporting, with some geographical and sectoral variations. Recommendations to strengthen LCA presence in CS reports are derived for method developers, policy-makers and companies.

Keywords

LCA; environmental assessment; CSR report; environmental management; environmental strategy; Corporate Register

1. Introduction

The United Nation´s (UN) Sustainable Development Goals (SDGs) chart a direction for global sustainability efforts in the coming decades (UN, 2015). Specifically, SDG number 12, aiming to "ensure sustainable consumption and production patterns", puts renewed attention to the role of business in sustainable development. Companies should proactively tackle the environmental issues related to their activities. Within their environmental sustainability strategies, businesses are expected to scrutinize their supply chains and life cycles of their products and seek to mitigate their associated environmental impacts (Comas Martí and Seifert, 2013; Pflieger et al., 2005).

Life cycle thinking is one of the dominant approaches to understand the environmental sustainability performance of systems, prescribed in scientific research, as well as in industry initiatives, standards and policies (Seuring, 2004; EU-JRC, 2010; Lehman et al., 2015; Dyllick and Rost, 2017). A variety of life-cycle based indicators covering different environmental impacts, such as carbon footprint and water footprint, have been developed to quantify the environmental performance of organizations or products and inform companies' environmental strategies (Laurent and Owsianiak, 2017). The Life Cycle Assessment (LCA) methodology provides a comprehensive account of potential environmental impacts, by covering all relevant environmental issues associated with the life cycle of an assessed product or service system, i.e. from the extraction of the raw materials through manufacture and use or operation up to the final disposal (ISO, 2006). Through intensive harmonization and standardization efforts, LCA has evolved into a robust methodology to assess the environmental impacts associated with a given system (ISO, 2006; Finnveden et al., 2009; Goedkoop et al., 2015). An increasing utilization of LCA in industry has been suggested (e.g. Goedkoop et al., 2015; Finkbeiner, 2016) and the use of this methodology has been promoted in various policy-making initiatives (Sonnemann et al., 2018). For example, at the EU level, LCA has been listed as one of the tools within the EU "Better regulation toolbox" to develop future regulations and adjust existing ones in Europe (EC, 2015). The development and testing of the LCA-based Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF) methodologies for application in industry has also been ongoing for the past years at the European level (EC, 2016; 2018a).

Within their corporate sustainability (CS) efforts, large companies now commonly release CS reports as part of their reporting cycles (Kolk, 2003; Siew, 2015; KPMG, 2015). The publication of CS reports is increasingly required by regulations (EC, 2014; KPMG, 2015; Ernst and Young, 2014), and the number of companies publishing CS reports was actually proposed as an indicator to monitor the SDG target 12.6 to "encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle" (UN, 2017). CS reports are defined as "public reports by companies to provide internal and external stakeholders with a picture of corporate position and activities on economic, environmental and social dimensions" (WBCSD, 2002). In CS reports, companies provide narratives of their sustainability efforts in order to meet their stakeholders' demands for higher transparency on sustainability matters (Lozano, 2016). CS reporting is an important communication tool for companies, both internally, as it aims to bring visibility on and increase employees' awareness of sustainability efforts (Searcy and Buslovich, 2014) and externally, by providing investors and rating agencies with an account of their sustainability practices and performance (Herzig and Schaltegger, 2006).

Only few studies exist on the link between LCA and CS reporting. Pflieger et al. (2005) suggested following the LCA methodology to further develop CS reporting away from its direct organizational focus, with higher focus on product-related information, and on providing information about environmental impacts beyond material and energy flows. Kaenzig et al. (2011) compared the environmental information disclosed in CS reports by companies with the environmental impacts from LCA studies of their products. They found that often only a limited share of the total environmental impacts of products was included in quantitative environmental disclosures present in CS reports because they did not take a life cycle perspective. Nygren and Antikainen (2010) explored the reference to LCA in the public communications, including CS reports, of twenty multinational company frontrunners belonging to diverse sectors and found that these companies generally reported a use of the LCA methodology and other life cycle-based practices. Earlier work has explored companies' sustainability practices based on their CS reports and revealed a life cycle approach in efforts of companies. For instance, Comas-Martí and Seifert (2013) explored the extent to which CS strategies considered the life cycle of the companies' products; Kozlowski et al. (2015) found that apparel companies indicated activities such as ecodesign, supplier monitoring programs or take-back systems which reflect life cycle thinking.

However, the extent to which companies refer to the LCA methodology in their narratives of sustainability efforts remains unclear. Exploring sustainability approaches of companies through the lens of their CS reports can be viewed as meaningful because they show "firms' understanding of how their environmental strategies should be 'best' presented" and they reveal "what each company believes to be its key messages" (Mikler, 2007, p. 14). For instance, Landrum and Ohsowski (2017) explored how companies' view sustainability based on their CS reports. In this perspective, the present study aims to investigate the presence of the LCA methodology in companies' narratives of their sustainability efforts in CS reports. Our research objectives are (i) to map the presence of LCA in CS reports at global and regional geographical scale and at the level of sector or company over the past two decades using keyword searching within an extensive database of CS reports; (ii) to analyze the observed trends in presence of LCA in CS reports in the light of development of the LCA methodology and its promotion by policy-making, research and industrial initiatives; (iii) to highlight possible challenges to the reporting of LCA in CS reports and opportunities associated with LCA presence in CS reports and (iv) to provide recommendations to strengthen the presence of LCA in CS reports.

In the following sections, we first present relevant background insights into LCA and CS reporting (Section 2). We then introduce the methodology used to perform the study (Section 3), including a description of assumptions and uncertainties, before presenting (Section 4) and discussing (Section 5) the results, together with the main limitations of the study and practical recommendations. Finally, conclusions are drawn and an outlook is presented for future research (Section 6).

2. Background

2.1. Life cycle assessment in industry

The LCA methodology was formalized at the beginning of the 1990s by the Society of Environmental Toxicology and Chemistry (SETAC) (SETAC, 1991) and standardized with the ISO14040-44 series (ISO, 2006) in the late 1990s, which pushed its promotion at a global level (Töpfer, 2002). From an original focus on assessing product or service systems, recent developments have broadened the scope of LCA applications, and opened it to assess organizational systems, lifestyles and countries (Hellweg and Milà i Canals, 2014). LCA has been the subject of intensive academic research and scientific publications on LCA have grown exponentially over the past years especially in Europe and North America (De Souza and Barbastefano, 2011; Chen et al., 2014; Hu et al., 2015).

Launched in 2002, the UNEP/SETAC Life Cycle Initiative has been working towards building an expert community of practitioners and reaching the worldwide dissemination of the LCA methodology and life cycle thinking among business, governments and consumers through its different working groups (Töpfer, 2002; Bjørn et al., 2018; Sonnemann et al., 2018). Regional LCA networks have flourished over the past 20 years, especially in the EU and North America (Bjørn et al., 2013). In North America, industrial initiatives such as the American Center for Life Cycle Assessment launched in 2001 and the Sustainability Consortium launched in 2009 (ACLCA, 2017; The Sustainability Consortium, 2017) also push the LCA agenda. In a European context, various EU recommendations and guidelines for sustainability approaches in industry pull from the LCA methodology, including the Integrated Product Policy directive (EC, 2003), the directive on the eco-design of energy using products in the EU region (EC, 2009), the eco-labelling scheme (EC 2010), the EU better regulation toolbox (EC, 2015) as well as the Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF) guidance documents (EC, 2016; 2018a). Type III environmental information on products, in the form of Environmental Product Declarations (EPD) (Ibanez-Fores et al., 2016), are directly associated with conducting an LCA following a set of product categories rules. Type I eco-labeling of products does not require the conduction of LCAs; yet, a type I eco-labeled product must fulfill a number of requirements along its life cycle.

The basic rationale for conducting LCA at companies is to quantify where the largest environmental impacts occur in their products' life cycles, and see how they can address them through conscious design decisions and collaborations with relevant value chain players (Owsianiak et al., 2018). Earlier studies on the uptake of LCA by industries have revealed that companies use LCA to identify environmental hotspots (Frankl and Rubik, 2000), inform and educate consumers and stakeholders (Frankl and Rubik, 2000; Cooper and Fava, 2006), compare existing products with planned alternatives (Frankl and Rubik, 2000), support product development activities (Frankl and Rubik, 2000; Cooper and Fava, 2006); inform and drive strategic decisions; improve the internal monitoring systems and make robust communication of green attributes to market stakeholders (Testa et al., 2016). A number of challenges faced by companies in the adoption of LCA have also been identified. Recurrent challenges include the complexity, time and cost of conducting LCAs, especially in relation to the collection of data, hiring of consultants or purchase of software (Schaltegger, 1997; Cooper and Fava, 2006), as well as the challenges and uncertainties related to interpreting and communicating the results (Testa et al., 2016).

In the early years of the methodology, Berkhout (1996) reported that its adoption in industry started in Europe and followed in North America and Asia. The early adoption of LCA was indicated to be particularly important in the Nordic region in the late 1990s (Hanssen, 1999). In these early years, packaging materials and consumer products were common sectors for applications (Gloria et al, 1995; Berkhout, 1996; Hanssen, 1999; Hauschild et al., 2005). The electronic goods, automobiles, chemicals, aluminum, food and paper industries are also historical sectors of application (Berkhout, 1996; Berkhout and Howes, 1997). In the late 1990s, the service industry was reported to be little involved in LCA activities due to a lack of regulatory incentives, applicable metrics and approaches to evaluate the environmental impacts associated to a service (Graedel, 1997; Baumann, 1996). Frankl and Rubik (2000) surveyed Italian, Swedish, German and Swiss companies for their adoption of LCA and found adoption of up to 40-45% among the largest companies, as well as indications that an increasing use of the methodology was planned in more than half of the surveyed companies. More recently, Hörisch et al. (2015) surveyed the use of diverse sustainability management tools in 186 large North American, Japanese, Spanish and South Korean companies in 2012, and found that nearly 50% of them indicated using LCA-based tools. A recent study of EPD practices show that the building and the food and beverage sector were particularly active in issuing EPDs (Ibanez-Forés et al., 2016). In a recent study based on a survey of 800 large European companies, Chiarini (2014) found that both service and manufacturing companies acknowledged the ability of LCA to effectively improve the environmental performance of their supply chains.

2.2. Corporate sustainability reporting

CS reports vary between companies in terms of coverage of sustainability aspects and reporting quality (Hahn and Kühnen, 2013), but they typically provide an account of practices for a selection of sustainability issues considered important or relevant by the company, including information on the tools and indicators used to address and measure the selected sustainability issues (Montabon et al, 2007; Roca and Searcy, 2012; Siew, 2015). CS reporting increasingly follows voluntary standards, with the Global Reporting Initiative (GRI) reporting framework (GRI, 2013) being the most popular voluntary reporting reference for companies worldwide (KPMG, 2015). CS reports contain a mix of organization and product-level disclosures (Comas-Marti and Seifert, 2013). Within the list of standard environmental disclosures recommended by the GRI 4 framework, 29 of them are framed at the organizational level while only 5 are defined at a product or service level (GRI, 2013). Traditionally, CS reports have been released by large companies, whereas smaller companies have been hindered by a lack of resources and adequate guidelines (Borga et al., 2009).

Earlier works on sustainability reporting have shown that CS reports play both external and internal roles (Pérez-López et al., 2015). From an external perspective, CS reporting is an instrument used by ranking agencies and investors to assess and compare CS efforts in industry (Herzig and Schaltegger, 2006). From an internal perspective, CS reporting has been found to serve as guidance to initiate sustainability work at companies (Hedberg and van Malmborg, 2003), to improve employee awareness and engagement by legitimating the company, celebrating progress, and bringing visibility of employee activities (Searcy and Buslovich, 2014), and to go hand in hand with organizational change for sustainability in a mutually reinforcing process (Lozano et al., 2016). On the other hand, various studies have questioned the extent to which CS reporting genuinely addresses sustainability issues and presents substantive actions from companies, as opposed to symbolic disclosures aimed at strengthening their corporate image and reputation (Hrasky, 2011; Milne and Gray, 2013; Tregigda et al., 2014; Gold and Heikkurinen, 2018).

3. Methodology

An overview is given of the overall methodology in Figure 1 with detailed description of the different steps in the following sections.

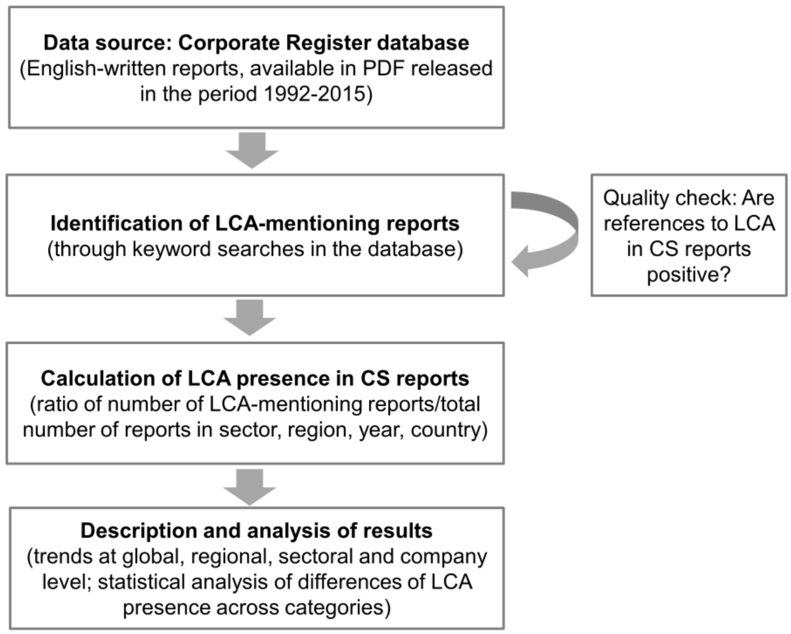

Figure 1. Overview of the methodological approach.

3.1. Data sources for CS reports

The study builds on a systematic mapping of LCA-related terms in CS reports. The names of these reports vary broadly and include among others “corporate sustainability reports”, “citizenship reports’, “Corporate Social Responsibility (CSR) reports”, “sustainable development reports”, and “environmental reports” (Roca and Searcy, 2012; Kolk, 2010). Hereafter, a report identified through any of the above-mentioned names is referred to under the term “corporate sustainability report” (CS reports).

The Corporate Register database, which is the largest online database of CS reports, was used to access publicly available reports (CR, 2017a). The database is reported to contain more than 80000 report entries associated to nearly 14000 companies since 1992 (CR, 2017a). It is estimated by its developers to cover more than 90% of all reporting companies and it is updated daily (CR, 2017b). A search engine is available on the website for conducting specific report content searches, as previously undertaken by Bjørn et al. (2017). Additionally it allows filtering reports by year, sector and country. The report search was conducted in the period August-November 2016 and covers all English-written CS reports available in PDF in the Corporate Register database (ca. 50000 CS reports). The database includes CS reports which were published between 1992 and 2016. The time period chosen in the study was 1992-2015, since CS reports released in 2016 were not all present in the database at the time of the study. Reports from governments, education and branch organizations were excluded to keep the sole focus on industry, leaving us with a total of ca. 45000 CS reports as a basis for the study.

3.2. Identification of references to LCA in CS reports

CS reports referring to LCA were identified by performing searches of LCA-related terms in the Corporate Register database using the embedded search function. Information about the CS reports containing LCA-related terms was collected, including report name, publishing company name, sector of the publishing company, country where the company's headquarter is located and report publication year. The list of LCA-related terms searched for was developed by the author team and included "life cycle assessment", "life-cycle assessment", "lifecycle assessment", "life cycle analys*", "life-cycle analys*" and "lifecycle analys*". The acronym "LCA" was considered, but eventually not used as a search term, because it would identify non-relevant terms such as "vo**lca**nized rubber", and because companies were assumed to first use the full name of the methodology before its acronym. "Product Environmental Footprint" (PEF) and "Organization Environmental footprint (OEF) were not included in the search term list since the introduction of the PEF and OEF guidelines were still at a very early stage at the time of the report searches. Considering the scope of the present study and its focus on the LCA methodology, only synonyms of LCA were included in the keyword search, whereas other broader terms referring to life cycle thinking or life cycle management were omitted. The number of LCA-related terms per CS report could not be taken into account in the database search function. Thus, the mapping disregards potential differences in LCA content richness across CS reports. This is an inherent limitation of the present study and will require future explorative work.

The methodology relies on the assumption that LCA references, i.e. presence of a LCA-related term, in CS reports corresponds to a positive reference to LCA. False positive references include for example reports only listing LCA in the glossary, having LCA as a headline but not providing any more information, listing a reference to an LCA source while actually not addressing LCA in the text or mentioning LCA as a tool stated not to be used by the company. CS reports containing LCA-related terms that correspond to positive references are hereafter called LCA-mentioning reports. In order to test the representativeness of this number, a quality check was performed on a sample of 331 reports. Details about sampling are provided in the Supplementary Methods. The test resulted in 94% of positive references to LCA. This means that for a confidence level of 95%, LCA references in reports correspond to positive references in 89%-99% of the cases. In the perspective of these results, the trends described in the following sections which are based on reports containing LCA-related terms are considered representative of LCA-mentioning CS reports.

3.3. Calculation of LCA presence in CS reporting

Sectoral categorization of LCA-mentioning CS reports: we adapted the sector classification of Corporate Register, which is very similar to the Industry Classification Benchmark classification (ICB, 2017) (see Table S1 in Supplementary Methods).

Calculations of LCA presence in categories: The LCA presence in CS reports of a given category, e.g. a sector in a given year or a country in a given year, is defined as the ratio of LCA-mentioning CS reports in a category to the total number of CS reports in that category. These ratios were calculated based on the information collected for each LCA-mentioning CS report (country, sector and year) and on additional searches in the Corporate Register database which consisted in collecting the information on the total number of CS reports contained in the database for each category. The unit of analysis in all LCA presence calculations is the CS report, as opposed to the reporting company, due to limitations of the search function available with the database used.

3.4. Description of trends and analysis

The subsequent analysis was focused on describing and discussing temporal trends at global, regional, sectoral and company level. We performed two additional analysis steps for the sectoral trends which were deemed relevant in the light of existing literature about LCA adoption in industry. First we studied the influence of business activity type (manufacturing versus service sectors) and customer type (business-to-business (B2B) versus business-to-consumer (B2C) sectors) on LCA presence in CS reporting. The division into B2B/B2C and manufacturing/service sectors was performed based on the sector descriptions provided for the ICB structure (ICB, 2017) – see Table S2 in Supplementary Methods. Pearson's chi-square was used to statistically test the independence of sector categories (B2B/B2C and manufacturing/service classification) with regard to differences in LCA presence in CS reporting. The tests were conducted for business activity type separately for B2B and B2C sector subsets, and for customer type separately for manufacturing and service sectors subsets. The data used to conduct the test is presented in Table S4 in Supplementary Results. The p-value threshold for independence of variables was set at $p = 0.05$. Second we qualitatively compared LCA presence in CS reports and the distribution of environmental impacts in the supply chain across sectors.

4. Results

LCA-related terms were identified in 2367 CS reports, which means that the LCA-mentioning reports correspond to approximately 5% of all English-written reports available as PDF in the Corporate Register database and published between 1992 and 2015 (data not shown; available upon request to the authors). These reports were published by 1167 unique companies in the period 1995-2015 (i.e. no LCA-mentioning CS reports in 1992-1994).

4.1. Global trend

As illustrated in Figure 2, the absolute number of LCA-mentioning CS reports published each year has overall increased since 1995, with a steep growth between 1995 and 2002, followed by a period of stagnation until 2007 and a new but slower growth since then. Relative to the total number of CS reports, LCA presence in CS reporting has undergone 3 phases: after a relatively high presence of LCA in CS reports in the 90s, with approximately 15-20% of the total CS reports, the LCA presence has experienced a net decrease between 1999 and 2007 before stabilizing at ca. 5% (see Fig. 2). This suggests that during the period 1999-2007, LCA has dropped on the CS reporting agenda, while an increasing number of companies were starting to release CS reports. Since 2007, references to LCA in CS reports have kept up with the increasing number of CS reports released by industry.

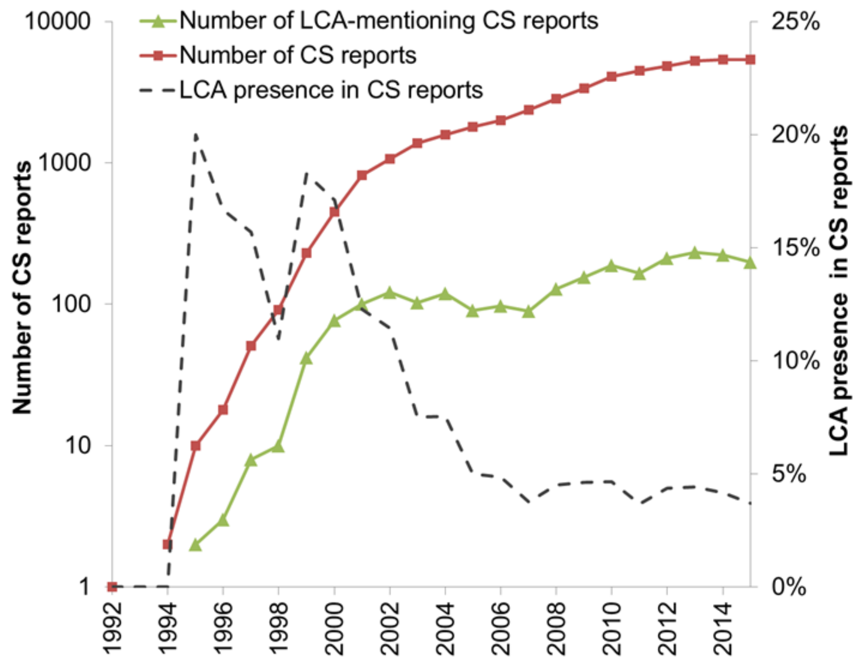

Figure 2. Temporal evolution in number of CS reports, LCA-mentioning CS reports (left y-axis) and LCA presence in CS reporting defined as the ratio between the two (right y-axis). Note the logarithmic scale on the left y-axis.

4.2. Regional and national trends

Figure 3a shows that since the late 1990s, CS reporting activities have overall increased in all regions, with the strongest developments being in Europe and North America, while the smallest are observed for Africa and South America. Figure 3b reveals that the developments of LCA-mentioning reports have been the strongest in Europe and North America, while Japan shows a net decreasing trend followed by a recent stabilization. A slower start in North America than in Europe for LCA presence in CS reports can be seen on Figure 3b.

With respect to LCA presence in CS reporting, Figure 3c confirms that North America and Europe are leading as of 2015, with a rate of ca. 5%. Various trends can be observed across the regions for LCA presence rates. In Europe and Japan, LCA presence in CS reporting has decreased from relatively high values (i.e. 20% for Europe; 40% in Japan in 2000) to stabilize at ca. 5% in Europe since 2005 and ca. 2-3% in Japan since 2013. In North America and Oceania the LCA presence in CS reporting has overall remained stable with an average presence of ca. 5%. Because of the limited number of CS reports mentioning LCA up to 2005, the LCA presence in CS reports in Asia (excl. Japan) shows series of spikes before stabilizing at ca. 2-3% from 2005 and on. In Africa and South America, LCA presence in CS reporting has remained very low over the entire period.

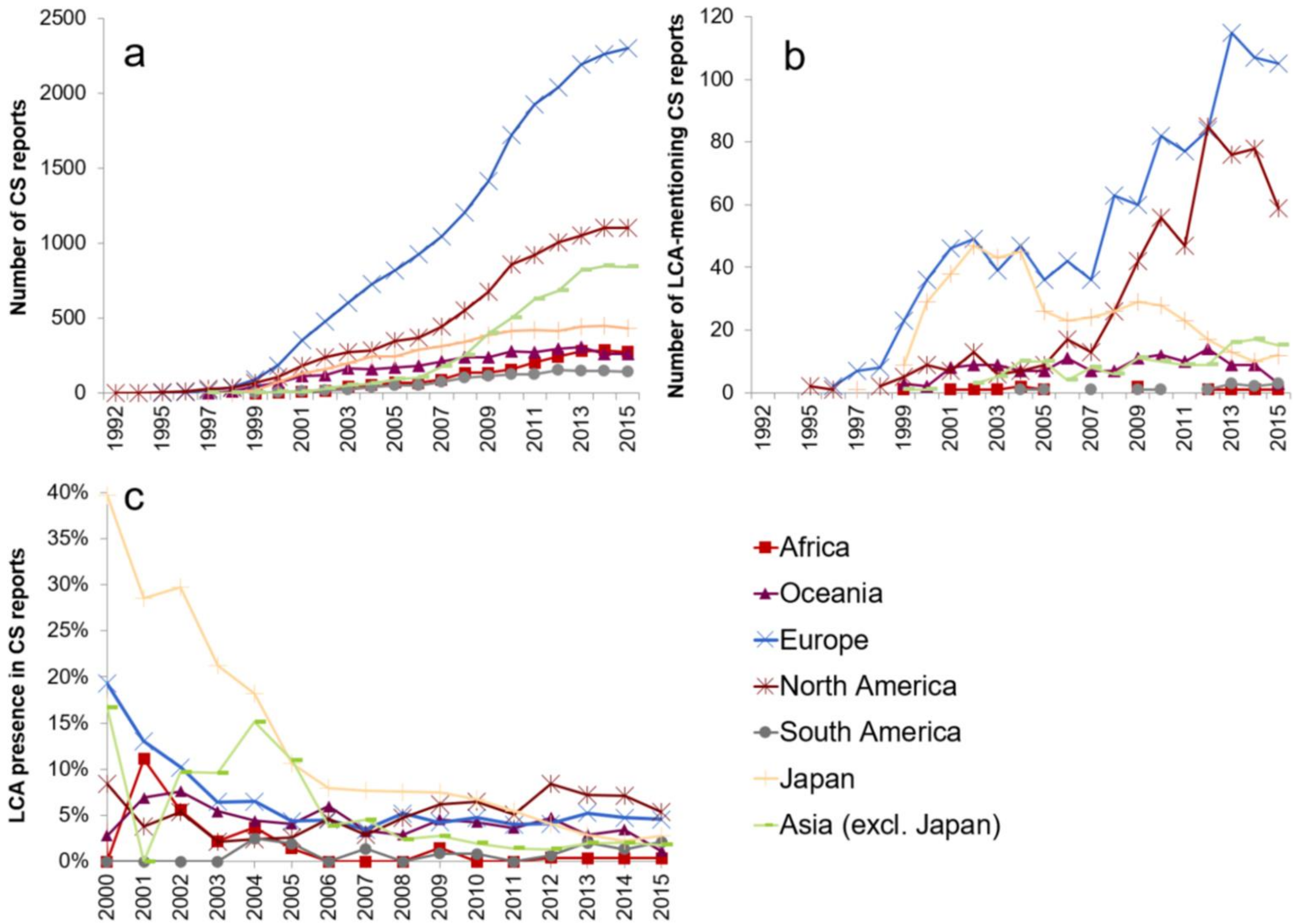

Figure 3. Temporal and regional evolutions in total number of CS reports (a), number of LCA-mentioning CS reports (b) and LCA presence in CS reports (c). Japan was singled out because of its unique pattern within Asia. Note that in Figure 3c, the period 1995-1999 is not represented as it would show a series of spikes for all regions due to a very limited number of CS reports released in that period.

Figure 4 shows the LCA presence in CS reporting for the top 12 countries with the highest LCA presence aggregated over the period 1995-2015, i.e. the total number of CS reports referring to LCA in a given country relative to the total number of CS reports in that country over the whole period. High LCA presence in CS reporting is mostly observed in European countries, especially in the Nordic region.

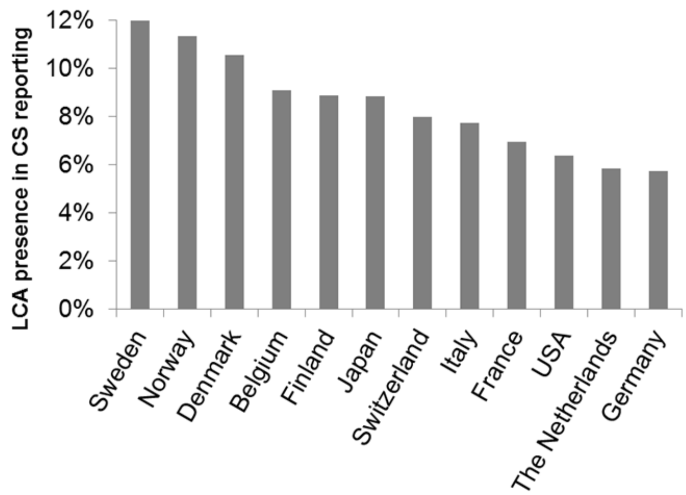

Figure 4. Top 12 countries with highest LCA presence in CS reporting aggregated over the period 1995-2015, i.e. the total number of CS reports referring to LCA in a given country relative to the total number of CS reports in that country over the whole period. A cut-off criterion of 500 CS reports per country and cumulated over the time period was applied to prevent possible biases caused by countries with high LCA presence in CS reporting on a limited number of total CS reports.

4.3. Sectoral trends

4.3.1. Sectoral differences of LCA presence in CS reports

As illustrated in Figure 5, the mapping of LCA presence in CS reporting at a sector-level shows the same temporal trends as observed in Figure 2, with LCA presence in CS reporting ranging higher than 50% for a number of sectors (e.g. Containers & Packaging, Industrial Machinery) in the late 1990s (Figure 5a), before decreasing in the early 2000s (maximum presence of ca. 20-25%; Figure 5b) and somewhat stabilizing in the 2006-2015 period with average LCA presence of ca. 5% (Figure 5c and 5d). Apart from the period 2001-2005, no sector presents both a high number of CS reports and a high presence of LCA, which means that large sectors, in terms of released CS reports, contain relatively few occurrences of LCA. This is for example the case for the finance sector.

Over the considered 20 year-period, the Containers & Packaging sector shows a systematically high LCA presence in CS reporting (above 18% in all periods; see Figure 5). In the last considered period of 2011-2015, it stands out with an LCA presence as high as 25%. The second highest LCA presence in 2011-2015 is observed for the Personal & Household Goods sector, which is associated with an increasing presence of LCA in CS reporting over the past 20 years. Further analysis of sectoral trends (See Table S3 in Supplementary Results) reveals a stable or increasing LCA presence in the Chemicals, Industrial Metals, and Forestry & Papers sectors, whereas other sectors have experienced a decreasing trend in recent periods, e.g. Electronic & Electrical, Automobiles & Parts, Diversified Industrials, Industrial Machinery, and Technology & Hardware Equipment.

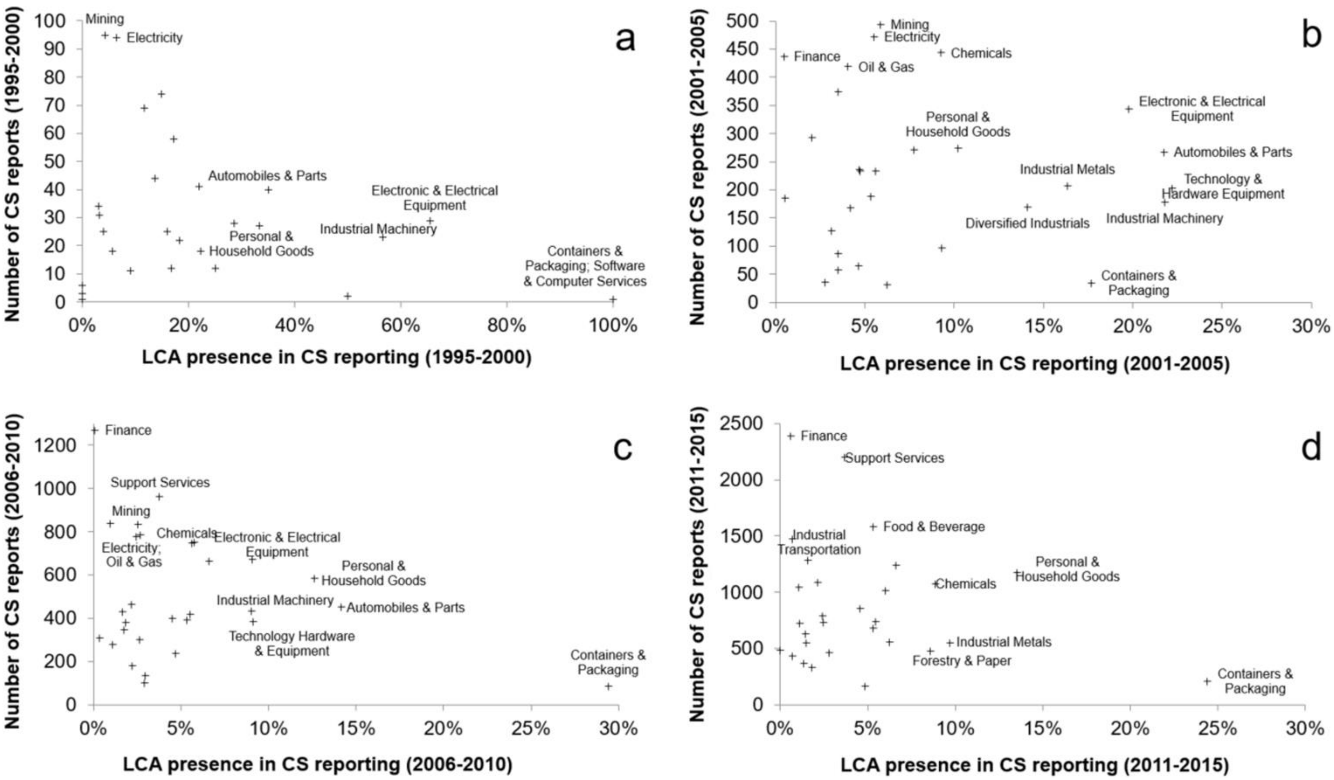

Figure 5. Sectoral LCA presence in CS reports and number of CS reports per sector in 1995-2000 (a); 2001-2005 (b); 2006-2010 (c); and 2011-2015 (d). Only largest sectors (top part of Figure 5) and sectors with highest LCA presence in CS reporting (right part of Figure 5) are labelled on Figure 5 to allow readability. All sectoral LCA presences in CS reporting are available in Table S3 in Supplementary Results. Note the different scales on the x-axis for the LCA presence as well as on the y-axis for all figures.

4.3.2. Comparative analysis of sector types

The business activity type was found to influence the presence of references to LCA in CS reports, with CS reports in manufacturing sectors showing higher presence of LCA than CS reports in the service sectors. This influence was statistically significant for both B2B and B2C subsets (p-values < $2.2*10^{-16}$). In contrast, the influence of customer type was less apparent. The type of customer (business or consumer) was found independent from the presence of references to LCA in CS reports for the service-oriented sector subset (p=0.35), but there was some dependency on the type of customer for the manufacturing sector subset ($p=7.2*10^{-8}$), with B2C manufacturing companies showing slightly higher presence of LCA in CS reports than B2B manufacturing companies. Subsequent analyses carried out for data separated further into subsets corresponding to the four periods of publications of CS reports, namely 1995-2000, 2001-2005, 2006-2010 and 2011-2015, showed that this dependency was only significant in the two latter periods 2006-2010 and 2011-2015 ($p=1.7*10^{-10}$ and $4*10^{-4}$, respectively), but not in the first two ones (p=0.10 and 0.39, respectively). This apparent recent influence of the customer type mirrors the results at sector level showing that LCA presence in CS reports has diminished in some B2B manufacturing sectors (e.g. Electronic & Electrical, Diversified Industrials, Industrial Machinery and Technology & Hardware Equipment sectors), while remaining strong in the Personal & Household Goods sector (B2C manufacturing sector) in the past years.

4.3.3. Contribution of supply chain to total impacts

Figure 6 shows the observed sectoral LCA presence in CS reporting for the period 2011-2015 in parallel to the proportion of indirect environmental impacts for each sector. Direct environmental impacts include the impacts generated by the companies' operations, while indirect environmental impacts are impacts lying in the supply chain. Estimated shares of indirect environmental impacts were retrieved from the study by GreenBiz and Trucost (2015). There seems to be no correlation between LCA presence in CS reports and the share of indirect environmental impacts. Especially, several sectors for which the impact contribution from supply chains is high (>75%) have very low LCA presence in CS reporting, for example the Finance, Software & Computer Service, Telecommunications, Media, Retail, Health Care Equipment & Services and Real Estate sectors.

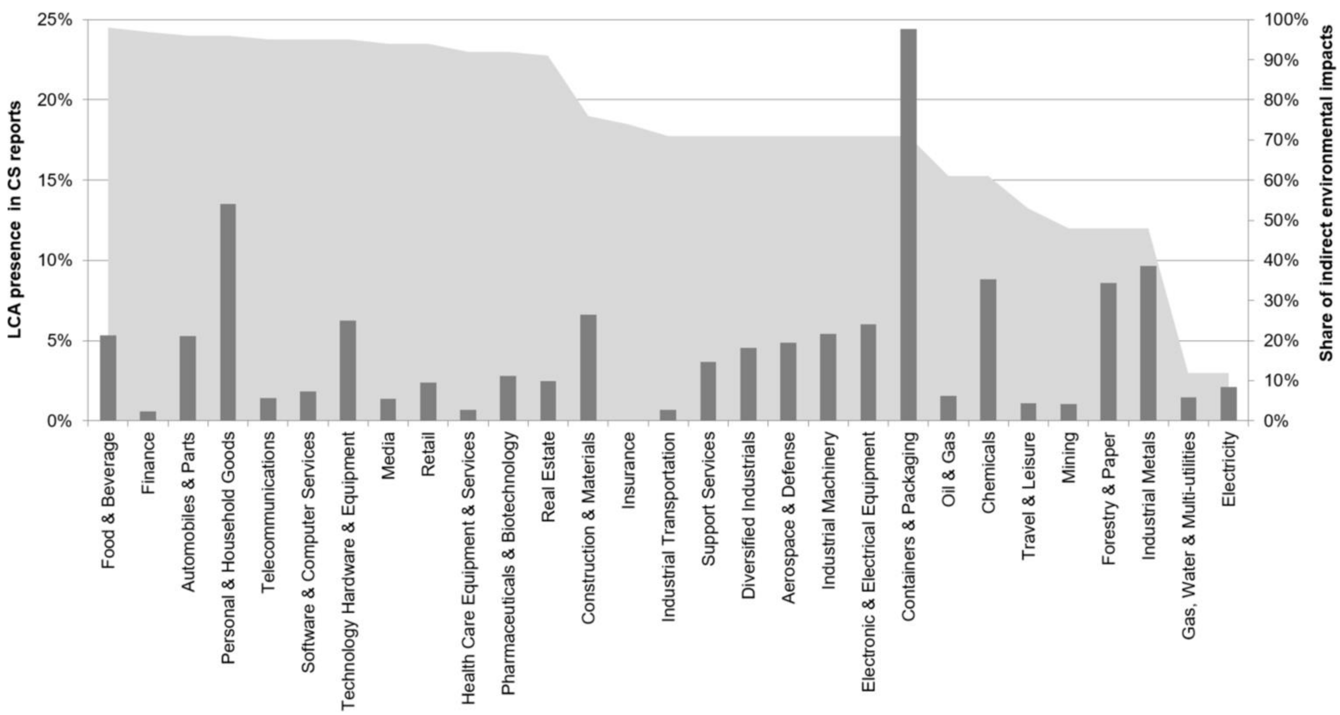

Figure 6. LCA presence in CS reporting (dark grey bars; left y-axis) opposed to the share of indirect environmental impact (light grey area; right y-axis) per sector over the period 2011-2015. Estimated shares of indirect environmental impacts were adapted from GreenBiz and Trucost (2015). The correspondence between the sectors used by GreenBiz and Trucost and the sectors used in this study is available in Table S1.

4.4. Company-level trends

As shown in Figure 7, amongst the total of 1167 companies referring to LCA during the 1995-2015 period, more than 75% of companies had made references in just 1 or 2 of the years. This clearly shows that very few companies mention LCA in their CS reports on a regular basis. Only 12% of the companies have referred to LCA in four or more years and only 1% in eight or more years in the 1995-2015 period (not visible in Figure 7).

However, it should be noted that not all companies release CS reports every year. Consequently, the observed discontinuities in LCA-mentioning reports may be due to either a discontinuity in the CS reporting or a discontinuity in the reference to LCA in CS reports. The analysis of the data shows that only 35% of all discontinuities of LCA references are due to discontinuities in CS reporting activities at the company (data not shown). Thus, there are large changes in the references to LCA in CS reports between years, regardless of the companies' CS reporting frequency.

Data show that the companies, which mentioned LCA in their CS reports at least once in the period 1995-2000 (111 companies), have mentioned LCA on average in three distinct years, in the period 1995-2015 (data not shown). In this group of companies, discontinuities in the presence of LCA in CS reports are explained by discontinuities in CS reporting activities in 31% of cases. Hence, early references to LCA in CS reports are not associated with continuous references to LCA over the full time period.

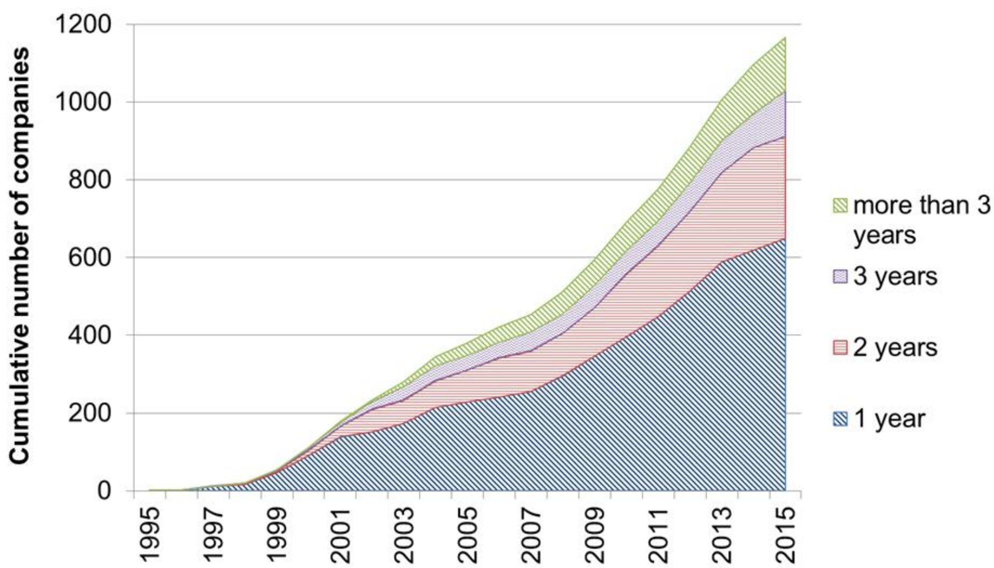

Figure 7. Cumulative number of companies having mentioned LCA in their CS reports before or at the indicated year.

5. Discussion

5.1. Analysis of trends

The observed temporal, regional and sectoral trends can be put in perspective by the developments of the LCA methodology and initiatives undertaken to drive its uptake by industry; yet the existence of causality in observed relationships should be regarded with care. The first instances of LCA in CS reports stem from approximately five years after the kick-off of the development of a life cycle impact assessment (LCIA) framework for LCA by SETAC (SETAC, 1991).

At a geographical level, the areas where LCA networks (Bjørn et al, 2013) and academic publications (De Souza and Barbastefano, 2011) have been reported to be the strongest, namely in Europe and North America, match the areas where the highest levels of LCA presence in CS reporting are observed. The contrasting low presence of LCA networks and LCA-related academic activities reported for Africa and South America are also consistent with the low LCA presence in CS reporting observed in these regions (Bjørn et al., 2013; De Souza and Barbastefano, 2011). However, the regional variation of LCA presence in CS reporting remains small, and regions where LCA is promoted strongly do not show much stronger LCA presence in CS reporting than regions where LCA promotion is weak. Such observations must be nuanced with the relative sizes of the involved regions in terms of CS reports, considering that North America and Europe have about five times more CS reports than Africa and South America over the whole period. The strong representation of Nordic countries among countries with high LCA presence in CS reporting is consistent with the strong uptake of LCA in the Nordic region, with respect to LCA application and method development (Hanssen, 1999; Bjørn et al., 2013; Laurent et al., 2014).

The two sectors with highest LCA presence, namely Containers & Packaging and Personal & Household Goods, were documented as sectors of early application of LCA in the literature (Gloria et al, 1995; Berkhout, 1996; Hanssen, 1999; Hauschild et al, 2005). The EU directive on packaging and packaging waste promoted the use of a life cycle approach to compare different types of packaging (EC, 1994). The sectors Personal & Household Goods, Chemicals, and Forestry & Papers demonstrate a coincidence between high LCA presence in CS reports and product categories with highest numbers of eco-labelled products, such as paints and varnishes, tissues, copy and graphic paper, cleaning products, textiles, and rinse-off cosmetics (EC, 2018c). The relatively high LCA presence in CS reports in the Industrial Metal, Forestry & Papers and Chemical sectors also seem to coincide with initiatives for promoting and harmonizing the application of the LCA methodology in these industrial sectors (PWC and FPAC, 2010; WBCSD Chemical, 2014; PE International, 2014; Santero and Hendry, 2016).

A comparison of the LCA presence levels in CS reporting and the development of EPD for different sectors shows correlations of varying strengths. EPDs have recently been promoted in the building sector by the EU regulation No 305/2011 (EC, 2011; Ibanez-Forés et al., 2016) and this sector has shown a net increase of issued EPDs (Ibanez-Fores et al., 2016). This is reflected to some extent in the current study since the Construction & Materials sector presents a LCA presence of approximately 7% in CS reporting for the past 5 years, hence slightly higher than the average (see Table S3 in

Supplementary Results). The sector Food & Agricultural products is also an area where EPDs have recently become very popular (Ibanez-Fores et al., 2016), but in our study, the Food & Beverage sector only shows average LCA presence in CS reports (5.3%) for the period 2011-2015.

The differences observed between service and manufacturing sectors echo studies that reported a low utilization of LCA in the service sector (Graedel, 1997; Baumann, 1996; Sousa and Ometto, 2011). More recently in a survey of 800 large European companies, Chiarini (2014) found equal recognition of the value of the LCA methodology to support purchasing practices among service and manufacturing companies. Yet, such balance is not reflected in our findings, where service companies were found to refer considerably less to LCA than manufacturing companies, even in the most recent period (7% for manufacturing sector and 2% for service sector – see Table S4). The relatively low LCA presence in CS reports of sectors with high environmental impacts in their supply chains is consistent with findings from the Carbon Disclosure Project (CDP, 2016), which revealed that Scope 3 greenhouse gas emissions are underreported, notably for sectors associated with high indirect emissions. Unlike Scope 1 and 2 emissions, Scope 3 emissions can only be assessed by adopting a life cycle perspective (GHG Protocol, 2011).

5.2. Challenges and opportunities for LCA presence in CS reporting

Overall, the mapping revealed a rather weak presence of LCA in CS reports (around 5% in the most recent period) and large variations in company reporting over years. Hence, in spite of initiatives from industry associations and policy-makers promoting the use of LCA in industry, companies are rarely referring to LCA in their CS narratives.

This relative absence of LCA in CS reports may reflect that the companies do not work with LCA. Earlier studies have indeed indicated that LCA could be regarded as too costly, too complex or unreliable (Schaltegger, 1997; Cooper and Fava, 2006). It may also be related to a decision not to communicate about LCA, possibly because the topic is regarded as of low importance by the reporting company, is weakly advocated in CS reporting guidelines or is not requested by stakeholders (Searcy and Buslovich, 2014). GRI 4 reporting guidelines suggest the use of LCA as a tool to identify material issues, “which reflect the organization’s significant economic, environmental and social impacts”; or “substantively influence the assessments and decisions of stakeholders” (GRI, 2013), and to document energy requirements of products or services throughout their life cycle. Yet the LCA methodology is not emphasized further in the guidelines. The company-level mapping further revealed that companies who mention the LCA methodology do not do so continuously over time, thus indicating either a discontinuity in LCA activities at the company or a reprioritization towards other or new sustainability practices in CS reports, with the LCA methodology being removed because CS reports need to remain short enough (Searcy and Buslovich, 2014). Since the company may well continue LCA practices without reporting it, such findings indicate that LCA presence in CS reports may not be a good proxy for LCA utilization at the company.

The low LCA presence may also be explained by the fact that some LCA results are unfavorable to the business activities (Berkhout, 1996), not peer reviewed (Jensen et al., 1997) or deemed unsuited for the audience (Goedkoop et al., 2015; Testa et al., 2016). Omitting references to LCA in CS reporting due to unfavorable results could be motivated by the company's use of CS reporting to legitimize its business and manage its sustainability reputation (Hooghiemstra, 2000; Hahn and Kühnen, 2013). Single life-cycle impact indicators, like carbon footprint or water footprint, may also be preferred over more complex LCA results because they are simpler to communicate (Weidema et al., 2008; Molina-Murillo and Smith, 2009). Harmonized guidance on how to conduct LCA of specific products, as offered by the PEF guidelines in the EU (EC, 2018a), is an opportunity to facilitate the communication of product life cycle information by companies and may contribute to more referring to product LCA in CS reports.

The diversification of sustainability disclosures in CS reports, i.e. from a sole focus on environmental issues to a broad variety of sustainability aspects, may have caused LCA to drop in the CS reporting agenda in the period 1999-2007 because of its strong focus on the environment (Kolk, 2003; Hahn and Kühnen, 2013; Siew, 2015). In this perspective, life cycle methodologies allowing a broader coverage of sustainability aspects, such as life cycle sustainability assessment (including environmental life cycle assessment, social life cycle assessment and life cycle costing), could be beneficial (Finkbeiner et al., 2010). A check in the CS reports database revealed that references to social LCA, life cycle costing and life cycle sustainability assessment were nearly absent in the pool of CS reports (data not shown). These methodologies have not yet reached the same level of maturity as environmental LCA, and method developments and consensus efforts are still required for their consistent application (Finkbeiner et al., 2010; Zamagni, 2012; Guinée, 2016).

Although organization and product-level information coexist in CS reports, we have highlighted in Section 2.2 that organization-level disclosures dominate in the GRI reporting guidelines. In this perspective, developments of the LCA methodology for application to an organizational scope, including the UNEP guidance document (UNEP, 2015), the ISO 14072 standard (ISO, 2014) and the EU general and sectoral guidance documents for OEF (EC, 2016; 2018b) may play a key role in strengthening LCA application in CS reporting. Organizational LCA may suit the reporting needs of companies with large product portfolios better, although the increased complexity associated with tracking a large number of products and product families has also been highlighted (Martínez-Blanco et al., 2016). Quantitative indicators used in current CS reporting have in earlier studies been found to cover only part of the life cycle of corporate activities and to be defined at a flow-level rather than at an environmental impact level, e.g. in terms of waste, energy or material flows (Pflieger et al., 2005; Kaenzig et al., 2011). Hence, integrating organizational LCA in CS reports would require an important shift from current corporate environmental assessment practices.

Masanet and Chang (2014) who conducted a survey on 900 prospective users of LCA located in North America and mainly working in the private sector found that more than 60% had the intention to apply LCA in their professional decisions and around 35% indicated that they intended to apply LCA in corporate environmental reporting. Although such engagement cannot be observed in our results, future evolutions of the presence of LCA in CS reports seem worth tracking.

5.3. Recommendations for strengthening the presence of LCA in CS reporting

LCA methodology developers and proponents of its use by industry can play a key role in strengthening the presence of LCA in CS narratives by (i) providing detailed guidelines for presenting LCA activities in CS reports, (ii) expanding its utilization to the organizational scope, i.e. through organizational LCA, and (iii) understanding and addressing the reasons behind a lower presence of the LCA methodology in CS reporting of service sectors.

In order to broaden the use of the LCA methodology in CS reports, adjustments in existing reporting guidelines and requirements from policy-makers would also create meaningful drivers. The recognition of LCA as an indication of sustainability management practice in industry among investors or evaluation approaches of external ranking agencies could facilitate a wider use and dissemination of LCA. Hence, more emphasis should be put on the LCA methodology in external evaluation approaches of CS reporting. For example, in the EU, the sustainable finance action plan launched in 2018 requires companies to strengthen their non-financial information disclosures. A strong life cycle focus could be anchored in such initiatives to complement the current focus on applicability of the EU eco-label framework for financial products (EC, 2018d).

Finally, companies are generally recommended to explore the possible inclusion of the LCA methodology to document their environmental sustainability efforts in CS reporting, especially within service sectors, where the LCA presence in CS reports is low, albeit relevant owing to their high known environmental impacts through their supply chains (Rosenblum et al., 2000). Moreover, companies should be encouraged to make explicit reference to the LCA methodology in order to ensure terminology alignment and allow readers to put specific company practices into a broader perspective by benchmarking them against industry practices.

5.4. Limitations of the study

Due to limitations in the database used and associated search function, only CS reports – and not the companies – could be considered as units of analysis for the calculations of LCA presence in CS reports. Some companies release several CS reports per year, while others release biannual CS reports. The use of CS reports as unit of analysis therefore introduces biases between the sectors, regions or countries, in which many companies release several reports per year and mention LCA in all of them, and those in which many companies release several reports per year but do not mention LCA. However, in our study, the results are intended to show the overall presence of LCA in CS reporting across sectors, regions and countries at large, and we therefore consider it appropriate to use CS reports as a unit of analysis.

The focus on CS reports written in English specifically led to discarding companies only publishing in their national language, thus introducing a potential bias for non-English-speaking regions. For example, searches in the Corporate Register database showed that only 30% and 52% of all CS reports included in the database and released by companies with respectively headquarters in Spain and France were written in English. Similarly, the Corporate Register database contains a limited number of CS reports from Chinese companies (518 released in 1992-2015) although other academic studies report higher numbers of reports published by Chinese companies (Wang et al., 2017).

The present mapping relies on the identification of references to the LCA methodology in CS reports. However, the terminology used by companies to communicate about LCA is not harmonized and companies may mention LCA-related terms for assessments that only cover climate-related impacts, while others will refer to such assessments as “carbon footprints”. They may alternatively have developed tailored indicators strongly based on the LCA methodology and refer to them in their CS reports with no explicit reference to the LCA methodology, hence not captured in the mapping. This lack of terminology alignment may have generated some discrepancies in the identified CS reports mentioning LCA.

Furthermore, some difficulties were experienced in filtering LCA-mentioning CS reports using the content search tool available from the Corporate Register database. A number of reports could be identified as mentioning LCA-related terms while not appearing in the search results, thus leading to possible underestimations in the number of identified LCA-mentioning CS reports. Given the large number of retrieved CS reports (> 2300), this limitation is not expected to impact the observations and analyses performed in this study. Yet, caution should be exerted when addressing specific regions or sectors with very few listed CS reports, as these are more likely to be significantly influenced (due to low number of data points).

CS reports are a communication tool for companies, and earlier academic studies have shown that companies may use them to shape their corporate reputation and image, without reporting substantial activities to tackle their sustainability challenges (Deegan and Rankin, 1996; Hooghiemstra, 2000; Hrasky, 2011; Talbot and Boiral, 2018). In this perspective, the context around LCA references in CS reports needs critical analysis, although it was considered outside the scope of the present paper. In particular, future studies could focus on exploring the purpose and actual use of LCA as narrated in CS reports.

6. Conclusions and outlook

The present study constitutes a first attempt to analyze the presence of the LCA methodology in companies’ narratives of their sustainability efforts in CS reporting. The results show that: (i) the absolute number of LCA-mentioning CS reports has greatly increased over time, (ii) LCA presence (relative occurrence) in CS reports has decreased over time and now stabilized around 5%; (iii) there are geographical and sectoral variations, and LCA presence is weak in CS reports of service companies; (iv) LCA presence in CS reports is variable across years at the level of individual companies. The visibility of the LCA methodology in CS reports, and hence in companies’ narratives of their sustainability efforts, needs strengthening, considering the recognition of the LCA methodology to guide sustainability efforts at companies. In this perspective, guidelines on how to document the application of the LCA methodology in CS reports, as well as a stronger focus on the LCA methodology in CS reporting guidelines, requirements from policy-makers, and expectations from investors and ranking agencies seem particularly needed.

To take this first study further, avenues for future research can be framed and prioritized according to three main directions. First, the relatively descriptive approach undertaken in the current study should be complemented by future statistical analysis testing the influence that additional factors, such as the use of reporting guidelines or the position of the company in the value chain, exert on the LCA presence in CS reports. Second, there is a need to survey companies about their motivations or lack thereof to refer to LCA in CS reporting, and to better understand the impact that various initiatives promoting LCA adoption in industry may have on reporting practices. Third, the specific references to LCA in CS reports need deeper investigation through reviews of the reports to see what information companies actually report with regard to LCA. This latter point will be addressed in a sequel paper (Stewart et al., in preparation).

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Supplementary Information

This document contains:

Supplementary Methods

Table S1. Concordance between sectors used in this study, sectors used in GreenBiz (2015) and ICB classification sectors (ICB, 2017).

Sectors used in this study	ICB structure	Sectors from GreenBiz (2015)
Aerospace & Defense	2710 Aerospace & Defense	Industrial Goods & Services
Automobiles & Parts	3300 Automobiles & Parts	Automobiles & Parts
Chemicals	1350 Chemicals	Chemicals
Construction & Materials	2300 Construction & Materials	Construction & Materials
Containers & Packaging	2723 Containers & Packaging	Industrial Goods & Services
Diversified Industrials	2727 Diversified Industrials	Industrial Goods & Services
Electricity	7530 Electricity	Utilities
Electronic & Electrical Equipment	2730 Electronic & Electrical Equipment	Industrial Goods & Services
Finance	8300 Banks; 8700 Financial Services	Financial Services
Food & Beverage	3500 Food & Beverage	Food & Beverage
Forestry & Paper	1730 Forestry & Paper	Basic Resources
Gas, Water & Multi-utilities	7570 Gas, Water & Multi-utilities	Utilities
Health Care Equipment & Services	4530 Health Care Equipment & Services	Healthcare
Industrial Machinery	2750 Industrial Engineering	Industrial Goods & Services
Industrial Metals	1750 Industrial Metals & Mining	Basic Resources
Industrial Transportation	2770 Industrial Transportation	Industrial Goods & Services
Insurance	8500 Insurance	Insurance
Media	5500 Media	Media
Mining	1770 Mining	Basic Resources
Oil & Gas	0001 Oil & Gas	Oil & Gas
Personal & Household Goods	3700 Personal & Household Goods	Personal & Household Goods
Pharmaceuticals & Biotechnology	4570 Pharmaceuticals & Biotechnology	Healthcare
Real Estate	8600 Real Estate	Real Estate
Retail	5300 Retail	Retail
Software & Computer Services	9530 Software & Computer Services	Technology
Support Services	2790 Support Services	Industrial Goods & Services
Technology Hardware & Equipment	3570 Technology Hardware & Equipment	Technology
Telecommunications	6000 Telecommunications	Telecommunications
Travel & Leisure	5750 Travel & Leisure	Travel & Leisure

Table S2. Categorization of sectors used in the study according to business activity and customer type. The division between B2B/B2C and between Manufacturing/Service sectors was performed based on the description provided for the ICB structure. When it was unclear whether a sector belongs to either category, it is included to a category "other". B2B: Business-to-business; B2C: Business-to-consumer.

	Business activity type			Customer type		
Sector	**Manufact.** [1]	**Service**[2]	**Unclear**	**B2C**	**B2B**	**Unclear**
Aerospace & Defense	X				X	
Automobiles & Parts	X			X		
Chemicals	X				X	
Construction & Materials	X					X
Containers & Packaging	X					X
Diversified Industrials			X		X	
Electricity			X			X
Electronic & Electrical Equipment	X				X	
Finance		X				X
Food & Beverage	X			X		
Forestry & Paper	X				X	
Gas, Water & Multi-utilities			X			X
Health Care Equipment & Services			X			X
Industrial Machinery	X				X	
Industrial Metals	X				X	
Industrial Transportation		X			X	
Insurance		X				X
Media		X		X		
Mining	X				X	
Oil & Gas			X			X
Personal & Household Goods	X			X		
Pharmaceuticals & Biotechnology			X			X
Real Estate		X				X
Retail		X		X		
Software & Computer Services		X				X
Support Services		X			X	
Technology Hardware & Equipment	X					X
Telecommunications		X				X
Travel & Leisure		X		X		

[1]*Manufactured goods are physical objects whose characteristics are maintained over time, that are exchangeable, can be owned but exist independently from their owner (Parry et al, 2011) and include e.g. food products, machinery and equipment, textiles (OECDb, 2017).*

[2]*Services are usually characterized as intangible, heterogeneous, inseparable and perishable (Parry et al, 2011) and include e.g. retail trade, restaurants, financial intermediation (OECD, 2017a).*

Construction of sample for quality check

Sample size

We used the formula defined in Naing et al. (2006) to estimate the required sample size – see Equation S1:

$$Sample\ size = \frac{NZ^2 p(1-p)}{e^2(N-1)+Z^2 p(1-p)} \text{ (Eq. S1)}$$

Population size: N=2367 corporate sustainability (CS) reports

Confidence level: 95%

Z-score (95% confidence) = 1.96

Margin of error (confidence interval): e=5%

Expected proportion: p=0.5 (it is the most conservative assumption, when lack of previous knowledge about the population)

The formula gives a sample size of 331 CS reports.

Sample stratification

First, we calculated the proportion of each sector in the total population of CS reports and deduced the number of CS reports that should proportionally be included in the sample. For example, the Automobile & Parts sector represents 7% of CS reports, thus 24 out of the 331 required reports were to be included in the sample. Within sectors, CS reports were chosen randomly using the random function in Excel to constitute a first sample version.

Second, the proportion of each region and LCA-related term in the total population of CS reports were calculated and compared with their proportion in the first sample version. Both for LCA-related terms and regions, the proportions were overall respected. It was also verified that all years are represented in the sample. Reports published in 1995 and 1996 had to be added. Removed CS reports were chosen among those that were published by a same company.

Supplementary Results

Table S3. Sectoral LCA presence rates in corporate sustainability (CS) reports for the periods 1995-2000 to 2011-2015

	LCA presence rates in CS reports			
SECTOR	**1995-2000**	**2001-2005**	**2006-2010**	**2011-2015**
Aerospace & Defense	50.0%	2.8%	2.9%	4.8%
Automobiles & Parts	35.0%	21.7%	14.2%	5.3%
Chemicals	14.9%	9.2%	5.7%	8.8%
Construction & Materials	16.0%	7.7%	5.6%	6.6%
Containers & Packaging	100.0%	17.6%	29.4%	24.4%
Diversified Industrials	16.7%	14.1%	5.5%	4.5%
Electricity	6.4%	5.5%	2.4%	2.1%
Electronic & Electrical Equipment	65.5%	19.8%	9.1%	6.0%
Finance	3.2%	0.5%	0.1%	0.6%
Food & Beverage	18.2%	5.6%	6.6%	5.3%
Forestry & Paper	17.2%	4.7%	4.5%	8.6%
Gas, Water & Multi-utilities	13.6%	2.0%	1.6%	1.5%
Health Care Equipment & Services	9.1%	4.6%	2.2%	0.7%
Industrial Machinery	56.5%	21.8%	9.0%	5.4%
Industrial Metals	28.6%	16.3%	5.3%	9.7%
Industrial Transportation	2.9%	3.5%	1.0%	0.7%
Insurance	0.0%	3.1%	0.3%	0.0%
Media	25.0%	9.3%	4.7%	1.4%
Mining	4.2%	5.9%	2.5%	1.1%
Oil & Gas	11.6%	4.1%	2.7%	1.6%
Personal & Household Goods	33.3%	10.2%	12.6%	13.5%
Pharmaceuticals & Biotechnology	4.0%	5.3%	2.6%	2.8%
Real Estate	0.0%	3.5%	1.1%	2.5%
Retail	5.6%	0.5%	2.2%	2.4%
Software & Computer Services	100.0%	6.3%	2.9%	1.8%
Support Services	0.0%	4.7%	3.7%	3.7%
Technology Hardware & Equipment	22.0%	22.2%	9.1%	6.2%
Telecommunications	22.2%	4.2%	1.8%	1.4%
Travel & Leisure	0.0%	3.5%	1.7%	1.1%

Table S4. Number of LCA-mentioning (column "YES" in the table) and non-LCA-mentioning corporate sustainability reports (column "NO" in the table) in sector categories for the full time period and the four subsets of the time period, respectively 1995-2000, 2001-2005, 2006-2010 and 2011-2015.

		All years		**1995-2000**		**2001-2005**		**2006-2010**		**2011-2015**	
Business activity	**Customer type**	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**
Manufacturing	B2C	587	5422	27	62	99	675	182	1522	279	3163
Manufacturing	B2B	804	10093	66	243	223	1715	206	3382	309	4753
Service	B2C	76	3260	4	29	13	356	27	1021	32	1854
Service	B2B	160	5960	1	39	24	586	44	1755	91	3580

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Article II

Life cycle thinking in the Nordic apparel industry: a review of corporate sustainability reports

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Draft manuscript

Life cycle thinking in the Nordic apparel industry: a review of corporate sustainability reports

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1. Introduction

As part of the global agenda set by the United Nations (UN) Sustainable Development Goals (SDGs), radical changes in our production and consumption systems are needed to tackle environmental sustainability challenges such as climate change and resource depletion (UN, 2015). Ranked as the fourth most environmentally-damaging area of consumption in the EU-27, the apparel (or clothing) industry drives various environmental problems ranging from the intense use of water and pesticides for cotton production, to pressure on water systems through the release of chemicals in wet treatments and garment care (EEA, 2014). The sector was estimated to account for 2-10% (depending on the impact considered) of environmental impacts caused by the EU-27 consumption (EEA, 2014). World-wide clothing sales have doubled in the past fifteen years and demand for clothes rapidly grows in developing countries (EMF, 2017). Faster wardrobe renewal is associated with increasing underutilization of garments and intensified disposal practices (Kozlowski et al., 2012, EMF, 2017). Clothing is a key economic sector with an estimated global apparel and footwear revenue of €1.5 trillion in 2016 and associated 60 million jobs along the value chain (Global Fashion Agenda (GFA) and Boston Consulting Group (BCG), 2017). Clothes are omnipresent in our daily lives and fulfill various human needs ranging from basic protection to identity building and expression (EMF, 2017; Roos et al., 2017). Transitioning towards sustainable clothing systems is thus a key challenge to be addressed in the coming decades.

Our current understanding of sustainability, as a property of a system rather than of elements of the system, ultimately requires addressing sustainability issues at a socio-technical system level (Ceschin and Gaziulusoy, 2016). Yet, a deep understanding of environmental sustainability impacts associated with products, and their associated life cycles (LC), is a critical basis for envisioning new ways customers' needs can be fulfilled (Ceschin and Gaziulusoy, 2016). This is the main idea behind Life Cycle Thinking (LCT) which requires "going beyond the traditional focus on production site and manufacturing processes [of environmental management] to include environmental, social and economic impacts of a product over its entire life cycle" (Life Cycle Initiative, 2018). LCT is typically operationalized into LC-based assessment methodologies, such as carbon footprint or life cycle assessment (LCA) (ISO, 2006). LCT can further be viewed as a "shared worldview" of environmental management which structures and guides our understanding of environmental sustainability issues (Heiskanen, 2002; Pennington et al., 2007; Sala et al., 2013). There are indications that practitioners in the clothing sector use LCT in the form of LC-based assessments (Van der Velden et al., 2014). Textiles were one of the pilot product categories for the development of the LCA-based Product Environmental Footprint guidance, and a LC perspective is strongly anchored in the metrics developed by the Sustainable Apparel Coalition initiative joined by the major apparel companies across the world (Kozlowski et al., 2015; Roos et al., 2017). Yet, the extent to which apparel companies build on LCT to develop their sustainability strategies remains unclear.

As part of their sustainability efforts, more and more large companies release Corporate Sustainability (CS) reports in which they inform their stakeholders about the way they currently do and plan to handle the sustainability challenges associated with their business (KPMG, 2017). Whether they are symbolic communications or representative of actual changes in business practices (Burrit and Schaltegger, 2010), narratives presented in CS reports reveal how companies understand that *"their environmental strategies should be "best" presented*", and what they consider *"their key messages"* for the reported period (Mikler, 2007, p. 14). In this context, the present study aims to explore the extent to which LCT is present in apparel companies' narratives of sustainability approaches as described in their CS reports.

The focus of the study is set on the Nordic apparel industry. Although the Nordic region remains a minor player globally, it is an important exporter of clothes with international players, among which one of the sector leaders H&M (Nordic council of ministers, 2015). The clothing industry has attracted the attention from the Nordic Council of Ministers who has stated an ambition to *"lead the way in sustainable design, consumption and production"* (Nordic council of ministers, 2015). This industry has been at the core of several initiatives, e.g. the Nordic prime ministers' green growth project on reducing textile waste and the LAUNCH Nordic project on developing sustainable materials focusing on clothes in 2014 (Nordic council of ministers, 2015). The Nordic countries have been suggested to have rather mature sustainability approaches both at country and company level (Strand et al., 2015). Nordic CS reports were found with relatively high presence of references to the LCA methodology (Stewart et al., 2018). In this context, the Nordic apparel industry can be expected to provide a relevant case for investigating LCT in sustainability approaches. The focus on a single industry and region allows for certain homogeneity in the institutional and cultural background (Gallego-Alvarez & Ortas, 2017; Ferri, 2016).

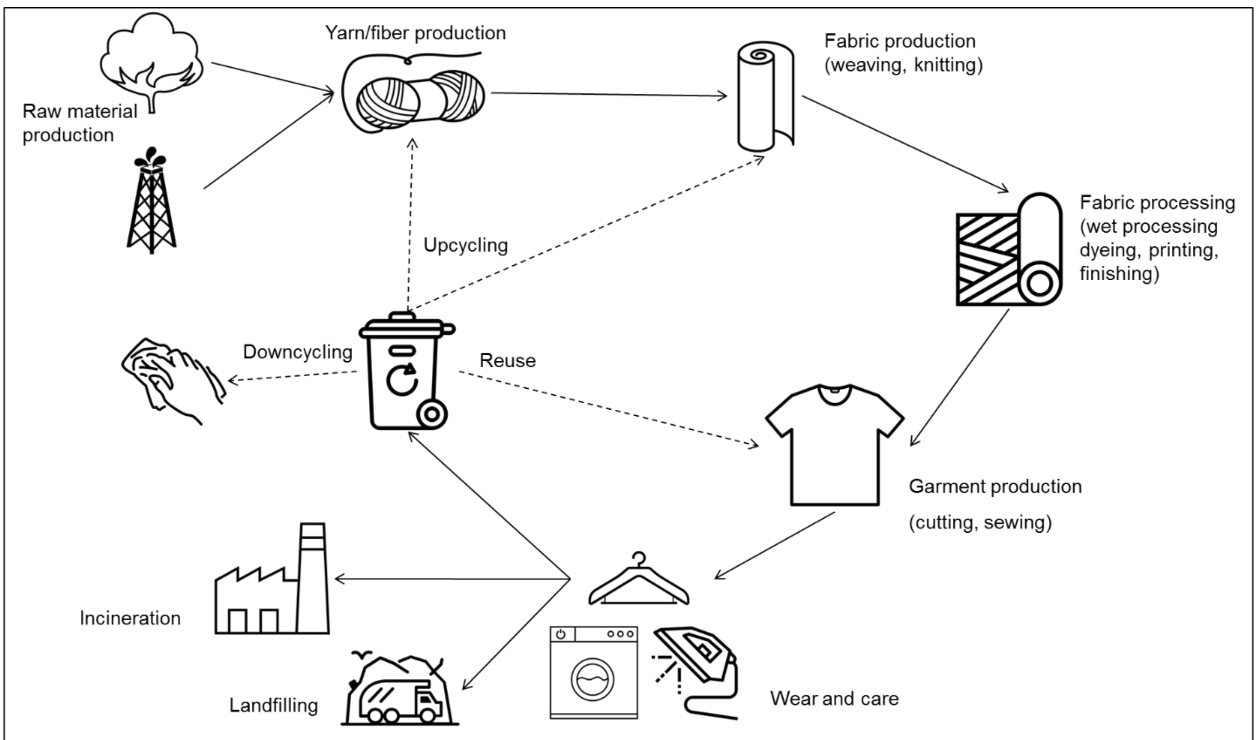
In the remainder of this article, first we introduce the conceptual background and set out the research questions in Section 2. In Section 3, we describe the methodology used to analyze CS reports of the Nordic apparel industry. In Section 4, we present our findings, before discussing and outlining the implications and limitations of our study in Section 5.

2. Conceptual background and research questions

In this section, we introduce further the concept of LCT and single out four different elements - product LC system, hotspots in the LC, tradeoffs in the LC and across environmental problems, and product environmental sustainability budget, which will be in focus in our study. We illustrate them in the case of garments and develop four associated research questions.

2.1. Product life cycle system

At the core of LCT is the convention that *“the environmental burden of a product equals the sum of environmental burdens of processes constituting the product system, which is made of physically and energetically linked processes and extends from raw materials acquisition to final disposal”* (Heiskanen, 2001, p. 36). This set of “*processes required to deliver [its] function*” is called the product LC system (Bjørn et al., 2018, p.12). In the case of garments, the product LC system can be decomposed into the following stages: raw materials (fossil-based or plant-based), fiber/yarn production, fabric production (knitting or weaving), fabric processing (e.g. wet processing, printing and dyeing), garment production (cutting and sewing), distribution, retailing, use (wear and care) and end-of-life (landfilling, incinerating, reuse, and recycling) (Beton et al., 2014; Muthu, 2015; Sandin and Peters, 2018). In the EU clothing market, cotton and polyester represent respectively 43% and 16% in weight (Beton et al., 2014). In the EU, 80% of garments are channeled towards landfill or incineration at their end-of-life (GFA and BCG, 2017). There are large disparities across countries with for instance in Germany more than 70% of disposed clothes collected for recycling, whereas in Finland and Norway most textile waste is incinerated with energy recovery (Laitala and Klepp, 2015; Dahlbo et al., 2017; EMF, 2017).



Icons from the Noun Project: Cotton by 1516; Oil by Ale Estrada; Yarn by Mick Geerits; Fabric by Karkki; Fabric by Ben Davis; Tshirt by Deemak Daksina; hanger by Nook Fulloption; Iron by Massupa Kaewgahya; Laundry by Bestdesignmarket; Landfill by Drew David Park; Power Plant by Ahock; wipe by Blair Adams; recycling by Creaticca Creative Agency.

Figure 1. The garment’s life cycle, based on Beton et al. (2014), Muthu (2015) and Sandin and Peters (2018).

The first research question to operationalize our analysis of LCT in companies' narratives relates to the idea of product life cycle system:

- **RQ1: To what extent is the product life cycle system addressed in Nordic apparel companies' narratives of their sustainability approaches?**

2.2. Hotspots in the life cycle

As part of LCT, the contributions of different LC stages, and related processes, to the environmental sustainability impacts of a given product are typically investigated in order to identify significantly impacting processes, and prioritize resource allocation on relevant improvement strategies (EU JRC, 2010; Hauschild, 2015; Barthel et al., 2015; Dyllick and Rost, 2017). This corresponds to the identification of hotspots in the LC defined as *"a LC stage, process or elementary flow which accounts for a significant proportion of the impact"* (Barthel et al., 2017). In the case of the apparel sector, an LCA of the EU-27 consumption of textiles (of which 70% are clothes) showed that garment production and use stage drive the LC environmental impacts (Beton et al., 2014). Within fabric production, spinning and weaving are reported as highly energy-demanding, while wet treatments involve the use of substance of concern and are associated with pressure on and pollution of local water systems, as well as issues of chemical exposure for consumers (Resta et al., 2016; Desore and Narula, 2017). Washing frequency and temperature, machine load and the choice to tumble-dry and/or iron clothes were factors found to greatly influence the environmental sustainability performance in the use stage (Chapman, 2010). Yet, depending on assumptions on consumer behaviors and type of garments, the relative contribution of the use stage to the LC environmental impacts may vary (Van der Velden et al., 2014; Muthu, 2015).

The second research question to operationalize our analysis of LCT in companies' narratives relates to the idea of hotspots in the life cycle:

- **RQ2: To what extent are hotspots in the product life cycle system addressed in Nordic apparel companies' narratives of their sustainability approaches?**

2.3. Tradeoffs in the product life cycle system and across environmental problems

The identification of possible tradeoffs or burden-shifting, i.e. the shift of environmental impacts from one LC stage to another, or from one environmental problem to another introduced by a modification in the product LC system, is core to the concept of LCT (EU-JRC, 2010). A given strategy to mitigate impacts in the raw material stage, e.g. shifting to a raw material with better environmental performance, might increase environmental impacts in the production or disposal stage, thus resulting in a tradeoff and possibly making it a worse option overall. Burden-shifting may also occur between environmental problems, e.g. a solution to mitigate the carbon footprint of a given product may introduce the use and emission of chemicals that cause an increase in toxicity impacts on humans. Hence, shedding light on these possible tradeoff situations is critical for informing product environmental sustainability approaches. In the case of garments, tradeoffs can for example be found between different types of fibers. A qualitative scoring model provided to the Department for

Environment, Food and Rural Affairs (DEFRA) classified acrylic as the most energy demanding, cotton as the most water-demanding, nylon as the most contributing to climate change, and wool as the most contributing to waste water and land use (Turley et al., 2009). The comparison of fibers (by units of mass) in Beton et al. (2014) found that nylon and acrylic fabric were found to perform worse for climate change, while for freshwater eco-toxicity, cotton fabric was found the most impacting fiber.

The third research question to operationalize our analysis of LCT in companies' narratives relates to the idea of tradeoffs in the life cycle and across environmental problems:

- **RQ3: To what extent are tradeoffs between different options in the product LC system addressed in Nordic apparel companies' narratives of their sustainability approaches?**

2.4. Product environmental budget

LCT has traditionally been applied to identify eco-efficiency gains, i.e. how a given function can be delivered with a lower environmental impact (Hauschild et al, 2015). Yet, the need to develop "eco-effective products", i.e. with a net benefit for the society rather than a lower negative environmental impact, has been emphasized (Dyllick and Rost, 2017). Recent developments in the LCT literature aim at addressing the idea of Earth's ecosystems' source and sink limited capacities, and accommodating it in LCAs of product systems' performance (Hauschild, 2015; Ryberg et al., 2016; Ryberg et al., 2018; Kara et al., 2018). Using the Planetary Boundaries framework developed by Rockström et al. (2009) which includes thresholds for nine control variables not to be overpassed in order to remain within Earth's safe operating space, these approaches introduce the idea of an environmental sustainability budget, i.e. the share of acceptable environmental impact to maintain Earth's life support functions (Hauschild, 2015). The idea of ecological limits for Earth's ecosystems has just started to be addressed in the apparel sector. Sandin et al. (2015) and Roos et al. (2017) attempted to translate the related Planetary Boundary framework into reduction targets for the different environmental impacts associated with the clothing sector. Ryberg et al. (2018) applied a Planetary Boundary-based LCA to the case of laundry washing in the EU in order to estimate the absolute sustainability of laundry washing in the EU, and were able to measure the sustainability gap between proposed scenarios and required performance to remain within the Planetary Boundaries.

The fourth research question to operationalize our analysis of LCT in companies' narratives relates to the idea of product environmental budget:

- **RQ4: To what extent is the idea of product environmental budget addressed in Nordic apparel companies' narratives of their sustainability approaches?**

3. Methodology

3.1. Data collection

All companies in the apparel sector and with headquarters in a Nordic country (i.e. Denmark, Sweden, Norway, Iceland and Finland) which released an English-written CS report in 2016 were included in the sample. In order to identify such companies, the Corporate Register (CR) database was used (CR, 2018). It is the largest commercially available online database of CS reports, with ca. 97,000 CS reports (CR, 2018), previously used by other scholars for similar purposes (Hrasky, 2011; Roca and Searcy, 2012; Bjørn et al., 2017). It includes any type of sustainability reports in Latin-script, e.g. integrated report, sustainability and environmental reports (CR, n.d.). The worldwide coverage of reporting companies is evaluated by the database developers to be more than 90% (CR, n.d.). In August 2017, we identified all companies with headquarters in Denmark, Norway, Sweden, Iceland and Finland companies in the apparel industry for which the CR database contained a report released in 2016 (year indicated in the CR database). The resulting 15 companies are shown in Table 1. No companies located in Norway and Iceland could be found to fit the sample criteria. The titles of the corresponding CS reports are displayed in Table S1. We chose not to limit the sample of reports to those following specific standards. This opened up for more variability in the selected CS reports which could be problematic to compare CS performance across companies. For the present research, this is not an issue since we do not compare performance; else we intend to collect the companies' description in their own words of their sustainability work. Yet, possible influence from chosen guidelines will be a point for discussion.

Table 1. List of companies included in the empirical study (Nordic apparel companies with CS report published in English in 2016). GRI = Global Reporting Initiative; UN = United Nations; SE = Sweden, DK = Denmark, FI = Finland.

Company	**Country**	**Size***	**Firm type****	**Reporting guidelines**	**Report length (A4 pages)**
Lindex	SE	Large	Specialty apparel retailer	GRI G4	70
Filippa K	SE	Large	Specialty apparel retailer	None	76
Bestseller	DK	Large	Specialty apparel retailer	None	99
Björn Borg	SE	Medium	Brand marketer	None	32
Gina Tricot	SE	Large	Specialty apparel retailer	GRI G4	40
H&M	SE	Large	Specialty apparel retailer	GRI G4	130
IC Group	DK	Large	Brand marketer (several brands)	UN Global Compact	12
KappAhl	SE	Large	Specialty apparel retailer	GRI G4	58
Mini Rodini	SE	Medium	Brand marketer (kids)	None	34
Modström	DK	Small	Brand marketer	UN Global Compact	8
MQ Retail	SE	Large	Specialty apparel retailer (also external brands)	None	44
Oriental Import Export	DK	Small	Design and production for brand owners	None	17
PompdeLux	DK	Medium	Brand marketer (online retail only)	UN Global Compact	11
Spectre	DK	Large	Production for brand owners	None	10
Marimekko	FI	Large	Brand marketer	GRI G4	49

*Large= more than 250 employees, Medium=between 50 and 250 employees, Small=fewer than 50 employees
** Firm type according to Fernandez-Stark et al. (2011): Brand marketer = Firm which owns the brand name but not manufacturing with products are sold at a variety of retail outlets; Specialty apparel retailer = Retailer which develops proprietary label brands that commonly include the stores' name.

3.2. Data analysis

In order to answer the four research questions, we systematically reviewed the content of CS reports using content analysis, which is a common method to analyze textual data in business studies (Kohlbacher, 2006; Duriau et al., 2007). Each research question relates to one specific element which is defined in Table 2: (i) product LC system, (ii) hotspots in the product LC, (iii) tradeoffs in the product LC and across environmental problems, and (iv) product environmental sustainability budget. In order to analyze CS reports, we used a combination of deductive and inductive approaches which was particularly suited for the explorative nature of our study (Hsieh & Shannon, 2005).

Table 2. Elements in focus in the study corresponding to the four research questions, their definitions and associated initial/deductive categories.

Element in focus	Definition	Initial/Deductive categories
Product life cycle system (RQ1)	All required processes to deliver the function of a product, from raw materials to final disposal, and which contribute to the total environmental sustainability impact of the product.	• Representation of the product LC (S1) • Explicit definition of the product LC (S2) • Explicit consideration of product LC in the environmental sustainability strategy of the company (S3) • LC stage addressed by operational practices (raw material, fabric production and processing, garment production, transportation, stores/offices, use, end of life) (S4)
Hotspots in the product LC (RQ2)	Processes in the product LC system which significantly contribute to the system's environmental sustainability impacts.	• Practice of analyzing hotspots in the LC to guide the environmental sustainability approach (H1) • Highlight hotspot processes relatively to other processes in product LC (H2) • Quantify contributions to environmental impacts throughout the LC (H3)
Tradeoffs in the product LC and across environmental problems (RQ3)	Shift of environmental sustainability impact from one LC stage to another, or from one environmental issue to another, revealed when comparing alternative options.	• Practice of identifying possible tradeoffs in the LC to guide the environmental sustainability approach (T1) • Highlight possible tradeoffs associated with alternative solutions for products (T2) • Quantify tradeoffs between different options (T3)
Product environmental sustainability budget (RQ4)	Account for Earth's ecosystems' source and sink limited capacities in the evaluation of the product system's environmental sustainability performance, i.e. assessment against absolute threshold.	• Practice of assessing absolute environmental sustainability impact of products to guide the environmental sustainability approach (B1) • Highlight ecological limits in relation with products (B2) • Quantify absolute environmental sustainability impact of products (B3)

The deductive approach relates to our use of an initial set of categories for each element, as presented in Table 2. These categories were developed based on initial reflections on the form(s) in which each element in focus of our analysis could be present in companies' narratives. For the product LC system, we could expect graphical representation (S1) or formal definition in the text (S2). Presence of the product LC system in companies' descriptions of the scope of their sustainability strategy (S3) and actual practices spanning the different product LC stages (S4) were also added as initial categories. For the other three elements (hotspots, tradeoffs and budget), we could initially expect (i) their consideration in designing sustainability approaches (H/T/B1), (ii) references in CS reports to specific hotspots, tradeoffs and ecological limits (H/T/B2) and/or (iii) their quantifications in CS reports (H/T/B3).

For each CS report, based on a thorough reading of the full report, we identified so-called "meaning units" associated with each LCT element. Meaning units are defined as *"words, sentences or paragraphs containing aspects related to each other through their content and context"* (Graneheim and Lundman, 2004). These meaning units were organized under the deductive categories, or under additional categories, inductively added based on the data found in CS reports. The inductive approach allowed for capturing information which was not expected before starting the analysis, and hence enhanced the validity of the analysis. Inductive categories are introduced in Section 4. The full list of meaning units is provided in Supplementary Information, Table S1, with the associated categories. One example of extracted meaning unit for each category (both deductive and inductive) can be found in Table A1. For the category S4, we conducted a mapping of sustainability operational practices affecting the following LC stages: raw material, fabric production and processing (in contrast with Figure 1, fiber/yarn production, fabric production and fabric processing were considered as one LC stage as distinction between the three difficult to grasp from companies' narratives), garment production, use (i.e. wear and care), and EOL. The results of the mapping can be seen in Table A2.

4. Results

4.1. Product life cycle system (RQ1)

The overall results from the content analysis for RQ1 are presented in Table 4. The product LC system was found present in most CS reports under different forms and explicit to different extents. Six companies visually displayed their product LC (Marimekko, Björn Borg), garment processes (Lindex) or value chain (H&M, KappAhl, Spectre) (S1). Most companies (4 out of 6) presented the product LC in a circular manner, while others displayed it as a flow chart (Table 3). Apart from Spectre, all companies included stages spanning from raw materials to end-of-life of their products, using different LC stage terminology (e.g. "value chain" or "garment processes"). Björn Borg's and KappAhl's CS reports were respectively fully and partly organized according to the LC stages and value chain stages. Björn Borg provided an explicit definition of its product LC in the text (S2): *"The natural starting point for Björn Borg's sustainability programs is the product lifecycle – the various stages involved in producing and marketing products, followed by the user phase by the consumer. The product lifecycle describes Björn Borg's operations based on which stakeholders are affected and the impacts on the environment and society through the value chain".*

For five companies, the sustainability work was explicitly indicated to be designed around the LC (Björn Borg, IC Group, Marimekko), value chain (H&M, KappAhl, Lindex), or expressed to cover the companies' value chain both upstream and downstream (Bestseller, Gina Tricot) (S3). For instance Björn Borg stated that "*the company's sustainability program is structured around the product* *lifecycle";* KappAhl indicated that "*the sustainability strategy is developed on the basis of challenges we see in our value chain*"; H&M claimed that *"[it] want[s] to "use [its] scale to bring about systemic change to the industry and across the lifecycle of [its] products"*; Marimekko committed to "*develop products and services which have a reduced environmental impact throughout their life cycle"*. Bestseller stated "*we work with suppliers to optimize our production processes and minimize the negative impact of our production on the environment. We engage with our customers to influence their consumption patterns and minimize the negative impacts of using and disposing of our products"* and Filippa K explained that "*to ensure long-term sustainable success [they] must have a holistic view of [their] business, understand how all parts interact and make sure [their] value chains are long-term sustainable."*

Table 3. Terminology used in CS reports displaying graphical representation of their product life cycle or value chain.

Companies	Terminology for life cycle	Terminology for life cycle stages
Spectre	Value chain (linear representation)	Raw materials, fabric/trim producers, suppliers/agents, transport, Spectre, transport, customers/distribution
Marimekko	Life cycle (linear representation)	Design and materials, sourcing and production, logistics, stores, use and care of products
H&M	Value chain (linear and circular representation)	Design, raw materials, fabric and yarn production, garment production, sales, use (and recycle and reuse, added in the circular representation).
KappAhl	Value chain (circular representation)	Design and purchasing, production, logistics, sales, consumption
Lindex	Garment processes (circular representation)	Design, raw materials, fabric mill, garment production, transportation, store, use, reuse and recycle (landfill is presented as an option to be avoided)
Björn Borg	Life cycle (circular representation)	Design and material, manufacture of fabrics, manufacture of garments, packaging and shipping, own operations and user phase

Ten companies expressed their ability to influence LC environmental impacts through design (S5 – inductive category). For example, Marimekko explains that "*the choice of materials affects directly the product's lifecycle environmental impacts. The material largely determines the durability of the product and the consumption of energy and detergent needed for product care";* KappAhl indicated that "*studies show that more than 80 per cent of a product's impact on the environment is already determined at the design stage. The materials we use, how we construct our patterns and how we intend the garments to be used influence the garments' total environmental impact";* and Filippa K explained that *"by examining every aspect – from the choice of materials to how our customers use and care for their garments until they finally reach their end of life – we learn how to do things right already at the drawing table".*

The distribution of sustainability-driven operational practices throughout the different product LC stages (S4), as visible in Table 4 (and detailed in Table A2), further revealed that even though no direct reference to the product life cycle is made by apparel companies in their CS reports, the analysis of Mini Rodini, Modström, and MQ Retail's environmental sustainability efforts revealed that these companies take a LC perspective. Nevertheless, the LC perspective was found incomplete in the CS reports of Oriental and PompdeLux with no reference to the use and end of life stages.

Table 4. Results from the content analysis for RQ1. Categories marked with an asterisk were inductively derived from the CS reports. Note, that for the coverage of LC stages, cells are colored in dark grey, if the company reports practice(s) related to this LC stage; and in light grey, if the practice related to the LC stage is reported as under consideration at the company.

	Categories	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
S1	Graphical representation of the product LC	■			■		■		■						■	■
S2	Explicit definition of the product LC				■											
S3	Consideration of product LC in the sustainability strategy of the company	■	■	■	■	■	■	■	■							■
S4	LC stage addressed by operational practices:															
	Raw material	■	■	■	■	■	■	■	■	■	■	■		■		■
	Fabric production and processing	■	■	■	■	■	■	■	■	■	■	■	■	■		■
	Garment production	■	■	■	■	■	■	■	■	■	■	■	■	■	░	■
	Transportation	■	■		■	■	■		■	■	■	■	■	■		■
	Packaging	■		■	■	■			■	■	■					■
	Stores/Offices	■	■	■	■	■	■		■	■	■	■	■	■		■
	Use		■	■	■	■	■	■	■		■	■				■
	End of life	■	■	■	░	■	■		■	░						■
S5	Possibility to influence product LC impacts through design*	■	■		■	■	■	■	■	■		■				■

Although the use stage was considered by most companies (10) in their sustainability efforts, operational practices addressing the use stage mainly focused on delivering information to consumers about best care practices; exception is Filippa K who indicated allowing consumers to lease its collection and having co-developed environment-friendly detergent and fabric softener. Few companies indicated their attempt to design long lasting garments, garments for attachment or timeless garments (Filippa K, Björn Borg, MQ Retail and Marimekko); yet, little emphasis is put on more in-depth understanding of actual lifetime of garments in consumers' wardrobes. Sustainability operational practices covered the end-of life stage very limitedly, and companies referred to difficulties stemming from the current lack of collection, sorting and recycling infrastructure and capabilities (Lindex, Björn Borg, Gina Tricot, H&M, KappAhl and Marimekko). A subset of companies indicated their willingness to influence current waste management systems through creating more demand for recycled material and investing in recycling technology development (Lindex and H&M) or through developing partnerships to develop new collection, sorting and recycling infrastructure (Gina Tricot, H&M, Filippa K and KappAhl).

4.2. Hotspots in the product life cycle (RQ2)

The overall results for RQ2 are presented in Table 5. Most companies indicated processes particularly impacting the environment in general (H4 – inductive category): e.g. cotton production (Björn Borg, MQ Retail, Bestseller, Gina Tricot, H&M and Lindex), denim production (Gina Tricot, Lindex and H&M), laundering (Gina Tricot), leather production (H&M, IC Group and Marimekko), chlorine wash treatment and the use of fluorocarbon (Mini Rodini), and production of viscose in terms of deforestation (KappAhl, H&M, Lindex). Both Gina Tricot and KappAhl emphasized that the actual short lifetime of garments is a hotspot in the life cycle as it is associated with wardrobe renewal practices and intensified use of resources.

Table 5. Results from the content analysis for RQ2. Categories marked with an asterisk were inductively derived from the CS reports.

	Categories	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach				■		■	■	■							
H2	Highlight hotspot processes relatively to other processes in product LC				■	■	■	■	■							■
H3	Quantify contributions to environmental impacts throughout the LC				■		■		■							
H4	Highlight processes particularly impacting in general*	■		■	■	■	■	■	■	■		■				■

As displayed in Table 7, six companies singled out hotspot process(es) relatively to other processes in the product LC (Björn Borg, KappAhl, H&M, Gina Tricot), value chain (IC Group, Marimekko) or in own operations (Björn Borg, Marimekko, Gina Tricot) (H2). Three companies explicitly stated that the environmental impacts lying in their value chain are significantly higher than those in their own operations (Björn Borg, H&M, Marimekko) (H2). For instance, Marimekko indicated that *"the environmental impacts of [its] sourcing are greater than in Marimekko's own production"* and H&M explained that *"it is usually easier to control what happens in our own operations, but often this is not where the most critical impacts take place".*

The approach to address environmental sustainability issues (e.g. climate change or water consumption) was reported to be based on the analysis of hotspots in the value chain or product LC by four companies (H1). To identify hotspots, these companies used various LC-based assessment tools as displayed in Table 6. KappAhl indicated that *"a relatively large part of the emissions are at the supplier stage, but also when using (washing) the clothes. Consequently it is crucial to include emissions in scope 3 to gain an understanding of KappAhl's total climate impact".* IC Group explained that *"to implement [their] Climate Policy [they] needed to know more about where [they] have* *opportunities and leverage to reduce our CO2 footprint"* and that *"for this reason [they] made an Environmental Profit & Loss (E P&L) project"*. H&M and Björn Borg indicated their willingness to increase influence over processes for which environmental impacts are high but control is limited as of today, because beyond the organizational boundaries or directly controlled value chain partners, e.g. yarn producers. Three companies displayed the quantified distribution of LC impacts throughout the product LC as described in Table 6 (H3).

Table 6. Details about hotspot identification displayed in the six CS reports mentioning this - with regard to the method used, highlighted hotspots and quantified distribution of environmental impacts in the LC. (n.a. = not applicable).

CS reports	Method	Quantified distribution of environmental impacts in the LC	Identified hotspots
Björn Borg	LCA ISO14040 Focus on air emissions and water pollution from GHG, acidifying and ozone-depleting gases and hazardous waste	*Single indicator (unclear aggregation approach)* Material and manufacturing – 36.8% (67% for fiber and fabric production) Transport – 1.6% (67% for air freight) Sales – 0.8% Washing – 59% Heat recovery – 0.7%	Production and use stages; fiber and fabric production within production; air shipping within own operations
KappAhl	LCA and scope 1-3 GHG accounting	*Carbon footprint* Design – 0.5% Production - 61.4% Logistics – 4.5% Sales – 10.2% Consumption – 23.5%	Supplier stage (i.e. production) and washing (within consumption)
H&M	Carbon and water footprint	*Carbon footprint/water footprint* Raw materials – 12% / 87% Fabric & Yarn production – 36% / 6% Garment production – 6% / 1% Transport – 6% / 0% Sales – 10% / 0% Use – 26% / 8%	Carbon footprint: fabric and yarn production and care and wash; water footprint: raw material production
Gina Tricot	n.a.	n.a.	Washing
IC Group	Environmental Profit and Loss (focus on climate change only)	n.a.	Supplier Tier 1 and 5
Marimekko	n.a.	n.a.	Sourcing; Fabric printing factory and transport within own operations

Four CS reports included a materiality analysis as recommended by the GRI 4 guidelines (GRI, 2013). In most cases, the analysis consisted in the ranking of items (displayed in Table A3) such as sustainability issues (e.g. anti-corruption, biodiversity, emission of GHG) or sustainability practices (e.g. close the loop on textile fibers, product and service labelling). LC stages were only limitedly present in the materiality analyses through items such as "sustainability in the production of raw materials” (KappAhl), “sustainable materials” (Gina Tricot), and “reduce use of chemicals in production” (KappAhl).

4.3. Tradeoffs in the product life cycle and across environmental problems (RQ3)

The overall results for RQ3 are presented in Table 7. Few references to the concept of tradeoffs across environmental problems or LC stages were found in the reviewed CS reports. Exceptions are Mini Rodini which indicated that toxicity issues for the consumers need to be taken into account when using recycled material; Gina Tricot and Lindex which emphasized the need for careful consideration of chemical use which could end up in recycled garments; Filippa K which highlighted that using fiber blends can be problematic for the recycling stage; H&M, Mini Rodini and Marimekko which mentioned a tradeoff between the use of recycled material and the associated quality of the fabric (which is also reported to be related to its lifetime); and H&M which mentioned that the introduction of polyurethane as a “vegan leather” may contain harmful solvents causing other problems related to air pollution with volatile compounds (T2). Filippa K introduced a discussion about the environmental sustainability performance of wool, explaining that it is difficult to tell whether it is *sustainable*: on the one hand, wool is long lasting, biodegradable, renewable, recyclable and compostable; on the other hand, the production of wool is resource-intensive (T2).

Table 7. Results from the content analysis for RQ3. Categories marked with an asterisk were inductively derived from the CS reports.

	Categories	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
T1	Practice of identifying possible tradeoffs in the LC to guide the environmental sustainability approach															
T2	Highlight possible tradeoffs associated with alternative solutions for products	■	■			■	■			■						■
T3	Quantify tradeoffs between different options															
T4	Multiple environmental problems referred to*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
T5	Use of multi-environmental impacts LC-based assessment tools*	■	■				■	■								■

Most companies presented their use of alternative fabrics and stated them as “sustainably sourced” (H&M), “sustainable” (Lindex, MQ Retail, Marimekko, Gina Tricot), “sustainability labelled” (KappAhl; Bestseller) or “better” (Mini Rodini) with no discussion of possible burden-shifting. Typically considered “better” fibers were organic cotton, wool and linen, BCI cotton, Tencel, CanopyStyle viscose, Modal, recycled fibers, material from renewable sources and reused materials (Lindex, H&M, MQ Retail, Mini Rodini, KappAhl). Marimekko and H&M based their definition of “sustainable” and “sustainably sourced” materials on the Made-by scoring system. Filippa K developed the so called “FK classes” which groups fibers in different classes according to their environmental sustainability performance.

The method used to develop these classes was not elaborated upon in the company's 2016 CS reports, yet on their website, we can learn that the classes are actually part of the "FK fibre tool" which was inspired by the Made-by benchmark, Nike's Material Sustainability Index (MSI) and complementary sources such as NGO reports, articles from trade news agencies and information from trade networks (Filippa K, 2018).

Although not mentioning them in a context of possible tradeoffs, all CS reports did mention various environmental issues (T4 – inductive category) (see in Table A4), mainly water consumption (10) and pollution (9), chemical use (14), energy consumption (12) and/or GHG emissions (13) and pressures on endangered forests (6). Fewer companies also mention biodiversity issues (2), soil (3) and air pollution (2). Half of the companies in the sample reported the use of LC-based tools including different environmental impacts to support their decisions (T5 – inductive category), e.g. Higg Material Selection Indicator* at H&M and IC Group, Made-By* material list at H&M and Marimekko, LCA at H&M and Filippa K, EP&L* at IC Group, and the Jeanologia Environmental Impact Measuring* at H&M and Lindex (the tools marked with an asterisks are described in Table S3).

4.4. Product environmental sustainability budget (RQ4)

The overall results for RQ4 are presented in Table 8. Only four CS reports were found to make references to ecological limits on a general level (B4 – inductive category), and no reference was found to products' absolute impacts (B1-3). At the organizational level, H&M reported its ongoing work on developing science-based targets "*in line with climate science to support limiting the global warming to well below a 2°C increase compared with pre-industrial levels*". Three companies made a reference to the "planetary boundaries": Lindex stated that "*it is clear that in order to maintain successful, we need to operate within the planetary boundaries*"; KappAhl cited existing research on planetary boundaries as one of the sources it used to establish its sustainability strategy; and Filippa K stated that it *"need[s] to understand the planetary boundaries, the planets limits"* and that it *"strive[s] to run a long-term sustainable business within our planetary boundaries".*

Table 8. Results from the content analysis for RQ4. Categories marked with an asterisk were inductively derived from the CS reports.

	Categories	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
B1	Practice of assessing absolute impact of products to guide the environmental sustainability approach															
B2	Highlight ecological limits in relation with products															
B3	Quantify absolute impact of products															
B4	Reference to ecological limits on a general level*	■	■				■		■							

Most recently, H&M has set up a collaboration project with the Stockholm Resilience Center to explore how the textile industry may operate within the planetary boundaries (H&M, 2018), and MQ Retail mentioned the planetary boundaries in its annual reports released in 2017 and 2018 where it explained that *"it is about minimizing emissions, energy consumption and the use of natural resources in order to operate within the planetary boundaries in the long term, so that no more natural resources are utilised than the planet can provide within a 12-month period"* (MQ Retail, 2017; 2018).

5. Discussion

5.1. Life cycle thinking in corporate sustainability reporting of the Nordic apparel industry

We found that the idea of product LC system was present in almost all CS reports, although in practice the use and disposal stages were more limitedly addressed by companies' sustainability operational practices. These findings corroborate claims from earlier studies according to which the product LC has become a common frame for companies to explore and address their environmental impacts (Heiskanen, 2001; Pennington et al., 2007). Yet, a particularly high focus on the product LC could be specific to the apparel industry due to the intense use of outsourced production in this sector, or to the Nordic region where LCT and LCA uptake was reported in earlier studies (Remmen, 2001; Søndergård et al., 2004; Stewart et al., 2018).

In one small and one medium company's CS reports, we could not find any reference to the product LC, which may indicate lower awareness of the product system in smaller companies. In his study of ecodesign practices in Canadian SMEs, Talbot (2005) found that SMEs typically concentrate their environmental efforts on their own operations and on making energy-efficient products but do not focus on the product's end-of-life. In their study of Venezuelan SMEs, Fernández-Viné et al. (2010) found that the concept of product LC was unknown by most managers. In contrast, in their study of Slovenian construction SMEs, Denac et al. (2018) found ecodesign practices addressing all LC stages and a particular focus on the use stage. Hence, there might be large differences between sectors or countries in terms of adoption of the product LC concept. Although the sample in the present study does not allow statistically studying the influence of reporting guidelines, we note that, in all CS reports using GRI 4 guidelines, the idea of product LC was found present, which aligns with the value chain perspective on sustainability reporting prescribed by the GRI 4 guidelines (GRI, 2013). Yet, most companies not using the GRI guidelines were also found to elaborate on their product LC or value chain (e.g. Spectre, IC Group, Björn Borg, Filippa K).

More than half of the companies expressed their willingness to address environmental sustainability challenges throughout their product's LC or value chain, which was highlighted as a normative assumption associated with LCT (Remmen et al., 2007; Heiskanen, 2001). In nearly half of the sample, companies expressed their ability to influence the LC impacts of their products through design that is one key tenet of ecodesign (Dyllick and Rost, 2017). Companies mainly exert their influence through the choice of specific materials and the request for materials and fabric certifications, and limitedly through design strategies and influence of consumer behaviors. Similarly, in their study of Swedish apparel companies, Clancy et al. (2015) found a strong focus on monitoring the supply chain, e.g. through material or supplier selection, and a limited focus on influencing consumer behaviors through design. In their study of communications by companies belonging to the Sustainable Apparel

Coalition, Kozlowski et al. (2015) also found a high focus on supply chain practices, while design practices and business models were more rarely reported on. We found that larger companies reported their willingness to influence the disposal stage of their products, and their engagement in various initiatives to develop necessary infrastructure, business model and technologies. Fulton and Lee (2013) analyzed the online content of 156 apparel retailers, and found that companies had very little focus on the end-of-life of their products. The focus we observed on the disposal stage may be associated with the concept of circular economy which has recently grown on corporate agendas and specifically in the apparel sector (EMF, 2017).

On the other hand, we found more limited analysis of environmental sustainability hotspots in the product life cycle system, few references to potential tradeoffs and very few references to ecological limits. Although most companies mentioned particularly impacting processes in their business, the analysis of environmental sustainability hotspots in the value chain or product's LC was mentioned as a step towards designing environmental sustainability strategies at four companies only. At these companies the use of various LC-based methodologies was mentioned as a way to build an understanding of LC impacts and guide sustainability approaches. Processes typically singled out as hotspots in the LC were the production and wash of garments. However, more in-depth discussion about the contribution of different production processes was usually lacking, e.g. spinning, weaving, dyeing and finishing of garments are particularly impacting processes which were not elaborated upon by companies. Materiality analysis as defined in the GRI 4 guidelines could in theory provide the ground for companies to highlight environmental sustainability hotspots in their activities. However, we found that the materiality analyses displayed by a subset of companies in our sample limitedly referred to environmental sustainability hotspots in the product LC. Previous studies on the application of materiality analysis by companies found that they seemed to reflect *"business continuity issues rather than environmental issues"* and did not allow representing the relative magnitude of importance and impacts (Jones et al., 2016).

The identification of potential tradeoffs was not explicitly stated as a common practice to guide product environmental sustainability work in the reviewed CS reports, although scattered examples of tradeoffs were referred to by nearly half of the companies. Several companies mentioned the need for careful chemical use or avoidance of fiber blending to facilitate increasing recycling practices in the apparel industry. On the other hand, particular tradeoffs associated with the use of various fiber types were not touched upon in CS reports.

Ecological limits were part of a minority of companies' narratives and kept at a general level. In their global mapping of ecological limits in CS reports, Bjørn et al. (2017) found that references to ecological limits had remained sparse in CS reporting (around 5% CS reports) in the past years and that companies mentioned such limits without specifying any consequent change in their business. The concept of Planetary Boundaries was fairly recently introduced in the scope of corporate sustainability (Whiteman et al., 2013) with initiatives such as the Science-Based Targets which actively promote their integration in companies' sustainability efforts (CDP, 2015). The relevance of integrating the Planetary Boundaries concept in CS reporting has been appraised in literature (Schaltegger, 2018). Yet, the inclusion of ecological limits in the analysis and design of strategies to improve the environmental sustainability performance of business activities will require further methodological developments, and subsequent coordination by international bodies and diffusion efforts in industry (Clift et al., 2017; Schaltegger, 2018).

5.2. Life cycle thinking and corporate sustainability reporting

Earlier academic studies have shown a lack of consideration of the LC perspective in CS reporting. Using a volumetric approach, Comas-Marti and Seifert (2013) analyzed the LC coverage of sustainability practice disclosed in CS reports from various sectors and found that the firm-level dominated to the detriment of other LC stages. The boundaries of CS reporting were found not to cover sufficiently the LC perspective of companies' activities and hence to poorly represent corporate sustainability performance (Kaenzig et al., 2011; Antonini and Larrinaga, 2017). In our study we found a rather high attention among Nordic apparel companies to the LC of their products. However, we found rather low reflections on hotspots and tradeoffs in the LC. Only few companies were found to i) provide detailed insights on the critical elements in the current apparel product system; ii) explicitly indicated that they lacked influence on hotspot processes as of today; or iii) discussed the advantages and drawbacks of alternative options (e.g. production processes or selection of fibers).

These findings echo earlier critiques of CS reporting on the risk to fall into an "evaluatory trap" with a tendency to use a ready-made set of disclosure items to be filled in with figures, rather than truly reflect on the relationships between activities and Earth's eco-systems (Dumay et al., 2010; Milne and Gray, 2013). The lack of self-criticism in CS reports was highlighted by Fonseca et al. (2010) who found that the GRI guidelines did not call for reflection around tradeoffs, assumptions and uncertainties. Higgins and Coffey (2016) have suggested that narratives delivered by companies in their CS reports are mainly under the form of an argument, i.e. written by companies to demonstrate that they are taking actions to address their sustainability challenges. Such attitudes from companies may reflect motivations behind CS reporting such as the use of CS reports by investors and external agencies to rate and rank companies according to their CS practices (Burrit and Schaltegger, 2010) and the use of CS reports by companies as communication tools to legitimize their business and shape their reputation (Hooghiemstra, 2000; Hahn and Kühnen, 2013).

Building further on analytical aspects of LCT in CS narratives, through explicitly discussing hotspots tradeoffs and ecological limits, would create the basis for a dialogue with stakeholders on how to improve the sustainability performance of the business (Thabrew et al. 2009; Fullana et al., 2009). It would also demonstrate a better understanding of environmental sustainability challenges associated with products and possibly denote higher competitiveness and business resilience. However, actions from policy-makers, investors and reporting guidelines developers would be required to orient CS reporting practices towards a more analytical and reflective exercise from companies. Moreover, availability of adequate methodological support for companies to analytically build on LCT in their CS reports remains to be investigated. Ongoing guidance development for the application of LCA at an organizational-level and for the conduction of hotspot analysis may be opportunities for an increased use in company narratives (Barthel et al., 2017; EC, 2018). The category sustainability profiles developed by the Sustainability Consortium based on LCA studies and dialogue with researchers, experts and stakeholders which contain information about the environmental and social hotspots for a variety of product categories could also be a tool used by companies (Dooley and Johnson, 2015).

5.3. Limitations of the study

Our analysis only included Nordic apparel companies which released an English-written CS report in 2016, and hence excluded companies which only reported in their national language and smaller companies which typically do not release CS reports (Borga et al., 2009). In this perspective, our findings are not directly applicable for the whole Nordic apparel industry; yet the study covered the largest Nordic apparel (H&M, Lindex, Bestseller) companies and hence a large share of sales by Nordic apparel companies. As 2016 CS reports were used as the single data source, our study only delivers a snapshot of sustainability narratives of Nordic apparel companies in a time dimension. A longitudinal approach could allow observing evolutions of LCT in companies' narratives. Further, a comparison with other regions would be meaningful in future research in order to test the specificity of the Nordic region. Investigating companies headquartered in Italy, Germany or Spain would be particularly relevant as they are the top 3 exporting clothing and footwear countries in the EU (EC, 2018). Investigating the presence of LCT in CS reports of other economic sectors would further provide relevant information about any differentiated uptake in various sectors. CS reports provide an overview of what companies consider relevant to communicate of their understanding and addressing of sustainability challenges. However, such reports may not be representative of actual CS practices in companies and they most certainly do not reflect the complexity of internal discussions on the topic of sustainability and bottom-up initiatives (Thijssen et al., 2016). In this perspective, our study provides meaningful insights on the publicly communicated thinking around environmental sustainability approaches at companies. Yet, complementary interview and field-based studies are needed to build a comprehensive understanding of the presence of LCT in environmental sustainability work at companies.

6. Conclusion

This study constitutes the first attempt to explore the presence of LCT in companies' narratives of their environmental sustainability work in CS reports, with a focus on the Nordic apparel industry. Our study showed that the concept of product LC system was rather anchored in Nordic apparel companies, with some limitations in smaller companies. Yet, hotspots and tradeoffs identification, were found only limitedly elaborated upon in Nordic apparel companies' narratives of their environmental sustainability work which match critiques among scholars of CS reports pertaining to their lack of self-reflection about environmental sustainability challenges. These findings suggest that future research should investigate (i) the extent to which CS reporting may be a suitable platform for companies to demonstrate a deeper understanding of their LC challenges and to provide the ground for a stakeholder dialogue on how to address them; and (ii) the extent to which methodological developments are needed to facilitate a discussion around hotspots, tradeoffs and ecological limits in companies' overall environmental sustainability work, and more specifically in their narratives in CS reporting.

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Appendices

Table A1. Examples of extracted meaning units from corporate sustainability for each category. The full list of meaning units is available in Table S2.

Code	Categories	Example of extracted meaning unit and corresponding CS reports
S1	Graphical representation of the product LC	The section "our value chain" introduces each life cycle stage: design and materials, sourcing and production, logistics, stores, use and car of products, recycling and end of life. For each stage, a comment on the company's practices is made (Marimekko, 2016)
S2	Explicit definition of the product LC	"The natural starting point for Björn Borg's sustainability programs is the product lifecycle – the various stages involved in producing and marketing products, followed by the user phase by the consumer. The product lifecycle describes Björn Borg's operations based on which stakeholders are affected and the impacts on the environment and society through the value chain." (Björn Borg, 2016)
S3	Consideration of product LC in the sustainability strategy of the company	"We want to use our scale to bring about systemic change to the industry and across the lifecycle of our products. Together with our colleagues, customers, stakeholders, business partners and peers, we have the opportunity to bring about serious change – all the way from improving the livelihood of a cotton farmer to lowering the impacts from washing and drying our clothes." (H&M, 2016)
S4	LC stage addressed by operational practices	See Table A2
S5	Possibility to influence product LC impacts through design*	"The choice of materials, whether it is the main fabric or the thread holding it together, has a big impact on a product's overall sustainability performance." (Filippa K, 2016)
H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach	"Taking a holistic approach to our value chain, we are extending our knowledge and influence over second tier supplier factories such as fabric and yarn mills. Our Lifecycle Assessments show that fabric production represents major environmental impacts, for instance, 36% of the climate impact of a garment's lifecycle occurs at this stage. Since several years back, we have been working continuously on a development program to help mills reduce these impacts" (H&M, 2016)
H2	Highlight hotspot processes relatively to other processes in product LC	"We are using the findings from our EP&L in the HIGG training with Peak's partner suppliers. GHG in Tier 1 and 5 were identified as having the most impact on our EP&L. This knowledge was combined with our partner's facility module scores to see where we should lay our combined efforts to gain the biggest positive impact." (IC Group, 2016)
H3	Quantify contributions to environmental impacts throughout the LC	The distribution of emissions through the value chain from design to consumption is as follows for 2015/2016: design, production, logistics, sales, consumer (KappAhl, 2016)
H4	Highlight processes particularly	"Cotton is our most important raw material, but

	impacting in general*	conventional cotton growing has a negative impact on the environment as the farmers use many pesticides and fertilisers and much water. Therefore we have set ourselves the goal that by 2020 the majority of our cotton must come from sustainable sources, such as better cotton, organic cotton or recycled cotton” (Bestseller, 2016)
T1	Practice of identifying possible tradeoffs in the LC to guide the environmental sustainability approach	n.a.
T2	Highlight possible tradeoffs associated with alternative solutions for products	“In terms of future recycling, it is also an advantage if the product is free from substances that we do not wish to end up in the recycling system. (Gina Tricot, 2016)
T3	Quantify tradeoffs between different options	n.a.
T4	Multiple environmental problems referred to*	See Table A4
T5	Use of multi-environmental impacts LC-based assessment tools*	See Table A5
B1	Practice of assessing absolute impact of products to guide the environmental sustainability approach	n.a.
B2	Highlight ecological limits in relation with products	n.a.
B3	Quantify absolute impact of products	n.a.
B4	Reference to ecological limits on a general level*	“We strive to run a long-term sustainable business within our planetary boundaries. To ensure long-term sustainable success we must have a holistic view of our business, understand how all parts interact and make sure our value chains are long-term sustainable.” (Filippa K, 2016)

Table A2. Distribution of environmental sustainability operational practices per product life cycle stage.

PRACTICES	No of reports	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
RAW MATERIAL																
Avoid certain fabric/use "eco-friendly" or "sustainable" fabrics	10	X	X	X	X	X	X		X	X		X				X
Use recycled material	4					X		X	X		X					
Recycle post-consumer garments into new garments	2	X					X									
Recycle pre-consumer fibers (cotton,	5	X		X			X					X				X

polyester, polyamide)																
Recycled PET from plastic bottles	4			X			X			X		X				
"Better than conventional"	9	X	X	X		X	X		X	X		X				X
Organic material	12	X	X	X	X	X	X		X	X	X	X		X		X
Reduce cotton in collections	1											X				
Renewable material	3						X		X							X
Water-based PU leather	1						X									
Research on new materials	3	X	X													X
Supply certifications (e.g. GOTS, OekoTex, GRS, OCS)	8	X		X			X		X	X		X		X		X
Portfolio of preferrable fibers (and associated KPIs and/or targets)	8	X		X		X	X		X	X		X				X
Leather graded by Leather Working Group	1						X									
Training of leather suppliers by Leather Working Group or BLC	1							X								
BCI farmer training	6	X		X		X	X		X			X				
Organic cotton accelerator	2						X		X							
Canopy-approved suppliers of man-made cellulosic fibers	3	X					X		X							
FABRIC PRODUCTION AND PROCESSING																
Chemical monitoring																
Chemical restriction list/testing	13	X		X	X	X	X	X	X	X	X	X	X	X		X
Phasing out/ban chemicals (e.g. PFC)	7	X		X			X		X	X		X				X
Reduce colours and colorants (ok associated to policy in PD)	1									X						
Replace solvent-based glues (e.g. water based, thermo)	1						X									
Treatment processes																
Wash processes (e.g. water stewardship in denims, wash without chlorine)	3	X					X			X						
Sandblasting ban	1											X				
Better processes to create faded looking denim (e.g. ice blasting)	2			X								X				
Natural tanning process (e.g. vegetable tanned leather)	2	X														X
Avoid wear and torn effect	1									X						
Projects to improve water/energy/ and/or chemicals management in production steps																
Committed to Zero Discharge of Hazardous Materials / promote better chemical practices in industry	1						X									
Reduce VOCs in factories	1						X									
Training suppliers on chemical use	1							X								
Reduce chemicals in process	7	X		X	X	X	X		X			X				
Swedish Water Textile Initiative (STWI)	7	X	X		X	X	X		X			X				
PaCT	4	X		X			X		X							

Training at suppliers by Bluesign chemicals providers	1	X													p	
Improve water, chemical and energy management in denim	3	X				X	X									
Support the development of measurement systems in factories (energy, water) and own strategies (e.g. Higg Factory module)	2						X	X								
Use of renewable energy in factories	2				X											X
Relocation of production in countries with better energy mixes	1				X											
Support from BLC Leather technology center	1							X								
Infrastructure change for water efficiency	1															X
Taking environmental aspects into account in machinery and equipment investments	1															X
Include (fabric and yarn manufacturers) in supplier assessment program	1						X									
GARMENT PRODUCTION																
Supplier code of conduct and audits/inspections/visits	13	X		X	X	X	X	X	X	X	X	X	X	X		X
BSCI code of conducts	9	X			X	X		X		X		X	X	X		X
Supplier selection and scorecards	8	X		X	X	X	X	X				X				X
Strategic partnership on sustainability with limited number of suppliers	5	X				X	X			X		X				
ISO 14001	1														p	X
Eco-friendly material for labels	2								X	X						
Pattern efficiency	2	X														X
Downcycle production waste	2				X											X
Assessment of external brand/licensee on sustainability criteria	2				X							X				
Use fabric leftovers from previous collection (pre-consumer waste)	4			X	X					X						X
Use fabric leftovers from suppliers	1		X													
PACKAGING																
Eco-friendly packaging	8	X		X	X	X			X	X	X					X
Reduce packaging	4	X			X	X					X					
Packaging recovery/reuse	3					X					X					X
Packaging easy to separate	1				X											
TRANSPORT																
Diminish air freight/prioritize sea, rail freight	10	X	X		X	X			X	X	X	X	X	X		
Clean Shipping Index, SmartWay	3	X					X		X							
Optimize routes/loads	4	X				X			X			X				
Locally sourced materials/location as a criteria in selection of suppliers	1									X						
Offsetting emissions from logistics	1															X
Ask sustainability strategy from logistic supplier	1		X													
OFFICES/STORES																

Energy efficiency	9	X	X	X		X	X		X	X			X			X
Green IT	2					X	X									
Renewable energy/Greener energy (e.g. "Good environmental choice" electricity)	7	X	X			X	X		X	X						X
Part of RE100	1						X									
Water efficiency	1						X									
Waste management	11	X		X	X		X		X	X	X	X	X	X		X
Reuse of non-sold garments	4	X		X		X						X				
Sell leftover fabrics	1															X
Business travels	3				X	X				X						
Eco-friendly materials in stores (e.g. hangers)	2								X	X						
USE																
Long lasting garment (technical quality)	4		X		X							X				X
Personal attachment/curated wardrobe	1		X													
Timelessness as a design criteria	2		X													X
Cooperation with rental libraries	1		X													
Co-development of an environment friendly detergent and fabric softener	1		X													
Care labels	7			X	X		X	X	X		X					X
Care instructions in shops, online	5			X		X	X		X			X				
Follow-up survey on care instructions	1				X											
In case of refund claim, propose repairing as an option (not enforced)	1											X				
END OF LIFE																
Collection of garments	0			p	p					p						
Take back system in stores (donation)	3	X				X	X									
Take back system in stores (vouchers)	2		X						X							
Online platform for swaping	2						X									X
Produce recyclable materials/garments	1		X			p										p
Research on recycling techniques	3	X	X				X									
Create demand for recycled materials	2	X					X									
Second hand shop	1		X													
Explorative projects to close the loop on garments (e.g. with EMF, Mistra)	4		X	X			X		X							
Label calling for prolonging or bringing back garments	1		X													
Project of sorting facility	1					X										

Table A3. Details about the most important topics as resulting from the materiality analysis performed in a subset of CS reports.

CS report	Most important topics as resulting from the materiality analysis
KappAhl	Promote good working conditions in production; Sustainable materials; Sustainability labelled products; Reduce emissions of GHG; Reduce use of chemicals in production.

H&M	Economic performance; close the loop on textile fibers; human right; conscious products and materials; industrial relations; water stewardship; supply chain management and fair living wages.
Gina Tricot	Animal welfare; anti-corruption; Energy consumption and emissions, particularly emissions from transports; Environmental impact of our suppliers; financial results; health and safety of our employee; health and safety at our suppliers; human rights at our suppliers; Non-discrimination, diversity and gender equality; Product responsibility (e.g. chemicals in products); Quality and environmental considerations in the design process; Sustainability in the production of raw materials
Lindex	List of aspects related to customer (e.g. customer satisfaction), employee (e.g. training and education), products (e.g. Product and service labelling), environment (e.g. materials), finance and governance (e.g. anti-corruption).

Table A4. Environmental problems mentioned in each CS reports

Environmental problems	No of reports	Lindex	Filippa K	Bestseller	Björn Borg	Gina Tricot	H&M	IC Group	KappAhl	Mini Rodini	Modström	MQ Retail	Oriental	PompdeLux	Spectre	Marimekko
Water use/scarcity	11	X	X	X	X	X	X		X	X		X		X		X
Water pollution/waste water	9	X		X	X	X	X		X			X	X			X
Energy	13	X	X	X	X	X	X		X	X		X	X	X	X	X
GHG/climate change	14	X	X	X	X	X	X	X	X	p	X	X	X	X	X	X
Chemicals	15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pesticides	5	X		X		X	X							X		
Endangered forests/deforestation	6	X			X		X		X	X				X		
Eutrophication	1				X											
Acidification	1				X											
Ozone depletion	1				X											
Air pollution	2						X	X								
Land use	5		X	X			X	X		X						
Biodiversity	2						X					X				
Soil pollution	3					X	X		X							

Supplementary Information

This document contains:

Supplementary Methods

Table S1. List of corporate sustainability reports included in the sample

Company	Title of corporate sustainability report
Bestseller	Sustainability Report 2015/2016
IC Group	Corporate Responsibility Report 2016
Spectre	CSR Report 2015
Moström	Global Compact Annual Communication on Progress – SME Version August 18th 2016
Oriental Import Export	CSR Report 2015
PompdeLux	UN Global Compact Communication on Progress Report POMPdeLUX ApS 2015
Marimekko	Sustainability review 2015
Filippa K	Sustainability report 2015
Gina Tricot	Sustainability Report 2015
H&M	Sustainability Report 2015. Conscious Actions
KappAhl	KappAhl 2016 (annual report)
Lindex	Sustainability Report 2015
MQ Retail	Sustainability Report 2014/2015
Björn Borg	Sustainability Report 2015
Mini Rodini	Sustainablity Report ’15

Supplementary Results

Table S2. List of extracted meaning units and corresponding category

Company	p.	Extract from report (meaning unit)	Code	Category
Filippa K	8	During 2014 we decided on a new vision for Filippa K, we want to create fashion where sustainability is the guide to growth. Both because we think it’s the right thing to do but also because we want to run a successful company also in the future. To succeed with that we need to understand the planetary boundaries, the planets limits. That is a natural evolvement of the strategy we always had, to make clothes that can live for a long time in both quality and design. But we also need a bigger transformation. We need to rethink everything from the materials we work with, to production processes and business models.	B4	Reference to ecological limits on a general level
Filippa K	8	We strive to run a long-term sustainable business within our planetary boundaries. To ensure long-term sustainable success we must have a holistic view of our business, understand how all parts interact and make sure our value chains are long-term sustainable.	B4	Reference to ecological limits on a general level
Filippa K	12	ECOSYSTEMS ARE OUR INSPIRATION. PLANETARY BOUNDARIES ARE KEY, NOT LIMITATION.	B4	Reference to ecological limits on a general

				level
Filippa K	67	We were during 2015 part of a project run by IVA, named Resource Efficient business models 2050. The global population growth and a growing middle class in developing regions are increasing the pressure to manage the planet's finite resources.	B4	Reference to ecological limits on a general level
Filippa K	76	We have some major challenges in our world today. International Energy Agency's chief of economics stated "The door for limiting the global warming to 2 degrees is about to close, in 2017 it will be closed for ever." So the time for change is now! We believe doing fair business within the planetary boundaries is the answer and that Circular Economy has an important role to play.	B4	Reference to ecological limits on a general level
H&M	84	In our partnership with the WWF and World Resources Institute (WRI), we are collaborating to set a path to support positive climate actions. We are committed to science-based target setting across our value chain and during 2016 we plan to have sciencebased targets for our value chain greenhouse gas emission reductions in place. These will be in line with climate science to support limiting the global warming to well below a 2°C increase compared with pre-industrial levels and the joint initiative Science Based Target, of which we are also a member.	B4	Reference to ecological limits on a general level
KappAhl	52	The sustainability strategy is developed on the basis of challenges we see in our value chain, for example with the help of life cycle analyses, the UN Development Goals and research around the planetary boundaries."	B4	Reference to ecological limits on a general level
Lindex	5	For us it is clear that in order to maintain successful, we need to operate within the planetary boundaries	B4	Reference to ecological limits on a general level
Björn Borg	5	In 2010 Björn Borg completed a lifecycle assessment (LCA) of a pair of underwear to identify the biggest environmental impacts. The assessment focused on air emissions and water pollution from greenhouse, acidifying and ozone-depleting gases as well as hazardous waste and was conducted according to the ISO 14040 standard. The conclusion was that the biggest impacts are in the production and user phases. [...] The company's LCA showed that as much as 67 percent of the total impact in the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production chain. The first step is to significantly improve transparency throughput the supply chain. [...] Björn Borg has formulated three focus areas for its sustainability program in coming years. The priorities are based on where the negative impact is greatest ("Impact") and Björn Borg's sphere of influence ("Control")"	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
Björn Borg	6	Behind the factories contracted by Björn Borg lies a chain of subcontractors that includes cotton growers, spinners,	H1	Practice of analyzing

		weavers and dyeing and printing houses. The company's LCA showed that as much as 67 percent of the total impact in the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production chain. The first step is to significantly improve transparency throughout the supply chain.		hotspots in the LC to guide the environmental sustainability approach
Björn Borg	11	The goal parameters are "Impact" and "Control." The idea is to concentrate efforts where the biggest positive effect can be achieved and where the company's sphere of influence is greatest.	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
Björn Borg	18	CO2 emissions in the manufacture of fabrics and other inputs used in Björn Borg's products are significant. The company is therefore working with garment-making factories to encourage them to place demands on and persuade their subcontractors to reduce CO2 emissions. Björn Borg's aim is to drive these improvements more actively as transparency in the production chain increases, which also creates more opportunities to influence participants at various levels of production.	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
Björn Borg	24	Air freight accounted for 8 percent of all transports (collection units shipped) and for as much as 67 percent of the total climate impact from transports in 2015.The percentage of air freight is too high and in 2016 the company will take several measures to reduce air shipments. Björn Borg's policy is that shipments from Asia should go by boat except in special circumstances. A priority here is to improve the planning of shipments as well as internal discipline in complying with the policy.	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
H&M	41	Taking a holistic approach to our value chain, we are extending our knowledge and influence over second tier supplier factories such as fabric and yarn mills. Our Lifecycle Assessments show that fabric production represents major environmental impacts, for instance, 36% of the climate impact of a garment's lifecycle occurs at this stage. Since several years back, we have been working continuously on a development program to help mills reduce these impacts	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
H&M	41	Taking a holistic approach to our value chain, we are extending our knowledge and influence over second tier supplier factories such as fabric and yarn mills. Our Lifecycle Assessments show that fabric production represents major environmental impacts, for instance, 36% of the climate impact of a garment's lifecycle occurs at this stage. Since several years back, we have been working continuously on a development program to help mills reduce these impacts	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
H&M	100	Our lifecycle assessments show that the most significant	H1	Practice of

		water footprint in our value chain occurs in raw material production (87%). It is mainly because cotton production is highly water intense and our goal is to use cotton solely from sustainable sources by 2020 at the latest. This is also why we are working with clothing recycling in order to decrease our dependence on virgin materials. The second biggest water footprint is in customer use and we have worked with Clevercare to help customers make washing decisions that are more energy- and water-friendly. The third biggest water footprint is from washing and dyeing processes in fabric production and garment finishing, for example to achieve the desired look of denims. We are working together with a variety of organisations and initiatives to address capacity building in factories, e.g. STWI, PaCT, NRDC, Solidaridad and the WWF. We want to go beyond ensuring compliancewith minimum requirements. In 2015, we therefore developed a new way of assessing our suppliers' sustainability performance that considers more than just compliance and instead focuses on actual impacts. This helps suppliers to better understand and – where needed with our support – develop their own strategies to tackle these impacts. As part of this, we have developed a broad set of additional measurements and amongst other things, we have incorporated what we have learned through our partnership with the WWF.		analyzing hotspots in the LC to guide the environmental sustainability approach
IC Group	6	We are using the findings from our EP&L in the HIGG training with Peak's partner suppliers. GHG in Tier 1 and 5 were identifi ed as having the most impact on our EP&L. This knowledge was combined with our partner's facility module scores to see where we should lay our combined efforts to gain the biggest positive impact.	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
IC Group	8	To implement our Climate Policy we needed to know more about where we have opportunities and leverage to reduce our CO2 footprint. For this reason we made an Environmental Profit & Loss (E P&L) project and the results were ready in Autumn 2014. We believe an EP&L is important as an awareness/transparency tool, for identification of environmental hotspots, for risk management and overall supply chain management and as an excellent means for communication.	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
IC Group	8	CLIMATE POLICY As members of a global industry we have a responsibility for reducing our carbon footprint. We believe that taking charge of our carbon footprint is not only a sustainability imperative but also a way to future-proof our business to be able to keep growing while respecting the boundaries of our planet. For IC Group this entails focusing on the leverage points where we can make the biggest difference in terms of climate change. Among others, we use Environmental Profit and Loss accounting and The Higg Index to learn more about our biggest challenges, where we can foster change and help set industry benchmarks. Knowing the climate impacts throughout our	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach

		value chain means we can make better decisions in the design phase and in the way we source products."		
IC Group	8	The aim of the project done in collaboration with the Danish Environmental Protection Agency and leading international experts was to be able to put a financial value on our environmental impact.The EP&L shows us where in the value chain we have the biggest environmental impact comparing our impact on water, GHG, land use and air in monetary terms and hence identifying sustainability hot spots. The E P&L also shows us the environmental impact of different choices of materials and therefore complements our work with the Rapid Design Module."	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
IC Group	11	For the Group this entails focusing on the leverage points where the Group can make the biggest difference in terms of climate change. Among others, the Group uses environmental accounting according to the Environmental Profit and Loss method (EP&L) and the Higg Index to learn more about where the Group can foster change and help set industry benchmarks. Knowing the climate impacts throughout the value chain means that the Group can make better decisions in the design and sourcing phases.	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
KappAhl	101	[about stakeholders' dialogue] "Eight representatives from interest organisations, the research sphere, investors, brand experts and board members were invited through in-depth interviews to give their view of the sustainability issues that are most important for KappAhl and where in our value chain the impact is greatest on humans and the environment."	H1	Practice of analyzing hotspots in the LC to guide the environmental sustainability approach
Björn Borg	5	In 2010 Björn Borg completed a lifecycle assessment (LCA) of a pair of underwear to identify the biggest environmental impacts. The assessment focused on air emissions and water pollution from greenhouse, acidifying and ozone-depleting gases as well as hazardous waste and was conducted according to the ISO 14040 standard. The conclusion was that the biggest impacts are in the production and user phases. [...] The company's LCA showed that as much as 67 percent of the total impact in the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production chain. The first step is to significantly improve transparency throughput the supply chain. [...] Björn Borg has formulated three focus areas for its sustainability program in coming years. The priorities are based on where the negative impact is greatest ("Impact") and Björn Borg's sphere of influence ("Control")"	H2	Highlight hotspot processes relatively to other processes in product LC
Björn Borg	7	In addition, Björn Borg has formulated three focus areas for its sustainability program in coming years. The priorities are based on where the negative impact is greatest ("Impact") and Björn Borg's sphere of influence ("Control"). Products - A very large share of the impact is in production, in	H2	Highlight hotspot processes relatively to other processes in product LC

		manufacturing the fibers and other inputs and in the production process itself. By making a more sustainable product, we create a framework to address impacts related to design and the choice of materials and in the production stage. Our own operations – Björn Borg undoubtedly has a responsibility in its own operations (including transports), and it is here that the company also has the greatest opportunity to make a difference. Transparency – Björn Borg is open about its sustainability goals and results. The aim is to gradually increase transparency in the production chain, with the goal over time of obtaining greater insight into the various stages of the chain of subcontractors.		
Björn Borg	24	Though the climate impact is greater in other parts of the product lifecycle, Björn Borg takes clear actions to reduce its own impacts in areas where it has the most control and which employees can see and impact daily. In addition to transports of products, as described above, business travel by employees and energy consumption in the company's premises are addressed.	H2	Highlight hotspot processes relatively to other processes in product LC
Björn Borg	26	Flying on the job has a significant climate impact, accounting for no less than 83 percent of the total impact from business travel, as indicated below.	H2	Highlight hotspot processes relatively to other processes in product LC
Gina Tricot	18	Companies, government authorities and organizations must work together to begin to tackle these issues and create circular models. What we as a company can do, first and foremost, is to develop products that meet customer demands and can be used for a long time. We can also inform our customers of how to best care for their garments and thereby prolong their lifespan, including less frequent washing, only full loads, and at lower temperatures. During the lifespan of a garment, washing is a highly significant part of its total energy consumption.	H2	Highlight hotspot processes relatively to other processes in product LC
Gina Tricot	27	[material aspects] Our operations consume energy, by heating, cooling and providing electricity in our stores and facilities. But above all, energy is consumed during transports, and it is precisely this part of our environmental impact that both we and our stakeholders estimate to be of high importance. (focus on freight in the report's body)	H2	Highlight hotspot processes relatively to other processes in product LC
H&M	9	We have stores and suppliers all around the world. Undoubtedly, we have an impact on the communities and the environment around us. Embracing positive impacts along our value chain, and working hard to reduce negative ones, is the core of H&M Conscious. It is usually easier to control what happens in our own operations, but often this is not where the most critical impacts take place. Teaming up with others is therefore key to make the difference that matters the most."	H2	Highlight hotspot processes relatively to other processes in product LC
H&M	41	Taking a holistic approach to our value chain, we are extending our knowledge and influence over second tier supplier factories such as fabric and yarn mills. Our Lifecycle Assessments show that fabric production	H2	Highlight hotspot processes relatively to other processes

		represents major environmental impacts, for instance, 36% of the climate impact of a garment's lifecycle occurs at this stage. Since several years back, we have been working continuously on a development program to help mills reduce these impacts		in product LC
H&M	83	Looking at our entire value chain, our stores, warehouses and offices have a rather small water impact."	H2	Highlight hotspot processes relatively to other processes in product LC
H&M	83	Looking at the lifecycle of our products, only about 10% of the climate impacts happen in our own operations. The remaining 90% result from transport (6%), raw material production (12%), fabric production (36%) packaging (5%), garment manufacturing (6%) and when our customers wash and care for their clothes (26%). So, while we are reducing our own emissions to a minimum, we want to look beyond our walls and **inspire** others to be climate smart. We want to use our scale to adopt a sciencebased approach moving our whole value chain to a more climate orientated operation to ensure we support limiting global warming to well below a 2°C increase compared with pre-industrial levels. We also work to inspire our customers to care for their clothes in a conscious way and we take a stand for strong public policies.	H2	Highlight hotspot processes relatively to other processes in product LC
H&M	100	Our lifecycle assessments show that the most significant water footprint in our value chain occurs in raw material production (87%). It is mainly because cotton production is highly water intense and our goal is to use cotton solely from sustainable sources by 2020 at the latest. This is also why we are working with clothing recycling in order to decrease our dependence on virgin materials. The second biggest water footprint is in customer use and we have worked with Clevercare to help customers make washing decisions that are more energy- and water-friendly. The third biggest water footprint is from washing and dyeing processes in fabric production and garment finishing, for example to achieve the desired look of denims. We are working together with a variety of organisations and initiatives to address capacity building in factories, e.g. STWI, PaCT, NRDC, Solidaridad and the WWF. We want to go beyond ensuring compliancewith minimum requirements. In 2015, we therefore developed a new way of assessing our suppliers' sustainability performance that considers more than just compliance and instead focuses on actual impacts. This helps suppliers to better understand and – where needed with our support – develop their own strategies to tackle these impacts. As part of this, we have developed a broad set of additional measurements and amongst other things, we have incorporated what we have learned through our partnership with the WWF.	H2	Highlight hotspot processes relatively to other processes in product LC
H&M	105	Looking at our entire value chain, our stores, warehouses and offices have a rather small water impact. Still, we want	H2	Highlight hotspot processes

		to act as a good example by reducing our water use as much as possible.		relatively to other processes in product LC
IC Group	6	We are using the findings from our EP&L in the HIGG training with Peak’s partner suppliers. GHG in Tier 1 and 5 were identified as having the most impact on our EP&L. This knowledge was combined with our partner’s facility module scores to see where we should lay our combined efforts to gain the biggest positive impact.	H2	Highlight hotspot processes relatively to other processes in product LC
IC Group	11	Environmental accounting according to the Environmental Profit & Loss method (PEP&L). Results show environmental hotspots and are used for communication on mutual transparency towards suppliers, for training and identifying areas for deep dives into the supply chain.	H2	Highlight hotspot processes relatively to other processes in product LC
KappAhl	108	KappAhl aims to be climate neutral in 2020. The purpose is to safeguard our climate and thereby contribute to long-term sustainable development for us and society as a whole. Our sustainability strategy, with concrete focus areas and activities, constitutes a central policy instrument to achieve this. Part of the work is to survey the climate impact in our value chain and its various links. [...] To better understand how and where emissions of greenhouse gases arise the GHG protocol (greenhouse gas protocol) is a good standard to follow as it aims to include the total climate impact of the business for a full year. This can be compared with a lifecycle analysis, which concentrates on the climate impact over the life cycle of a garment. A GHG analysis gives a good basis for creating an action plan that will effectively reduce emissions from our operations. Our emissions are reported broken down into three scopes (1–3), where scope 1 is the direct emissions, scope 2 the indirect emissions for producing purchased energy and scope 3 is other indirect emissions. For operations like KappAhl’s a relatively large part of the emissions are at the supplier stage, but also when using (washing) the clothes. Consequently it is crucial to include emissions in scope 3 to gain an understanding of KappAhl’s total climate impact.”	H2	Highlight hotspot processes relatively to other processes in product LC
KappAhl	108	KappAhl aims to be climate neutral in 2020. The purpose is to safeguard our climate and thereby contribute to long-term sustainable development for us and society as a whole. Our sustainability strategy, with concrete focus areas and activities, constitutes a central policy instrument to achieve this. Part of the work is to survey the climate impact in our value chain and its various links. [...] To better understand how and where emissions of greenhouse gases arise the GHG protocol (greenhouse gas protocol) is a good standard to follow as it aims to include the total climate impact of the business for a full year. This can be compared with a lifecycle analysis, which concentrates on the climate impact over the life cycle of a garment. A GHG analysis gives a good basis for creating an action plan that will effectively reduce emissions from our operations. Our emissions are reported broken down into three scopes (1–	H2	Highlight hotspot processes relatively to other processes in product LC

		3), where scope 1 is the direct emissions, scope 2 the indirect emissions for producing purchased energy and scope 3 is other indirect emissions. For operations like KappAhl's a relatively large part of the emissions are at the supplier stage, but also when using (washing) the clothes. Consequently it is crucial to include emissions in scope 3 to gain an understanding of KappAhl's total climate impact."		
Marimekko	17	A significant part of the environmental impact of our operations is due to transportation of our products from place to place - from manufacturers to the logistics centre and onward to the stores or online store and to the customer. The modes of transpor t used are road, sea and air transpor t, and route optimisation aims not only for cost-ef fectiveness but also for the environmentally optimal routing.	H2	Highlight hotspot processes relatively to other processes in product LC
Marimekko	33	The most significant environmental aspects of Marimekko's in-house manufacturing relate to the operations of the Helsinki fabric printing factory. We mitigate climate change with the help of energy efficiency and the use of renewable energy sources, by reducing water consumption and minimising, recycling and reusing waste.	H2	Highlight hotspot processes relatively to other processes in product LC
Marimekko	39	Marimekko takes care of energy, water and material efficiency of its own production and reuse and recycling of waste. In addition to that, it is also important that environmental impacts are also reduced in the supply chain. The environmental impacts of our sourcing are greater than in Marimekko's own production. Marimekko is often only one of a supplier's many customers. Therefore the impacts of the suppliers are a part of a number of customer companies supply chain.	H2	Highlight hotspot processes relatively to other processes in product LC
Marimekko	39	From the perspective of climate change and carbon dioxide emissions, the fabric and glass factories are the most critical parts of Marimekko's value chain. Energy efficiency is important to manufacturers economically as well as environmentally. In some manufacturing countries, for example, the potential for using renewable energy is limited, but several manufacturers have already started using more energy efficient lighting such as LED lamps, for example.	H2	Highlight hotspot processes relatively to other processes in product LC
Björn Borg	5	In 2010 Björn Borg completed a lifecycle assessment (LCA) of a pair of underwear to identify the biggest environmental impacts. The assessment focused on air emissions and water pollution from greenhouse, acidifying and ozone-depleting gases as well as hazardous waste and was conducted according to the ISO 14040 standard. The conclusion was that the biggest impacts are in the production and user phases. [...] The company's LCA showed that as much as 67 percent of the total impact in the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production	H3	Quantify contributions to environmental impacts throughout the LC

		chain. The first step is to significantly improve transparency throughput the supply chain. [...] Björn Borg has formulated three focus areas for its sustainability program in coming years. The priorities are based on where the negative impact is greatest ("Impact") and Björn Borg's sphere of influence ("Control")"		
Björn Borg	6	Behind the factories contracted by Björn Borg lies a chain of subcontractors that includes cotton growers, spinners, weavers and dyeing and printing houses. The company's LCA showed that as much as 67 percent of the total impact in the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production chain. The first step is to significantly improve transparency throughput the supply chain.	H3	Quantify contributions to environmental impacts throughout the LC
Björn Borg	6	IMPACT IN PRODUCTION IS THE KEY The LCA showed that about 37 percent of the environmental impact is in production, in the process stretching from fibers to finished garment. This part of the lifecycle lies with external parties. However, Björn Borg uses a relatively small, manageable number of factories, which facilitates dialogue and monitoring.	H3	Quantify contributions to environmental impacts throughout the LC
Björn Borg	21	Packaging is also part of the total environmental footprint in the product lifecycle – both the packaging used in logistics and product packaging. Transporting products has a significant impact as well. In the climate footprint from Björn Borg's own operations, shipping accounts for about 60 percent of total CO_2 emissions. This represents a large part of the impact that the company has direct control over, and it is therefore an area where the company can make a difference through various types of measures.	H3	Quantify contributions to environmental impacts throughout the LC
Björn Borg	24	Air freight accounted for 8 percent of all transports (collection units shipped) and for as much as 67 percent of the total climate impact from transports in 2015. The percentage of air freight is too high and in 2016 the company will take several measures to reduce air shipments. Björn Borg's policy is that shipments from Asia should go by boat except in special circumstances	H3	Quantify contributions to environmental impacts throughout the LC
Björn Borg	26	The company's product transports clearly have the biggest climate impact, nearly 60 percent of the total footprint (see more above), followed by business travel.	H3	Quantify contributions to environmental impacts throughout the LC
Björn Borg	30	The lifecycle analysis Björn Borg conducted on a pair of underwear showed that nearly 60 percent of the climate impact is in the user phase, mainly from washing. The company's products, especially underwear and sports apparel, are washed often and usually at high temperatures. Frequent washing and high temperatures have a significant environmental impact and affect the	H3	Quantify contributions to environmental impacts throughout the LC

		useful life of the garment in that its color and quality can deteriorate more quickly. Björn Borg therefore tries in various ways to encourage consumers to handle garments in a way that reduces the environmental footprint and extends their useful life. The company provides customers with simple washing instructions on the label and in more detail on and in the packaging. The company measures its ability to build engagement for sustainability by consumers in periodic surveys.		
Björn Borg	30	The lifecycle analysis Björn Borg conducted on a pair of underwear showed that nearly 60 percent of the climate impact is in the user phase, mainly from washing. The company's products, especially underwear and sports apparel, are washed often and usually at high temperatures. Frequent washing and high temperatures have a significant environmental impact and affect the useful life of the garment in that its color and quality can deteriorate more quickly. Björn Borg therefore tries in various ways to encourage consumers to handle garments in a way that reduces the environmental footprint and extends their useful life. The company provides customers with simple washing instructions on the label and in more detail on and in the packaging. The company measures its ability to build engagement for sustainability by consumers in periodic surveys.	H3	Quantify contributions to environmental impacts throughout the LC
H&M	9	Relative contributions (%) of the different value chain phases to the carbon and water footprint are displayed at the beginning of the report, together with a summary of what the company does in relation with each stage. "*Climate and water impacts are based on the estimated H&M value chain footprint from our total use of cotton, organic cotton, polyester and viscose in 2011/2012. For the footprint analysis, primary and secondary data has been used and the principles of the Lifecycle Assessment methodology have been applied. The remaining 5% climate impacts result from packaging. The water footprint is based on the Water Footprint Network's methodology and includes green, blue and grey water footprint. Deviation from 100% due to rounding effects."	H3	Quantify contributions to environmental impacts throughout the LC
H&M	10	Caring for our clothes at home represents about 26% of all of the greenhouse gas emissions in a garment's life. Our challenge is to create affordable fashion that our customers will love from season to season and that is easy to care for with the lowest possible impact. We need to inspire our customers to be more conscious in the way they care for their clothes, for example as regards washing and drying, and make it easy and effortless to recycle any garment that might no longer be wanted.	H3	Quantify contributions to environmental impacts throughout the LC
H&M	24	Teaming up with our customers helps us make an even bigger impact. Did you know that washing and drying represents 26% of a garment's climate impact according to our calculations? Not only do we need to inspire our customers to make conscious wardrobe choices, we also	H3	Quantify contributions to environmental impacts throughout the

		need to help them care for their clothes so they last as long as possible, have less impact on our climate and water, and are easy to recycle.		LC
H&M	76	About 26% of the carbon emissions in its life occur when it's washed and cared for at home. Washing at 30°C instead of 60°C will cut energy use in half and save you money, too.	H3	Quantify contributions to environmental impacts throughout the LC
H&M	83	Looking at the lifecycle of our products, only about 10% of the climate impacts happen in our own operations. The remaining 90% result from transport (6%), raw material production (12%), fabric production (36%) packaging (5%), garment manufacturing (6%) and when our customers wash and care for their clothes (26%). So, while we are reducing our own emissions to a minimum, we want to look beyond our walls and **inspire** others to be climate smart. We want to use our scale to adopt a sciencebased approach moving our whole value chain to a more climate orientated operation to ensure we support limiting global warming to well below a 2°C increase compared with pre-industrial levels. We also work to inspire our customers to care for their clothes in a conscious way and we take a stand for strong public policies.	H3	Quantify contributions to environmental impacts throughout the LC
H&M	83	Pie chart showing the breakdown of climate impacts in the value chain	H3	Quantify contributions to environmental impacts throughout the LC
H&M	100	Our lifecycle assessments show that the most significant water footprint in our value chain occurs in raw material production (87%). It is mainly because cotton production is highly water intense and our goal is to use cotton solely from sustainable sources by 2020 at the latest. This is also why we are working with clothing recycling in order to decrease our dependence on virgin materials. The second biggest water footprint is in customer use and we have worked with Clevercare to help customers make washing decisions that are more energy- and water-friendly. The third biggest water footprint is from washing and dyeing processes in fabric production and garment finishing, for example to achieve the desired look of denims. We are working together with a variety of organisations and initiatives to address capacity building in factories, e.g. STWI, PaCT, NRDC, Solidaridad and the WWF. We want to go beyond ensuring compliancewith minimum requirements. In 2015, we therefore developed a new way of assessing our suppliers' sustainability performance that considers more than just compliance and instead focuses on actual impacts. This helps suppliers to better understand and – where needed with our support – develop their own strategies to tackle these impacts. As part of this, we have	H3	Quantify contributions to environmental impacts throughout the LC

		developed a broad set of additional measurements and amongst other things, we have incorporated what we have learned through our partnership with the WWF.		
KappAhl	108	The distribution of emissions through the value chain from design to consumption is as follows for 2015/2016: design, production, logistics, sales, consumer	H3	Quantify contributions to environmental impacts throughout the LC
KappAhl	n.a.	[at the beginning of each section focusing on a differnt life cycle stage, KappAhl indicates the contribution of the stage to the climate impact]	H3	Quantify contributions to environmental impacts throughout the LC
Bestseller	71	Cotton is our most important raw material, but conventional cotton growing has a negative impact on the environment as the farmers use many pesticides and fertilisers and much water. Therefore we have set ourselves the goal that by 2020 the majority of our cotton must come from sustainable sources, such as better cotton, organic cotton or recycled cotton	H4	Highlight processes particularly impacting in general
Björn Borg	14	Like most clothing companies, Björn Borg uses a lot of cotton. Cotton currently accounts for more than 80 percent of the fibers used in the company's garments (based on number of units and percentage of cotton in them). As a fiber, cotton poses considerable sustainability challenges. Significant amounts of chemicals are used to cultivate cotton and extract the fiber, which has an adverse impact on people and the environment. In addition, a great deal of water is required to grow and process cotton.	H4	Highlight processes particularly impacting in general
Björn Borg	15	Significant amounts of chemicals and water are typically used in the manufacture of fabrics, which poses a number of environmental challenges. Björn Borg has no direct contractual relationships with this part of the supply chain, but has a chemical management program that indirectly has an impact. An important next step is to find ways to more directly influence impacts at this level as well. This work is being carried out within the framework of the company's focus area Transparency.	H4	Highlight processes particularly impacting in general
Gina Tricot	7	A fundamental sustainability challenge when working with fashion is that the materials of the garments last longer than the fashion.	H4	Highlight processes particularly impacting in general
Gina Tricot	7	A fundamental sustainability challenge when working with fashion is that the materials of the garments last longer than the fashion. "We're constantly trying to increase the proportion of sustainable materials, but recycling is obviously also extremely important. We really try to encourage our customers to donate their used garments to us – or to a charity of their choice – so that they can be sorted and recycled. The important thing is that they are put	H4	Highlight processes particularly impacting in general

		back into circulation and not incinerated or dumped at landfills. As recycling processes change, we will adapt our design processes as well, for example, by ensuring that our material compositions are optimal for recycling." However, it's not just the materials of our garments that create an environmental impact. Wear is also highly significant. In our washing instructions we recommend less frequent washing and lower temperatures. This is actually one of the best environmental suggestions there is. Only wash when necessary, always run full loads, and try to keep the temperature to a minimum. This will also help you to better preserve your clothes!"		
Gina Tricot	14	For Gina Tricot, this implementation process involves us working with two denim laundry factories in Turkey, our largest producing country. […] It's also important to remember that denim is a highly water- intensive part of the textile industry."	H4	Highlight processes particularly impacting in general
Gina Tricot	16	Cotton is one of the world's most water-intensive crops, as well as the most sprayed. Precious water and expensive fertilizers and pesticides create a fi nancial and environmental challenge in themselves: More fertilizers lead to finer and greener plants, which leads to more pests, and in turn more pesticides, which leads to more contaminated water.	H4	Highlight processes particularly impacting in general
H&M	9	Processing raw materials such as cotton is a part of the value chain that is often associated with concerns for working conditions and intense water and chemical use. By making the right choices at this stage, we can reduce such impacts significantly. Ultimately, we achieve a closed loop in which old garments can be recycled into new ones.	H4	Highlight processes particularly impacting in general
H&M	18	Cotton is the material we use the most and we are one of the biggest users in the world of certified organic cotton according to the Textile Exchange's latest Organic Cotton Market Report. Cotton is a natural, renewable fibre that offers many advantages, but also comes with a number of concerns. For example, the amount of conventional cotton needed for an average t-shirt requires about 11 bathtubs of water to grow. Also, about 16% of all insecticides and pesticides in the world are used in cotton production.* This not only impacts people and the environment, it also results in higher costs.	H4	Highlight processes particularly impacting in general
H&M	20	Producing man-made cellulosic fibres such as viscose requires pulp, which usually comes from trees. Annually, an estimated 120 million trees* are cut down for fabric production, with the growth of viscose production projected to double by 2025. In the worst cases, these trees come from ancient or endangered forests, and from the habitat of endangered species. We do not want any endangered or ancient forests cut down to make any of the fabrics that we use. That's why we teamed up with the NGO Canopy and a number of other leading brands to ensure that the man-made cellulosic fibres we use for making our products do not contribute to such deforestation	H4	Highlight processes particularly impacting in general

H&M	42	Leather products can require intense chemical treatment that can affect both the environment and workers.	H4	Highlight processes particularly impacting in general
H&M	86	According to a study conducted by WRAP, around one-third of clothing in the UK goes to landfill, while the U.S. Environmental Protection Agency (EPA) estimates that textile waste occupies nearly 5% of all landfill space in the US. About 95% of this could be reused or recycled. This is why we need to change something about the fact that resources are extracted on one end and wasted on the other. This opens up great opportunities. A new source for making new garments with low-impact materials, for example, while reducing waste and minimising the need for land, water,chemicals and more to make virgin raw materials.	H4	Highlight processes particularly impacting in general
H&M	86	We strive to reduce, reuse and recycle wherever we can – packaging, hangers and shopping bags, to name a few examples. However, the biggest concern is the actual clothes and textiles, and what happens when consumers no longer want or need their garments. Today, far too much fashion goes out with the household waste and ends up in landfills.	H4	Highlight processes particularly impacting in general
H&M	97	Producing denim requires significant amounts of water. However, this denim is made with the lowest possible environmental impact compared with traditional production methods. This is thanks to the environmentallyfriendly denim expert consultancy Jeanologia and their methods to measure and reduce the negative effect of treatment processes on our planet.	H4	Highlight processes particularly impacting in general
H&M	103	Producing denim requires significant amounts of water. In order to reduce water impacts, we focus on innovative production methods without compromising our customers' demands. Since 2014, such low-impact production methods are part of our conscious consumer labelling for products with the highest sustainability standards.To define the products with the lowest impacts, we use a tool developed byJeanologia, a Spanish consultancy and experts on sustainable denim washes. Their Environmental Impact Measurement tool (EIM) helps to rate the treatment process impacts, for example, with regard to water use, energy use and chemical management. The ratings are divided into three categories – green, yellow and red.	H4	Highlight processes particularly impacting in general
H&M	104	Producing raw materials and making fabrics can have significant water impacts. That's why we want to make the best possible fabric choices and help cotton farmers and fabric millsin particular to reduce their waterimpacts. And of course make waterconscious fabric choices right from the start when designing our products. One way to do this is to choose recycled materials. In 2014, we launched our first closed-loop denim collection using at least 20% recycled cotton from collected clothes. We estimate that each of	H4	Highlight processes particularly impacting in general

		these denim pieces uses up to 1,000 fewer litres of water compared to using only conventional virgin cotton.		
H&M	104	Producing denim requires significant amounts of water. In order to reduce water impacts, we focus on innovative production methods without compromising our customers' demands. Since 2014, such low-impact production methods are part of our conscious consumer labelling for products with the highest sustainability standards.	H4	Highlight processes particularly impacting in general
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IC Group	9	Chemical management and deep dives into the supply chain will also continue to be in focus as a result of our due diligence processes. Leather, down and wool supply chain transparency are challenging and continue to require our full attention. Closely connected are the awareness building activities and training, which we will continue to conduct across own employees and suppliers.	H4	Highlight processes particularly impacting in general
KappAhl	29	ABOUT 10 PER CENT of our garments contain cellulose-based fibres such as viscose, lyocell and modal. As studies show that a third of the world's viscose comes from endangered primeval forests, during the year KappAhl joined Canopy, an organisation that works to ensure that the textile industry's cellulose-based fibres come from sustainable forestry.	H4	Highlight processes particularly impacting in general
KappAhl	46	If we could extend the period of use by just three months, a garment's footprint in terms of carbon dioxide emissions, water consumption and waste would be 5-10 per cent lower than today. We therefore endeavour to design clothes on average that work for several seasons, but also to pass on knowledge on how customers themselves can contribute.	H4	Highlight processes particularly impacting in general
Lindex	33	Water is especially used in textile production in the washing processes that gives the garment the right color, look and feel. The amount of washes a garment go through is decided by raw material, technical equipment and look. Denim production can require one of the most water intense textile processes, due to intensive washings, which is why we took a holistic approach to our denims in 2014 as an extension of our ongoing work with cleaner and more sustainable production projects.	H4	Highlight processes particularly impacting in general
Lindex	39	Growing cotton is highly water and pesticide intense and have a large negative environmental impact. By choosing organic and better cotton, we want to contribute to a more sustainable cotton production using less water, chemicals and pesticides and to improve the life conditions of small holder farmers.	H4	Highlight processes particularly impacting in general
Lindex	40	Man-made cellulosic fibers, such as viscose, are madefrom cellulose from e.g. wood or cotton. Viscose can have a heavy negative environmental impact in both the sourcing of wood pulp and in the production process where a vast	H4	Highlight processes particularly impacting in

		amount of chemicals are required. As a more sustainable option to viscose we are using Tencel®, a fiber made of eucalyptus tree in a closed process where 99.5% of all process chemicals can be recycled and used again.		general
Marimekko	29	Leather production associated with the meat processing industry and leather tanning have significant environmental impacts in terms of deforestation and chemical contamination from the manufacturing, for example. We require all our suppliers to report us about the origin of leather products and the leather tanning location. In respect of tanning, we find it important that the wastewater from the process is treated and purified properly and that workers are trained to take the chemical health risks of manufacturing into account.	H4	Highlight processes particularly impacting in general
Mini Rodini	14	It is then also processed through an alternative machine instead of the traditional and still very commonly used super wash method with chlorine treatment that is very harmful for nature. The method we use saves 80 % chemicals and needs zero litres of water.	H4	Highlight processes particularly impacting in general
Mini Rodini	21	One of the reasons fluorocarbons are so harmful apart from not degrading in nature and being hormone disruptive, is that they can travel extremely easy from one material to another through the natural air- and waterways	H4	Highlight processes particularly impacting in general
MQ Retail	32	The textile industry's largest environmental challenge is the tremendous amount of water and chemicals required to produce textiles – particularly cotton. To fulfil its commitment to responsible production, MQ has chosen three paths: • Reduce the proportion of cotton used in the long term • Increase the proportion of sustainable cotton (organic cotton and sustainably grown cotton under the Better Cotton Initiative) • Increase the proportion of sustainable materials	H4	Highlight processes particularly impacting in general
Björn Borg	6	The report is structured around the different life cycle stages with descsription of environmnetal issues and related actions at the company	S1	Graphical representation of the product LC
H&M	9	Display of value chain stages and associated sustainability challenges	S1	Graphical representation of the product LC
H&M	89	[display life cycle from raw material to reuse to illustrate the idea of closing the loop]	S1	Graphical representation of the product LC
KappAhl	23	[KappAhl displays its value chain stages: design and purchasing, production, logistics, sales and consumption and outline its initiatives in each step]	S1	Graphical representation of the product LC
KappAhl	n.a.	[the report is partly structured around the value chain stages with summary of issues and practices]	S1	Graphical representation of the product LC

Lindex	38	Display of the "garment processes" as a cycle, from design and materials to end of life	S1	Graphical representation of the product LC
Marimekko	17	The section "our value chain" introduces each life cycle stage: design and materials, sourcing and production, logistics, stores, use and car of products, recycling and end of life. For each stage, a comment on the company's practices is made	S1	Graphical representation of the product LC
Spectre	2	[The company displays its value chain from raw materials to customers/distribution and highlight environmental challenges]: Spectre's business model is illustrated as seven steps. However, the model is a simplified guide to understanding our business and value chain. The seven steps serves as a tool for mapping issues of relevans in our CSR efforts.	S1	Graphical representation of the product LC
Björn Borg	5	STARTING POINT IN PRODUCT LIFECYCLE The natural starting point for Björn Borg's sustainability programs is the product lifecycle – the various stages involved in producing and marketing products, followed by the user phase by the consumer. The product lifecycle describes Björn Borg's operations based on which stakeholders are affected and the impacts on the environment and society through the value chain.	S2	Explicit definition of the product LC
Bestseller	7	[in answer to SDG 12] we work with suppliers to optimize our production processes and minimize the negative impact of our production on the environment. We engage with our customers to influence their consumption patterns and minimize the negative impacts of using and disposing of our products.	S3	Consideration of product LC in the sustainability strategy of the company
Björn Borg	6	SHARE OF ENVIRONMENTAL IMPACT ACCORDING TO LCA Based on these conclusions, the company's sustainability program is designed with the ambition to minimize negative impacts throughout the product lifecycle, even when they are caused by external production partners or the consumer.	S3	Consideration of product LC in the sustainability strategy of the company
Björn Borg	14	MEASURES AND RESULTS DURING THE PRODUCT LIFECYCLE The company's sustainability program is structured around the product lifecycle with the Björn Borg Sustainability Roadmap as a foundation. The concrete issues topping the agenda, the results achieved in 2015 and the priorities going forward are listed below.	S3	Consideration of product LC in the sustainability strategy of the company
Filippa K	8	There are many challenges in being part of the textile industry, an industry with a long and complex supply chain and one that leaves significant environmental and social footprints. We try to reduce our negative impacts through the choice of our materials, our practices in production, and our partners in the value chain. But perhaps most importantly, our aim is to not produce more than needed and to not contribute to overconsumption. For us, that means increasing our purchase precision, and offering long-lasting products of quality, style and simplicity, as well as enabling our products a second life, for example through	S3	Consideration of product LC in the sustainability strategy of the company

		our second hand store.		
Filippa K	8	We strive to run a long-term sustainable business within our planetary boundaries. To ensure long-term sustainable success we must have a holistic view of our business, understand how all parts interact and make sure our value chains are long-term sustainable.	S3	Consideration of product LC in the sustainability strategy of the company
Filippa K	16	We aim to create products with minimal negative impact on people and the environment, which we refer to as our Front Runners of long lasting fashion. We help our customers take better care for their garments so as to make them last for as long as possible and to minimize any negative environmental impact in the user phase. We encourage people to give their used garments a second life by passing them on to others or by returning them to one of our stores so that we can help pass them on. We want to encourage our customers to take their old worn-out clothes back to a Filippa K store, so that we can recycle them wherever there is infrastructure available to do so.	S3	Consideration of product LC in the sustainability strategy of the company
Filippa K	19	This store is one way of taking responsibility for the entire lifecycle of our products and providing an alternative to the practice of shopping and disposal.	S3	Consideration of product LC in the sustainability strategy of the company
Filippa K	27	Taking into account not only the fibre sourcing phase but also the use phase and the disposal at end-of-use, things are looking up. Despite the longevity characteristics mentioned above, wool is biodegradable, renewable, recyclable and compostable. There's no one correct answer to the question of whether wool is sustainable. The truth is, it's complicated, and the classification of wool has to be diversified as wool production differs a lot depending on things like farming methods and countries of origin.	S3	Consideration of product LC in the sustainability strategy of the company
Gina Tricot	8	BY 2028: All products will be produced from sustainable materials, All production will be performed in a sustainable way, All shipments will be made using sustainable practices, All products will serve as a resource when the customer no longer wants them	S3	Consideration of product LC in the sustainability strategy of the company
H&M	6	We want to use our scale to bring about systemic change to the industry and across the lifecycle of our products. Together with our colleagues, customers, stakeholders, business partners and peers, we have the opportunity to bring about serious change – all the way from improving the livelihood of a cotton farmer to lowering the impacts from washing and drying our clothes.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	9	We have stores and suppliers all around the world. Undoubtedly, we have an impact on the communities and the environment around us. Embracing positive impacts along our value chain, and working hard to reduce negative ones, is the core of H&M Conscious. It is usually easier to control what happens in our own operations, but often this is not where the most critical impacts take place. Teaming up with others is therefore key to make the difference that matters the most."	S3	Consideration of product LC in the sustainability strategy of the company

H&M	13	By making conscious choices all the way from the cotton field to the point when you may no longer want a beloved piece, we can make a big difference to our planet. It starts with the design and the importance of creating products in innovative and more sustainable ways without compromising on looks, quality or comfort. But we don't want to stop there. We want to inspire our customers to wash at lower temperatures and make it as easy as possible to recycle the clothes that are no longer wanted or needed.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	27	We use our influence to promote better working conditions, ensure that human rights are respected and reduce environmental impacts throughout our value chain – from working with individual factories to pushing for systemic change in countries and in the textile industry.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	83	In 2015, we started the implementation of our new supplier sustainability assessment programme SIPP (Sustainable Impact Partnership Programme). This means a major shift, particularly for our climate work in the value chain. The new programme creates the base for suppliers to measure and manage their own climate impact and at the same time it helps us to shift resources to provide our suppliers with more effective support (s. 2.2). As part of this, we are gathering climate impact data from our first- and second-tier suppliers and integrating it into reward systems for good sustainability performance. We encourage our suppliers to set their own reduction targets and support them in reaching these through capacity building, for example, through a set of different cleaner production programmes that we run together with partners such as NRDC and Solidaridad. In terms of raw materials, we can make a major difference already in the design phase by choosing the right materials, for example, by using sustainably sourced cotton instead of conventional cotton (s. 1.2), but also by using raw materials that do not contribute to deforestation (s. 1.5). And finally, we want to inspire our customers to wash their clothes at lower temperatures (s. 6.6). This may seem like the final step in the garment's lifecycle, but it could also just be the beginning. We encourage everyone to bring unwanted garments to our stores for reuse and recycling. (s. 5.2). From a climate perspective, extending the life of textile fibres as long as possible is the best option. To underline our commitment to climate leadership, we are in the process of becoming a member of the WWF Climate Savers. This partnership will not only lift our commitment to promoting climate consciousness throughout our own operations and our value chain, but also show that we are taking a stand for a strong climate policy.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	84	For many years, we have been working to reduce climate impacts in different phases of the value chain. For example, choosing organic cotton means 46% less climate impact as compared to conventional cotton. By involving our suppliers	S3	Consideration of product LC in the sustainability strategy of the

		in cleaner production programmes including the Better Mills Initiative and PaCT, we contribute to improved energy efficiency, which again has led to reductions in greenhouse gas emissions. We are currently applying what we have learned from our various value chain initiatives to develop a reporting method. The method will include data from our use of more sustainable materials, our garment collecting initiative as well as both first- and second-tier suppliers to measure and report our emissions reductions in our value chain.		company
H&M	84	For many years, we have been working to reduce climate impacts in different phases of the value chain. For example, choosing organic cotton means 46% less climate impact as compared to conventional cotton. By involving our suppliers in cleaner production programmes including the Better Mills Initiative and PaCT, we contribute to improved energy efficiency, which again has led to reductions in greenhouse gas emissions. We are currently applying what we have learned from our various value chain initiatives to develop a reporting method. The method will include data from our use of more sustainable materials, our garment collecting initiative as well as both first- and second-tier suppliers to measure and report our emissions reductions in our value chain.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	96	In the textile industry, water plays a particularly critical role, from growing cotton to washing our clothes at home.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	99	What's most important is what we, together with our peers, do to ensure that water is used responsibly throughout the value chain.	S3	Consideration of product LC in the sustainability strategy of the company
H&M	99	Growing cotton, dyeing fabrics, creating washed-out looks and not least washing our clothes at home all have an impact on water resources.Operating in a water-intense industry, we have a keen interest and responsibility to not only reduce water impacts across our value chain, but also to help the communities along our value chain to ensure that clean water is available to everyone."	S3	Consideration of product LC in the sustainability strategy of the company
IC Group	6	The Higg Index is a tool developed by the Sustainable Apparel Coalition (SAC). The implementation of this tool is continuously one of the Group's key focus areas. SAC is an organization bringing together some of the key players in the fashion industry accounting for approximately 40% of the world market for apparel and footwear. SAC leads the way in creating a common sustainability standard throughout a product's full lifecycle - both environmentally and socially. The core tool, The Higg Index, allows companies and suppliers to benchmark their scores against other users of the index in a transparent forum, supporting **a new, partnership-based approach to value chain**	S3	Consideration of product LC in the sustainability strategy of the company

		management. Since IC Group joined SAC, the Group has participated actively in developing The Higg Index and implemented all three modules of the index – the product, the brand and the facility modules.		
IC Group	8	Knowing the climate impacts throughout our value chain means we can make better decisions in the design phase and in the way we source products.	S3	Consideration of product LC in the sustainability strategy of the company
KappAhl	23	KappAhl's value chain is complex and contains many challenges, as well as opportunities. The work of integrating the sustainability aspect into all parts of the value chain– from design, to production, logistics, selling, marketing and consumption– is taking great steps forward every year"	S3	Consideration of product LC in the sustainability strategy of the company
KappAhl	52	The sustainability strategy is developed on the basis of challenges we see in our value chain, for example with the help of life cycle analyses, the UN Development Goals and research around the planetary boundaries."	S3	Consideration of product LC in the sustainability strategy of the company
Lindex	34	Textile production consumes large quantities of water, which makes the water issue critical for a sustainable fashion industry. As a fashion company, our largest water impact lies in the production process, but we also affect through buying cotton that is water-intensive, and by selling products that are then washed by our customers. Through long-term co-operation projects within the industry, we work to minimize the environmental impact in the entire value chain."	S3	Consideration of product LC in the sustainability strategy of the company
Lindex	39	Lindex long-term sustainability ambition is to minimize the negative environmental impact in all parts of the value chain, and to create a positive impact together with suppliers, partners and customers.	S3	Consideration of product LC in the sustainability strategy of the company
Lindex	49	At Lindex we place great importance on sustainability in all aspects of our processes- from design to reuse and recycling. We are working to minimize the impact we have on our environment by using the earth's resources wisely. We strive to be one of the mostsustainable, open and trusted companies in the industry.	S3	Consideration of product LC in the sustainability strategy of the company
Marimekko	15	[In "Our commitments and targets for 2020"] "We develop products and services which have a reduced environmental impact throughout their life cycle."	S3	Consideration of product LC in the sustainability strategy of the company
Björn Borg	5	In 2010 Björn Borg completed a lifecycle assessment (LCA) of a pair of underwear to identify the biggest environmental impacts. The assessment focused on air emissions and water pollution from greenhouse, acidifying and ozone-depleting gases as well as hazardous waste and was conducted according to the ISO 14040 standard. The conclusion was that the biggest impacts are in the production and user phases. [...] The company's LCA showed that as much as 67 percent of the total impact in	S5	Possibility to influence product LC impacts through design

		the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production chain. The first step is to significantly improve transparency throughput the supply chain. [...] Björn Borg has formulated three focus areas for its sustainability program in coming years. The priorities are based on where the negative impact is greatest ("Impact") and Björn Borg's sphere of influence ("Control")"		
Björn Borg	6	Behind the factories contracted by Björn Borg lies a chain of subcontractors that includes cotton growers, spinners, weavers and dyeing and printing houses. The company's LCA showed that as much as 67 percent of the total impact in the production stage is in the first steps of the process, fiber selection and fabric manufacturing. Björn Borg currently does not have any direct contractual relationships at this level, but the long-term goal is to find effective ways to address impacts in these earlier stages of the production chain. The first step is to significantly improve transparency throughput the supply chain.	S5	Possibility to influence product LC impacts through design
Björn Borg	14	The sustainability performance of Björn Borg's products is largely determined in the planning stages in product development. When collection work is kicked off and design work initiated, many decisions are made that affect the sustainability impact of a garment over its lifecycle. The choice of materials and the garment's quality and useful life are critical and are therefore high priorities for Björn Borg.	S5	Possibility to influence product LC impacts through design
Björn Borg	15	Significant amounts of chemicals and water are typically used in the manufacture of fabrics, which poses a number of environmental challenges. Björn Borg has no direct contractual relationships with this part of the supply chain, but has a chemical management program that indirectly has an impact. An important next step is to find ways to more directly influence impacts at this level as well. This work is being carried out within the framework of the company's focus area Transparency.	S5	Possibility to influence product LC impacts through design
Filippa K	17	We focus all our efforts on making these selected styles as sustainable as possible before moving on to the next set of products. By examining every aspect – from the choice of materials to how our customers use and care for their garments until they finally reach their end of life – we learn how to do things right already at the drawing table. The design practices, production techniques and material choices etc. that we adopt will be used for our main collections in the future.	S5	Possibility to influence product LC impacts through design
Filippa K	24	The choice of materials, whether it is the main fabric or the thread holding it together, has a big impact on a product's overall sustainability performance.	S5	Possibility to influence product LC impacts through design
Gina Tricot	7	As recycling processes change, we will adapt our design	S5	Possibility to

		processes as well, for example, by ensuring that our material compositions are optimal for recycling.		influence product LC impacts through design
H&M	93	Recycled materials in particular have two major benefits – they reduce the need for extracting virgin resources and less waste ends up in landfills.	S5	Possibility to influence product LC impacts through design
IC Group	8	The aim of the project done in collaboration with the Danish Environmental Protection Agency and leading international experts was to be able to put a financial value on our environmental impact.The EP&L shows us where in the value chain we have the biggest environmental impact comparing our impact on water, GHG, land use and air in monetary terms and hence identifying sustainability hot spots. The E P&L also shows us the environmental impact of different choices of materials and therefore complements our work with the Rapid Design Module."	S5	Possibility to influence product LC impacts through design
IC Group	8	CLIMATE POLICY As members of a global industry we have a responsibility for reducing our carbon footprint. We believe that taking charge of our carbon footprint is not only a sustainability imperative but also a way to future-proof our business to be able to keep growing while respecting the boundaries of our planet. For IC Group this entails focusing on the leverage points where we can make the biggest difference in terms of climate change. Among others, we use Environmental Profit and Loss accounting and The Higg Index to learn more about our biggest challenges, where we can foster change and help set industry benchmarks. Knowing the climate impacts throughout our value chain means we can make better decisions in the design phase and in the way we source products."	S5	Possibility to influence product LC impacts through design
IC Group	11	For the Group this entails focusing on the leverage points where the Group can make the biggest difference in terms of climate change. Among others, the Group uses environmental accounting according to the Environmental Profit and Loss method (EP&L) and the Higg Index to learn more about where the Group can foster change and help set industry benchmarks. Knowing the climate impacts throughout the value chain means that the Group can make better decisions in the design and sourcing phases.	S5	Possibility to influence product LC impacts through design
KappAhl	24	Our customers think sustainability is important and studies show that more than 80 per cent of a product's impact on the environment is already determined at the design stage. The materials we use, how we construct our patterns and how we intend the garments to be used influence the garments' total environmental impact. Many sustainability initiatives in design and purchasing also contribute to reduced costs and more effective production. Work on the range is partly controlled via range and sustainability strategies, product policy and the criteria for sustainable design that were drawn up during the year and are being	S5	Possibility to influence product LC impacts through design

		implemented at the time of writing		
KappAhl	24	[about opportunities related to design and purchasing] Sustainable decisions on design and purchasing bring improvements throughout the value chain.	S5	Possibility to influence product LC impacts through design
Lindex	37	SUSTAINABILITY IS OF GREAT IMPORTANCE FOR US THROUGHOUT THE ENTIRE GARMENT PROCESS. BY MAKING CONSCIOUS CHOICES STARTING ALREADY WITH THE DESIGN, WE DO WHAT WE CAN TO MAKE A SUSTAINABLE DIFFERENCE IN ALL PARTS OF THE PROCESS.	S5	Possibility to influence product LC impacts through design
Lindex	40	Using denim fabric from the post-consumer recycling flow is a natural part of our ongoing work to reduce our environmental footprint. When upcycling using old garments that normally would have gone to waste to become new products, we reduce the use of raw materials, saving water, energy and chemicals in production.	S5	Possibility to influence product LC impacts through design
Marimekko	4	The circular economy offers a lot of opportunities in our sector as well, and I am pleased that Marimekko products are popular, for example, in online second-hand stores.We can contribute to prolonging the life cycle of products on our part, and I also expect a lot from textile waste recycling opportunities in the future.	S5	Possibility to influence product LC impacts through design
Marimekko	17	[In the section “our value chain”] In design, important choices are made in terms of product lifecycle. With the help of timeless and responsible design, materials manufactured with respect for the environment and people, we can promote more sustainable consumption and help our customers reduce their own environmental impact.	S5	Possibility to influence product LC impacts through design
Marimekko	19	The choice of materials affects directly the product’s lifecycle environmental impacts. The material largely determines the durability of the product and the consumption of energy and detergent needed for product care. A wide range of materials is used for Marimekko products and the choice of these is strongly guided by the use of the product and the feel and other properties of the material.”	S5	Possibility to influence product LC impacts through design
Marimekko	19	The choices made in design and product development have a significant impact on the product’s use and life-cycle environmental impacts. A well-designed, timeless, highquality and fit-for-purpose product brings its user joy for a long time and is therefore a sustainable choice. We extend our products’ life cycles through product development and quality control, but each product must also have that special something – the Marimekko magic which makes the user fall in love with the product and to take good care of it.	S5	Possibility to influence product LC impacts through design
Mini Rodini	12	Every season, we use leftover waste materials to create new products with new need and new value. This production process minimizes our general waste and makes less impact on natural resources, energy and water.	S5	Possibility to influence product LC impacts through design

MQ Retail	34	Recycled polyester fibres come primarily from PET bottles and raw material waste from the manufacturing industry. Using recycled polyester requires less petroleum and creates a new recycling cycle for polyester clothes and used materials.	S5	Possibility to influence product LC impacts through design
Filippa K	28	Today, mixing natural and synthetic fibres such as cotton and elastane makes separation at the end of a product's life difficult. There is a lot of research and development going on within this area, so we will most likely see solutions for successful recycling of mixed fabrics in the nearby future.	T2	Highlight possible tradeoffs associated with alternative solutions for products
Gina Tricot	11	In terms of future recycling, it is also an advantage if the product is free from substances that we do not wish to end up in the recycling system.	T2	Highlight possible tradeoffs associated with alternative solutions for products
H&M	20	Polyurethane (PU) is a material often referred to as "vegan leather" as it contains no animal products. Its downside is that it usually contains solvents requiring workers to wear protective gear and raises environmental concerns. Water-based alternatives would allow fewer precautions. However, in the past, these alternatives have not provided sufficient quality or durability. This is why we have been working for the past few years with several partners to find the required innovation. During 2015 we continued our work and placed two test orders for various kinds of products.	T2	Highlight possible tradeoffs associated with alternative solutions for products
H&M	93	There are certainly challenges on the road towards a closed loop for textiles. For example, the fact that we currently cannot make products with more than 20% recycled cotton from collected garments without a loss in quality and durability. By creating demand for solutions and actively working with innovators and scientists, however, we are positive that we can overcome these challenges. We are currently involved in a number of different promising initiatives and projects	T2	Highlight possible tradeoffs associated with alternative solutions for products
Lindex	50	[challenges related to using recycled clothes] • access to recycled materials which can be reused in the production • challenges of managing mixed materials • challenges with the risk of contamination of unwanted substances and chemicals in recycled material • traceability of the material source in order to ensure consumer safety • the need for large-scale and cost-effective solutions	T2	Highlight possible tradeoffs associated with alternative solutions for products
Marimekko	21	Although environmentally friendly materials can sometimes be challenging from the perspective of quality, I was glad that the recycled material performed very well in tests.	T2	Highlight possible tradeoffs associated with alternative solutions for products
Mini Rodini	14	For the first time, our swimwear collection was made in	T2	Highlight

		recycled polyester coming from mainly PET bottles in Spring/Summer 2015 collection. The fabric was also certified by Oeko-Tex® Standard 100 meaning chemically controlled and independently tested. With swimwear having a skin-tight fit and also being used in water, it is extra important the fabric is safe and certified from harmful chemicals.		possible tradeoffs associated with alternative solutions for products

Table S3. Information about life cycle-based tools mentioned in CS reports.

Life cycle-based tool	**Description**	**Reference**
The Sustainable Apparel Coalition Higg Index	Driven by the Sustainable Apparel Coalition, the Higg Index includes a product-level methodology that scores garments and footwear items based on a life cycle evaluation. This evaluation is based on the impacts of raw materials (LCA-based including the impact categories: climate impact, fossil fuel depletion, water scarcity, chemical inputs and eutrophication) and a rating of practices and processes occurring in the rest of the product's life cycle (Manufacturing, Care & Repair, Quality & Lifetime, and End of Use). For these aspects of the life cycle, no assessment against a set of impact categories is conducted but the scoring methodology increases the total score (i.e. higher impact) if the garment cannot be repaired or has to be dry cleaned, is not designed for recycling or disassembly or is not designed for a long life, etc. Each life cycle stages has its own weight in the scoring, the largest weight is given to the raw materials, on the basis that it the stage for which designers have most control. H&M and IC Group both mention their involvement in the development of the Higg Index methodology.	Sustainable Apparel Coalition, 2018
Environmental Profit & Loss (EP&L)	EP&L was first used by PUMA and is a method of natural capital valuation. Natural capital valuation is a form of accounting, in financial terms, for the impacts that business activities have on natural resources and ecosystem services. "Profit" stands for any industry activity that benefits the environment, and "Loss" stands for all activities that adversely impact the environment.	Danish Ministry of Environment and Environmental Protection Agency, 2014.
Environmental Impact Measure by Jeanologia	The Environmental Impact Measure (EIM) is a tool developed by the company Jeanologia to assess the environmental impact of different garment finishing processes. It provides information in terms of water consumption, energy consumption, chemical product use, and worker health and delivers an overall score for a given process (low, medium or high impact process).	Jeanologia, 2018
The Made-by material list	The consultancy Made-By developed a scoring model which classifies fibers into four classes based on a	Made-by, 2013

	weighted life cycle assessment of their environmental impacts, including GHG emissions (20%), human toxicity (20%), eco-toxicity (20%), energy input (13.33%), water input (13.33%) and land use (13.33%) (Made-by, 2013). Mechanically recycled nylon, mechanically recycled polyester, organic flax, organic hemp, recycled cotton and recycled wool obtain the highest score.	

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Article III

Circular economy in corporate sustainability strategies: A review of corporate sustainability reports in the fast-moving consumer goods sector

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Circular Economy in corporate sustainability strategies: a review of corporate sustainability reports in the Fast-Moving Consumer Goods sector

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Abstract:

Despite the increasing interest of business and academic research towards Circular Economy, the investigation of its uptake by industry remains limited. To contribute filling this gap, we perform a systematic review of 46 corporate sustainability reports in the Fast-Moving Consumer Goods sector aiming to explore how companies incorporate the Circular Economy concept in their sustainability agenda. We focus on (i) the companies´ uptake of Circular Economy, (ii) the relationship between Circular Economy and sustainability and (iii) the Circular Economy practices presented. Our results show that Circular Economy has started to be integrated into corporate sustainability agenda. Most reported activities are oriented towards the main product and packaging, focusing on end-of-life management and sourcing strategies, and to a lesser extent on circular product design and business model strategies. Most identified collaborations are with businesses, whereas initiatives addressing consumers are largely missing although considered critical for the transition towards Circular Economy.

Keywords: CSR report; sustainable development; packaging; household; food and beverage; textile

1. Introduction

The concept of Circular Economy (CE) provides a central vision within the debate about how society may tackle the increasing resource scarcity and depletion of non-renewable resources. Blomsma & Brennan (2017) have defined CE under an "umbrella concept", as "an emergent framing around waste and resource management that aims to offer an alternative to prevalent linear take-make-dispose practices by promoting the notion of waste and resource cycling". Since its creation in 2010, the Ellen Mac Arthur Foundation (EMF) has played a key role in bringing CE on the agenda of decision makers, both in the private and public sectors. National and regional strategies for CE have been developed e.g. in China and the European Union (Jones and Comfort, 2017). The body of research around CE is also increasingly gaining ground in the academic literature, where a number of critical reviews have recently investigated the CE concept, but most studies focused on its origin or theoretical background

(Ghisellini et al., 2016; Blomsma and Brennan, 2017; Winans et al., 2017, CIRAIG, 2015, Kirchherr et al. 2017).

The role of businesses in the development of the CE has been emphasized (Lewandowski, 2016) and the interest of companies towards CE has grown over the recent years (Linder and Williamder, 2017). Chinese companies took the lead in CE implementation as a response to the Chinese governmental policy, and applications of CE in business practice from Western countries are also increasing (Murray et al., 2015). However, only a few studies shed light on CE implementation at the company level, and the implementation of CE worldwide is in its early stages (Ghisellini et al., 2016). Based on a state-of-the-art review of academic insights into CE, Lieder and Rashid (2016) concluded that in the manufacturing industry CE development is to largest extent done from a resource scarcity and environmental impact perspective disregarding the economic implications. This attitude could be detrimental since the essential activities for a successful CE implementation, such as business models, product design, and choice of material, are in control and hence finally determined by manufacturing companies to gain economic benefits (Lieder and Rashid, 2016).

Recent work has focused on providing support for companies to implement CE at a micro level, i.e. product or organization (Aminoff et al., 2016; Lewandowski, 2016; Pauliuk et al., 2018) and shedding light on the barriers and challenges faced by companies in relation with CE implementation (Linden & Williander, 2017; Singh and Ordonez, 2016; Ritzen and Sandström, 2017). Other studies deliver insights on best practices and enablers of CE implementation: De los Rios and Charnley (2017) performed an in-depth analysis on case studies from a limited set of multinational enterprises that are transforming their product strategies for closure of material loops, meanwhile Jones and Comfort (2017) presented and discussed the circular approaches of a limited set of companies. Bocken et al. (2017) recently explored the presence of CE thinking in a sample of corporate press releases from Standard & Poor’s 500 listed large capitalized firms. Yet, investigations of the uptake of CE in industry remain limited hitherto.

An increasing number of mainly large companies yearly release corporate sustainability (CS) reports which provide their external stakeholders with a description of their sustainability strategies and practices (Montabon et al., 2007; Borga et al., 2009; Siew et al., 2017, Landrum and Ohsowski, 2017). When it comes to companies’ approaches to corporate sustainability, CS reports are considered to be their most direct expression (Comas Martí and Seifert, 2013). Hence CS reports have been used as a data source by a growing number of scholars to investigate CS activities. For instance, Comas Martí and Seifert (2013) performed a content analysis of CS reports for a cross-sectoral sample of sustainability leaders to investigate the comprehensiveness of firms’ environmental strategies throughout supply chains. Meckenstock et al. (2016) analyzed 142 CS reports across 12 industries to investigate how sustainability evolves from abstract ideas to operational practices across the supply chain. Sihvonen and Partanen (2017) conducted a review of CS reports in the Information and Communication Technology (ICT) sector, to identify, among others, CE-related activities present at companies. However, the overall role and influence of the CE concept in CS agenda were not addressed. The large pool of publicly available CS reports gives the opportunity to explore the role of

CE in CS strategies and how companies have been incorporating the core ideas of CE within their main external communication tool.

A sector with large potential in applying CE principles is the Fast-Moving Consumer Goods (FMCG) industry, which includes products characterized by high throughput volumes, frequent purchases and large physical volumes available at relatively low prices (EMF, 2013). FMCG currently account for 35% of material inputs into the economy, a significant part of total consumer spending on tangible goods, and 75% of municipal solid waste (EMF, 2012). Within the FMCG sector, food, beverages, textiles, and packaging represent 80 % of the total market by value (EMF, 2013). To our knowledge, no previous study has reviewed the integration and implementation of CE in the FMCG sector. Therefore, this study aims to explore how the recently highly promoted concept of CE affects FMCG companies' sustainability agenda as reported in their CS reports. In this perspective, the study contributes to fill the gap on the missing link between academic research and business practice on CE.

The remainder of the article is structured as follows. In the next section, we provide a theoretical background on CE from which we derive three research questions. Further, the methodology to answer these research questions is introduced. Then, we present the results from the CS reports analysis for each research question and discuss our findings in the light of previous academic work. Finally, we shed light on the limitations of the present study and provide the theoretical and managerial implications of the results, before outlining our conclusions.

2. Theoretical background

2.1. The concept of Circular Economy

The CE concept is not new, yet the momentum recently created around the concept turned into a business approach is without precedent (Sauvé et al., 2016). In their recent analysis of 114 CE definitions both from academic and grey literature, Kirchherr et al. (2017) reveal that a variety of CE conceptualizations coexist. According to Stahel (2016), the objective of CE is "to maximize value at each point in a product's life". The French environment and energy management agency (ADEME) defines the CE as an economic model which values resource efficiency at every stage of the value chain, stating that "Circular economy aims at reducing the waste of natural resources and more generally aims at protecting the environment (climate change, preserving biodiversity). The transition towards this new economy require the development of new production and consumption models and the involvement of stakeholders at all levels" (ADEME, 2016). It emerged that some authors consider CE and recycling interchangeably, while practitioners tend to exclude "reduce" from the core principles of CE (Kirchherr et al., 2017). An alignment of the concept among scholars and practitioners is needed, if the CE is to "deliver on its promise of fundamental change" (Kirchherr et al., 2017).

CE is a concept into which many "Design for X" strategies promoted by the eco-design community (e.g. design for recyclability, design for reuse) and other long-lasting promoted environmental management practices (e.g. material efficiency) can fit in (Moreno et al., 2016). However, a "casual interpretation" of CE can lead practitioners to view it as a mere refreshing of recycling schemes and reverse supply chains rather than a true systemic change (Webster, 2013). CE requires a shift from current systems, rather than an “incremental twist” (Kirchherr et al., 2017). Kirchherr et al. (2017) suggest that the concept of CE is constructed on a set of R-principles (reduce, reuse, recycle, recover), in a systemic perspective, at all economic levels.

The transition towards CE as a new business paradigm is associated with critical challenges in terms of resource management, stakeholder management, financial and regulatory aspects, organizational barriers and consumer acceptance (Stewart et al., 2018; Ritzen and Sandström, 2017). Thus companies’ commitments towards CE might remain mainly aspirational (Jones and Comfort, 2017). In this context, there is a risk for business actors to symbolically uptake the concept for greenwashing purposes (Sauvé et al., 2016). CS reports have an important legitimacy role for companies, since through such communication tools they may seek to maintain their license to operate and reduce possible gaps between their stakeholders’ expectations in terms of sustainability and their own practices (Hahn and Kühnen, 2013). The risk for organizations to include CE in their CS rhetoric without anchoring CE in their actual practices is thus elevated. Knowledge about how companies understand and conceptualize the CE concept is limited in existing literature.

RQ1: How is companies’ uptake of CE in their CS reports?

2.2. Circular Economy and sustainability

The popularity of CE among both practitioners and scholars has been linked to its promise to attractively operationalize the concept of sustainable development (Kirchherr et al., 2017). Yet, in the definitions they reviewed, Kirchherr et al. (2017) found that in the academic literature CE is mostly linked to the aim of economic prosperity which contradicts some views from industry that CE is strongly related to environmental sustainability (e.g. Lieder and Rashid, 2016). The most circular option is not necessarily the environmentally preferable option when CE is applied on the micro-level (Haupt and Zschokke, 2017). Korhonen et al. (2018) outline that stronger links with environmental science need to be established to guarantee that CE effectively contributes to sustainability. Overall, different ways to position the CE concept in relation with sustainability coexist in literature. Geissdoerfer et al. (2017) suggest a typology of relationships between CE and sustainability to illustrate the variety of views: a *conditional relationship* means that CE is considered as a condition for reaching sustainability; a *beneficial relationship* means that CE is considered as one way to progress towards sustainability among others; a *trade-off relationship* means that CE is considered to lead to sustainability trade-offs (both benefits and negative outcomes). There are academic efforts to conceptually link circular business model and environmental value creation (Manninen et al., 2018). Nevertheless, scholars emphasize the need for methods to assess the environmental, social and economic sustainability performance of circular products and business models (Bocken et al., 2016; Elia et al., 2017; Pauliuk et al., 2018) and a lack of circularity indicators at the micro level (Linder et al., 2017). As far as the industry is concerned, little is known about how companies position CE in their sustainability agenda and measure the sustainability performance of circular approaches.

RQ2: How do companies link CE and sustainability in their CS reports?

2.3. Circular Economy practices

The well-known illustration of CE provided by the EMF distinguishes between the so-called technical and biological metabolisms (EMF, 2013). The technical metabolism illustrates how the value of technical materials should be kept through continuous loops aimed at strategies such as maintain, reuse/redistribute and refurbish/remanufacture, and recycle. The biological metabolism refers to a system where ‘nutrients’ are designed to re-enter the biosphere safely for decomposition to become valuable feedstock for a new cycle. CE principles can be applied to different application systems, namely packaging, main products or by-products.

According to Bocken et al. (2016), CE is about closing, slowing or narrowing resource loops. Closing loops refers to reuse of material through (postconsumer waste) recycling, slowing loops is about prolonged use and reuse of goods over time, through design of long life goods and product life extension, whereas narrowing loops is about reducing resource use associated with the product and production process, i.e. efficiency improvements (Bocken et al., 2016). Scholars identified three main categories of CE activities reported by companies, namely resource and waste management (Ghisellini et al., 2016; Potting et al., 2016), product design stage (Bocken et al., 2016, Witjes and Lozano, 2016; Linder and Williander, 2017; De los Rios and Charnley, 2017) and development of new business models (Bocken et al., 2016; Lewandowski, 2016). Moreno et al. (2016) proposed a conceptual framework for circular product design by linking available Design for Sustainability approaches to the current literature on circular business models. Beyond design and business model, and as outlined by the CE principles (EMF, 2015), the general optimization of resources and use of renewable resources are also at the core of CE. Thus, sourcing strategies, e.g. the use of recycled content and renewable material, operation strategies, e.g. energy efficiency, use of renewable energy and recovery of operation waste and end-of-life strategies, e.g. actions supporting recycling/recovery infrastructure/initiatives, are also activities under CE. With regard to recycling, the CE agenda raises the issue of quality of recycling, first introduced in the context of the Cradle to Cradle® (C2C) design framework, through the term “upcycling” which refers to the redesign of ingredients or additives so they improve the quality of materials with respect to maintaining or improving value in continuous loops (McDonough and Braungart, 2002). Korhonen et al. (2018) argue that one specific contribution of CE is its focus on the importance of high value and high quality in material cycles.

Another key area of CE practice is collaboration in business ecosystems which is outlined as one pillar of a transition towards a well-functioning CE (Witjes and Lozano; 2016). Collaboration is also closely related to the system perspective which is another fundamental aspect of CE practice (Webster, 2013). There has been limited attempts to explore CE practice in the industry (De los Rios and Charnely, 2017; Jones and Comfort, 2017), and broader investigations are recommended by scholars (Moreno et al., 2016).

RQ3: Which CE practices do companies present in their CS reports?

3. Methodology

3.1. Sample definition

The sample of companies to be included in this study was systematically built using the Corporate Register database. It is the largest online database of CS reports with possibility of doing content searches (CR, 2017), previously used by Bjørn et al. (2016) in a similar context, i.e. to perform a comprehensive review of references made to ecological limits in CS reports in 2000-2014. Corporate Register seeks to include all sustainability reports "without limitations of country or company size and across all sectors, public and private" and it estimates that more than 90% of all reporting companies and other organizations are covered in the database which is updated daily (CR, 2017). The database includes any type of sustainability reports in Latin-script, e.g. integrated report, sustainability and environmental reports (CR, 2017). In January 2017, we identified all sustainability reports of companies (i.e. excluding other organizations) listed in the above-mentioned database released until 2016 and mentioning at least once the term "circular economy". The term "circular economy" was specifically searched for, rather than including other entries connected to the topic such as "closed-loop" and "close the loop". Indeed, the focus of this study is to explore the influence of the recently highly promoted concept of CE on corporate sustainability strategies. We do not aim to explore the extent to which CE-related practices are already used in the industry at large, e.g. reuse and recycling of production waste or use of recycled material, but we focus on how companies uptake the CE concept as a source of inspiration or even a new framework for their sustainability work.

The temporal evolution of the resulting CS reports is illustrated in Figure 1, showing that the popularity of the CE term drastically increased in 2015 and 2016. Such increase could be correlated with the release of the first EMF report in 2012 (EMF, 2012) and the first European Communication on CE (EC, 2014). A total of 630 CS reports were retrieved, among which we selected those published in 2016 (representing more than half of all CS reports mentioning "circular economy") by companies in the FMCG sector, i.e. Food & Beverage, Household Goods & Textiles, Packaging, and Personal Care & Household Products. Additionally, we included the CS reports of the FMCG companies listed in the CE100 directory and founders of the EMF (EMF, 2017a), provided that they contained information about CE, since these companies are expected to be engaged with CE.

The final sample contains 46 CS reports released by 46 companies (See Table A1) whose geographical and sectoral distributions are shown in Figure A1. Most companies included in the sample belong to the Household Goods & Textiles (39% of the sample) and Food & Beverage (37%) sectors, meanwhile a limited set represents the Personal Care & Household Products (11%) and Packaging (13%) sectors. In terms of geographical distribution, the majority of the companies included in the analysis are based in Europe (i.e. 65% of the sample) and North America (26%). Companies from Africa, Asia and Oceania are represented to a very limited extent, i.e. 2%, 4% and 2% of the sample, respectively. This differentiated distribution may be partially explained by the relative representation of sectors and regions in the Corporate Register database, i.e. the database contains fewer reports in the Packaging sector than in the Household Goods & Textiles sector and European reports represent almost half of all reports while South America and Africa only a few percentages. Considering the explorative nature of the present study, no statistical tests were used to search for differences between sectors and regions. Nevertheless, similarly to the study by Comas-Martí and Seifert (2013) also performed on a rather limited set of CS reports, the main differences found in our results are qualitatively indicated in the results when relevant, between North America and Europe, and between Food & Beverage & Household Goods & Textiles which concentrate most of the sample.

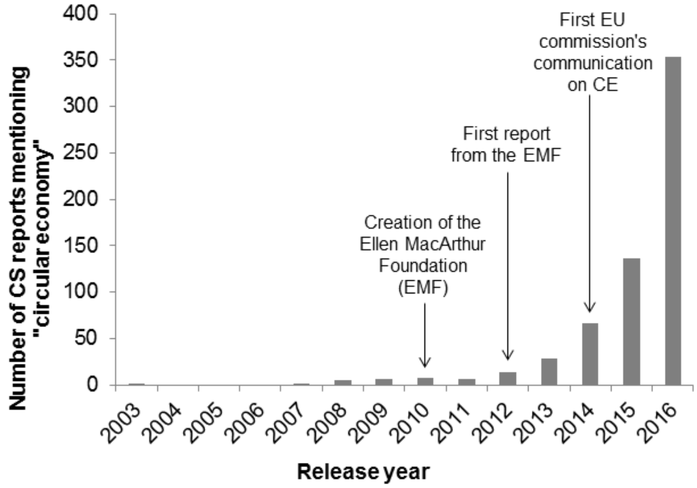

Figure 1. Temporal evolution of corporate sustainability (CS) reports included in the Corporate Register database mentioning the term “circular economy” (CE). EMF: Ellen MacArthur Foundation.

3.2. Analysis methodology

In order to answer the research questions previously formulated, we systematically analyzed the content of the CS reports using (i) a content analysis approach (RQ1 and RQ2) and (ii) a mapping approach (RQ3). The stepwise procedure adopted for the analysis is displayed in Figure 2.

Content analysis

RQ1 and RQ2 are both directly related to how companies present the CE concept in their CS reports. Thus, an analysis of meaning (or recording) units where CS reports introduce and discuss CE seemed best suited to address these questions. Meaning units are defined as sets of sentences “containing aspects related to each other through their content and context” (Graneheim and Lundman, 2004). As first step, all extracts where companies make explicit reference to CE were systematically collected from reports and stored as recording units in an excel sheet, similarly to the approach adopted by Hrasky (2011) to study the topic of “carbon footprint” in CS reports. We identified as explicit reference to CE where the company makes reference to “circular economy”, but also more broadly to “circular”, e.g. “circular model”, “circular business”, “circular development”, “circularity”, “circular thinking”, to account for slightly different terminology. The second step consisted in coding the recording units, using a combined deductive and inductive approach (Hsieh and Shannon, 2005), as shown in Figure 2.

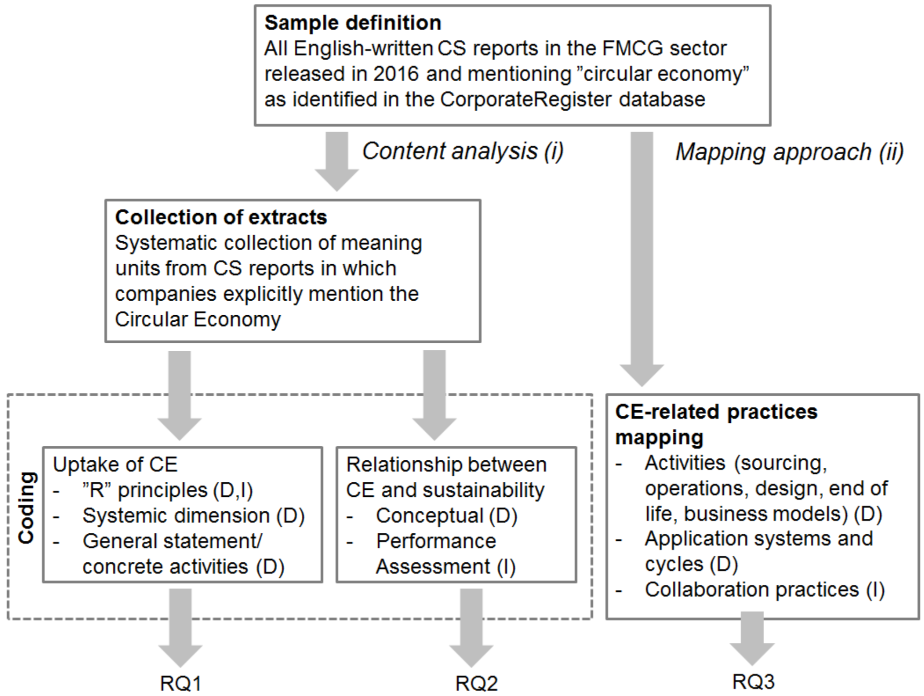

Figure 2. Stepwise procedure used to answer the three research questions (RQ), with indication of the methodological approach adopted. CE= Circular Economy, CS= Corporate Sustainability, FMCG = Fast Moving Consumer Goods. I= inductive approach. D= deductive approach.

For RQ1 we first coded the recording units against the list of “R” principles adapted from the work by Kirchherr et al. (2017). The coding of “R” principles was assisted with keyword searches taken from Kirchherr et al. (2017) and complemented with keywords inductively derived from the data (see the list of keywords used in Table A2). Occurrences were checked for relevance with the principles of CE, e.g. in the case of a reference to “reduce” as “reduction of greenhouse gases”, the occurrence was ignored. Second, we coded the recording units for references to the systemic dimension of CE (see Table A3). Third, we coded the recording units against the categories “general statement”, i.e. general statements or aspirations about CE, versus “concrete activities”, i.e. concrete activities undertaken by companies in relation with CE (see Table A3).

For RQ2, we first coded meaning units against sustainability aspects they mention (environmental, economic, and social). Second, we used a deductive approach based on the first-level typology of relationships between sustainability and CE suggested (conditional, beneficial and trade-off) by Geissdoerfer et al. (2017), see Table A3. If distinct relationships could be retrieved from different meaning units in the same report, an unclear relationship was indicated. Last, we inductively noted for each CS report if sustainability performance indicators or assessment methodologies were indicated in relation to the CE approach at the company.

Mapping

In order to answer RQ3, we adopted a mapping approach, similarly to Roca and Searcy (2012) and Kozlowski et al. (2015) in their investigation of sustainability indicators in CS reports. Contrarily to RQ1 and RQ2, which address explicit references of CE in CS reports, RQ3 focuses on CE practices whether they are labeled under CE by companies or not. Thus, full reports had to be considered and a mapping approach was deemed better suited than the coding of full CS reports.

With regard to the activities, we adapted the framework developed by Moreno et al. (2016), including circular design strategies, i.e. design for closing resource loops, design for reducing resource consumption, design for reliability & durability, design for product attachment & trust, design for extending product life, design for dematerialization of products, design for resource recovery, design to reduce environmental backpacks (terms used by the authors to refer to design for the entire value chain and for local value chains) and design for regenerative systems and circular business model archetypes (circular supplies, resource value, product life extension, extending product value, and sharing platform), by adding sourcing, operations and end-of-life activities. The full mapping framework of CE activities is displayed in Table A4. With regard to the application systems, we distinguished between "main product", "packaging" and "by-products", further classified into technical and biological systems. For collaboration practices, inductive categories were formed based on collaboration aspects mentioned both in the meaning units collected in the content analysis and in relation with CE activities. The inductive categories are: research/innovation/technology development project; support of local recycling system; working group/forum/dialogue; system for circulating goods; partnership for reprocessing; and campaign/education.

Validity and reliability are two important criteria to be addressed in any research design and were enhanced through researcher triangulation throughout the study. Each researcher reviewed half the sample of CS reports. The analysis for each research question was first performed by a single author and second checked for consistency with the second author. Both authors discussed each critical case until consensus could be obtained (Bengtsson, 2016). On the other hand, an important aspect to increase reliability is to ensure a clear-cut definition of coding categories: basing categories on concepts established in literature for most RQ facilitated differentiation between categories (Kohlbacher, 2005).

4. Results and discussion

4.1. How is companies' uptake of Circular Economy in their corporate sustainability reports?

In most CS reports, no clear-cut definition for CE is provided by companies, yet defining elements can be retrieved in extracts where CE is introduced by most companies. Several companies make reference to the EMF (Amcor, Luigi Lavazza, Tetra Pak, H&M, CCE, Sealed Air Corp, Groupe SEB, IKEA, Tarkett) and the EU Action plan (Karl Fazer, Heineken, CCE, SCA, IKEA) when mentioning CE. Figure 3 shows the respective presence of the "R" principles in extracts where CE is referred to in CS reports. "Recycle" is mentioned in almost two third of reports, and to a lesser extent, "reuse" (40%), reduce (35%) and "recover" (20%) also appear in CE extracts. The Food & Beverage sector contains more reference to “recover”, and less to “recycle” which can be related to the importance of by-products recovery in this sector (see Table A7).

Around one third of the sample (17 CS reports) contains references to a systemic change related to CE (see Table A5). These CS reports mention e.g. the will to “lead the fashion industry away from the make, use, dispose economy to one that allows us to keep resources in use for as long as possible” (C&A, 2016), the idea that “resources and products should be designed and used in continuous loops” (Carlsberg, 2016) or reference to a “future society based on a circular economy” (Åhlens, 2016).

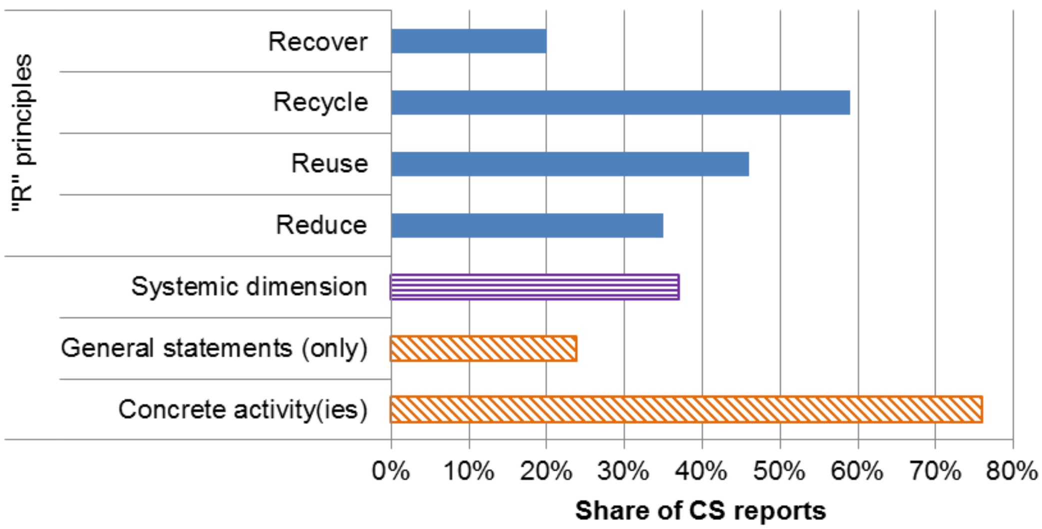

Figure 3. Main conceptual elements used by companies to introduce and/or define Circular Economy in their corporate sustainability (CS) reports, with regard to the “R” principles introduced by Kirchherr et al. (2017), link to systemic dimension and presence of either general statement (only) or concrete activities in relation to CE.

One fourth of the sample (11 CS reports) contains only extracts referring to CE coded as “general statement” as shown on Figure 3. For instance, Åhlens (2016) simply mentions its ongoing reflection about the role that the company can play “in a future society based on a circular economy”; Mayr-Melnhof Karton (2016) states that “circular economy is thus an immanent part of our business activity” and Ball (2016) argues that its “[metal] cans represent a perfect example of truly recyclable packaging and a product that fits a circular economy model very well”. All other CS reports contain at least one extract where CE is mentioned in relation with concrete activities, e.g. joining the New Plastics Economy initiative “for a more effective plastics system based on circular economy principles - a new plastics economy” (Amcor, 2016), creating a hub to incubate circular technologies (C&A, 2016), launching a rental service system of kitchen appliance (Groupe SEB, 2016) or valorizing operations’ by-products (Pernod Ricard, 2016).

All in all, our findings show that in reviewed CS reports, CE is mostly associated with the idea of recycling and reusing, its systemic dimension is referred to in one-third of the sample and in most CS reports it is associated to concrete activities, as opposed to sole general statements. With regard to the presence of "R" principles in CE definitions, our results are aligned with the findings of Kirchherr et al. (2017). The lesser presence of "reduce" (in comparison with "recycle" and "reuse") in our results echoes their findings for practitioner definitions in comparison with academic definitions, which they argue can be explained by the negative connotation of this principle for economic growth. Furthermore, Kirchherr et al. (2017) found that definitions of CE rarely contain a reference to the systemic dimension of CE, which seems to hold true as well in our sample of CS reports. Our results show that overall the discussion about CE in CS reports is articulated around concrete activities and does not remain solely on an aspirational level, although symbolic references to CE in CS reports could have been expected considering the strong traction of CE in the industry (Jones and Comfort, 2017).

4.2. How do companies link Circular Economy and sustainability in their CS reports?

Different aspects of sustainability, i.e. environmental, economic and social aspects, are mentioned in CS reports in relation with CE as show in Figure 4. The most mentioned aspects are environmental ones (around 50%), either in relation with resource scarcity, climate change or more generally environmental pressures, followed by economic aspects (around 30%). Social aspects are largely ignored in references to CE in CS reports.

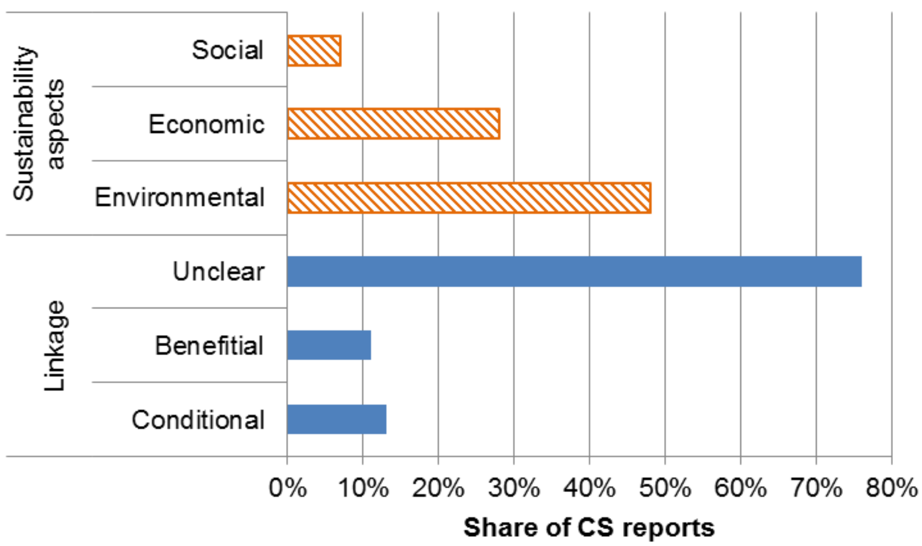

Figure 4. Share of corporate sustainability (CS) reports for (i) sustainability aspects associated to Circular Economy (CE) and (ii) different linkages between CE and sustainability based on the categories introduced by Geissdoerfer et al. (2017).

The analysis on the linkage between CE and sustainability reported in Figure 4 suggests that for around 75% of CS reports there is an unclear linkage, and CE seems to be considered as a purpose to be pursued *per se* in many CS reports. What is most interesting to note is that no company outlines the existence of trade-offs between CE and sustainability, therefore suggesting that CE inherently contributes to the sustainability agenda. On the other hand, companies might be aware of trade-offs, but decide not to expand on them in CS reports, which are targeted to a non-technical audience. A few examples of beneficial (Barilla, Growmark, Inditex, Luigi Lavazza, Tarkett) and conditional (Carlsberg, CCE, Colgate, Davines, H&M, IKEA) relationships could be inferred from companies' narratives about CE in 2016 (See Table A6 for the details of coding results). For instance, IKEA (2016) states its aim to "converting to a circular economy" in order to address the Sustainable Development Goal 12, "ensure sustainable consumption and production patterns", which expresses a conditional relationship. Luigi Lavazza (2016) is "developing sustainable solutions that are inspired by the philosophy of a circular economy", thus outlining a beneficial relationship.

References to sustainability performance indicators or assessment methodologies were lacking in most CS reports which elaborate on CE. Only a minority of companies presents a dedicated set of Key Performance Indicators (KPIs) for their CE approach. CCE (2016) uses a set of KPIs to achieve their goal to "support the development of the circular economy, use recycled and renewable materials and recycle more packaging than [they] use" and which includes among others percentage of recycled material used, percentage of renewable material used, percentage of weight reduction, percentage of recyclable products and amount of items collected or recycled. Fromageries Bel (2016) reports on its recovered byproducts in the section "circular economy". We also found that Carlsberg's and SCA's 2016 CS reports, mention their use of the life cycle assessment (LCA) methodology in parts where CE is discussed. Similarly, CCE (2016) explicitly mentions reducing its carbon footprint in relation with CE. On the other hand, most companies do mention footprint methodologies (LCA, carbon footprint or water footprint) elsewhere in their reports, with no link with CE. Furthermore, we found three companies mentioning the C2C design framework and C2C certification program as a performance indicator (Carlsberg, 2016, Tarkett, 2016, and Shaw Industries Group, 2016).

Interestingly, our results show that environmental challenges are present in companies' narratives about CE, which contrasts the findings of Kirchherr et al. (2017) who found economic prosperity to be the mostly mentioned aim in CE definitions. On the other hand, our findings confirm that the social aspects are barely mentioned in relation with CE (Kirchherr et al., 2017). Most examples found in academic literature describing the link between CE and sustainability refer to a beneficial relationship, meanwhile only a limited set of authors refer to the possibility of trade-offs (Geissdoerfer et al, 2017). This is consistent with the absence of tradeoffs relationship in our analysis. In addition, the high presence of unclear linkage suggests that companies regard CE as inherently contributing to the sustainability agenda. Our results further show that most companies do not link CE with sustainability assessment which stress the need for performance indicators and assessment methodologies outlined in academic literature (Linder et al., 2017; Pauliuk, 2018). The references to LCA and other footprint methodologies in companies' CS reports show potential for them to explore the environmental sustainability relevance of CE-related activities. LCA has been explored in several studies as a tool to evaluate the environmental sustainability potential of CE approaches (Niero et al., 2016; Haupt and Zschokke, 2017; Niero et al., 2017) and is outlined as a promising tool (Elia et al., 2017), meanwhile the C2C certification program should be used with caution as a way to monitor environmental performance (Niero et al., 2016).

4.3. Which Circular Economy practices do companies present in their CS reports?

4.3.1. Which systems do companies apply Circular Economy activities to?

As illustrated in Figure 5a, most of CE-related activities are oriented towards the main product and packaging. Particularly in the Food & Beverage sector, efforts are aiming at implementing CE strategies to packaging (see Table A7). This trend is confirmed by analyzing the type of nutrient cycle which CE-related activities are applied to. As shown on Figure 5b, almost all companies refer to CE-related activities with regard to the technical cycle and around one-third of the sample report actions in both cycles.

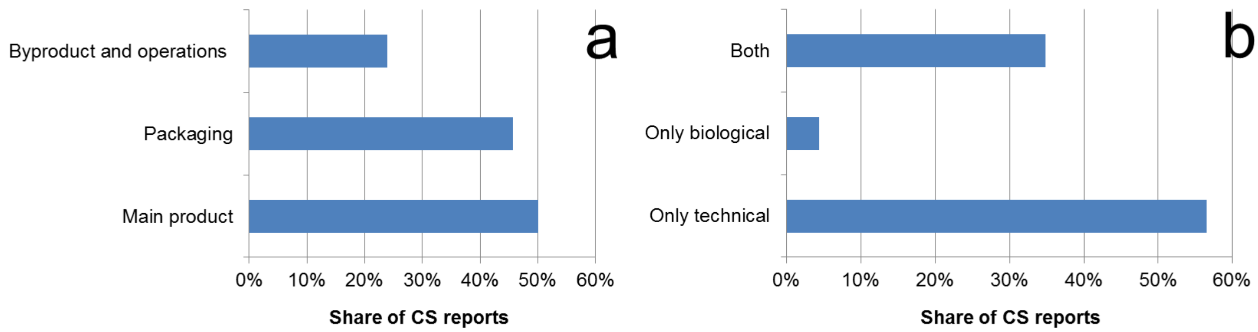

Figure 5. Systems where Circular Economy-related activities are applied to (a) and nutrient cycles considered (b). Note that the percentages do not sum up to 100% in Fig. 5b because no system could be identified in 2 corporate sustainability (CS) reports.

Our findings can be explained by the prominent role that has been given to packaging both in the business agenda, particularly plastic packaging e.g. in the EMF reports (EMF, 2017b, 2013) and in the political agenda, e.g. the recycling targets for packaging waste included in the EU Action Plan for CE (EC, 2015). Both plastic and food waste are included as focus areas in the EU Action Plan for CE (EC, 2015), but from our analysis little emphasis has emerged on food waste reduction in the Food & Beverage sector.

4.3.2. Which Circular Economy activities do companies apply?

As illustrated in Figure 6, among CE-related activities, most companies report initiatives addressing improvement in their operations, such as energy efficiency, increased share of renewable energy and recovery of production waste. The second most spread activities in the ranking are connected with raw material sourcing and with promoting the use of recycled content or renewable material. Almost half of the companies report engagement in supporting recycling and resource recovery infrastructure through recycling campaign or initiatives with suppliers.

Our findings show that activities addressing circular product design and circular business models are reported to a lesser extent, except for design for reduce resource consumption and design for resource recovery. Within the former category, most of the reported activities aim at design for light weighting, e.g. Barilla (2016), Bonduelle (2016), and Diageo (2016), and design for reducing material/resource use (e.g. Marimekko, 2016, Mohawk Industries, 2016 and P&G, 2016). In terms of design for resource recovery, the emphasis is on the recyclability of the products or packaging, e.g. SCA (2016), Groupe SEB (2016) and Nike (2016). The Household Goods & Textiles sector is the only one with examples in extending product life both in the design stage (mainly through design for easy maintenance, reuse, repair) and circular business models, by primarily setting take back systems for reuse, e.g. H&M (2016), KappAhl (2016), for repair (e.g. IKEA, 2016) and to a lesser extent by extending product value through rental service (e.g. Tarkett, 2016) (see also Table A7).

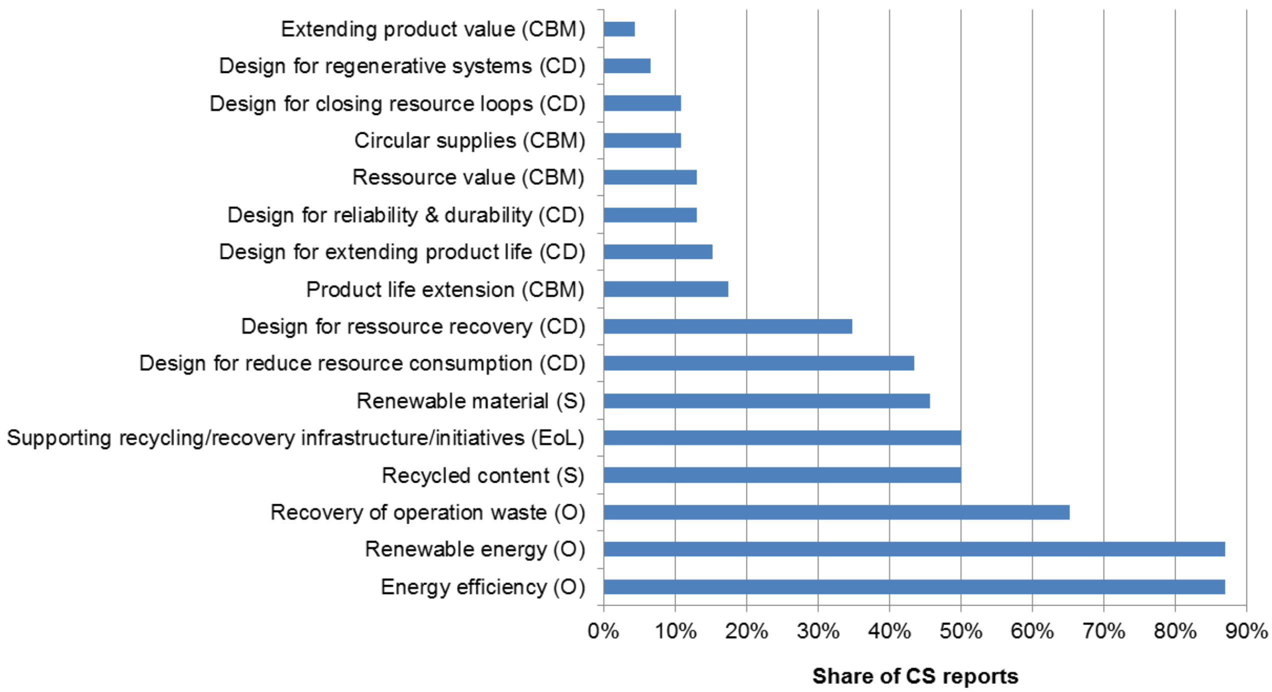

Figure 6. Summary of Circular Economy-related activities reported by companies in their corporate sustainability (CS) reports, including Circular Economy-flagged and non-flagged activities, and considering the five categories: operations (O), raw materials sourcing (S), end-of-life (EoL), circular design strategy (CD) and circular business models (CBM).

Most activities reported by companies with regard to recycling focus on the quantitative aspect of recycling. Some reports tackle the importance of maintaining the quality of material, therefore highlighting a more advanced analysis of the CE challenges (Carlsberg Breweries, 2016, H&M, 2016, Inditex, 2016). Some companies even recognize the challenges inherent in keeping material quality. Pespsico (2016) highlights the need to “eliminating materials in Pepsico designed packaging that impact recycling sorting or contaminate recovery stream” in order to achieve their 2025 goal of designing 100% of their packaging “to be recoverable or recyclable”. Nike (2016) sees “chemistry as an important tool to unlock some of the key innovations for the future, including performance-maximizing material, component improvements and overcoming roadblocks to closed-loop processing”.

Based on Bocken et al.'s (2016) categorization it can overall be concluded that the reviewed companies primarily report the implementation of activities aiming at narrowing loops, somehow already in place in linear economic system, secondly closing loops and only to a limited extent slowing loops. No examples were found for design for dematerialization of products and design for trust & attachment, which are circular design strategies more strongly connected to consumer behaviors. Circular business model strategies are also very limited in the sample. Although the activities considered in this mapping were included whether labeled under the CE or not by the company, the results reveal that among the activities at the core of a CE, the reviewed companies seem to be very involved in resource-efficiency measures in their operations and sourcing, but less active when it comes to circular offers through design or business model initiatives. These outcomes confirm the findings of Kirchherr et al (2017), i.e. that circular business models are mentioned only marginally within CE conceptualizations. Blomsma and Brennan (2017) outline that the value of CE in the broader debate around resource and waste is to put forth a set of "strategies to extend resource life as a means to facilitate additional value extraction and reduce value loss and destruction". Yet our results indicate that only a limited set of the latter strategies seem to be implemented by the reviewed companies. Interestingly, this lack of a larger set of circular strategies in current activities is coupled with limited references to maintaining material quality, although it is one main strength of the CE concept in comparison with other sustainability initiatives (Korhonen et al., 2018; Webster, 2013).

4.3.3. Which CE-related collaboration practices do companies have?

More than half of CS reports indicate collaboration(s) with external players in a CE-related context. As shown in Figure 7, the most common collaboration types are working group/forum/dialogue identified in nearly a third of CS reports and research/innovation/technology development project identified in nearly a fourth of CS reports. Working group/forum/dialogue collaborations reveal that several companies have initiated or engaged in active dialogue with e.g. peers, knowledge partners, value chain partners and regulators, to explore the role of CE in their specific business. For instance, Carlsberg (2016) has established the Carlsberg Circular Community as a forum for the beverage value chain to explore future circular packaging options. IKEA (2016) is part of a coalition of companies with Michelin, Phillips, Unilever, DSM, Suez, Tetra Pak and Umicore to advocate changes to the EU CE Package.

Research/innovation/technology development project collaborations reveal that concrete projects are already happening in several companies to implement CE principles concretely in their technologies and products together with relevant players such as innovation consultancy, knowledge partners, competitors, technology developer. For instance, H&M (2016) in partnership with Kering and Worn Again works on developing a textile-to-textile recycling technology. Amcor (2016) participates in the Project Reflex, which is a "UK-based program evaluating the recyclability of films and multilayer laminates through innovative product designs and recycling technologies", meanwhile C&A's Foundation hosts a technology innovation incubator to boost CE initiatives (C&A, 2016). These collaborations mainly focus on technological innovation and to a lesser extent on consumer-based research and design. One notable exception is CCE's (2016) research on recycling behavior of 20 households in Great Britain and France together with the University of Exeter.

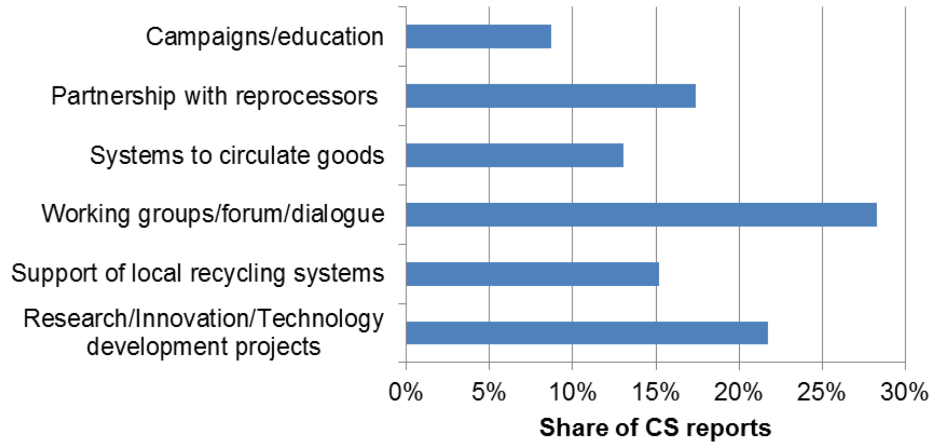

Figure 7. Summary of external collaboration types in the context of Circular Economy as reported in the corporate sustainability (CS) reports.

Partnership for reprocessing and system to circulate goods can be directly related to the respective circular business model strategies resource value and product life extension. They respectively involve joint ventures with recycling factories or cooperation with secondary raw material suppliers on the one hand; and on the other hand collaboration with online platforms, retailers, charities or reprocessors. For instance, Shaw Industries Group (2016) has a joint venture with the company DAK Americas which is a manufacturer of monomers, resins and fibers, to run a recycling facility (resource value) and H&M (2016) collaborates with the online platform Sellpy to support sales of items that are not used anymore by consumers (product life extension). For such circular business model strategies to thrive, more collaboration with external players will be needed in the future.

Our results reveal that part of the companies already engage at different levels with their business ecosystem in relation with the CE, which goes in the direction of academics outlining the importance of business ecosystem interactions for a transition towards the CE (Witjes and Lozano, 2016, Linder and Williander, 2017). Yet, interestingly most identified collaborations are with businesses, and few initiatives focus on consumers apart from some campaigns and education initiatives. This seems to confirm trends outlined in literature (Young et al., 2017, Kirchherr et al. 2017; Jones and Comfort, 2017; Hazen et al., 2017) that consumer involvement and acceptance are largely missing although considered critical for a transition towards the CE.

5. Limitations, implications and future research

5.1. Limitations of the study

Our study presents some limitations which should be highlighted before deriving theoretical and managerial implications. First, the data set only contains FMCG companies that publish CS reports in English. This implies that the sample excludes most small and medium companies which often do not publish such reports (Borga et al., 2009) and is under-representative of countries where it is not common to publish CS reports or to communicate in English. For example, Chinese companies are reported to implement CE in literature, but their experience and views were very limitedly addressed in the present study since only one Chinese company was identified as fulfilling the sample criteria. The sample also excludes companies that use the CE concept, but did not communicate about it in their 2016 CS reports. For instance, Unilever has a full section dedicated to CE on its website (Unilever, 2017), but does not address the topic in its CS report published in 2016 (Unilever, 2016). In this perspective, the sample included in this study cannot be considered fully representative of the FMCG sector at large. Future work is needed to appraise CE uptake in the sector more comprehensively and to statistically account for differences across sub-sectors and regions, which was outside the scope of this study. Moreover, the role of institutional factors, e.g. laws, norms or beliefs in specific regional contexts, on CE uptake in the industry could be particularly interesting to explore (Ranta et al., 2017).

Furthermore, the source of information used to analyze each company is limited to its CS report published in 2016. The latter only gives selected insights of the company's sustainability work, since it outlines key topics of that year, filtered by the company's communication team and according to stakeholders' concerns. The time scope in this study did not allow any longitudinal exploration of companies' activities that is, through comparing reports across years (Hrasky, 2011). Thus it was not possible to investigate further a possible symbolic uptake of CE in CS reports. Moreover, CS reports are concise documents presenting practices that may have reached a certain maturity in the organization, thus the information communicated in CS reports might be too thin to appreciate actual ongoing efforts towards CE. Results based on CS reports provide a partial picture and must be taken with caution when drawing conclusions at the level of the companies that publish these reports. Hence, future work based on longitudinal and primary data is needed. Yet, we consider that what companies provide about CE in their CS reports delivers relevant information about business thinking around the concept and allows for providing insights and trends about the business uptake of CE.

5.2. Theoretical implications

Our study contributes to the academic knowledge of CE uptake at a micro-level and sheds light on several aspects particularly relevant for the CE research community. First, only limited symbolic references to CE could be elicited, whereas most of the CS reports considered report concrete actions on CE implementation. Second, the systemic dimension of CE is not systematically acknowledged in CS reports and rather poorly represented in practices, i.e. limited focus on business model changes, consumer engagement and material quality. The "reduce" principle is under-represented in companies' narratives about CE. These findings are consistent with previous observations in the academic literature (Kirchherr et al., 2017) and indicate the need for research to further inspire and support business players towards systemic changes and more radical innovations in their businesses if the CE is to deliver on its promises (Kirchherr et al., 2017). Although we found that most companies envision CE as a way of addressing their environmental challenges, their understanding of the linkage between sustainability and CE remains implicit or absent and CE-related practices are rarely associated to sustainability assessments or performance indicators. These results show that CE remains primarily regarded by companies as a vision (Goedkoop et al., 2015) and strengthen the existing call in academia for more methods which allow evaluating how good a CE strategy is from a sustainability perspective, i.e. including environmental, economic and social aspects (Niero and

Hauschild, 2017). If not assessed, the relevance of CE approaches could be challenged due to overlooked burden shifting. Based on these considerations, we strongly recommend an increased focus on the systemic dimension and sustainability relevance of CE in future academic work on the implementation of CE in business sustainability strategies.

5.3. Managerial implications

Although our study reveals that the CE concept has started being implemented in corporate sustainability agendas of the reviewed FMCG companies, our findings highlight that its concrete application can be strengthened in different ways. We encourage practitioners to reflect on the meaning of CE for their business activities, beyond sourcing, operations efficiency and end-of-life initiatives, e.g. by taking a multiple life cycle perspective, i.e. considering material quality and limitations to recycling (Grosso et al., 2017) and rethinking their product design and business models, in collaboration with consumers and other business partners. If CE is “casually interpreted” (Webster, 2013) and its application remains constrained to narrowing loops (Bocken et al., 2016) while failing to challenge our production and consumption models more broadly (ADEME, 2016), there is a risk to miss out opportunities to drastically reduce pressures on earth’s resources. Our results further reveal that CS reports seem to convey a strong faith in the CE as an approach to solve environmental challenges in the industry, which is consistent with its key role as a clear vision to move away from the throw-way society. However, practitioners are encouraged to clarify their objectives to engage in CE activities and perform quantitative sustainability assessment or hotspot analysis to avoid burden shifting between life cycle stages.

6. Conclusions

This explorative study aimed to contribute to fill the gap on the missing link between academic research and business practice on CE by investigating how the CE concept affects FMCG companies’ sustainability agenda as reported in their CS reports. The 2016 CS reports of the 46 companies in the FMCG sector identified as referring to “circular economy” were systematically analyzed to unearth (i) their uptake of the CE concept, (ii) the linkage established between CE and sustainability and (iii) the breadth of CE-related practices undertaken by these companies. A fair share of CS reports indicate concrete activities in relation to the concept of CE, mainly oriented towards the main product and packaging, which reveals that companies have started a journey towards CE implementation. However, our analysis revealed that the breadth of CE-related activities remains to be explored and the systemic dimension of CE is rarely present in companies’ narratives about CE, as well as poorly rooted in CE-related activities (i.e. limited focus on consumer engagement, material quality, and business models). Furthermore, the results show that the linkage between CE and sustainability remains largely implicit both conceptually and practically due to limited use of performance indicators or quantitative sustainability assessments. Based on these findings, we outlined the need for researchers and practitioners to respectively further explore and support the systemic dimension of CE and its link with quantification of sustainability performance. Our findings are a first attempt to systematically explore CE conceptualization and related practices in a business context for FMCG, but cannot be generalized to the whole sector, and neither can give a direct account for the actual practices of the reviewed companies. Future work should thus expand our analysis by exploring other periods of time and sectors to test the statistical significance of differences among sub-sectors and regions, as well as focusing on in-depth investigations of companies' approaches to CE based on interviews and field studies.

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Appendices

Table A1: List of reviewed corporate sustainability reports, including company name, report name, region where the headquarters are registered and sector of activity. All subsidiaries' reports that had featured the list were excluded, thus the focus is solely on mother companies.

Company name	Report name	Region	Sector
Amcor Limited	Sustainability Review 2016. Creating a new world of packaging	Oceania	Packaging
Asics Corporation	Sustainability Report 2015. We are Asics	Asia	Household Goods & Textiles
Ball Corporation	2016 Sustainability Report	North America	Packaging
Barilla G e R Fratelli SpA	Good for You, Good for the Planet 2016 Report	Europe	Food & Beverage
Bonduelle Groupe	Registration Document 2015-2016	Europe	Food & Beverage
C&A Global[1]	Global Sustainability Report 2015 Summary. Material Impacts	Europe	Household Goods & Textiles
Carlsberg Breweries AS	Carlsberg Group Sustainability Report 2015	Europe	Food & Beverage
China Agri-Industries Holdings Limited	2015 CSR Report	Asia	Food & Beverage
Coca-Cola Enterprises Inc (CCE)	Corporate Responsibility & Sustainability Report 2015/2016	North America	Food & Beverage
Colgate-Palmolive Company	Colgate Sustainability Report 2015. Giving the World Reasons to Smile	North America	Personal Care & Household Products
Dairy Crest Group plc	Annual Report 2016. Going for Growth	Europe	Food & Beverage
Davines SpA	Sustainability Report Davines Group 2015	Europe	Personal Care & Household Products
Diageo plc	Annual Report 2016	Europe	Food & Beverage
Eco-Products	Sustainability Report 2016	North America	Household Goods & Textiles
Expresso Fashion BV	Social Report [1st April 2015 31st March 2016]	Europe	Household Goods & Textiles
Fromageries Bel SA	2015 Communication on Progress of the Bel Group's CSR	Europe	Food & Beverage
Groupe Rocher	The Essentials of CSR 2015	Europe	Personal Care & Household Products
Groupe SEB	2015 Financial Report and Registration Document	Europe	Household Goods & Textiles
Growmark Inc	Corporate Responsibility Report 2016. Taking Care. Paying Forward	North America	Food & Beverage
H&M[2]	Sustainability Report 2015. Conscious	Europe	Household Goods &

Company name	Report name	Region	Sector
	Actions		Textiles
Heineken NV	Sustainability Report 2015. Brewing a Better World	Europe	Food & Beverage
IKEA AB	IKEA Group Sustainability Report FY16	Europe	Household Goods & Textiles
Inditex SA	Annual Report 2015	Europe	Household Goods & Textiles
KappAhl Holding AB	KappAhl 2016	Europe	Household Goods & Textiles
Keurig Green Mountain	Sustainability Report Fiscal Year 2015	North America	Food & Beverage
Luigi Lavazza SpA	Sustainability Report 2015	Europe	Food & Beverage
LVMH-Moët Hennessy Louis Vuitton SA	LVMH 2015 Environmental Report	Europe	Household Goods & Textiles
Marimekko Corporation	Sustainability Review 2015	Europe	Household Goods & Textiles
Mayr-Melnhof Karton AG	Annual Report 2015	Europe	Packaging
Mohawk Industries Inc	2015 Corporate Responsibility & Sustainability Report	North America	Household Goods & Textiles
Nike Inc	FY14/15 Sustainable Business Report. Sustainable Innovation is a Powerful Engine for Growth	North America	Household Goods & Textiles
Oy Karl Fazer AB	Fazer Groups Corporate Responsibility Review 2015	Europe	Food & Beverage
Pepsico Inc	Sustainability Report 2015. Performance with Purpose. 2025 Agenda	North America	Food & Beverage
Pernod Ricard SA	Registration document 2015/2016	Europe	Food & Beverage
Procter & Gamble Inc	P&G 2016 Citizenship Report	North America	Personal Care & Household Products
RCL foods Limited	Our Sustainability Business Report for the Year Ended 30 June 2016	Africa	Food & Beverage
SABMiller plc	Sustainable Development Report 2016	Europe	Food & Beverage
Scottish Leather Group Limited	Group Sustainability Report Year ending 31st March 2015	Europe	Household Goods & Textiles
Sealed Air Corp	Sustainability Report Issued 2016	North America	Packaging
Shaw Industries Group Inc	Sustainability Report 2015	North America	Household Goods & Textiles
Société BIC	2015 Sustainable Development Report. Made to Last	Europe	Household Goods & Textiles
Svenska Cellulosa Aktiebolaget AB[1]	Sustainability Report 2015	Europe	Personal Care & Household Products
Tarkett SA	2015 Activity & Sustainability Report. Committed to Better Living Spaces	Europe	Household Goods & Textiles
Tetra Pak Group	Sustainability Update 2016. Food. People. Future	Europe	Packaging

Company name	Report name	Region	Sector
Thimm Holding Gmbh & Co Kg	Sustainability Report 2016. People, Ideas, Solutions	Europe	Packaging
Åhléns AB	Sustainability Report 2015	Europe	Household Goods & Textiles

[1] *Report added to the sample since the company is included in the categories "FMCG & Packaging" and "Furniture, Textile and Flooring" of the CE100 directory (https://www.ellenmacarthurfoundation.org/ce100/directory)*

[2] *Report added to the sample since the company is a founding company of the EMF and belongs to the textile industry*

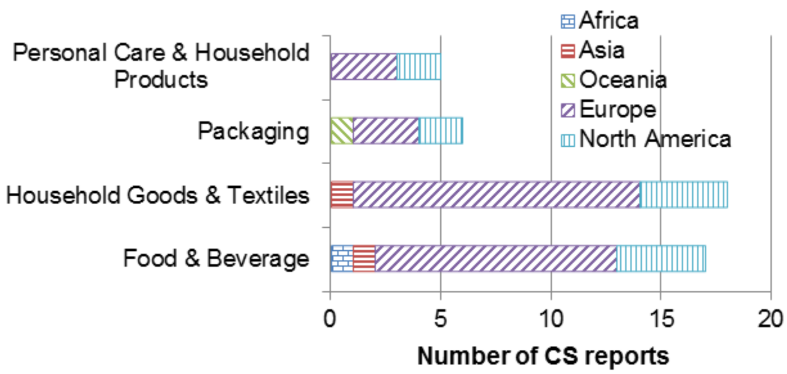

Figure A1. Regional and sectoral distribution of CS reports in the sample.

Table A2. List of keywords used in RQ1 based on Kirchherr et al. (2017)

Principle	Keywords
Reduce	Rethink, re-think, refus, redesign, re-design, minimiz, minimis, prolong, *extend**,
Reuse	Reus, *repurpos*, refurbish, repair, *second life*, *maintain*
Recycle	Recycl, remanufactur
Recover	Recover

*In italics are keyword added inductively from the data.

Table A3. Overview of coding categories for RQ1 and RQ2.

Category	Definition
Systemic dimension	CE is mentioned in relation with the need for a shift/radical change/transition away from today's system (economy, sector, business).
General statement	CE is mentioned in a general descriptive, normative, aspirational statement.
Concrete activities	CE is associated to concrete undertakings internally or externally.
Beneficial linkage	CE is considered as one way to progress towards sustainability among others. (Geissdoerfer et al., 2017)
Conditional linkage	CE is considered as a condition for reaching sustainability. (Geissdoerfer et al., 2017)
Tradeoff linkage	CE is considered to lead to sustainability trade-offs (both benefits and negative

	outcomes). (Geissdoerfer et al., 2017)

Table A4. Overview of mapping framework for CE-related activities (RQ3), adapted from Moreno et al., (2016). S= sourcing. O=operations. EoL=End-of-life. CD=circular design. CBM=circular business model.

Categories	**Definition**
Recycled content (S)	The company reports using recycled material in its products
Renewable material (S)	The company reports using material from renewable sources in its products
Energy efficiency (O)	The company indicates adopting measures to save energy
Renewable energy (O)	The company indicates using energy from renewable sources
Recovery of operation waste (O)	The company reports measures for reusing/recycling the waste/byproducts it produces in its operations
Supporting recycling/recovery infrastructure/initiatives (funding, campaign, research) (EoL)	The company indicates measures to support the recycling system
Design for closing resource loops (CD)	Design for biodegradability, Design with healthy/smart processes/materials (Moreno et al., 2016)
Design for reduce resource consumption (CD)	Design with healthy/smart processes/materials; Design for reduction of production step; Design for light weighting, miniaturizing; Design for eliminating yield loses/material/resources/parts/packaging; Design for reducing material/resource use (Moreno et al., 2016)
Design for reliability & durability (CD)	Design on demand or on availability; Design the appropriate lifespan of products/components (Moreno et al., 2016)
Design for product attachment & trust (CD)	Create timeless aesthetics; Design for pleasurable experiences; Meaningful design (Moreno et al., 2016)
Design for extending product life (CD)	Design for repair/refurbishment; Design for easy maintenance, reuse and repair; Design for upgradability and flexibility (Moreno et al., 2016)
Design for dematerialization of products (CD)	Design for product-service systems; Design for swapping, renting and sharing. (Moreno et al., 2016)
Design for resource recovery (CD)	Design for easy end-of-life cleaning, collection and transportation of recovered material/resources; Design for cascade use; Design for (re)manufacturing and dis- and re-assembly; Design for upcycling/recycling (Moreno et al., 2016)
Design to reduce environmental backpacks (CD)	Design for the entire value chain; Design for local value chains (Moreno et al., 2016)
Design for regenerative systems (CD)	Design for biomimicry; Design for biological and technical cycles (Moreno et al., 2016)
Circular supplies (CBM)	"A business model based on industrial symbiosis in which the residual outputs from one process can be used as feedstock for another process" (Moreno et al., 2016)
Resource value (CBM)	"A business model based on recovering the resource value of materials and resources to be used in new forms of value" (Moreno et al., 2016)
Product life extension (CBM)	"Those business models that are based on extending the working life of a product" (Moreno et al., 2016)
Extending product value (CBM)	"Those business models based on offering product access and retaining ownership to internalize benefits of circular resource productivity" (Moreno et al., 2016)
Sharing platforms (CBM)	"Those business models that enable increased utilization rates of products

	by making possible shared use/access/ownership (Moreno et al., 2016)

Table A5. Coding results for the systemic dimension addressed in RQ1.

Company name	**Extract coded for "systemic dimension of CE"**
Amcor	"With an explicitly systemic and collaborative approach, the initiative aims to advance the plastics value chain into a virtuous cycle of value capture, stronger economics, and better environmental outcomes" (Amcor, 2016)
C&A	"We want to help lead the fashion industry away from the make, use, dispose economy to one that allows us to keep resources in use for as long as possible." (C&A, 2016)
Carlsberg Breweries	"Resources and products should be designed and used in continuous resource loops. The only long-term sustainable answer to waste is to reduce and, ultimately, eliminate it." (Carlsberg Breweries, 2016)
CCE	"We are very clear that our economy cannot continue in its current take-make-dispose model and we need to transform to a circular economy model" (CCE, 2016)
Davines	"All these signs are telling us that the future lies in a circular economy. Unlike the old linear system, the new model is based on ethical and sustainable development, thanks to re-use and minimising waste. A circle has no beginning and no end, and therefore can renew itself, assuring the future of generations to come." (Davines, 2016)
Eco-products	"At the end of the day, everything comes back to waste diversion for us. It's our reason for being and it is reflected in our new mission statement that you will find if you keep reading. Compostable foodservice packaging is at its best when it enables the diversion of food scraps and other organic material from landfills. In order for that to happen, there has to be a systems approach that takes into account all inputs, incorporates a consistent communications strategy, and integrates with the haulers and facilities who will accept the material and turn it into an ecologically essential and economically valuable product. That is starting to sound like the kind of circular economy we want to be a part of." (Eco-Products, 2016)
Groupe SEB	"Circular economy requires an approach of fitting of channels (e.g. recycling, reuse…). This economic system is based on exchanges and production. At every stage of the life cycle of the products, goods and services, it aims to increase the efficiency of the resources and to reduce the impact on the environment while enabling the welfare of the individuals." (Groupe SEB, 2016)
H&M	"We want to move towards a 100% circular business model. This means nothing less than completely turning around how our industry has been operating for decades – moving away from a linear production model to one that uses once-created products as the resource for new desirable fashion." (H&M, 2016)
Heineken	"There is increasing focus on how businesses can move from a linear value chain model towards a Circular Economy in which products and resources are reused or refurbished as part of new product life-cycles." (Heineken, 2016)
IKEA	"Transitioning to a circular economy. Take make dispose. That's the model our economy is based on. But it's not sustainable." (IKEA, 2016)
KappAhl	"We have also joined phase two of the Mistra Future Fashion programme that aims to create conditions for a circular economy in the fashion industry." (KappAhl, 2016)
Nike	"We envision a transition from linear to circular business models and a world that demands closed-loop products – designed with better materials, made with fewer resources and assembled to allow easy reuse in new products." (Nike, 2016)
SABMiller	"In working towards the ambitious new climate goals, society needs to move to a more efficient, circular economy focused on eliminating waste and emissions and creating value from what remains." (SABMiller, 2016)

SCA	"In 2015, the EU Commission presented its circular economy strategy that will lead to societal change in many areas. SCA recognizes the need for solutions that drive the circular economy and actively applies this thinking to all of its products." (SCA, 2016)
Tarkett	"CONTRIBUTING TO A CIRCULAR ECONOMY Tarkett is committed to the transition from a linear to a circular economy model, which consists of recycling resources in a loop from the design and production phases to later use and recovery stages." And "A key element of our approach is our longstanding commitment to the circular economy. As we move away from a linear economy that depletes finite resources, we take advantage of all opportunities to select materials that are good for people's health and the environment, and recycle and reuse our products or materials from other industries." (Tarkett, 2016)
Tetra Pak	"We have also signed up to the CE100, an innovative programme set up by the Ellen MacArthur Foundation to support the long-term development of a circular economy: one that is restorative and regenerative by design. (Tetra Pak, 2016)
Åhlens	"We have also asked ourselves: what role can Åhléns play in a future society based on a circular economy?" (Åhlens, 2016)

Table A6. Coding results for the linkage between CE and sustainability (conditional and beneficial linkages) with regard to RQ2.

Company name	Linkage	Extract
Carlsberg Breweries	Conditional	"Resources and products should be designed and used in continuous resource loops. The only long-term sustainable answer to waste is to reduce and, ultimately, eliminate it." (Carlsberg Breweries, 2016)
Colgate-Palmolive	Conditional	"Building a circular economy in which industrial materials and packaging can be recycled and reused is an important part of a sustainable future." (Colgate-Palmolive, 2016)
Davines	Conditional	"All these signs are telling us that the future lies in a circular economy. Unlike the old linear system, the new model is based on ethical and sustainable development, thanks to re-use and minimising waste. A circle has no beginning and no end, and therefore can renew itself, assuring the future of generations to come." (Davines, 2016)
H&M	Conditional	"The fashion industry is using more resources than the planet allows. As demand increases, so will waste, pollution and carbon emissions while resources will become increasingly scarce. Moving towards a circular model will be key for our future success and growth. This is why we are currently working to update our sustainability strategy." (H&M, 2016)
IKEA	Conditional	"Transitioning to a circular economy. Take make dispose. That's the model our economy is based on. But it's not sustainable." (IKEA, 2016)
Barilla	Beneficial	"Promote cooperation with farmers to make the agricultural sector more sustainable according to circular economy models" (Barilla, 2016)
Growmark	Beneficial	"Our dedication to sustainable measures is not limited to the land. In business, we look for opportunities that have impact far beyond our core purpose and that support a circular economy." (Growmark, 2016)
Inditex	Beneficial	"In 2015 we also made progress towards the circular economy model with the Closing the Loop project, which combines environmental and social sustainability to pursue the goal of ensuring no used textile item ends up in landfill." (Inditex, 2016)
Luigi Lavazza	Beneficial	"This served as an opportunity for Lavazza to confirm its commitment that sees it involved in an intense activity of research and innovation aimed at developing sustainable solutions that are inspired by the philosophy of a circular economy." (Luigi Lavazza, 2016)

Tarkett	Beneficial	"We innovate by developing technology and specific designs to improve people's well-being, for example by contributing to indoor air quality, by creating an inspiring colorful environment and by improving sound control in living spaces. Our eco-innovations based on healthy materials and our recycling model contribute to our vision of a sustainable and profitable development. This commitment to the circular economy is beneficial for society and the planet, as well as improving our teams' pride and motivation." (Tarkett, 2016)

Table A7. Overview of results for RQ1-3 with sectoral and regional differentiation. With regard to the sectors, we only provide the results for the Food & Beverage (FB) and the Household Goods & Textiles (HGT) sector since Packaging and Personal Goods and Household Products are very limitedly represented in the sample. Similarly, with regard to the regions, we only provide the results for Europe and North America.

	FULL SAMPLE	**SECTORS**		**REGIONS**	
Research question		**HGT**	**FB**	**Europe**	**North America**
RQ1:	**Share of reports**				
"R" principles					
Reduce	35%	41%	29%	37%	25%
Reuse	46%	53%	41%	47%	50%
Recycle	59%	71%	29%	57%	58%
Recover	20%	18%	35%	20%	25%
Systemic dimension					
Presence of systemic dimension	37%	47%	24%	43%	25%
Level of implementation					
Concrete activity(ies)	76%	88%	71%	80%	67%
Only general statements	24%	12%	29%	20%	33%
RQ2					
Linkage					
Conditional	13%	12%	12%	13%	17%
Beneficial	11%	6%	18%	13%	8%
Unclear	76%	82%	71%	73%	75%
Sustainability aspects					
Environmental	48%	41%	47%	57%	33%
Economic	28%	12%	41%	23%	33%
Social	7%	6%	0%	10%	0%
RQ3					
Application system					
Main product	50%	67%	18%	47%	58%
Packaging	46%	28%	71%	47%	42%
By-products	24%	17%	41%	33%	0%
Nutrient cycles					
Both	35%	17%	59%	43%	17%
Only biological	4%	0%	12%	3%	0%
Only technical	57%	78%	24%	50%	75%
CE-related activities					
Recycled content (S)	50%	61%	41%	47%	67%
Renewable material (S)	46%	50%	35%	50%	33%
Energy efficiency (O)	87%	94%	82%	87%	92%

Renewable energy (O)	87%	89%	82%	90%	83%
Recovery of operation waste (O)	65%	56%	76%	63%	75%
Supporting recycling/recovery infrastructure/initiatives (EoL)	50%	39%	53%	47%	67%
Design for closing resource loops (CD)	11%	11%	12%	10%	17%
Design for reduce resource consumption (CD)	43%	28%	59%	30%	75%
Design for reliability & durability (CD)	13%	22%	6%	13%	17%
Design for product attachment & trust (CD)	0%	0%	0%	0%	0%
Design for extending product life (CD)	15%	33%	6%	10%	25%
Design for dematerialization of products (CD)	0%	0%	0%	0%	0%
Design for resource recovery (CD)	35%	33%	35%	27%	58%
Design to reduce environmental backpack (CD)	0%	0%	0%	0%	0%
Design for regenerative systems (CD)	7%	11%	6%	7%	8%
Circular supplies (CBM)	11%	11%	18%	13%	8%
Product life extension (CBM)	17%	44%	0%	23%	8%
Extending product value (CBM)	4%	11%	0%	7%	0%
Collaboration practices					
Research/Innovation/Technology development projects	22%	22%	18%	23%	17%
Support of local recycling systems	15%	0%	24%	3%	42%
Working groups/forum/dialogue	28%	39%	18%	30%	25%
Systems to circulate goods	13%	33%	0%	17%	0%
Sourcing partnership with reprocessors	17%	33%	6%	17%	25%
Campaigns/education	9%	6%	12%	7%	17%

Article IV

Architect, Catalyst, Advocate, and Prophet: A four-lens view of companies to support ecodesign integration

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Architect, Catalyst, Advocate, and Prophet: A Four-Lens View of Companies to Support Ecodesign Integration

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Abstract: Companies are increasingly expected to develop products with better environmental performance throughout their life cycle. Academic literature on ecodesign integration, which investigates firms' practices of dealing with environmental concerns associated with their products, indicates a need for more focus on formal and informal organizational aspects. From the general management literature, the four-lens view of organizations provides a rich understanding of organizations by embracing their formal (structural lens) and informal (human, political and symbolic lenses) functioning. This article aims to explore the extent to which the four-lens view may support ecodesign integration in companies. This exploratory study builds on fifteen interviews about ecodesign integration at seven manufacturing companies in Denmark and Norway. The main results are threefold: (i) the different lenses of organizations could be found in measures mentioned at the case companies; (ii) measures from the architect's perspective seemed necessary to provide an official scene for ecodesign and help prioritizing it in organizations; and (iii) the catalyst's, advocate's, and prophet's perspectives seemed necessary to facilitate or complement the architect's perspective. In the light of these findings, the four-lens view seems relevant to strengthen ecodesign integration, and its potential use as a reflective tool is an avenue for future work.

Keywords: sustainability; ecodesign; product development; product innovation; change; organization; industry; case study; interview; Nordic

1. Introduction

As sustainability has become a central topic in our societies, companies are increasingly expected to tackle their environmental sustainability challenges. The product life cycle is a key perspective to address such challenges, as emphasized in academia and recent developments in industry, e.g., update of ISO 14001 environmental management system standard with greater emphasis on products' life cycle environmental impacts [1,2]. Ecodesign is a product-oriented approach defined as "a proactive management approach that integrates environmental considerations in product development and related processes (e.g., purchasing, marketing and research and development) [and] aims to improve environmental performance of products throughout their life cycle" [3]. The market of products labelled as environmentally superior has noticeably been thriving [4,5]. In the EU, regulations such as the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulation and the Restriction of Hazardous Substances (RoHS) directive, as well as the Energy related Products (ErP) and the Waste Electrical and Electronic Equipment (WEEE) directives, respectively require the avoidance of substance of concerns (REACH and RoHS), energy efficiency measures (ErP) on e.g., home appliances and motors, and producer extended responsibility measures on electrical and electronic equipment (WEEE) [5]. Nevertheless, there is an urgent call for more radical changes in production and consumption patterns that would enable a transition towards sustainability as stated in UN Sustainable Development Goal 12 [6]. Our current understanding of environmental sustainability implies that environmental sustainability challenges ultimately need to be addressed at a socio-technical level [7]. Such endeavor requires companies, as a key stakeholder, to have a more comprehensive understanding and addressing of environmental concerns in the products and solutions they develop, e.g., by developing environmentally superior product/service systems or designing circular products and business models by intention [8,9]. However, empirical studies have shown that companies face challenges to develop and successfully implement proactive ecodesign practices [10–13].

Ecodesign tools, techniques and decision supports have been intensively developed in the past decades; e.g., Rousseaux et al. found more than 600 ecodesign tools in their literature review [14]. However, ecodesign scholars agree that these need to be complemented with a focus on business implementation and management problematics to help advance ecodesign uptake by industry [11,15–18]. In that perspective, scholars have explored how to formally integrate ecodesign aspects in business organizations, e.g., in project management [19–22], at different decision-making levels (operational, tactical and strategic—[18]), in environmental management systems [23], and in business procedures and strategy [11,24]. The ISO 14006 standard provides guidance for the implementation of ecodesign in companies as a management system [25,26]. On the other hand, scholars have highlighted that informal aspects of organizations also influence ecodesign integration in companies [11,17,18,27–29]. Hence, we identify a need for approaches embracing both aspects, i.e., the combination of formal aspects ("structures, processes, systems, etc. which are designed to motivate and facilitate individuals in the performance of organizational tasks" [30] (p. 193)), and informal aspects ("patterns of communication, power, and influences, values and norms which characterize how an organization actually functions" [30] (p.193)).

In management literature, Bolman and Deal elaborated a four-lens view of organizations which builds on four groups of management theories depicting organizational functioning from different perspectives [31]. In this four-lens view, organizations are viewed on the one hand as formal structures designed to fulfill a given mission, applying specific procedures, systems, and roles (structural lens). On the other hand, firms are informal communities where employees have needs, aspirations, preferences and fears (human lens), personal or group agendas with possibly conflicting objectives (political lens), as well as a shared understanding of "how things work around here" (e.g., habits and routines) (symbolic lens) [31]. The four-lens view underlines that single situations in organizations can be looked at, interpreted, and leveraged from different perspectives offered by the different lenses. In that sense, the four-lens view invites leaders and change agents in organizations to reframe their views of their organization to better understand situations and adopt relevant courses of action.

Within internal stakeholders driving sustainability in organizations, we can distinguish between employees primarily working with environmental management, e.g., a sustainability manager or

Environment, Health and Safety specialist, and employees working in core business roles who seek to drive the sustainability agenda based on individual interest [32]. These two types of stakeholders have been found to be central in driving sustainability practices in companies [33–36], and have been expected to drive sustainability integration in their organization as “champions”, “change agents” or “leaders” [32,35–39].

Because it provides a framework to approach the richness of organizational functioning with a focus on both formal and informal aspects, and because it may deliver practical support for change agents in organizations, the present study draws on the four-lens view of organizations and aims to answer the following research question: To what extent can the four-lens view of organizations support ecodesign integration at companies? To address this question, first we build on existing academic literature to identify the potential relevance of the four-lens view of organizations in the light of common challenges associated with ecodesign integration. Furthermore, we empirically investigate the presence of and relations between the different lenses of organizations in ecodesign integration efforts in industry, with the purpose to further our understanding of a multi-lens approach.

Ecodesign proponents in companies, including both sustainability or environmental management teams and employees from core functions proactively involved in pushing the ecodesign agenda within their organization, are the target audience of our study, together with consultants and scholars working with supporting ecodesign integration in companies. In the remainder of the article, we first elaborate the conceptual framework and link the four-lens view of organizations to existing knowledge of ecodesign integration in academic literature (Section 2). Then we investigate how the four-lens view emerges from ecodesign integration as described in interviews conducted at a set of case companies: Section 3 explains how the empirical evidence was collected and analyzed; the results are presented in Section 4. In Section 5, the findings are discussed in the perspective of earlier work, the research design, and the limitations of the study, before providing concluding remarks and an outlook for future work in Section 6.

2. Conceptual Framework

2.1. Introducing the Four-Lens View of Organizations

Bolman and Deal’s four-lens view of organizations was developed with the aim to bring together different groups of management theories to pragmatically support the work of managers and change agents in organizations [31]. The structural lens (or frame) builds among others on Taylor’s scientific management theory [40], Weber’s bureaucratic management theory [41], and Mintzberg’s work on organizational structures [42]. The human lens is derived among others from the Theory Y (as opposed to Theory X) developed by McGregor [43], and the work of Argyris on the relationships between organizations and individuals [44]. The political lens is anchored among others in the work of Kotter and Pfeffer about political skills of managers [45,46]. The symbolic lens draws among others from the work of Schein on organizational culture [47]. The structural lens emphasizes division and coordination of work and embraces well defined rules, policies and goals; the human lens focuses on the relationships between employees and the organization and pays specific attention to individual needs; the political lens views organizations as arenas where stakeholders compete for power and resources; and the symbolic lens focuses on creating meaning in a chaotic environment [48].

The purpose of the four-lens view is to invite leaders and change agents in organizations to reframe, and hence expand, their views of their organization to gain a deeper understanding of hotspots or challenges and a better overview of available levers. This is done by alternatively using an architect's, catalyst's, advocate's, or prophet's perspective corresponding to different metaphors of organizations. Through the structural lens, the architect views its organization as a machine or a factory and design targets, functions, processes, and coordination mechanisms. Through the human lens, the catalyst views its organization as a family and aims at embracing employees' needs, fears and aspirations and supporting them. Through the political lens, the advocate views its organization as a jungle and aims at building coalitions, gaining power, and negotiating agendas. Through the symbolic lens, the prophet views its organization as a temple and focuses on fostering sense-making, challenging common beliefs and inspiring people. Figure 1 displays the four-lens view of organizations as a conceptual framework which includes for each lens (i) the corresponding metaphor of organization, (ii) the perspective adopted by change agents, (iii) the summary of associated basic assumptions about organizations, and (iv) examples of courses of action, adapted from the work by Bolman and Deal [31,48].

Organizational research scholars have used the four-lens view as a main conceptual framework in empirical studies focusing on four distinct topics. They have investigated (i) change management [49–51], (ii) current organizational situations [52–54], (iii) specific roles or positions [55], and (iv) lens preferences of leaders and managers [48,56–58]. Applicative studies have focused primarily on educational organizations [48–50,58], and to some extent on healthcare organizations [50,56,57]. In the first group of studies, the four-lens view has been used to interpret challenges associated with the investigated change, e.g., innovation in higher education [49], implementation of a participatory management approach in a hospital [51] or academic reform in pharmacy [50]. Scholars agreed that using a multi-frame approach enabled deeper understanding of situations and should be used to design relevant solutions and improvements [49–51]. In the second and third group of studies, the model has been used to interpret current challenges, experienced in general in the organization [52,53] or by specific individuals [55]. It was also used to interpret the success factors of a given program [54]. In the last group of studies, the model has been used to explore the use of lenses by managers and leaders in organizations, as well as to study the influence of lenses' use on managerial and leadership effectiveness. For instance, Bolman and Deal used their model to study the extent to which managers, mainly in academic institutions, used different lenses in their approaches, based on analyses of critical incident reports, and how it affected their effectiveness as managers or leaders as perceived by their colleagues, based on a survey [48]. In the analysis of critical incident reports, they found that the structural frame was particularly prominent among managers and the symbolic frame, particularly absent. To survey the lenses currently used by managers in their work, Bolman and Deal developed a leadership orientation instrument operationalizing each lens into a set of activities or attitudes [48]. The survey revealed that effective managers were associated with the structural lens, whereas effective leaders were associated with the political and symbolic lenses. The leadership orientation instrument was further used by several scholars for a similar purpose [56–58]. In the context of schools and universities, Thomson found that fully balanced managers, i.e., managers who scored high on all lenses, performed better on all leadership dimensions, than unbalanced managers, i.e., mainly using one or two lenses [58]. In their study of health information program directors, Sasnett and Ross found that the structural and the human frames dominated, to the detriment of the political and symbolic frames [56]. McGowan and Stokes surveyed a sample of Irish physiotherapy managers and also found that the political and symbolic lenses were underused, whereas the structural and human lenses highly used [57]. They further found a correlation between the number of lenses reported as used by managers and higher self-rating of effectiveness as leaders and managers [57].

LENS	STRUCTURAL	HUMAN	POLITICAL	SYMBOLIC
METAPHOR OF ORGANIZATION	FACTORY OR MACHINE	FAMILY	JUNGLE	TEMPLE
PERSPECTIVE ADOPTED BY THE CHANGE AGENT	ARCHITECT	CATALYST	ADVOCATE	PROPHET
SUMMARY OF BASIC ASSUMPTIONS	❑ The organization exists to achieve established goals and objectives. ❑ What matters is that tasks are clearly and rationally divided, defined by procedures and coordinated so that work gets done.	❑ People and organizations need each other: organizations need ideas, energy, and talent; people need careers, salaries, and opportunities. ❑ What matters is to align people's needs and aspirations with the organization's goals.	❑ The organization is an arena where individuals and interest groups fight over resources to advance their agendas. ❑ What matters is to gain power, create strong alliances and manage to secure resources and priority in agendas.	❑ Organizations are chaotic, uncertain and ambiguous places where much is open to interpretation. ❑ What matters is to create meaning and to understand deeply anchored aspects ruling in the organization.
EXAMPLES OF COURSES OF ACTION	❑ Reorganize, implement or clarify policies and procedures ❑ Develop new information, budgeting, or control systems ❑ Add new organizational units ❑ Plan processes	❑ Processes of participation and involvement (task forces, open meetings, etc.) ❑ Train, coach ❑ Empower ❑ Address individual needs, personal aspirations	❑ Bargain ❑ Negotiate ❑ Advocate ❑ Build alliances ❑ Network with other key players ❑ Anticipate conflicts	❑ Create or revitalize ceremonies and rituals ❑ Work to develop or restate the institution's vision ❑ Use heroes, stories, symbols ❑ Energize, inspire

Figure 1. Conceptual framework around the four-lens view of organization, including for each lens (i) the corresponding metaphor of organizations, (ii) the perspective adopted by change agents, (iii) the summary of basic assumptions about organizations, and (iv) examples of associated courses of action, elaborated based on the work by Bolman and Deal [31,48]. Icons from left to right: Architect by Augusto Zamperlini from Noun Project; Family by Luis Prado from Noun Project; Lawyer asking question by Gan Khoon Lay from Noun Project; Hero by Andrew J. Young from Noun Project.

2.2. The Four-Lens View of Organizations in the Context of Ecodesign Integration

Earlier scholars have considered ecodesign integration as an organizational change and built on the change management literature to investigate the phenomenon [28,59]. Ecodesign proponents are expected to play the role of leaders or change agents in their organization. In these perspectives, transposing the four-lens view of organizations to the context of ecodesign integration appears as a meaningful potential approach to support ecodesign proponents in their efforts to strengthen ecodesign integration. Furthermore, the academic literature on ecodesign integration has reported several internal challenges which can interestingly be shown to pertain to the four lenses of organizations as described in the following paragraphs [60].

Through the structural lens, scholars have reported the lack of strategy or concrete goals to integrate environmental aspects in products [17,61–63], the absence of a predefined toolset to support ecodesign decision-making, and the lack of formal presence of ecodesign aspects in project assessment frameworks [19,22], and performance measurement systems [61,63]. Additionally, scholars reported lack of clear responsibility allocation and presence in the organigram [17,39], and the absence of specific mechanisms to collect information related to sustainability from the market and regulation [62]. Scholars have recommended exploring possibilities to integrate ecodesign aspects in existing processes [11,12,19,21,64–66], in order to create an official arena for discussing environmental aspects [65], and investigating how to formally integrate ecodesign aspects in the different levels of organization, i.e., operational, tactical and strategic [18]. The establishment of clear environmental goals for product design is also recommended, as well as the creation of environmental specialist roles to support development processes [39,64,66].

Through the human lens, earlier studies have shed light on the fact that employees in companies may fear work overload associated with ecodesign [28,61], as well as losing flexibility [28]. Some employees may also be highly uncomfortable with the topic [13,28], not aware of the challenges [67], or not capable of addressing them [12,28,64,67,68]. Some employees may have high interest, motivation and commitment for ecodesign aspects while others lack one or the three [12,64]. Exploring how to best empower employees on sustainability topics and what drives motivation and resistance of/among employees has been suggested as a key enabler to support ecodesign integration [13,69].

Moving on to the political lens, scholars have reported that environmental sustainability aspects may have rather low priority on senior management agendas which mainly focus on short term objectives, mainly lowering costs, and do not see environmental concerns as major risks since market and regulation drive is perceived as low [13,62,68]. It has also been indicated that project teams may struggle to secure resources for ecodesign activities [13], or translate environmental information into information useful for the business and possible to integrate in a business case that senior management could be interested in [12,62]. Maintaining consistent support from management for ecodesign aspects over time is also a reported challenge [13,16]. Because people have different agendas and areas of interest, due to their position in the company, they may value information differently. Hence, concretely it may be the case that employees observe some trends regarding environmental sustainability concerns of customers but do not pass them on further in the organizations [70]. In response, it has been recommended for instance to review key performance indicators of the people who need to be convinced for environmentally preferable solutions to be pushed for, and to adapt communication strategies accordingly [71].

Finally, through the symbolic lens, earlier studies have reported resistance to ecodesign integration pertaining to general beliefs such as “sustainability is not my responsibility”, “sustainability is not invented here” [28], “sustainability is a distraction” [61], or “sustainable options lead to costly or poor quality products” [13]. Common understanding around what sustainability means for the business may be lacking [72]. The needs for a new “mindset emphasizing the importance of the environmental considerations” [64] (p. 103), or for a different “storytelling” around environmental aspects closer to the company’s reality, have been evoked [13]. Skelton et al. reported that although environmental specialists are listened to by project teams, they may remain considered by the latter as very much outside the project community which limits their influence on projects [29]. The use of rituals, e.g., a dismantling event taking place every year to build awareness about the end-of-life of developed products [29], may be leveraged through the symbolic lens.

Hence, existing knowledge of ecodesign integration indicates the potential relevance of the four-lens view of organizations to support ecodesign proponents in their efforts to strengthen ecodesign integration in their company. The following sections explore how the four-lens view can be addressed in a consistent manner and further translated into the ecodesign integration context with learnings from empirical data.

3. Methodology

An overview of the methodological approach adopted in this study is displayed in Figure 2. The following sections provide detailed descriptions of data collection and data analysis.

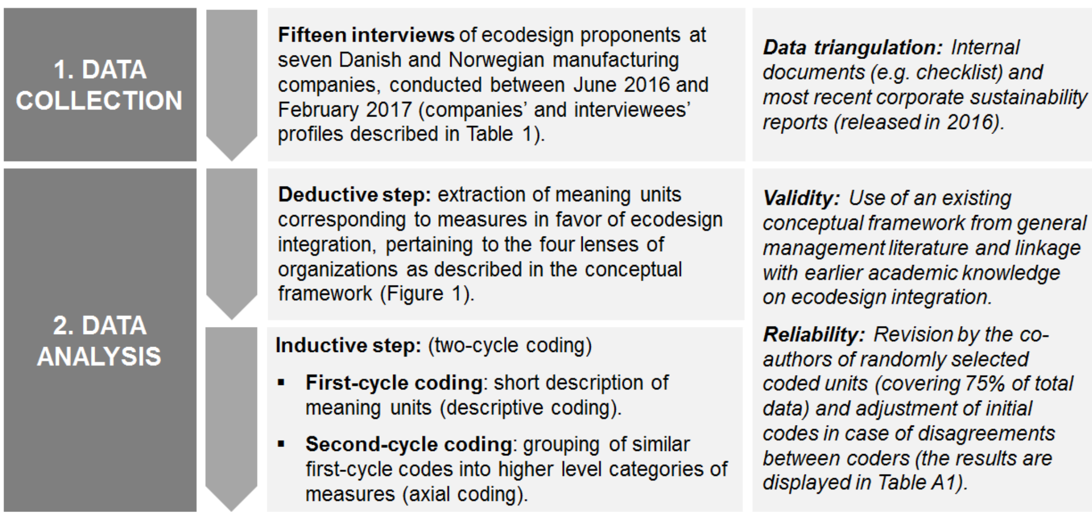

Figure 2. Overview of the methodological approach.

3.1. Data Collection

The empirical basis of the present study consists of a set of fifteen interviews at a sample of seven case companies in the Danish and Norwegian manufacturing sector. There is no specifically recommended number of cases in case study research, but four to ten cases are typically targeted [73]. Earlier empirical studies of ecodesign integration in companies have typically included four to twelve case companies and most studies have involved two or three interviewees per case company [12,13,27,62,63,66,67,74–76]. Manufacturing companies were of particular interest for the present study because they are key players in designing and manufacturing products [77]. Moreover, there are indications that the manufacturing sector has a stronger focus on life cycle thinking than the service sector [78,79]. The selection of case companies is based on convenient sampling, i.e., based on previous or new established contact with companies, and on a set of criteria, namely (i) headquartered in the Nordics, (ii) manufacturing companies with in-house product development, and (iii) presence of a sustainability strategy. The case companies are large organizations, with all but one (which is not stock exchange listed) included in the Dow Jones Sustainability Index (DJSI). From this perspective, the set of cases presents characteristics of homogenous sampling, but also characteristics of variation sampling because the case companies were at different steps of their sustainability journey and belong to different industrial sectors [80].

Lasting between 60 and 90 min, two authors of the present article conducted the fifteen interviews between June 2016 and February 2017. The details about the interviewees' profiles are displayed in Table 1. The set of interviewees includes two types of ecodesign proponents. The first type includes employees working in sustainability-related functions, e.g., sustainability managers or Environment, Health and Safety specialists, and the second type includes employees involved in product development with personal interest in pushing the ecodesign agenda. Interviews were semi-structured and designed to further the knowledge about ecodesign integration in companies, based on a review of existing academic knowledge of the topic. The interview focus was on (i) investigating how ecodesign practices have been and are being integrated in the organization and (ii) exploring internal (across departments) and external (in the business ecosystem, e.g., with suppliers and customers) interactions around ecodesign at the company. The themes addressed during interviews are provided in Appendix A. In the present study, the interview transcripts are thus used as a secondary data source to explore the presence of the different lenses of organizations in ecodesign proponents' elaborations about ecodesign integration at their company.

Table 1. Interviewed case companies, sectors of activity, number of interviews conducted and interviewees' job area. EHS = Environment, Health and Safety; CR = Corporate Responsibility; R&D = Research and Development.

Company	Sector	Number of Interviews	Interviewees' Job Area
Company A	Medicare	2	A1: EHS A2: EHS
Company B	Biotechnologies	1 *	B1: Sustainability
Company C	Energy	2	C1: EHS C2: EHS
Company D	Construction	2	D1: Regulation (incl. environment) D2: Sourcing and technologies
Company E	Consumer products	2	E1: EHS E2: CR
Company F	Consumer products	2	F1: Communication F2: Sourcing
Company G	Consumer products	4	G1: R&D G2: R&D G3: R&D G4: Marketing

* Information about ecodesign activities collected at a university lecture given the same year by another sustainability expert of the same company was also included in the analysis.

Internal documentation provided by the case companies (e.g., stage gate model used by the company in product development projects, ecodesign checklist and ecodesign tool) and their most recent corporate sustainability report (released in 2016) were used as complementary data source and enabled some extents of data triangulation. Corporate sustainability reports were particularly suited to grasp the overall sustainability context at each case company and in order to elicit companies' sustainability vision, drivers (e.g., presence of a market for ecodesigned products), strategy (e.g., reducing the life cycle environmental impacts of products) and targets (e.g., reducing greenhouse gas emissions in the product portfolio, reaching a certain percentage of recycled material in packaging and phasing out substances of concern), in relation to the architect's perspective. However, corporate sustainability reports provide poor inputs on other organizational aspects associated with sustainability integration [81].

3.2. Data Analysis

The unit of analysis, defined as the phenomenon under study [82], is ecodesign integration at each case company, including all activities which aim at bringing environmental considerations in the company's products. To address the research question, we analyzed the interview data with the two following objectives: (i) exploring the presence of the different lenses of organizations in descriptions about ecodesign integration at the case companies, and (ii) gathering indications of relations between the different lenses of organizations.

To explore the presence of the different lenses, we analyzed each interview transcript using a deductive-inductive content analysis method [83]. The deductive step consisted of identifying "meaning units" (or coded units) corresponding to measures stemming from the different lenses of organizations. Meaning units are defined as "words, sentences or paragraphs containing aspects related to each other through their content and context" [84]. In our case, sentences or paragraphs were manually unitized from the transcripts as meaning units based on thorough reading of interview transcripts. An example of meaning unit is the following extract "Stage gate is the normal process. And life cycle assessment is part of the stage gate project. And we use the stage gate model in development projects, for all new products actually". A "measure" was broadly defined as an action or solution indicated by the interviewees as happening or necessary to facilitate ecodesign integration. The deductive coding of meaning units with respect to the four lenses of organizations was based on the conceptual framework derived in Section 2, see Figure 1. The meaning units were stored in a spreadsheet for the second (inductive) step of the analysis. In the inductive step, we coded the extracted meaning units, using a two-cycle coding approach, as suggested by Saldaña [85]. The first-cycle coding phase consisted of descriptive coding, i.e., associating each meaning unit with a short phrase summarizing the described measure [85]. For the example of meaning unit mentioned above, the first-cycle code we chose is *"Life cycle assessment is used as part of the product development process"*. The second-cycle coding phase consisted of grouping the first-cycle codes into higher-level categories of measures using an axial coding approach, i.e., seeking to group together codes that had been split in the first-cycle coding but were then considered to reflect similar aspects [85]. For the example of meaning unit mentioned above, the second-cycle code we chose is *"Integrate ecodesign procedure in product development process"*. To explore the relations between the different lenses of organizations in supporting ecodesign integration, instances where they could be found to interact with each other were analyzed.

To ensure the quality of the analysis, we followed the guidelines provided by Riege [86]. Validity was enhanced by anchoring the findings in a conceptual framework derived from management literature and comparing the results with insights from the ecodesign integration literature. The use of the four-lens view to conduct content analysis was found challenging by Bajis et al. who reported initial overlaps between each lens [50]. This aspect pertains to the reliability criterion and was addressed in the present study through the recording and transcribing of the interviews and through involving multiple researchers in the data analysis [86]. The full coding process was initially performed by one author (the main coder). Seventy-five percent of the coded units were randomly selected for a revision by the co-authors. The selection was designed to respect the proportions of coded units for each case company, e.g., a total number of 100 coded units for one case company would lead to 75 randomly selected coded units for the revision. The selected coded units were then divided into three parts and checked by the co-authors against (i) the lens of organization the coded unit was considered to relate to, and (ii) the choice of second-cycle coding. The division was done so that one co-author would review the full set of selected coded units corresponding to a given case company, to build an overview of that case company. The revision and associated discussion led to slight changes in the coding results (see Table A1) and wording chosen for second-cycle codes. The most challenging part of the coding was the deductive phase consisting of associating measures for ecodesign integration to an underlying lens of organization. The team agreed that to conduct such exercise, the coder should rely on the basic assumptions of what an organization is, as displayed in Figure 1, which are implicitly present in the interviewee's explanation. Illustrative quotes inserted in the following sections are extracted from the interview transcripts. They were corrected for grammar errors, false starts and filler words, as well as neutralized, e.g., by removing references to country markets or specific materials, so that neither the case companies nor the interviewees could be recognized [87].

4. Results

4.1. Mapping of Measures for Ecodesign Integration in the Four-Lens View

Table 2 shows for each case company and lens of organizations the identified measures resulting from the second-cycle coding phase. The distribution of coded units in the different perspectives of organizations is shown in Table A2 and examples of first-cycle coding phrases associated with second-cycle coding categories are given in Table A3. We make a difference between the measures indicated as currently happening at least to some extent in the company (i.e., established for the architect's perspective or leveraged approaches for catalyst's, advocate's, or prophet's perspectives), and the measures identified as lacking and needed. However, the distinction is not in focus in the present study which concentrates on measures as levers for ecodesign integration, rather than measures being practiced. Our findings indicate that for most case companies, measures stemming from the architect's, catalyst's, advocate's, and prophet's perspectives were present in discussions about facilitating ecodesign integration within the organization. Most frequent measures (both happening and lacking ones) across case companies include "integrate ecodesign procedure in product development process", "acquire/develop tools for decision-making", "design strategy related to products" and "set direction/target/goals" (architect's perspective); "support/chaperon initiatives" (catalyst's perspective); "align with business/stakeholders' agenda", and "negotiate for prioritization" (advocate's perspective); and "manage beliefs/"truths" in the company" (prophet's perspective).

Table 2. Results from the second-cycle coding. For each lens, mentioned measures in favor of ecodesign integration are mapped against the case companies. H = indicated as happening at least to some extent in the organization; N = indicated as lacking and needed.

MEASURES	Company A	Company B	Company C	Company D	Company E	Company F	Company G	No of companies
Architect's perspective								
Integrate ecodesign procedure in product development process	H	H	H	H	N	N	N	7
Acquire/develop tools for decision-making	H	H	H	H	H		H	6
Design strategy related to products		H	H	N	N		N	5
Set directions/goals/targets		H		N	N	N	N	5
Develop guidelines related to product development					H	H		2
Formally define "sustainability" (e.g., standard, criteria)				H		N		2
Translate strategy into action plan for specific business units/functions					H		N	2
Translate corporate targets into targets for individual innovation projects		N						1
Create sustainability roles				H				1
Set up new KPIs					H			1
Use a process with more experimental approach							H	1
Catalyst's perspective								
Support/chaperon initiatives	H		H	H	H			4
Increase comfort of people to work with the topic of ecodesign		N	H		H			3
Build individual awareness of impact of decisions	H			N				2
Leverage people's aspirations	H		H					2
Participative approach to adapt the product development process		H	H					2
Frame ecodesign challenges in familiar terms			H					1
Give autonomy					H			1
Trigger people/"plant seeds"	H							1
Advocate's perspective								
Align with business/stakeholders' agenda	H	H	H		H	H	N	6
Negotiate prioritization of ecodesign in agendas	N			H	H		N	4
Emphasize criticality/emergency for business	N			H	H			3
Target efforts/"pick battles"	H	H					H	3
Ally with/get support from relevant people in the company	N					H		2
Have answers to all technical questions			H	H				2
Leverage network in the company			H		H			2
Secure present resource allocation for long term/more prospective objectives	N						N	2
Leverage existing umbrella projects			H					1
Prophet's perspective								
Manage beliefs/"truths" in the company	H		H	H			N	4
Change perceived vision/mission of the company				N			N	2
Leverage "typical ways of doing"	H			H				2
Preach in the company	H			H				2
Provide inspiration from outside						H	H	2

4.2. The Architect's Perspective

Within the sample of case companies, some had rather formalized integration of environmental aspects in product development through e.g., the systematic conduction of environmental assessments, whereas others had lesser formal integration in their product development processes. In all case companies, the role of formal integration of environmental aspects in product development processes or strategy in facilitating ecodesign integration was emphasized. At Company A, formal integration is established through the systematic conduction by environmental specialists of a life cycle assessment (LCA) summarized in a brief report using simple color coding to support each product development project. There, the latter measure was described as an enabler for ecodesign integration, because it makes it normal to look at environmental criteria in product development.

> *"And, they listen and they use it also as a part of their decision. They may not do it as I recommend, but that is also because there are so many other criteria for the new product they look into. But they do listen and look into my inputs. […] it is closely embedded in each stage. They cannot just skip it, if they think it is not relevant." (Interviewee A2)*

At Company B, the presence of a top-down strategy for developing sustainable products was presented as an enabler for ecodesign integration, because it leads to higher prioritization in agendas.

> *"If it is not top-down, it is really hard. It is really hard to go bottom up, I can tell you from experience. Of course you can try to push in the doors, but without management commitment… […] So, if you are not being told that this is your target and this is your agenda, you need to make sure that you develop some sustainable product or you engage customer on these topics, you won't prioritize it." (Interviewee B1)*

The case companies where formal integration of environmental aspects in product development processes was described as lacking, or only partly in place, indicated that more formal integration was necessary to support ecodesign. At Company D, LCA models were indicated to be available for all products but a lack of systematic use by project teams was mentioned, and more emphasis on using such tools in product development projects was suggested as a way forward. Furthermore, the interviewee indicated a current effort in the organization to design a tool to assess material environmental sustainability performance to establish a currently missing common language around sustainability. At Company E, F and G, the need to formally integrate environmental aspects in processes and systems was highlighted by most interviewees. Interviewees E1 and F1 highlighted the need for guidelines to channel efforts in the organization.

> *"I think, it's working okay so far and towards the targets we have set, I think it's working okay. But if we want to take a larger step, it should probably be more guidelines and support from central to be able to take a larger step." (Interviewee E1)*

> *"What we want to do is a sort of 4–5 guidelines that you should always consider in an innovation process or communication or other things, you always consider that. […] So it has been more ad hoc in the way we have introduced these subjects, but what I really believe in is that we have to write a lot of these. You don't succeed in doing it, if you don't have it as part of the structure. What kind of questions should you ask when you [approach] this kind of product? Yes, you should ask these, these and these questions and those sustainable*

questions […] And I think that natural or routine guidelines on that level are important, if not, it is more accidental. […] So again, I believe more in guidelines and structure. Otherwise, it is going to be, like I think this is a good idea and this one is a good idea etc. But I think it should be part of the whole structure." (Interviewee F1)

Interviewee G2 emphasized the need for a strategic approach and dedicated budget so that solutions can be developed by teams to achieve tangible goals.

"I think that it is number one to have a good strategic approach to it and handle sustainability in the way you would handle other elements of your business. Plan for it, give it a budget, not an economic budget, but a sustainable budget saying that we need to reduce this and this. And then track it. So it is easy for us also to promote good solutions, because then you have a reason when you launch something that is recyclable, then you reduce the footprint. This then, you can use in your work in achieving the strategic goals. So I think we are in a little slow or this is very early for us to be… so we need hopefully to have more of this." (Interviewee G2)

Interviewee G1 argued that specific ecodesign tools should be included systematically in all innovation projects.

"We need to be much clearer on what we mean in our innovation work, how we take it in on board or what kind of tools we need to implement in our projects. It should not be a question about if it is a sustainable or ecodesign project. It should be included into every single project." (Interviewee G1)

The need for solutions from the architect's perspective was put forth by one interviewee at Company G when describing a measure stemming from the advocate's perspective, namely identifying low-hanging fruit, and suggesting targeted actions to reduce the carbon footprint of a set of products, because the latter was considered tedious without the support of architect's measures.

"I had the initiative to develop CO_2 calculations for 8 case projects to try to figure or to map out which elements with the products have the biggest influence, which projects have the lowest hanging fruits you can tackle. And that was an initiative that was not from the management, so it was tough for us, because you needed to have sustainability anchored or embedded with the management team. Or else you will have hard time to getting it through the system, getting the funds and things like that. So, this was an initiative which I hope would give a lot of options further down the road." (Interviewee G2)

At Company C, there was an ongoing discussion about integrating LCA as a tool in the product development process, the latter being expected to create an entry point for product developers to get closer to LCAs.

"That is where we are in the process of making an official process for the LCA and then the hope is that traditionally, when we have a new procedure, you have a group of people that review the document and then it is associated with an implementation plan. And the goal of this will be to…Actually, in our EHS plans, we have traditionally EHS reviewers, and the goal with the LCA procedure is not to have actually EHS reviewers but to have reviewers from the

product development and the sales functions. And that will be to somehow act as an introduction and then we will take some communications" (Interviewee C1)

Interestingly, setting environmental targets for products was mentioned as a non-taken measure at Company A and Company C. At Company A, the reported foremost priority of the company is to provide solutions to people who need medical support in their daily life and environment-friendly solutions are weakly driven by the market. Hence, improving the environmental performance of new product generations was considered as a nice-to-have but could not be set as a must in projects. At Company C, the interviewees indicated that material and energy efficiency gains from one generation of products to the other were inherently driven by the business and thus no target was defined from an ecodesign perspective. At Company D, one interviewee also highlighted this idea that energy efficiency was core to the business activity, but that targets regarding material recyclability should be developed. Another interviewee at Company D indicated that there was a lack of direction or focus from top management when it comes to taking decisions in favor of material sustainability, which she explained by a lack of pull from the construction market for "green stamped" products.

4.3. The Catalyst's Perspective

Interviewees at Company B and Company C indicated that the formal establishment of ecodesign aspects in the product development process (architect's perspective) had been designed with the participation of stakeholders from product development, which pertains to the catalyst's perspective.

"We developed this procedure and instruction and before then going on into a second review, we brought it into the project management and engineering functions and we sat in workshops with them, trying and testing it out, piloting it and just talking about it, making sense about it to see if it really fits because it was having to align with another process." (Interviewee C1)

At Company A, when commenting on the extent to which environmental criteria were looked at and taken into account by project teams, one interviewee indicated the high dependence on employees' (project managers or specialists) own aspirations to push for the ecodesign agenda in projects and hence the importance to assure that employees who are eager to drive the change can be supported. Such observations can be associated with a catalyst's perspective. The importance of identifying and building on employees' aspirations for ecodesign was also indicated at Company C.

"It always comes down to the passion of the project manager or the specialist, when it comes to this area, environment, responsibility in general, yes for sure. So that's a huge difference between one that thinks "this is very important to me", then they will really take care of it and try to get it into the project as long as they can drive it, as far as they can drive it you could say; while others would be more reluctant saying "this is not something that's on my list". […] what we can do is that we can support the ones that really want to make a difference here, to give them good evidence so they can go and argue." (Interviewee A1)

"And I would also argue, beyond just personal relations it might also be the personal ambitions or the flexibility of the people you approach. Because you could possibly have someone in your personal network that maybe isn't as ambitious or burning about the topic, in

that sense. And I just think also the person in this position was also aligned with somehow same interest and excitement in circular economy topics and was aware of that, whereas somebody else wouldn't have been as willing to drive it. I think." (Interviewee C1)

At Company B, the interviewee outlined that increasing the comfort of employees related to using environmental information was key and sought to be achieved through producing "digestible" material but that more training might be necessary to foster higher levels of comfort.

"LCA is a very scientific tool. We try very much to make it easy to communicate, by preparing slideshows and other materials for them that is easy to digest. And maybe what we are lacking is this training to make them comfortable, because level of comfort depends on person to person, whether they are comfortable in bringing the messages that we could give them." (Interviewee B1)

At Company C, one interviewee mentioned that efforts from a catalyst' perspective were deployed to frame environmental challenges into technical problems for engineers, who are very familiar and good at solving this type of problems, to be empowered and work on solutions.

"So I think the technical engineers are really good at doing a lot of stuff, especially if they know where to end, they are good at solving those problems. So I think if you could remove the fuzzy front end and standardize the work flow, say: "I have a [certain type of material] which wastes production and I don't want that", "I can solve that problem". So, at least that is what we are talking about now, trying to set up something where we can reach larger audience from technical side to have these ideas implemented." (Interviewee C2)

4.4. The Advocate's Perspective

The advocate's perspective could be identified in different measures for instance regarding deploying targeted efforts (i.e., "picking battles") (e.g., at Company B), emphasizing criticality for the business (e.g., at Company D) and aligning with business/stakeholders' agenda (e.g., at Company G).

"I think we are having the approach, instead of approaching the marketing in general, that we pick out some areas that we focus on. So we try to pick out some specific projects and deep dive into these from a sustainability point of view and leave the rest. So that has been our approach, also to show what we can bring to the table." (Interviewee B1)

"We had a pilot case running in [a certain market country] during the analysis so we were working very closely with them on [circular economy]. And they are one of our main markets in Europe, so also an important market. And that made management listen better. Because it was not, I mean, [the home] market is important to us, but it is a very small market compared to the rest of Europe. So, if something happens in [the home market], I think we will survive. But, if something happens in [the other market country], we have to react because it will influence the company." (Interviewee D1)

"I don't have all the knowledge to convince them why this is so correct. So, it is… knowledge about sustainability and why it is good for your business. I mean why it is good for

environment is easy to say. But why is it good for your business. How it can help to increase the profits, for example." (Interviewee G4)

Although environmental aspects were mentioned to be integrated in their product development through the systematic use of an ecodesign procedure as part of the process, Company A had experienced so far rather low demand from the market and regulations in terms of ecodesign No target for product environmental performance is in place in the company, beyond the "rule of thumb" to decrease impacts from one generation of product to the other. It was mentioned that product development teams need for off-the-shelf materials to be used in projects and that the latter must meet very high property requirements. Environmentally preferable materials may not be mature enough to meet these criteria. One interviewee mentioned the need to have senior managers understand environment-related risks for the business in the future and secure resources to conduct research and development activities around new materials that can be both environmentally preferable and meet the high property requirements.

"The big challenge is that there will be an increased demand for sustainability and the challenge is then to find sustainable materials that fulfill the requirements that we have. Because we have so many really specific high demands for the materials, that they are [with a certain product characteristic] and so on. So that's a challenge. And that's where I think some innovation projects could help on that. Because it's not a shelf product we are looking for here we need to develop some new… […] I think it is more on prioritizing resources for innovation of sustainable materials" (Interviewee A2)

Another example of an advocate's perspective at Company A was associated with the idea of engaging people who are trusted and listened to when it comes to product development topics, to speak up for environmentally preferable solutions. The idea of allying with relevant people in the organization was also indicated at Company F.

"So that's what you need from these guys is that, if we stand up and tell something it would be "yeah okay but you are also the environmental guys, you don't know anything of the business case and you are the tree lovers", more or less, right? Whereas if it is the marketing person saying: "we see this and this and this and by the way we also think from an environmental point of view that we could do like that", then it is more coming from the guys they are used to listening to giving the normal inputs on this." (Interviewee A1)

"I also work with lobbying and mapping stakeholders, so all the time I think about who else I should get support from to help this through. […] I have more experience working with that now, and I tell you that I need to have support from other important persons" (Interviewee F1)

At Company E, new key performance indicators (KPIs) were set up to support the responsible sourcing strategy, yet one interviewee outlined the importance of engaging with sourcing managers to have them actually prioritize these new KPIs in their daily work, which reflects an advocate's perspective. At Company B, sustainability teams developed an assessment tool able to rate product development projects against their ability to deliver on the UN Sustainable Development Goals which is a relevant reference framework for senior management and thus enables negotiating ecodesign projects in terms that make sense for decision-makers. At Company C, an advocate's perspective was required to convince internal stakeholders to use a specific material by answering the concerns of engineers, mainly focused on technical aspects, e.g., material properties. At Company D, a coalition of the sustainability manager and LCA people took an advocate's perspective to broadly engage core business managers in the organization around the topic of circular economy by systematically highlighting criticality to the business through business risks and opportunities associated with it.

4.5. The Prophet's Perspective

Some measures could be found stemming from a prophet's perspective, for instance associated with the idea of "preaching". At Company D, one interviewee mentioned that in their presentations to senior managers, the teams recurrently seek to bring-in sustainability aspects. At Company A, it was indicated that at the beginning of each product development project, which formally includes the conduction and consideration of an environmental assessment in decisions, the interviewee seeks to give a "ten-minute of fame" speech to brief the team about the environmental sustainability challenges associated with products.

> *"I try to give a speech in a startup project, I ask for 5–10 min, where I deliver the main issues that could be from our yearly environmental report. But it could also be like mass flows. Pointing out the importance and that could be something like that. Ok, we produce so much waste; we produce CO_2 from products developed 5–10 years ago. That is because we still produce these products and they still involve waste and so on. So, that is my key point, so we very much like to reduce waste, and energy consumption is important for our whole CO_2 account. It is now that we have to do it. And also, as we are still producing products designed and developed even 20 years ago, things that we talked about before about the environmental awareness from our user side, in 20 years they will still use the products that we developed today and in 20 years, they may have a lot of high requirements to use of bio-waste, recycled waste, reduced packaging or so. So, I ask for these 10 min of fame when we start and it is really well taken." (Interviewee A2)*

Associated with the idea of having trusted people from the product development community speak up for environmentally preferable solutions, an interviewee at Company A also seemed to indicate the symbolic importance of such people taking the lead on ecodesign topics, aligned with a prophet's perspective.

> *"If they start telling new stories then that time, I think that management will start softening up as well. It's a question of followers. So we start to get the specialists to dance and at some point, even management will as well." (Interviewee A1)*

Changing common believes about products was mentioned at Company D, where false ideas about products are sought to be changed, similarly at Company C where new truths about products are sought to be established by environmental teams. Changing the common belief that sustainability is necessarily associated with higher costs was also highlighted as a need at Company G. At Company A, efforts are on to change the common beliefs among product development teams that environmental experts can influence product sustainability performance solely by conducting environmental assessments during the product development process. This reveals that the establishment of a procedure formally bringing environmental aspects in the product development process may not be sufficient to push the ecodesign agenda in the organization. The idea of leveraging "what works best" in terms of communication in the organization was reported at Company A and Company D, also stemming from the prophet's perspective.

> *"I mean the core of our traditions and values is to have something you have you can feel, touch, hear or see. That is always better than a long report. So we tried to do it better and as concrete as possible. And based on that, we had a pilot case running in [a certain market country] during the analysis so we were working very closely with them on this." (Interviewee D1)*

4.6. Indications of Relations between the Different Lenses of Organizations

In several cases, measures from an advocate's, catalyst's or prophet's perspective seemed to develop in the absence of an architect's approach at the company. For instance, Interviewee F1 reported that, so far, the inclusion of environmental criteria in product development had been "*mostly about convincing the right people*" (advocate's perspective). At Company E, both interviewees indicated the absence of procedures for ecodesign in innovation processes and reported that their work is much about supporting and chaperoning companies which are eager to act and that their approach should not give the impression to "*dictate*" managers (catalyst's perspective). Interviewee D2 reported that she recurrently seeks to bring-in the focus on sustainability aspects in her presentations to senior managers (prophet's perspective), in a context where no specific direction or target come from a top-down perspective for product development.

Measures pertaining to the architect's perspective were considered or expected in several instances to facilitate other perspectives, especially the advocate's perspective. For example, formally incorporating sustainability in the organizational system was expected to provide the official scene for prioritizing time and resources on searching environment-friendly solutions at Company G (Interviewee G2). Having corporate environmental targets was indicated to raise sustainability up in agendas throughout the organization at Company B. Interviewee E2 indicated that the establishment of a sustainability strategy had been a facilitator to bargain sustainability implementation with managers. Adding an ecodesign procedure to the product development process at Company A seems to have made it "normal" for project teams to look at environmental criteria throughout the project which may be interpreted as the influence of an architect's measure on the prophet's perspective.

We noted some instances where from a prophet's perspective, interviewees indicated methods which "work best" at their companies and how the latter were actually leveraged in measures from the architect's or advocate's perspective. Numbers and graphs are the normal way to display information at Company A, and in that sense integrating LCA in the product development process fits well with the scientific culture of the company as indicated by Interviewee A1. At Company D, concrete experiments are in the DNA of the organization, hence demonstrating the urgency for the company to integrate circular economy principles through a pilot study was found relevant, as reported by Interviewee D1.

We found a set of instances where the advocate's, catalyst's and prophet's perspectives seemed to act as facilitator for, or to complement the architect's perspective. From the catalyst's perspective, we noted for example the use of participatory approaches to design how to add ecodesign procedures to the current product development process together with product development teams (Company B;

Company C). We also noted the influence of employees' own aspirations for ecodesign on the actual efforts deployed in developing solutions in projects, even if environmental assessments are formally part of the process, and thus the importance to intensively support those who are eager (Company A). From the advocate's perspective, we observed for instance a need to secure resources for more prospective projects to complement what can be done in common product development projects (Company A), and the idea that setting up new performance indicators is not enough to have people prioritize them (Company E). We also noted how taking an advocate's approach and putting efforts on those product development projects with a promising business case allows getting the marketing department onboard, and thus complement the architect's measure according to which an LCA must be conducted for each product development project (Company B). Finally, the prophet's perspective was associated for example with fighting misconceptions about who has the ability to influence product environmental performance in product development projects, and thus an important lever to encourage project teams to actually design environment-friendly solutions and to actually build on LCAs conducted for each project as a decision-support tool, rather than a mere documentation exercise (Company A).

5. Discussion

5.1. Presence of the Four Lenses of Organizations

The architect's perspective was evidently present in the results and directly corroborates the common recommendations from academia on integrating ecodesign aspects in the company's structure and processes [11,12,19,21,64,65]. We further noted the idea that strategies and goals need to be translated or broken down in lower levels of the organization, for specific business areas or on a project basis, which aligns with findings from earlier work [17]. The presence of the architect's perspective was further found in relation to challenges experienced by companies working with sustainability, about the difficulty to set a direction, doubts of where to set priorities and what KPIs to measure; calling for an architect's perspective to establish rational priorities, indicators and goals [12,28,62]. The importance of having capabilities specified in the company's organigram was highlighted at Company D which echoes with the findings of Boucher et al. [39]. On the other hand, we found that the discussion around having environmental targets for products varied depending on the context of the company, and more particularly on the nature of its products and drivers to develop environment-friendly products. In the present study, we could observe that in the case of ameliorative products [88], i.e., which inherently address sustainability-related needs (e.g., products developed to save energy or products developed to improve the life of seriously ill people), the development of a strategy related to products or performance targets which would include a broader range of sustainability issues was not a priority. Taking into account companies' strategic drivers to design relevant ecodesign integration approaches was also highlighted in earlier academic work [11]. Such insights from the present study are interesting to put in the perspective of literature insights which identified clear environmental goals, both at organizational and product development project level, or establishing environmental policies and targets for products as key success factors for ecodesign integration and green product innovation in companies, respectively [64,89].

The results regarding the catalyst's perspective align with earlier studies recommending participatory approaches [21,29]. The idea indicated at one case company consisting of framing problems in terms engineers are familiar with, e.g., as an engineering problem, could be considered as a form of nudging, i.e., leading employees towards certain choices without inducing guilt or being prescriptive [18]. Also matching earlier findings, the need for increasing comfort of teams with the topic was evoked in several instances [28]. The advocate's perspective was clearly present in interviewees' elaborations about ecodesign integration, which contrast findings from studies on general managers' approaches [56,57]. The prominence of challenges for ecodesign integration related to resource allocation, tradeoffs management and low priority on senior management agenda, may explain a high focus on an advocate's perspective from ecodesign proponents. The importance of building the "business case" for sustainability and presenting product environmental information in terms which make great sense for the business was also acknowledged in existing literature [13,71,90]. Interestingly, we found a somewhat lower presence of the prophet's perspective in measures indicated at the case companies. Earlier studies in the general management literature found that managers did not make extensive use of the symbolic lens [48,56,57]. The confusion around who has the responsibility and ability to influence the product environmental performance mentioned at one case company was previously highlighted by Johansson and Magnusson; in their study, it was identified as driven by the existence of a separate work stream dealing with environmental aspects in the investigated project [65].

5.2. Relations between the Lenses of Organizations

Our findings regarding the relations between perspectives of organizations interestingly echo with different aspects outlined in existing literature on ecodesign integration. In earlier academic work, scholars have highlighted the facilitating role of architect's measures on the other perspectives of organizations. Measures from an architect's perspective, e.g., integration in process and targets, have been found to result in a change in mentalities and higher motivation among employees [91]; more familiarity with, cooperation around, understanding and acceptance of ecodesign practices [12]; more cross-functional cooperation, networking and understanding of each other's roles [65]; higher priority for ecodesign in agendas both of product development teams and senior management [65,92]. In the present study, we found similar examples of a facilitating role played by architect's measures, yet no example of facilitation over the catalyst's perspective were mentioned. The facilitation was mostly emphasized by interviewees in the context of prioritizing ecodesign in agendas and daily work, hence on the advocate's perspective.

The observed facilitating or complementary roles of the advocate's, catalyst's, and prophet's perspectives on architect's measures match conclusions from other studies in which informal aspects of organizations were emphasized. Building on interviews conducted at four large companies, Kivimaa argued that the sole use of codified practices, e.g., LCA, does not guarantee a common understanding within the organization and emphasized the role of people-based approaches, i.e., cross-functional integration and training in environmental issues, for environmental integration in innovation [27]. Based on field work in two large companies, Skelton et al. concluded that the use of boundary objects for ecodesign integration, e.g., environmental improvement targets, which can be associated with an architect's perspective, "only establish specific instances where the environmental specialists can communicate around ecodesign and increase the engineers' level of awareness" [29] (p. 54). They further found that the use of boundary objects was not sufficient to integrate brokers, i.e., people working in functions supporting ecodesign integration, inside the product development community; neither to change the behavior of the product development community [29]. Arguing that nowadays managerial approaches tend to place less emphasis on command and control mechanisms (architect's perspective) to the benefit of increasing team autonomy, Brones et al. highlighted the need for "soft" mechanisms to lead the organization towards green innovation practices, e.g., fostering employees' engagement [18]. The insufficiency of architects' measures to guarantee successful ecodesign integration was also highlighted by Dekoninck et al. who indicated that solutions to address ecodesign integration challenges were often about introducing new tools, to the detriment of understanding why employees may lack motivation or be resistant [13].

Earlier academic studies exploring and comparing companies' trajectories of sustainability integration found that they did not all use architects' versus informal measures to the same extent, but rather adopted approaches which would best suit their organizational culture [76,93,94]. In the current study, all case companies seemed to agree to the importance of measures from the architect's perspective and none mentioned an integration effort solely based on informal aspects. Yet, the idea of matching the company's culture appeared in the mentioned prophet's measure consisting of using "what works best in the organization" to support ecodesign integration. The relative importance of measures from different lenses of organizations in different company contexts could be relevant to investigate in a larger sample of companies.

5.3. Influence of Interviewee Position and Company Context

Interviewees involved in the present study had either a sustainability-related position in their company or worked in a core business function and had some interest in pushing the ecodesign agenda in their organization. All interviewees indicated measures related to the architect's perspective. However, the formal integration of ecodesign aspects in the company's activities was one of the focuses of the interviews, and hence could have biased to some extent the perceptions of interviewees towards the relevance and need for measures from the architect's perspective. The advocate's perspective was also present in most interviews. Considering the sample size, it is difficult to draw any firm conclusion regarding the influence of the interviewee's position. We found that the interviewees in sustainability functions mentioned measures pertaining to at least three perspectives and more than half of them to all the four perspectives of organizations. On the other hand, more than half of the interviewees in core activity functions indicated measures from three different perspectives, and the others from one or two. Seniority in the organization or experience with working with sustainability-related topics did not seem to influence the number of lenses expressed by interviewees, as we did not observe clear differences in lens coverage between experienced and less-experienced interviewees. Yet, the influence of the above-mentioned parameters should be further studied in future research based on direct inquiries of the four lenses, as in the present exploratory study only weak indications could be retrieved.

The present work constitutes a Nordic case study as all case companies were in Nordic countries. This regional focus may have influenced the extent to which the different lenses of organizations could be observed. For instance, one interviewee from Company E referred to a Nordic style of working when describing that she seeks to empower employees by making them "*understand why they need to do something and what is expected from them*", before letting them "*find out what is needed to be done in detail*". This echoes with observations reported in earlier work touching upon the relative freedom of employees in Nordic organizations on how to achieve given targets [95], and could be in favor of the catalyst's perspective. At Company A, it was emphasized that there is a *consensus culture*, which leads to discussing solutions rather intensively in development projects. At Company D, one interviewee indicated that the organizational structure is rather flat and that they "*can go directly from [their] department to another department*". Both these factors could create a favorable ground for approaches stemming from the catalyst's, advocate's, and prophet's perspectives. On the other hand, the companies included in our sample are large market players, externally recognized for their sustainability efforts (e.g., listed in DJSI). From this perspective, the coverage of lenses found in the present study may not be representative of smaller companies or companies with less mature sustainability approaches.

5.4. Limitations of the Study

Only a limited number of interviews could be conducted at the case companies, especially at Company B where only one could be conducted. It is thus important to acknowledge that the phenomenon under study and presented in this article remains closely related to interviewees' perceptions, which is yet common for this type of research. Deriving concrete recommendations for the case companies would require a larger scope of investigation, but for the present study, the views of interviewees constitute relevant indications about the different lenses of organizations. This work was exploratory per definition and based on a case study design; hence this naturally limits the statistical generalizability of our findings which should be tested in future work on larger samples of companies [82]. Although the interview data allowed for tracking the presence of the different lenses of organizations in interviewees' descriptions of ecodesign integration at their company, the empirical part of the study remains based on a secondary data source, and thus may not give a fully representative picture of the presence of the lenses. More targeted questions could have yielded different results in terms of lenses' relative presence. Yet, the absence of questions targeted for each lens may, on the other hand, have been an advantage as it avoided social desirability or prestige biases, which can typically occur in direct questioning settings and imply that respondents tend to answer based on what is most socially accepted rather than based on the truth or on what is perceived as expected by the interviewer, respectively [96]. It also prevented any potential connotations associated with the different perspectives of organizations, e.g., "architect" (positively connoted) versus "prophet" (negatively connoted). However, future research designs based on direct inquiries of the four lenses, e.g., using a questionnaire adapted from the leadership orientation instrument [48], are needed in order to further our understanding of the role of the four lenses in ecodesign integration in companies.

6. Conclusions

Departing from the need to investigate and support ecodesign integration at companies, while accounting for formal and informal aspects of organizational functioning, we drew on the four-lens view of organizations and explored the presence and relations between the different lenses in ecodesign integration. The study built on interviews of ecodesign proponents at a set of Danish and Norwegian case companies in diverse manufacturing sectors. First, the analysis revealed the presence of the architect's, catalyst's, advocate's, and prophet's perspectives in the measures mentioned to support ecodesign integration at the case companies. Second, the results provided indications about relations between the different lenses, among which two seemed to stand out: (i) measures from the architect's perspective seemed considered or expected to provide an official scene for prioritizing ecodesign in the organization, hence facilitating the advocate's perspective; and (ii) measures stemming from the catalyst's, advocate's and prophet's perspectives were observed to act as facilitator or complement of measures from an architect's perspective to push the ecodesign agenda at companies. Overall, this exploratory study suggests that the four-lens view of organizations is pertinent to investigate and support ecodesign integration in organizational contexts.

From a theoretical point of view, our study contributes to the research field of ecodesign integration in companies with a new theoretical perspective stemming from the general management literature. Based on exploratory case studies, this work has investigated the potential of the four-lens view of organizations to support ecodesign integration in companies and brought initial evidence on the need for embracing the different lenses. This is a starting point for future work. Direct investigations of the lenses' presence in ecodesign integration efforts of larger samples of companies in different contexts should be the object of future studies to test the generalizability of our findings and expand our understanding of a multi-lens approach to support ecodesign integration in companies. Notably, interconnections between lenses need further investigation. Furthermore, it could be particularly relevant to (i) identify lenses which are critical, i.e., weakly established although recognized as highly necessary, in the opinion of ecodesign proponents in industry; (ii) study possible correlations between the lenses' coverage in ecodesign integration efforts and ecodesign performance indicators; (iii) study the relative importance of lenses in different organizational contexts, e.g., depending on the company persona [97]. From a practical perspective, our study provides ecodesign proponents in companies with a conceptual framework from the general management literature and its translation into the ecodesign integration context, with concrete measures to support ecodesign integration from the different perspectives of organizations and insights of the relative role of the different lenses.

Considering the challenges associated with ecodesign integration in companies together with the recurrently acknowledged need to account for the specific context of companies rather than providing one-size-fits-all models [18,59,76,98], the development of reflective tools whose primary objective would be to steer reflections from company practitioners about their current situation and challenges, seems a particularly interesting area to explore [99]. From this perspective, the potential formalization of the four-lens view of organizations into a reflective tool for ecodesign proponents is identified as an avenue for future research.

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Appendix A. Themes Addressed during the Interviews

- Current integration of ecodesign in the company: Processes? Tools? Strategies? Goals? Challenges?
- Interactions with other departments on ecodesign: form, challenges, and enablers?
- Interactions with other businesses on ecodesign (suppliers, distributors, customers, reprocessors, competitors, companies in other business areas): form, challenges, and enablers?

Appendix B. Details about the Coding Results

Table A1. Results from the revision of the coding results.

	Number of Reviewed Coded Units	Percentage of Discussed Coded Units	Percentage of Changed Coded Units
Co-author 1	52	12%	4%
Co-author 2	49	18%	6%
Co-author 3	49	39%	18%

Table A2. Lens distribution of coded units identified for each case company. Please note that the total number of coded units varies from one case company to the other.

	Architect (Structural)	Catalyst (Human)	Advocate (Political)	Prophet (Symbolic)	Total Number of Coded Units (=100%)
Company A	36%	19%	33%	11%	36
Company B	53%	16%	32%	0%	19
Company C	37%	26%	33%	4%	27
Company D	54%	7%	18%	21%	28
Company E	59%	21%	21%	0%	34
Company F	67%	0%	22%	11%	9
Company G	71%	0%	13%	16%	38
Total number of coded units	101	26	46	18	191

Table A3. List of second-cycle coding categories in each lens of organizations and examples of associated first-cycle coding phrases. LCA = Life Cycle Assessment; ERP = Enterprise Resource Planning; KPI = Key Performance Indicator.

Second-Cycle Coding Category	Examples of First-Cycle Coding Phrase
Architect's Perspective	
Integrate ecodesign procedure in product development process	"There is a mandatory procedure in product development projects for dealing with environmental aspects"; "The project manager has the responsibility to show environmental documentation at gates"
Acquire/develop tools for decision-making	"Development of in-house LCA capabilities"; "LCA used to compare products with competitors' or earlier generations"
Design strategy related to products	"Need for having sustainability as part of the business strategy, so that teams can take decisions based on environmental criteria"
Set	"The company has targets for products at high level"; "Set up a direction to be able to

directions/goals/targets	ask some funding to try out some alternative options in products"; "Set up a direction to be able to go all in when scouting for alternative options and have more margin to discuss with suppliers directly"
Develop guidelines related to product development	"Create a shared repository about eco-labels"; "Produce central guidelines for packaging material"
Formally define "sustainability" (e.g., standard, criteria)	"Define what "sustainability" means for the department"; "Define what a sustainable product is formally"
Translate strategy into action plan for specific business units/functions	"Define what the sustainability strategy implies at the function level"; "Develop a sustainability strategy and tailored translation tools"
Translate corporate targets into targets for individual innovation projects	"Breaking down high level targets to innovation project targets"
Create sustainability roles	"Slowly building the organizational structure around sustainability in the organization"
Set up new KPIs	"Set up new KPIs for the purchasing department"
Use a process with more experimental approach	"The set up for the sustainability dedicated project outside the stage gate model of the company is great because decisions can be taken more quickly"
Catalyst's Perspective	
Support/chaperon initiatives	"Make sure that the parties continue the project (since it is side track for them)"; "Support individual managers in their attempt to integrate sustainability issues in their work"
Increase comfort of people to work with the topic of ecodesign	"Make material digestible, focus on having teams comfortable discussing sustainability"; "Clarify tasks and implied workload for people to feel comfortable about it"
Build individual awareness of impact of decisions	"Have people understand how their decisions impact the product environmental performance"
Leverage people's aspirations	"Involve people who burn for the topic"; "Specifically support people that are eager to bring change because it all comes down to people's passion"
Participative approach to adapt the product development process	"Co-design with product development teams how the LCA tool will be used in the process"
Frame ecodesign challenges in familiar terms	"Translate ideas into concrete technical challenges to be solved by engineers who are good at it"
Give autonomy	"Tell people what their end goal is and let them find the way there"
Trigger people/"plant seeds"	"Trigger people by evoking the ecodesign topic"
Advocate's Perspective	
Align with business/stakeholders' agenda	"Identify critical resources in ERP system, match with business case to convince sourcing manager"
Negotiate prioritization of ecodesign in agendas	"Need for more priority on sustainability aspects when prioritizing projects"; "Bargain with management for sustainability KPIs to actually be prioritized in purchasing"
Emphasize criticality/emergency	"Make top management understand the underlying risks of sustainability aspects"

for business	
Target efforts/”pick battles”	“Target areas of the organization where change is easier to operate, e.g., in product maintenance rather than product development”; “Focus on high potential for sustainability story, sustainability needs to be shown as a win to marketing”
Ally with/get support from relevant people in the company	“Get people that are listened to, to speak up for environmentally preferable options”
Have answers to all technical questions	“Seek good arguments from expert judgements”; “Convince people that something is technically possible”
Leverage network in the company	“Leverage personal relationship to have people work outside the normal working flow”; “Create a network of sustainability responsible people in the organizations where they share knowledge, best practices and can collaborate”
Secure present resource allocation for long term/more prospective objectives	“Need prioritizing resources for projects specifically targeted at finding alternative to conventional plastics because no obvious green solutions”; “Need to invest in knowledge and competence for sustainability even if it is long term”
Leverage existing umbrella projects	“Leverage existing project as an umbrella for activities so that resources and momentum are already there”
Prophet’s Perspective	
Manage beliefs/”truths” in the company	“Change mindset that sustainability is a cost”; “Challenge common beliefs in the organization by delivering data”
Change perceived vision/mission of the company	“Change what people believe they are working for”; “Spread around that the company has ambition for sustainability”
Leverage “typical ways of doing”	“Use experiments which are in the DNA of the company to show relevance of ecodesign aspects”
Preach in the company	“Use a 10-min of fame to brief teams about environmental challenges at beginning of each project”; “Spread around the concept of circular economy (make sure everyone knows what it is about)”
Provide inspiration from outside	“Gain insights from young generations’ thoughts on sustainability”; “Bring external inputs to change mindsets”

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Article V

Exploration of the barriers to implementing different types of sustainability approaches

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Exploration of the barriers to implementing different types of sustainability approaches

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Abstract

Integrating sustainability into business is gaining increased attention. Yet, implementing long-lasting sustainability approaches remains a complex task. Many empirical studies have identified the barriers to such implementation but the variation in challenges faced by companies, depending on the focus of the approach being implemented, is not addressed. The aim of this paper is i) to explore the barriers related to implementing different types of sustainability approaches and ii) to look for indications of similarities and differences across types of approaches. The research builds on data about the barriers, collected from a sample of twenty-two empirical studies in academic research and additional reports. The findings show that performance measurement systems and access to industry-specific information, benchmark or reference cases are common areas of difficulty across all types. The main variation is an increase in barriers beyond the company's boundaries, when shifting from a production to a value proposition focus. The results are limited by the unbalanced distribution of studies and the variety in methodologies present in the sample. Further research on barrier identification, prioritization and influential parameters is recommended.

Keywords: Sustainability; approaches; implementation; empirical studies; barriers.

1. Introduction

Integrating sustainability considerations in business is gaining increased attention due to concerns of policy-makers, other external stakeholders, and companies' own agendas related to strategic and market positioning interests [1]. This has led companies to seek to develop their own sustainability approaches. An "approach" can generally be defined as a way of considering or doing something, dealing with a situation or a problem, and it often relates to a strategy and its underlying activities.

The matter of sustainability for a company relates to the concept of corporate sustainability. Based on a parallel with the definition of sustainable development established in the Brundtland report [2], the International Institute for Sustainable Development defines sustainable development for business as "adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future” [3]. According to Bertels et al., business sustainability is defined as “managing the triple bottom line, i.e. taking into consideration financial, social, and environmental risks, obligations and opportunities in decision-making” [4].

The concept of corporate or business sustainability is associated with a wide set of challenges and aspects to take into account. However, it is often the case that companies only address part of the sustainability matter by focusing on certain aspects and/or on certain business activities. At the same time, different international and national regulations require tackling certain specific sustainability issues, while companies may as well select for their sustainability work a number of additional sustainability aspects. For the purpose of this study, a sustainability approach is defined as “the way and method, voluntarily developed, for addressing one or several parts of the sustainability matter at a company”.

Many tools have been developed, refined and made available for companies [5,6]. Similarly, in a growing number of companies, pilot-projects and sustainability strategies are elaborated. Nonetheless, long-term implementation of sustainability approaches often fails, highlighting the complexity of the issue. Epstein et al. argue that even though most CEOs consider the importance of improving corporate sustainability performance, the very implementation of sustainability presents major challenges [7]. Pigosso et al. contend that companies struggle to make Eco-design projects shift from pilots to anchored practices [5]. Preuss reveals that there may be a significant gap between “corporate rhetoric” about sustainable supply chain management in environmental policy statements and actual practices [8]. Høgevold et al. argue that for a company to develop and implement a sustainable business model, it has to generate a shift in business practices and corporate culture, which is difficult to manage [9].

In this context, a broad set of empirical studies have been conducted by scholars to identify the barriers and challenges to the implementation of diverse sustainability approaches in companies, such as Cleaner Production [10–12], Eco-design [13,14], Sustainable Design [15], Design for Environment [16], Design for Sustainability [17], Environmental [18] or Sustainable Supply Chain Management [19–21], Green Business Model [22,23], etc. Such studies are usually based on case studies, using interviews, or surveys as prime sources of empirical data. They seek to highlight different factors or barriers that may hinder the implementation of the respective sustainability approaches. Nonetheless, the current body of knowledge does not appear to sufficiently address the potential variation in challenges and barriers faced by companies, depending on the type of sustainability approaches being implemented, although a change in focus could lead to different difficulties. The aim of this paper is i) to explore the barriers and challenges related to the implementation of different types of sustainability approaches and ii) to look for indications of similarities and differences across types.

Section 2 introduces the methodology chosen in the present study (scope definition, data collection process and elaboration of a matrix to support data analysis). In section 3, the results are presented with a focus on outlining similarities and differences across sustainability approaches. In section 4, the findings are discussed in the light of the limitations. Finally, section 5 contains a summary of the study and the key concluding remarks.

2. Methodology

2.1. Scope

Classifying sustainability approaches is not a straightforward task. Many classification frames are available in literature but they do not align, and there is a risk for overlapping. For instance, the list of Sustainable Business Model archetypes provided by Bocken et al. includes “maximizing material and energy efficiency”, and “substitute with renewable and natural processes” [24] which could just as well be classified under Cleaner Production [25]. Bisgaard et al. include Green Supply Chain Management in their compendium of case studies of Sustainable Business Model innovations [22] while the approach stands on its own for many scholars [8,20,21]. In order to encompass the multitude and diversity of sustainability approaches, a classification key is proposed for the purpose of this study. It categorizes approaches depending on whether they focus on the production system, the product, the supply chain or the value proposition. Figure 1 shows examples of sustainability approaches considered in this study, under each category.

Moreover, the implementation process studied in this study refers to the shift from a specific sustainability strategy, policy or pilot project to its content being integrated into day-to-day business activities. This excludes the upstream process of implementing sustainability into the company strategy, a policy or a pilot project. In essence, the research presented here focuses on a situation where a company already has decided to engage into sustainability implementation. Figure 1 shows the scope of this study.

2.2. Data collection

The research builds on data about the barriers to the implementation of the four sustainability approach types, collected from previously published empirical work. The search was performed using the database Scopus. The sample of studies was based on two criteria: the year of publication is between 2000 and 2015 and the focus is on a set of companies located in developed countries.

The sample mainly includes case studies, published in academic research articles. Most are based on interviews but in few cases, a survey is used, either as the main method or in addition to interviews. The studies focus on companies in various industries and of various sizes. For product-oriented approaches, which are addressed in a large set of papers, priority is given to most-cited articles. For value proposition-oriented approaches, there is little empirical content available in academic research articles. Thus, studies published by other types of organizations are used. The sample of studies is reported in Table 1.

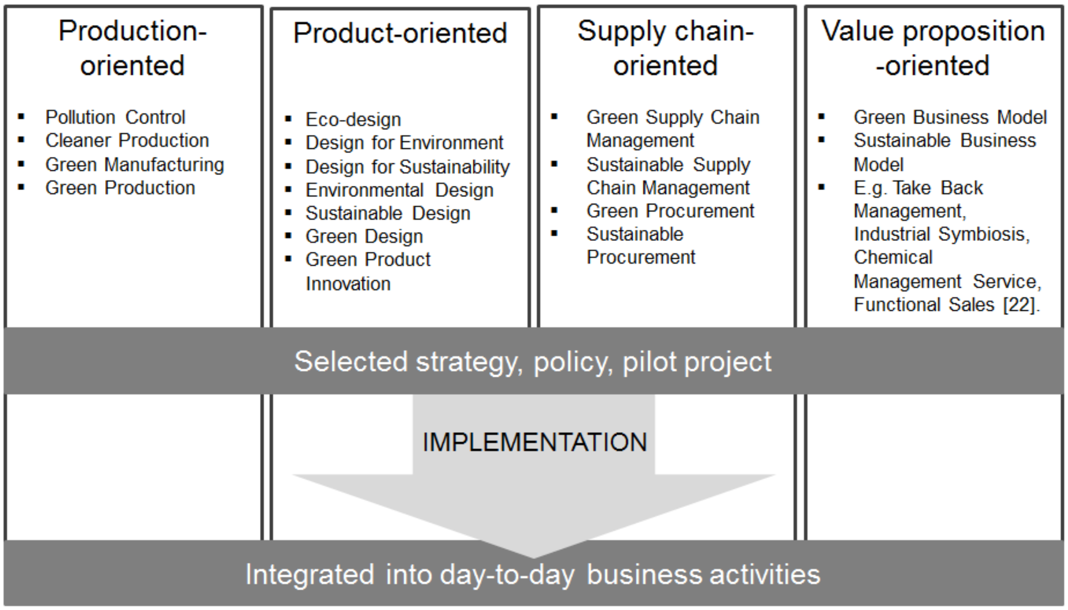

Figure 1. Scope: Focus on four types of sustainability approaches, introduced with examples; focus for the implementation process, e.g. from strategy to integration into day-to-day business activities.

2.3. Matrix design

In order to bring all barriers together in a common frame and allow for comparison, a matrix is elaborated. The most common categorization method across literature is set between internal or organization-related and external or industry-related barriers [18,21,26–28]. The internal set includes, for instance, financial and other resource constraints, managerial and employee attitudes, poor communication and past practices [27]. The external set includes, for instance, capital costs, competitive pressures, industry regulation, technical information, green market opportunities and technical solutions [27]. Similarly, the first level of categorization in the presented matrix splits dimensions within and beyond the company's boundaries.

Table 1. Sample of empirical studies used in the present research.

Approach orientation	**Empirical studies**
Process	[10] [11] [12][28]
Product	[13] [14][15][16][17] [29] [30] [31] [32] [33]
Supply chain	[8][18] [19] [20] [21] [34]
Value proposition	[22] [23] [1]

[1]Both studies for value proposition-oriented approaches were conducted in collaboration with a single research organization. Thus it limits the diversity of data inputs for this approach type.

In order to further structure the set of internal dimensions, the four-lens view upon organizations suggested by Bolman & Deal is used [35]. This includes structural, human, political and symbolic (here named cultural) aspects that should be taken into account when initiating a change within the organization [35]. This choice is consistent with considering sustainability integration as an organizational change [15] and with the need for abandoning a single bureaucratic view of organizations [36]. The structural dimension focuses on the architecture of the organization: the design of its units and subunits, the rules and roles as well as the goals and policies [35]. The human dimension focuses on understanding people, their strengths and weaknesses, their rationale and emotion as well as their desires and fears [35]. The political dimension focuses on the way to allocate scarce resources, the competing interests, and the fights for power and advantage [35]. Finally, the cultural dimension focuses on meaning, beliefs and faith, i.e. how humans make sense of the chaotic and ambiguous world in which they live [35].

Market, regulation, technology & tool and value network are the four entities used for structuring the set of external dimensions. The fourth entity is not commonly included in lists of barriers available in literature. It is added based on insights from Bertels et al. who argue that one reason for the complexity of implementing sustainability approaches lies in the high dependence on factors whose control is located beyond the company boundaries and that intense collaboration within the value network is often required for implementing sustainability [4]. A “value network” is defined as a set of players, i.e. suppliers, partners, allies, consumers, working together to co-produce value [37].

The barriers mentioned in the empirical studies are reported under the relevant dimension in the matrix. For a specific barrier and a specific approach type, the cell contains an “X” if the barrier was highlighted in more than one of the related empirical studies and an “x” if it was outlined in a single study. It was decided to put no emphasis on the exact number of studies mentioning each barrier. This choice is consistent with the goal of the study and acknowledges that the empirical studies in the sample are not built on a single theoretical framework which does not allow for quantitative analysis of the barriers.

3. Results

The results of the comparison are displayed in Table 2 and Table 3. A code is provided for each barrier. Out of the fifty-nine barriers identified, two seem to be relevant across all approach types. These are non-adapted performance measurement systems (S8) and lack of industry-specific information, benchmarks or reference cases (T6). On the one hand, production-, product- and supply chain-oriented approaches and on the other hand, product-, supply chain- and value proposition-oriented approaches respectively show nine and ten barriers in common. The similarity in barriers for product- and supply chain-oriented approaches is remarkable: they share twenty-five barriers.

Within the company’s boundaries, in the structural dimension, the difficulty to define relevant sustainability performance metrics or perform reporting (S3), the information aspect (S4), and the difficulties related to decision-making processes (S7) are highlighted in the context of production-, product- and supply chain-oriented approaches. S3 shows more evidence in the sample of studies than the other aspects. The information aspect is based e.g. on the absence of channels for bottom-up communication or on the fact that sustainability policy fails to communicate corporate commitment [10]. It is also raised in relation to the typical delay occurring between design decisions and information collection [29,33] and to the absence of company-specific filtering structure for environmental information [32]. Examples of difficulties related to the decision-making processes (S7) are lack of willingness to iterate among designers [29] and absence of environmental criteria in the conceptual phase, combined with other general flaws in design practice [17,31]. The lack of integration across functions within the organization (S5) is a common barrier for product-, supply chain- and value proposition-oriented approaches [13,20,23].

In the political dimension, difficulty to elaborate the business case and manage trade-offs (P1), low priority on agendas or short term priorities (P2) and lack of financial (P6) as well as time & human resources (P7) are common barriers to several approach types. They are all mentioned in more than one study for most approach types.

The human dimension is mainly outlined in studies on production and product approaches. The lack of skills, knowledge or training (H5) seems to be a recurrent barrier in the context of product, supply chain and value proposition approaches. Knowledge issues can also materialize in difficulties to learn (H6) [11]. Lack of awareness (H1) shows different facets, e.g. it is stressed as being quite a poorly influential factor [8] or coupled with the regulatory context [31].

Table 2. Matrix of barriers within the company's boundaries, for the different approach types.

		Production	Product	Supply Chain	Value proposition
	Barriers within company's boundaries				
Code	*Structural dimensions*				
S1	Difficulty to scope / prioritize / set goals, lack of strategy		x	X	
S2	Lack of goal translation to functional / department basis		X	X	
S3	Difficulty to define relevant sustainability performance metrics / perform reporting	X	X	X	
S4	Issues of information filtering / flows / timing to support decision making	X	x	x	
S5	Lack of function integration / cooperation		x	x	x
S6	Lack of clear responsibility distribution		x	X	
S7	Difficulties related to decision making processes	x	X	x	
S8	Non-adapted performance measurement and incentive systems	x	x	X	x
S9	Locked-in situation related to capital / technology investments	x			
	Political dimensions				
P1	Difficulty to elaborate business case, conflict, difficulty to		X	X	X

	manage trade-offs				
P2	Low priority on agenda, short term priority	X	X	X	
P3	Lack of continuity due to changing agenda	x			
P4	Lack of alignment with other projects	x			
P5	Power of resisting versus promoting groups	x			
P6	Lack of financial resources	x		X	X
P7	Lack of time & human resources	x	X	X	
P8	Lack of local empowerment (department, business unit, subsidiary)	x		x	
P9	Lack of R&D / innovative capabilities	x	x		
	Human dimensions				
H1	Lack of awareness		x	x	
H2	Lack of interest / commitment	x	x		
H3	Lack of involvement and empowerment	x	x		
H4	Lack of support from management for employees	x		X	
H5	Lack of skills/knowledge/training		X	X	x
H6	Difficulties linked to learning process	x			
H7	Fear to lose creativity / flexibility		x		
H8	Fear of work overload	x	X		
H9	Discomfort / uncertainty about topic		x		
H10	Difficulty to find sustainability ambassadors with necessary set of skills	x			
	Cultural dimensions				
C1	Scepticism regarding potential benefits		X	X	
C2	Lack of entrepreneurial spirit / room for out-of-the-box thinking		X		x
C3	It is not the company's responsibility		X		

C4	Sustainability is a distraction	x
C5	Language barriers	x
C6	Sustainability is "not invented here"	X
C7	Sustainability input is constraint / criticism	X

The cultural dimension is stressed in the context of product-oriented approaches. Scepticism regarding potential benefits (C1) and lack of entrepreneurial spirit (C2) are the only exceptions. However, some studies do point out cultural barriers in the context of other approaches, e.g. [10] and [21], be it in a fuzzy way.

Regulation is overall a common dimension of difficulty across approaches but in varying aspects: from either a matter of multiple, complex, changing regulations (R2) or to a lower extent, a matter of low legislative pressure (R3) in the context of production, product and supply chain approaches, regulation may also become an obstacle to innovation (R4) for value proposition approaches [23].

Low market demand or willingness to pay (M3) as well as lack of understanding and knowledge among customers (M2) and a difficulty to propose competitive offerings (M5) are mentioned for product, supply chain and value proposition approaches. In production-oriented approaches only the latter is outlined.

Within the technology & tool dimension, few similarities are seen apart from T6 previously identified and a dependency on available technology (T1). There is evidence that product-oriented approaches face the challenges of tool and framework customisation (T3), their complexity or high demand in resource (T4) and the difficulty to link them with other business concerns (T5).

In the reviewed literature, barriers related to the value network are nearly inexistent for production-oriented approaches but in case of high industry interdependency [28]. Product, supply chain and value proposition approaches are associated with many challenges related to the value network. Common barriers are lack of trust, reluctance to share information, make joint investment (V4), the risk of a current or future locked-in situation or lack of bargaining power (V5) and difficulty to collaborate within and coordinate the value network (V7). Value network is the main dimension of difficulty for value proposition-oriented approaches.

4. Limitations and discussion

The lack of consistency in theoretical frameworks across studies in the sample both triggered and challenged the present work. Such difference might have biased the barriers mentioned by the interviewees or identified in document analysis. Moreover, the unbalanced distribution of studies related to the different approach types leads to different levels of richness in terms of explored barriers. However, the purpose of this study was formulated to take these challenges into account and the discussion aims at putting the results into their perspective. It is also important to keep in mind the weak representativeness of value proposition-oriented approaches in the sample.

It is acknowledged that a lack of focus on cultural barriers in the sample of studies may be the reason for the poor evidence of this dimension being a key area of difficulty across types. The empirical results for product-oriented approaches would be an interesting basis for further field research in other approach contexts. Key terms such as scepticism, distraction, not-invented-here and constraint could be used for such a purpose.

Also concerning other dimensions, certain barriers mentioned in a study of a specific approach showing no evidence within the approach or apparent resonance across approaches could be explored in future field research. Examples of this are fear of work overload, fear to lose creativity or flexibility and discomfort or uncertainty about sustainability [15], as well as lack of continuity [11] or consistency across projects within the company [10], fuzziness of regulation and customer messages [32], and increased scrutiny by stakeholders [30]. The matrix developed could be used as a framework for future research on the variation in barrier intensity across approaches.

Table 3. Matrix of barriers beyond the company's boundaries, for the different approach types.

		Production	Product	Supply chain	Value proposition
	Barriers beyond company's boundaries				
Code	*Regulation*				
R1	Unclear / fuzzy message from regulation		x		x
R2	Multiple / complex / changing regulation	x	X	x	
R3	Low pressure from regulation /control	x		x	
R4	Regulation limits room for innovation				x
	Market				
M1	Unclear / fuzzy message from customers		x	x	
M2	Lack of understanding / knowledge among customers		x	x	X
M3	Low market demand / willingness to pay		X	X	x
M4	Lack of influence on customers		x		
M5	Lack of competitiveness	x	X	X	
	Technology & tool				
T1	Dependency on available technology	x	x		x
T2	High research costs / risks for new technologies	x			x

T3	Lack of framework / tool customisation	x	X		
T4	Complex / time consuming / information-intensive tools		X		
T5	Difficulty to make links with other business concerns when using tools		X		
T6	Lack of industry-specific information / benchmark / reference cases	x	X	x	x
	Value network				
V1	Dependency on current infrastructure / value network setting	X		x	X
V2	Lack of understanding / knowledge			x	X
V3	Lack of commitment			x	x
V4	Lack of trust, reluctance to sharing information /making joint investments		x	X	X
V5	Current/future locked-in situation or lack of bargaining power against other players		x	X	X
V6	Difficulty to communicate and exchange data across the value network		x	X	
V7	Difficulty to collaborate within / coordinate the value network		x	x	X
V8	Discrepancy across accounting / contracting practices / incentives				X
V9	Risk of scrutiny by stakeholders		x	x	

The present research focuses on the variable “type of sustainability approach being implemented”. However, other parameters might have an influence. Verhulst & Boks reveal differences in barriers across the company departments [15]. Preuss highlights potential differences related to the company size, in terms of awareness, acknowledgement of company’s responsibility and clear task distribution [8]. Van Hemel & Cramer outline that sustainability initiatives in an industrial sector play a role in the implementation of Eco-design in this sector [14]. This relates to an idea of sector culture that could be further explored. Walker et al. recommend investigating the differences between private and public sectors [18]. Linnenluecke et al. argue that the barriers may vary on an employee individual basis, depending on the subculture to which the employee belongs [38]. These additional parameters would help better understand the relevant barriers in a given context as well as their interactions; Aschehoug et al. for example link the challenge of information filtering to the cultural framing of the groups receiving the information in the company [39]. If no systematic filtering mechanism is applied, the availability of information in the company remains uncontrolled [39].

Several scholars tend to support that internal barriers are the main obstacles to the implementation of sustainability in companies [4,33]. For instance, it is argued that the adoption of corporate sustainability principles happens through the adoption of a sustainability-oriented organizational culture [36]. Nonetheless, in the present study, external barriers – in particular regulation and access to industry-specific information, benchmarks or reference cases – seem to play a crucial role across approach types. This is consistent with the findings by Walker et al. [18].

It is further noticed that external barriers seem to play an increasingly intense role, when shifting from production- to value proposition-oriented approach. This finding may be related to the fact that the group of players, who may enable or impede, the long-lasting implementation into business activities, changes and grows, from mainly company-internal to beyond the company's boundaries, along with such a shift. Indeed, in a supply chain-oriented approach, the coordination and collaboration of the company with its suppliers is a necessary precondition to its long-lasting implementation. This is also the case for product-oriented approaches since they might involve action across the value chain. Similarly, in a value proposition-oriented approach, value network players have a key role in the offering's long-term success.

5. Conclusion

The aim of this paper was i) to explore the barriers related to the implementation of different types of sustainability approaches and ii) to look for indications of similarities and differences across types of approaches. For the exploration of barriers, the authors suggested and applied a categorization of sustainability approaches into four types according to the particular focus: production-, product-, supply chain- and value proposition-oriented approaches.

Data on the barriers to the implementation were collected from 22 empirical studies. A matrix was built to compare the barriers mentioned for different types of approaches. The matrix distinguishes between dimensions "within the company's boundaries" (being: structural, political, human and cultural) and "beyond the company' boundaries" (being: regulation, market, technology & tool and value network).

Within the company's boundaries, the non-adaptation of performance measurement systems is highlighted as a common barrier across approach types. Beyond the company's boundaries, the lack of industry-specific information, benchmark or reference cases is outlined as a recurrent challenge. Other similarities across several approach types were explored. The apparent lack of similarities between some dimensions may be due to the unbalanced distribution of studies and the lack of methodology consistency across studies. The main variation across types is an increase in external barriers, when shifting from production to value proposition orientation.

As a central contribution, this paper presents a large set of potential barriers and structures these into eight dimensions but it does not propose any prioritization or customization key. Future research could focus on identifying criticality and priority areas, depending on other parameters such as the company size or sector, as well as the department or group of employees being studied. It could also be relevant to relate the barriers to necessary factors that a company should secure before, or actively manage while, undertaking a certain sustainability approach. For instance, it could be investigated whether a certain value network sustainability "maturity" is necessary to the long-lasting success of a value proposition approach.

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Article VI

Company personas as a tool for improved Design for Sustainability implementation

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Draft manuscript

Exploring “Company personas” for informing Design for Sustainability implementation in companies

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Abstract: The need for understanding the context of the case company during Design for Sustainability (DfS) implementation has been a long identified need among the researchers in the field. Yet, contextual studies have majorly focussed on studying, enlisting and prescribing standardised solutions for companies or clustering companies based on similarities. Such approaches have not been able to overcome the organisational “soft side” challenges that have been long addressed in DfS literature. This explorative paper takes insights from 20 case interviews conducted in Norwegian and Danish manufacturing companies and the concept of persona from Design studies to explore the potential of defining “company personas” to better define the context of the company. The interview analysis produces 14 persona dimensions including both hitherto identified technical needs of companies and soft-side elements required to create a company persona and thereby inform practitioners and researchers in taking DfS implementation approach tailored to the company context.

Keywords: Design for Sustainability (DfS), eco-design, persona, case study, implementation, industry, Nordics

1. Introduction

The need for sustainability considerations in product design processes has been gaining greater acceptance in industries. Design for sustainability (DfS) is one stream of design research towards more sustainable products acknowledging this acceptance. Even though the concept of DfS has been a focus subject in both academia and industry alike, academic reviews suggest that DfS implementation has faced a number of barriers and challenges in actual implementation stages [1]. Addressing these challenges, a part of academic discussions has focused upon the contextual human factors existing within and beyond the company boundaries that can have a possible impact on DfS implementation. Solutions put forward by academia to overcome these challenges have been mostly in the form of standardized DfS tools, checklists and matrices [2]. However, most of these solutions have failed to create desired results or have not been widely used in industry [3]. This is mainly because most challenges and enablers for DfS implementation vary according to the context of the company and standardized solutions are less likely to be effective in such situations [1,4].

Some studies in the DfS literature have focused on highlighting the contextual differences that exist within companies involved in sustainability implementation. Such studies have mostly focussed on describing such company contexts and grouping them based on the commonalities observed between the companies' preparedness on sustainability topics or their approach to sustainability implementation [5,6]. Clustering of companies based on their similarities brings back the discussion to the ongoing dilemma on how to customise sustainability solutions to better fit the company needs. A contrary approach to this can be observed in Domingo et al. [7], where the authors characterise companies based on a list of factors existing in the business context of the firm and by identifying the key development areas. Hence, a potential solution to overcome the challenges of standardised solutions to DfS implementation is to proceed beyond mere description and grouping of companies in order to understand the factors that differentiate them from one another.

Such an approach can be seen in design literature, where designers aim to provide design solutions that better fit to the needs of their product users by identifying the distinguishable characteristics of the users and collectively addressing users with similar characteristics as “personas”. Drawing from this area of design research and combining it with aforementioned DfS implementation scenario, we assume that companies, as product users, possess certain characteristics that distinguish them from others; and on the other hand, there will be companies that are comparable to each other in terms of their operational internal and external contexts. If we assume this, it is interesting to attempt to identify what characteristics may be relevant to distinguish from a DfS perspective, what dimensions they will entail, and whether those dimensions can be identified in a comprehensive manner. This is the starting point of this explorative paper, where the aim is to gain insight in the feasibility of constructing 'company personas' from a sustainability perspective, and in the potential of eventually using these personas to facilitate choices related to what DfS tools and methods may be most suitable for that company, and how they can be implemented best. For this purpose, a company persona is tentatively defined as a stereotypical set of characteristics of the company in functional, organisational, business strength and value chain dimensions that can be used to distinguish the company it is projected on from other types of companies, or enables it to be grouped with other similar companies. Drawing parallels from academic and design studies on user-based (or end-user) design strategies, where the user occupies the centre stage in the design process, this paper proposes the idea of placing the company in the centre focus of academic research on mitigating DfS implementation challenges. As design practitioners often resort to the “user persona” as a design method to facilitate user centred design approaches, this paper investigates the “company persona” in a similar way.

In order to better inform this process, the paper firstly presents the conceptual framework of persona from design literature and explores how this can contribute to such a discussion. Secondly, the paper discusses existing literature on DfS implementation that has tried to identify the different contextual aspects of companies and how they may impact the success or failure of the DfS implementation project. Finally, the literature findings are corroborated with results from 20 semi-structured interviews carried out in 7 different companies having a DfS focus in their product development and 4 sustainability experts who have worked with DfS implementation in companies. This paper aims to discuss the role of contextual factors of organisations in DfS implementation further. The authors approach the case by presenting academic view points and insights from interviews with industrial actors on how identifying and defining the "persona" of an organisation may improve development of tools, methods and approaches for integrating sustainability considerations in design processes. It thereby also aims to explore the potential of future prescriptive research that can be placed in between generalist and customised approaches. Theoretical research is often accused of lacking practical application potential; general guidelines for DfS implementation may lack relevance for individual companies due to the different contexts they operate in. On the other hand, customised approaches, for example based on individual case studies, may lack the potential of generalisation and applicability beyond a single context. It is our hypothesis that zooming in on a company persona level when developing a company-specific approach avoids disadvantages that exist on either side of this spectrum. The targeted audience for the use of such "company personas" are mainly twofold, firstly sustainability/eco-"champions" in companies or proponents of sustainability initiatives who can use it as a self-reflective tool in the implementation process. Secondly, scholars and sustainability consultants working towards improving DfS adaptation and implementation in companies.

The following research question is addressed in this paper: *How can dimensions of a "company persona" help in the characterisation of companies' and thereby contribute to developing tailored DfS implementation approaches?*

2. Conceptual framework

Academic research on DfS increasingly acknowledges the need to address the overall socio-organisational context of the company in addition to the technical details that DfS projects demand [8–11]. These include the change management perspective for eco-design implementation in companies [11], company characterisation based on the business features for eco-design activity planning in companies [7] and managerial motivations behind sustainability activities in the company [12] among others. In one of the earlier works on the "soft-side" of DfS, Boks [13] mentions that companies need to emphasise their communication structure, need of cooperation between companies, alignment of needs and expectations between proponents and executors and need for establishment of market demand for DfS products in addition to focussing on the technicalities of the products.

Even though there is an abundance of eco-design tools available on the market [14], these tools are seldom used due to the lack of required knowledge capacity within the company, insufficient resources and commitment from management, absence of clear environmental information [3] and most often do not cater to the need and context of the company [15]. Lack of integration of DfS and corporate strategy [2], difficulties in defining and planning the activities for DfS implementation as well as challenges in prioritizing the eco-design practices in companies [16] also add to these barriers. Researchers who studied the external environment of a company and the role of stakeholders from a sustainability implementation perspective identify the need of stakeholder involvement and management of the stakeholder relationship both internally and externally [17,18]. Companies also act as communities with their own aspirations, ambitions, beliefs and hardships in different contexts, thus warranting differential treatment [19]. The DfS activities they undertake will need external stimulus for generating a consistent demand for sustainable products and this in turn should be integrated in the actual Project Management process within the company to be successful [8,20]. Johansson [9] also mentions the need for regular and recurring environmental assessment in all stages of the PD process. The following subsections present the contextual framework based on the existing literature on such company characterisation from a sustainability management perspective and the insights from "personas" in the design literature.

2.1. Design for sustainability implementation and relevance of company context

Various contextual factors, termed as “soft-side” factors in a few academic literature [1,13,21], include the cultural, linguistic and organizational elements of the company and its employees, among others. These could also include factual aspects about the company such as its history, product offerings, market conditions, size, geographic location and industry branch. In addition, a number of other factors existing within and beyond the company boundaries such as the position in the value chain, influencing its capability to integrate/collaborate or negotiate higher or down in the hierarchy of value chain, may also affect how DfS implementation can best be approached. The way sustainability is communicated in companies, different expectations among employees on sustainability issues in the company, the prioritization of (or the ability to prioritize) DfS in the company’s project portfolio, overall strategy and vision statement of the company are some elements in the company culture that may negatively or positively influence the implementation process [9,22–24]. Dealing with 7 "sustainability blunders" that companies usually commit in eco-design implementation, Doppelt [25] suggests that companies need to restructure their strategies, their way of organising sustainability strategy team and ensuring alignment in the vision and activities of the team as a first step to create a sustainable enterprise. Elsewhere, studying the role of resistance against sustainability and internal communications in sustainable design implementation in companies, Verhulst and Boks [11] highlight the need for different communication styles that will inform, support and involve the employees of the company. In parallel to this discussion on “soft-side” there has been significant research focus on DfS tools and methods development, which have been primarily quantitative in nature with a few exceptions of semi-quantitative or qualitative tools [26]. However, the uptake of these tools are marred by the need for specific knowledge to use and understand the results [9] over simplification of certain results [26], overwhelming number of tools to choose from [2] or lack of envisaged market opportunities for eco-design products [27]. Hence, it is evident that most often the “off-the shelf” solutions such as LCAs, design matrices, Design for X solutions, checklists and tool-based prescriptions offered to DfS challenges are likely to be ineffective, or at least insufficient without a customised implementation plan.

Some of the earlier research works that look into understanding these company contexts have enlisted methods for clustering companies based on contextual similarities. Domingo et al. [7] present one such case study based on two companies where the context of the companies are characterised using a three stage process, namely mapping the company’s business context, identifying its key development areas and developing an eco-design introduction plan. The characteristics identified include the management structure, product development process in the company, environmental knowledge in the business, strategic focus of the company, business drivers for DfS and its feasibility, and role of the company in the value chain. Elsewhere researchers clustered companies into sustainability leaders, environmentalists and traditionalists based on their approach to sustainable development [12]. With an exception of Domingo et al. [7], these mentioned studies have primarily focussed on clustering the companies based on commonalities existing in its company context and sustainability preparedness. In a later study to assess companies based on their sustainability readiness, Pigosso et al. [2] propose a sustainability maturity model for companies that look into the level of formalisation for eco-design implementation, capability level existing within the company and steps to progress to higher maturity among others. While the maturity model prescribes an indepth path of progression for companies in the sustainability journey based on its capabilities and eco-design evolution, the prescriptions are often unidirectional in nature irrespective of the companies' niche characteristics. Such an approach also inadvertently lead to making propositions that define a pathway to improved DfS implementation often at the cost of ignoring the meaningful adage "one size does not fit all" when it comes to sustainability. Thus this paper aims at placing itself at this conjunction between importance of company context and hitherto lesser addressed "soft-side" of DfS implementation.

2.2. Persona origin, definition and dimensions

The origin of the persona as a research topic is widely found in user centred design literature, where the user is placed in the centre of the design process. Alan Cooper introduced persona as a method for designers in late 1990s in his seminal work titled, "The inmates are running the asylum". In the book, Cooper observes that designers often have unclear or vague ideas of the end user of the product and are most often driven by user scenarios similar to the designer himself/herself. To overcome this shortcoming, Cooper suggests the "goal-directed-design", where multiple user centred research methods such as interviews, ethnographies etc. are combined with market research, user requirements and goals to better define the user and his/her needs [28]. For this paper, personas are defined as user classes fleshed out into "user archetypes", that gives the required precision to the design activity of the designer.

2.2.1. Benefits of using personas

The popular support for personas come from its advantage over scenarios due to close proximity to the reality of the design goal and the engaging nature of personas [29]. Personas help design teams in thinking about users during the design process, make efficient design decisions without inappropriate generalization, and facilitate communicating about users to various stakeholders [30,31].

Miaskiewicz and Kozar [31] use the Delphi technique to rank the benefits of using a persona identified from literature. Firstly, audience focus- where the end user of the product is the main focus. Secondly, product requirements prioritisation - on product requirements and ensuring that the right problem is being solved. Thirdly, audience prioritisation - bringing about a focus on the most important audience, and finally challenge assumptions - that are often incorrect about the users/customers are some of the top benefits identified in that paper. Further, literature also observes that the creation of personas has made communications in design environment easier and more explicit. The efficacy of driving the debate and arriving at design decisions made the technique popular among designers [33]. Political and social characteristics of users remained mostly unaddressed in earlier design cases; however, the use of personas helped in recognizing and challenging such characteristics [33–35]. Using personas helps to create an embodiment of the needs and goals of the users thus providing additional specificity and avoiding the higher level of abstraction in the definition of the user [36].

A common application of persona tool can be observed in IT systems implementation in companies, where we could identify a predominant number of examples that tend to define the persona characteristic of the user being targeted. Rönkkö et al. [35] identify certain characteristics for a case company where persona as a design technique was used but failed to overcome the design challenge. These characteristics include the demographics of the company, the field of work, their expertise in the field, years of experience, department structure etc. The article however notes that the persona technique failed because it did not take into account the external environment of the company, stakeholders outside the company. Mathews et al., [31] observe that despite its limitation, the power of persona as a technique lies in bringing out the "some irreconcilable differences between various design stakeholders". The authors of this paper believe that while defining the company persona, explained in detail in the following sections, it should include characteristics both external and internal to the company for successful implementation of DfS.

2.2.2. Creation of personas from design literature

Faily and Flechais [29] identify three main steps in creating a persona, firstly, summarising the proposition by identifying the thematic propositions that the persona shall address. Secondly, enumerating and explaining the characteristics identified for the persona. Finally, creating detailed narratives of the persona characteristics and other supporting narratives.

Floyd et al. [37] identify the different kinds, attributes and characteristics of personas based on existing literature and case studies. They categorise the persona technique into seven major kinds, based on the detail of description, intended purpose and what kind of data is sourced to create a persona. The first classic kind of persona identified by Floyd et al. [37] is the one proposed by Alan Cooper, it relies on in-depth ethnographic research and tries to create as many initial personas as possible [28]. Floyd et al. [37] further observe that in "Cooperian" style of personas, the initial personas developed to capture the basic understanding of user characteristics are then merged through analysis to arrive at one primary persona for each user kind. These final personas are then maintained throughout the rest of the design process and discarded at the end of the project. Floyd et al. [36] classify these Cooperian personas into two kinds, Cooperian Initial Personas (CI) and Cooperian Final Personas (CF).

The second type of persona are the kind as used by Pruitt and Grudin, which is characterised by its massive data driven approach, quantitative and qualitative. The personas developed that way are then retained even after the project is completed, to be used and adapted in future projects, because of its data backed approach [29,37]. The third kind of persona identified by Floyd et al. [36] is Sinha personas, which are data driven, primarily quantitative but less comprehensive in comparison to the other kinds [38]. Floyd et al. [36] further explains three other types of persona, namely ad hoc personas and marketing personas. The ad hoc persona is derived from intuition and experience of the designer but discarded after the design cycle is complete. The user archetypes are similar to personas, except that they are more generic and cater to a larger group of audience than designer’s extreme user personas. It is less precise compared to a persona, thus also qualifies with more general information. Dantin [39] studies the user archetypes intended for two online platforms, outlining the general public targeted with the service, making it "elastic" [37] and describing several people simultaneously.

Further, Cooper [28] notes that each human persona has a work environment, socio-economic dimension and demographic dimension of culture, ethnicity or race to it. Pruitt and Grudin [33] further elaborates on these by looking into a set of dimensions in the case example, this include goals, fears and aspirations of the user, market size and influence, knowledge, skills and abilities, communication, views and opinions, attitude towards the solution/product etc.

3. Research Method

The research methodology adopted in this paper is outlined in Error! Reference source not found.. The follow section further explains the interview process, the interviewees and the data analysis approach taken in this paper.

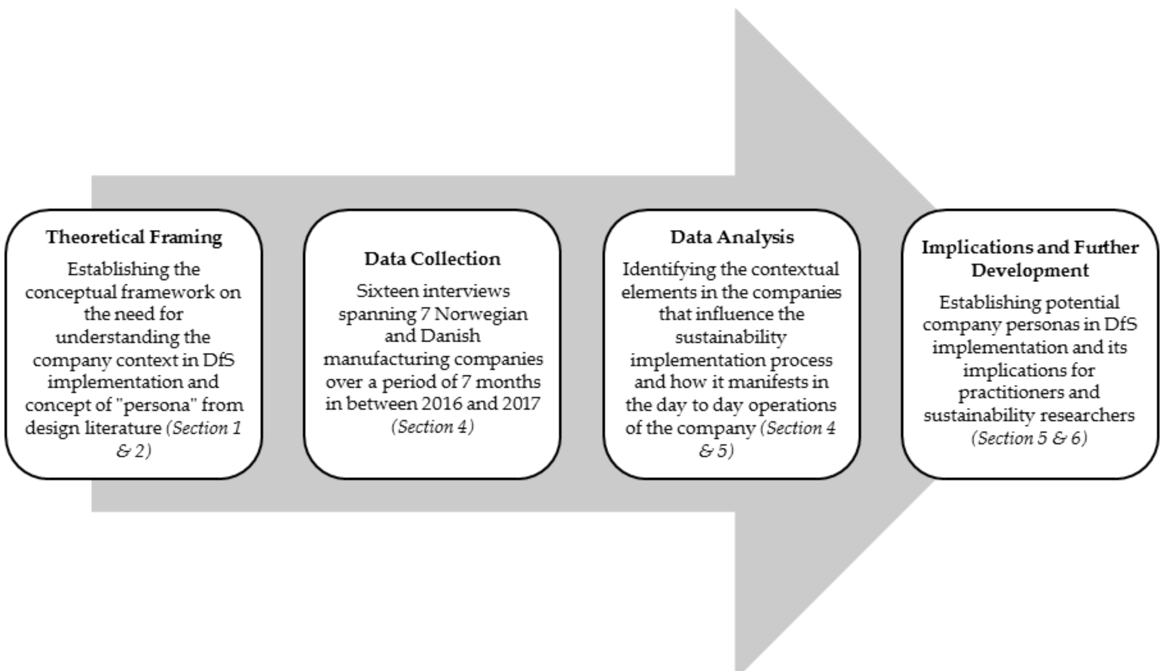

Figure 1. Outline of the research methodology

3.1. Case Interviews

The sixteen case interviews were carried out in seven Norwegian and Danish manufacturing companies that had a sustainability focus in their in product development and clearly outlined sustainability goals in their official communication in form of annual financial and sustainability reports. Additionally, four interviews were carried out with sustainability experts in the field of Eco-design implementation for validating the findings from case companies. Among the interviewees from the case companies, seven respondents and their departments were directly involved in sustainability activities to a large extent as part of their work. Among the other departments that were represented in the interviews, product developers and project managers formed the next biggest group. The functions of other respondents vary between communication directors, EHS (Environment, Health and Safety) personnel and R&D managers. The details of the respondents and case companies are further detailed in Table 1. The interviews were aimed at corroborating the literature findings and enriching it with real case experiences of implementing sustainability strategies in the product development and how the company context influenced the overall implementation process. Given the explorative nature of the study, semi-structured interviews were a judicious choice [40]. In order to further complement the data collection process and enrich the information gathered from case company interviews, we used an interactive map (Figure A1) that was designed to help the respondents graphically organise their thoughts thus overcoming some of the commonly identified challenges in interviews such as losing the context of answer [41], difficulty in verbally communicating one's ideas [42] and factual disconnect between what they say and what they mean [43]. While using the map, the respondent was asked to identify a set of internal actors that their department interacted with when it comes to a DfS implementation project. Then, they were asked to pick 2-4 major actors and highlight the different factors that influenced their interaction with those actors during the implementation process. The identified actors included personnel, departments, project groups, different management positions within the company, suppliers, competitors and customers.

Table 1. Interview respondent details, case company background and number of interviews. EHS = Environment Health and Safety, R&D = Research & Development, CR = Corporate Responsibility, PM = Project Management

ID	Company/ Respondent Group	Industry	Major Business Region	Number of Interviews	Respondent background
A	Pouch	Medicare supplier	Global	3	A1: EHS A2: EHS A3: PM
B	Microbes	Biotechnology	Global	1	B1: Sustainability
C	Watt	Renewable energy	Global	2	C1: EHS C2: EHS
D	Wood	Construction	Global	2	D1:Sourcing D2: Product regulations
E	Vitamin	Health care	Scandinavia	2	E1: Communications E2: Sourcing
F	Food	Consumer Goods	Global	2	F1: EHS F2: CR
G	Soap	Personal Care	Scandinavia	4	G1: R&D G2: R&D G3: R&D G4: Marketing
SE	Sustainability Experts	-	-	4	SE1: Consultant SE2: Consultant SE3: Researcher SE4: Researcher

3.2. Interview Analysis

All the authors of this paper curated the interview questions jointly and two of the authors carried out the interview. Each case company interview lasted between 60-90 minutes, was recorded, and transcribed using qualitative data analysis software, NVivo. As stated earlier, a combination of both deductive and inductive approach [44] was taken while analysing the data. Contextual factors of companies that influence DfS implementation as presented in Section 2 were probed for in the deductive part of the coding activity. Additionally, factors that emerged from the interview data were coded and analysed in the inductive approach. The coded entity included words, phrases or complete answers to interview questions that had key elements pertaining to the company context and its influence on the DfS implementation process. The results of the coding process are presented in Section 4.

4. Interview findings

Table 2 presents an overview of all the different dimensions identified from coding the interview data. Each dimension is matched against the case companies where it was found to be an influential contextual factor when it came to DfS implementation. These are marked as "x" in the table. Further, the final column of the table corroborates these findings with the inputs from sustainability experts (SE) who based on their experience in working with companies identified the most influential factors in a company involved in DfS implementation. The description of all these dimensions are provided in Appendix C. Definitions of company persona dimensions

Table A1. As can be observed from Table 2, the deductive coding approach showed a certain trend in the characteristics of the dimensions, namely factors that were partly or fully influenced by happenings/relations external to the company and factors solely by the company's own function and style. Drawing inspiration from philosophy and metaphysics literature, these are categorised as extrinsic and intrinsic characteristics respectively.

In philosophical studies ascription of extrinsic characteristics to a product or entity is not entirely about the product or entity, rather it may well be part of a larger context of which the product or entity exist as a part [45]. In our context of companies, this could include factors external to the company that influence the company's activities, such as product offerings, value proposition and strategies. Contrarily, a "sentence or statement or proposition" that ascribes intrinsic properties to a product or entity is entirely about that thing [46]. In our context, this translates to the internal organisation of the company, DfS implementation process and functional goals to DfS among others. Sections 4.1 and 4.2 explain how the 14 different dimensions under extrinsic and intrinsic characteristics were identified from the interview data.

As can be seen from Table 2, the identified dimensions have a certain level of interconnectedness among them. This is primarily because the company persona is a reflection of the company context and the context is often dependent on factors that are important on its own on one hand and on the other hand are influenced by other factors of the company. For example, a company's strategic focus, product offering and company history influence its market conditions. Hence, the results presented in the following sections are an outcome of a coding process that looked for such factors, both independent and dependent, in defining the company context and should be read within this pretext/ on this grounds.

Table 2. Overview of persona dimensions as identified as an influential factor in case companies and as experienced by sustainability experts. Dimensions that were identified to be significant in the companies' DfS implementation context is marked as "x". E- Extrinsic Characteristics, I- Intrinsic Characteristics

ID	Dimension	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Sustainability Experts
E1	Board of Directors	x	x	x	x			x	x
E2	Value proposition of the company	x		x	x	x			x
E2	Drive of the company on DfS issues	x			x	x		x	x
E3	Strategic focus of the company	x	x		x		x	x	
E4	Market Conditions	x	x	x	x	x	x	x	x
E5	History of the company				x		x		
E6	Risk sensitivity	x	x	x	x		x		x
I1	Senior management approach to DfS	x			x	x	x	x	x
I2	Organisational constitution	x			x		x	x	
I3	DfS implementation	x		x	x	x	x	x	x
I4	Sustainability understanding	x		x	x	x	x	x	
I5	Sustainability definition	x	x		x		x	x	
I6	Functional goals in DfS	x	x	x	x	x		x	x
I7	DfS chaperoning	x			x	x	x	x	

4.1. Extrinsic Characteristics of the companies

4.1.1. Board of Directors

Following our interviews with the sustainability experts (SE) in the field, a prominent extrinsic characteristic that was identified by all the four SEs was the role of Board of Directors, especially in the context of medium and small-scale companies that are often family owned or partly owned by the workers. In such companies, SE1 and SE2 opined that DfS implementation in companies is a decision making process that necessitates larger commitment in terms of resources and time for the implementation process. Convincing the Board of Directors in most companies SE1 and SE3 worked with what was the first step in establishing a sustainability strategy in the company. However, this characteristic was not evidently observed in the first cycle of coding case company interviews, primarily because they were all large companies. Nevertheless, following the observations from the SE interviews, the case company interviews were explored again for this dimension in a second cycle of coding resulting in the findings presented below. For example, Company D being a family owned company had certain instances were a family ownership roots of the company played an important role in sustainability issues as can be seen from the quote below:

> *"Our stakeholder is a foundation that owns us and the family that established the company. And, as long as they agree with what we do, we are able to (sic). And we are economically sound company and we can put investments in to things we like to invest in. Of course we dont have, I mean there are limited amount of money, but if we say, we want to do this and it is agreed upon by our board, we can go ahead and do it. Therefore, in that sense we are very fortunate and I know that the son of our founder he is not active in the business. However, he is very keen on these issues (sustainability). Him being there on the backseat somewhere, still overlooking what we are doing, that is also a big driver for us. And that is the charm of being in a family owned company as well."(D2 – Wood)*

On the other hand, other larger companies such as Company A, B, C and G had the senior management including the CEOs as the more prominent decision making entity when it came to implementation of sustainability in product development.

4.1.2. Value proposition of the company

Companies tend to focus on different value proposition in their activities, ranging from Product-Service Systems (PSS) to consultancy services. The nature of this value proposition is another important factor that helps define the context of the company. As all the seven case companies were manufacturing companies, their biggest value proposition was the product itself. However, as could be observed in Company A and C, the product itself could connote different priorities for the company. While in Company A, the product is intended to provide the best user experience for the customer and has user comfort as a priority.

> *"No, it (sustainability) is not a main part of our strategy, the main part of our strategy is to make it easier for our users. Actually, we have our mission, vision and values here. And this is really, what is important for the company. It is making life easier for people with intimate care needs." (A1 – Pouch)*

While for Company C in the renewable energy sector, the efficiency of the their product and the indirect sustainability benefit emanating from it in the form of lower cost, less wastage, easier transportation and better functioning of the products are the priority.

> *"And you would see that we stand out looking into eco-design or what we found out is that development in our industry is driven by the levelled cost […]. So all we do is to minimize the cost and we do that natural thing in PD is to have less material because you need to buy that transport that, service that anything. So, that is the cost that every time we put a kilo on there is a cost associated with that. So Eco-design is not implemented in the way it is in some other businesses. Because […]setting targets will be outdated in 2 years times because our engineers outperform the targets that we dare to set for them."(C1 – Watt)*

Whereas, consumer goods manufacturers such Company E, F and G had a strong focus on maintaining their performance with successful products followed by introducing new sustainable alternatives or improving the existing products with respect to sustainability. Company B and Chad a more B2B (business to business) context and the value proposition was quality products with certain indirect sustainability benefits such as lower energy consumption and longer durability while using their products.

4.1.3. Drive of the company on DfS issues

Another significant extrinsic characteristic of the company that was identified is the drive of the company in sustainability activities. The case companies interviewed, invariably had a strong focus on the prices of their products while ensuring compliance with the legal requirements. Given the nature of the industry, the cost factor was more prominent in consumer goods companies such as E and G. Company E had strong influence from competition making it more wary to the cost involved in the products as can be seen in the following quote.

> *"But most often, if they (marketing and supply chain) don't find it most relevant for the consumers or so, it might be that it costs, and if we should really do that. But, if it is something that we have to do anyways (compliance), that is not part of this. This is more kind of questions where you actually have to go one step further. These kinds of projects I am talking about (that are not the common ones)"(E1 – Vitamin)*

While in Company G, sustainability is very much linked to how it translates to increased sales.

> *"I think you can see that for management sustainability is important part. But if the link to that is to increase sales, it is a longer link. So, to be able to see that link, I think is important and we felt the link tougher than may be how they have seen it. (G2 – Soap)*

At company D, even though cost was the most important driver in the company, there were certain product development projects under process where the sustainability in form of material and energy consumption was prioritized over other factors.

> *"Many of our PD projects have energy performance as their only focus and then you have quality, delivery, price and then you have some market relevance like colour, sizes or whatever. But energy performance is the main in eco-design. And that is formalised very much so. We have colleagues in R&D dept. who work on it." (D2 – Wood).*

In addition to this the other major factors driving companies on sustainability were identified from the interviews with experts, namely, philanthropy (SE 2), CSR initiatives (SE3, SE2), compliance with legal and regulatory norms (SE1, SE3, SE4) and total sustainability in its activities (SE4, SE3). None of the case companies was found to have an existing total-sustainability agenda.

4.1.4. Strategic focus of the company

Defining a clear sustainable strategy often helps companies in prioritising DfS activities [9]. However, the interview results show that level of defining such strategies could range from general statements to setting clear operational goals in the day-to-day functioning of the company. Company B was observed to have clear goals and targets on sustainability topics and ensured that these were followed up at each stage gates in the company's product development process. Such an approach helped the company in prioritising sustainability issues in decision making related to product development practices.

> *"I do think that it is the right approach (to have strategic focus). Because, if it is not a top down, it is really hard. It is really hard to go bottom up, I can tell you from experience. Of course you can try to push in the doors, but without management commitment. […] So, if you are not being told that this is your target and this is your agenda, you need to make sure that you develop some sustainable product or you engage customer on these topics, you wont prioritise it." (B1 – Microbes)*

Whereas Companies E and G had sustainability goals and targets as communicated from their corporate level and needed to translate those to match their product development activities. This translation often needed more resources to tailor the corporate level strategy to the company level.

> *"I think the key is the understanding and strategic planning for this, it is what is lacking, for us because we have worked on and have launched just before summer our sustainability strategy which said about where we are going. So when we have a structure which says about where we are going, you can all go in the same direction and make tools and good goals for going in that direction. And that has been lacking last years. So we didn't know where we wanted to go and it is hard to get funding when you don't have a plan and a reason for why you need the" (G2 – Soap)*

The interview results also showed that certain companies could also spend considerable time and resources in developing a consensus around the sustainability strategy of the company, as in Company F. This mutual understanding on setting sustainability targets and goals help companies in incorporating it more systematically into each department's activity and overcome the challenges associated with sustainability understanding in company as highlighted in Section 4.2.5. Such an approach to sustainability strategy also equipped Company F to provide general guidelines to its departments rather than rigid structures, thus providing the latter with sufficient freedom to operationalise the sustainability strategy as per its context.

> *"First solution was to develop the sustainability strategy. Which we did through a very thorough process. I think we actually spend 1.5 years on this strategy process. We involved of-course all the functions, but also all the key persons in the companies. So then the strategy was send approved by the board of directors. So then, when we had agreed on the targets, it was easier to go with a specific agenda to the management teams of the business areas of the companies." (F2 – Food)*

Another company characteristic observed on sustainable strategies is how the business context of the company influences the priorities of the company in relation to sustainability topics. Given the unique customer base of Company A, mostly patients with serious illness, despite acknowledging the need for more sustainable product solutions, the company has a clear focus on prioritising the user experience above all the other aspects. Such a focus also awards Company A a formidable position in its market.

> *"And I think that (sustainability strategy) basically boils down to what you think. I think the major part of the work we do here, is because, we like to make people better and help them the best we can. So that will basically change what you are doing. What is little ground that*

can be better, we are changing it. On the other hand, we are looking to substitute some of the worst candidates away. On a long term" (A3 – Pouch)

4.1.5. Market Conditions

As all the interviewed case companies were manufacturing companies, the market conditions surrounding their product offering was found to have a strong influential role in the DfS implementation process adopted. Companies such as E, F and G experienced a strong pull for greener products from their customers, necessitating changes in the product portfolio of company. Another aspect observed regarding market conditions is the strong role marketing and sales departments play in highlighting and driving new initiatives in companies. As the marketing department forms the interface between the company and customers, they have a bigger say in project meetings and in Company G, the marketing department was always the project manager in all product development projects.

"I work closely with them (marketing department). So at the moment, they have, they see the need in the market and there is the white spot on sustainability. So for them also to, they are very enthusiastic when you are presenting solutions to them. Moreover, I think it is good communication that makes it also easier and I have worked with marketing so I see also their struggle. I know what they are facing and what they need in a way." (G2 – Soap)

Whereas in certain other company contexts such as in Company A and B, the utility and efficiency of the product is most demanded for, and the product development activity is fine-tuned to ensure that those issues as flagged by their respective customers are addressed. This include better durability of their medical products, ease of use and disposal, ensuring high quality and low risk of product failure in case of Company A. Similarly, in Company B such demands translates to adaptive solutions in biotechnology that can be used for specific needs of customers (companies), lowering energy requirements and efficiency of the end products. Such requirements necessitate that companies A and B choose suppliers that can ensure a sustained supply of raw material for a long term over smaller suppliers that can supply sustainable alternatives.

"Always this high in (product development) process is the (importance of) whole supplier demand. As in, we would like to have materials that can be readily sourced, so if it is more likely to have more sourcing options, that could also be one way that we say, OK, there is potentially an environmentally better option here. But if it is only a small supplier and it is only one in the world, whereas there are two large suppliers that can supply us, we might actually decide to go with the one and based on the fact that we would like to have the steady supply of materials." (A3 – Pouch)

Another important market condition that was observed in Company D was the high price competition existing in the construction industry. The customers of Company D thus had larger alternatives to choose from making them more price conscious in their choice of products than the sustainability credentials of the product. Thus necessitating the company to look for more sustainable alternatives without increasing the price of their product to level unattractive to the buyers.

"I had actually some workshops with our market people here and it's not that our market (is green conscious), that our way of selling things is not really (based on) a green stamp or a green swan. It (eco-labelling) is not anything that can bring our sales up or can justify a higher

price. If you have two products and the price were the same, then the customer would choose the one with the green stamp. But the customer from our market sales' perspective, our feeling is that customers are not willing to pay (extra) for a product with a green stamp." (D1 – Wood)

4.1.6. History of the company

A few of the interviews highlighted on how the history of the company has been a factor in the sustainability activities of the company. At Company C, the primary business model has been to develop and deliver products catering to renewable energy production. The indirect benefit stemming from this business, according to one of the respondent, is greener energy in the world and lower carbon footprint. Thus, the historical trend existing in the company has been to make its products more efficient in delivering more energy output in the use phase of the product.

"It's (eco-design) already happening without it being called eco-design or before we are setting targets specifically to reduce waste. Coming in from a cost-target perspective in getting this level-ised cost of energy down and somehow our product is being innovated in ways that also have an add-on benefit for the environment (green energy) so there is not the need to do these eco-design projects (specifically) because so much is already happening"(C1 – Watt)

Similarly, at Company D, the product offering has helped in improving the indoor living quality of commercial and residential buildings. A focus on improving the indoor living quality has been a primary focus of the company right from its beginning translating indirectly to sustainability benefits for the end user of its products. Such an approach encourages both companies C and D to further work on the technicalities of their product, however does not necessarily create a need to reduce the footprint of the production process or to look for more sustainable raw materials in the product development process.

"It (Sustainability in Product Development) depends a little bit how you look at it because if you say eco-design project, we have a lot of focus on the properties of our product. [..] So in that terms we have a lot of focus on the eco-design if you look at it in the way that we produce products that will save energy in your house so it's a little bit how you look at it because that has a great focus through the whole project. So, that's my point and it is the whole idea about our products actually so that is a very natural thing that is the driver (for DfS) in our products." (D1- Wood)

Interestingly, as mentioned in Section 4.1.4, at Company F the focus on sustainability is rather recent and the company is working on operationalizing its sustainability strategy. Nevertheless, as pointed out by one of the interview respondent, the presence of harmful chemicals and hazardous raw materials had necessitated Company F to look for safer and consumer friendly alternatives much before establishing a sustainability strategy. Thus underlining the relevance of company context and its history with respect to product offerings when it comes to sustainability issues.

"We have a long history of product development to reduce their environmental impact. So that is not something that is new to them (and has existed before the sustainability strategy). And

earlier I guess, it has been the Product Development Department. or a similar department like it (that had an) important (role) in putting this on the agenda." (F2 – Food)

4.1.7. Risk sensitivity

Risk sensitivity has been another important topic that was discussed during the interviews. The case companies tended to most often take a "watch and replicate" approach when it came to launching new DfS products in its markets. Some of the respondents identified the following reasons for such an approach; the inherent risk of losing their existing customer base, huge initial investment involved in developing and marketing new products over existing ones and lack of short term returns or results. This is very rightly reflected in the following quote from Company D.

"But when it comes to doing something new, taking risk, adding cost, the answer is no […] So that is why it's complex. It is not like a problem because they (senior management) are very supportive. The management really wants to do the right things also about thinking green. But it's always a balance, and uh a balance of risk if you go into new things, new materials." (D1 – Wood)

Further, the companies were also concerned about the long-term investments the project needed and risks involved in being the first mover on environmental issues as a risk factor in investing in DfS.

"This project "X" we had, that was with a lifetime of 30 years, which is very long, and that was why that fell to the ground, because OK 30 years, we don't know we have these sites in 30 years. So, that was way too long. So, I think if I can come up with a project with a payback time before 2020, I think that will go through, but that is not the case at the moment." (A1 – Pouch)

"That is how we see it and we don't have to be front runners and sometimes that is a good when you are looking at environmental issues. Because it can be very expensive to be the front-runner. Moreover, when you are doing projects/products that have a long lifetime. Like, you don't want to put something in your home that might damage in half a year right? It is expensive; you do not buy that many products in your lifetime" (D2- Wood)

Consumer goods companies such as E, F and G often based new product launches on their ongoing product development processes or looked for successful solutions from larger players in other geographic markets in rest of Europe and the world. These observations from the interviews point to the need for evaluating the risk taking nature of the company while understanding its context from a DfS implementation perspective.

4.2. Intrinsic Characteristics of the company

4.2.1. Senior management approach to DfS

The way the senior management in the companies approach the topic of sustainability was found to have a meaningful impact on the whole implementation process. All the case companies that were interviewed invariably acknowledged the need for sustainability in their activities and mentioned that their senior management also holds a similar view. However, this commitment from senior management towards sustainability implementation was observed to be different in each of the companies. While some of the case companies already had very well established positions in senior management that focussed on sustainability activities of the companies, certain others had it embedded along with other management responsibilities, such as sub task for EHS department. At the Company F, the sustainability strategy has been developed in close association with the senior management, that made anchoring the sustainability activities much easier in the group and business units under it.

> *"They have used time to develop their own sustainability strategy so I think is has been a very good process together with them and the whole management team involved with the work. It has been much better anchored with the management team. (F1 – Food)"*

While at Company A given the nature of its products and priorities of providing better service to their customers, the management often prioritized using the best material possible for their products and sustainability was only indirectly prioritized in the product development process.

> *"But in the end, if your alternative gives a less good user experience, then you have to prioritise between what you are doing...so in that sense, that is why said there is a lot of conflicts, because we have kind of these guys and as along as you are within the boundaries of what we are doing, are you use rules and discuss with our colleagues that you do the correct choices, or the best choices, then basically they are OK with that. (A3 –Pouch)"*

Not having the necessary senior management support and follow up often made it difficult for companies to proceed with the implementation of sustainability aspects in their products. This also meant that the senior management needs to be often be updated on the changes being implemented and how they deliver both economic and environmental returns to the company. A case example from Wood can be seen in the following quote:

> *"By the end of 2014 we started the analysis […] and we addressed assessing CE. Our management group, they are like, 6 of them I think, half of them forgot what they had approved. So they were like ...NO you shouldn't do CE and we had a lot of a big hurdle to get this analysis started. So, it (the senior management) was a very complicated group to handle because they are management, they have a lot of opinions, they are very fast. They don't have time to actually sit down and listen to context or ...On the other hand, if you don't have their acceptance on what you are doing, you will get nowhere. (D2 – Wood)*

Further, some of the senior managements were strongly driven by "the global sense of economics" that unless there is clear business plan for any investment being made on sustainability topics, it would be hard to prioritize DfS in the company's activities. These observations definitely underline the importance of understanding the role and attitude of senior management to sustainability topics in a company while trying to define its company persona.

4.2.2. Organisational constitution in DfS activities

Another important extrinsic dimension observed from the interviews was the way people and departments are organised in the company. Some of the case companies had sustainability departments that oversaw the complete sustainability activities in the company. Whereas certain other had sustainability as part of the R&D department in the company or embedded in the Environment Health and Safety department (EHS). Having a complete overview of sustainability activities helped companies to push for changes needed in product design and development easily than when it was just an additional task within R&D or EHS. At Company B, the sustainability development group that was anchored as part of the senior management oversaw the sustainability activities. This bridged the communication gap between the sustainability activities in the company and strategic decision making process happening within the senior management of the company.

> *"I think that (top be anchored within senior management) has been an advantage, allows us to work across. Which is really super important. I don't really know where else should we be really anchored. Of course, I would think we could be anchored in project management or in marketing. But that would make it more difficult for us to work across the depts. Like in any environmental / sustainability department, we need to work across." (B1 – Microbes)*

While, Company G had a very top down management style where the decision making was time consuming and often the lack of overview and absence of a sustainability department made it difficult to communicate the importance of different sustainability actions to the management.

> *"Yeah, that (department constitution) is one thing and also we are quite hierarchical (sic) so, every decision takes a lot of time. Moreover, when we are trying to have, for example. sustainability strategy, we would need a budget and when it takes may be 4 months before you get an answer whether we can have the money or not, because it is all this layers". (G1 – Soap)*

At Company F, the senior management provided guidance on sustainability matters to the different business units below it and thus followed a decentralized structure on DfS implementation.

> *"Then it is a decentralized structure. So I, don't have authority, we don't want to be normative. Nevertheless, we want to inspire, guide and discuss with each companies' management team. But at the end, what a unit does will be decided by the management team of that company. So in order to implement the sustainability strategy, there is a need for all of these departments". (F2- Food)*

At Company C, the flat cross-functional teams collaborated closely with each other on DfS projects making it easier to learn from each other and communicate the expectations from projects among themselves more effectively. Such a flat structure of project teams also helped the company bridge the communication gap between project teams located at different offices of the company.

> *"You have a directional system for products, for marketing, for manufacturing and in those directional systems you have managers that goes across different functions to coordinate. SO of course we have a hierarchy, but we don't have to go up and then go down to get a decision from the management. We can go directly from our department to another and say, well because this and that we have to do like so. So, it is a flat structure." (C2 – Wood)*

4.2.3. DfS implementation

Researchers have earlier mentioned about how the level of formalisation can influence DfS implementation in companies [9,47]. The interviews showed that the each of the case company approached DfS implementation differently. The major distinction can be drawn between the formalised and in-formalised approach to DfS implementation. Stage gate models, checklists, feedback loops and additional tools such as LCA in the PD stages, supported the formalised approach. While setting general guidelines and requirements, ad-hoc measures and client dependent evaluation of the product's sustainability characterised the informal approach. At Company B, LCA was used early in the product development phase to provide a rough estimate on the environmental impact of the product and later again in the stage gate process to evaluate the actual impact of the process. However, these steps were also client dependent in some cases, and the respondent mentioned the need for ensuring that it is followed in all project teams unanimously.

> *"We have a very formalised process here, so called stage gate model. The development projects are being set up that way all. […] LCA is integrated in that process. We have two entry points, one at the very ealry stage. […] As soon as the concept is ready in early stage, we usually enter into the project and try to make these initial assessments. Because already at an early stage it could be beneficial for the project to know if we have a very good sustainability story here? But once we had identified in the early stage that we have some sort of sustainability benefits, then we can pursue these during product development and make sure that we collect wide range of LCAs to take place towards the end (of stage gate process)." (B1 – Microbes)*

Meanwhile respondents from Companies E, F and G mentioned a more informal approach to DfS implementation. As mentioned earlier, Company F had a practice of providing guidance on DfS projects rather than strict structures for the implementation process. The respondent also mentioned how they provided support on LCA for the company's units who wanted to carry out an analysis based on the sustainability guidelines provided to them. As Company F was in the early stage of DfS implementation, this need-based approach was good start for the company rather than enforcing eco-design tools for all projects

> *"It's like setting the directions for the company, giving guidelines or giving requirements from senior management to over units (sub-business units) and how to work with and what we mean should be in place. It is like setting the directions for them, giving guidelines or giving requirements from the senior management to over organizations and how to work with and what we mean should be in place. Yeah there have been questions from some of the units about doing like life cycle assessment. That's where I have been involved to support them in how to do this, to find out how to do it, could there be someone that can support them and to understand more the theories behind using those types of tools." (F1 – Food)*

At Company E and G the respondents observed that there is need for eco-design tools and methods and the competence within departments to use it. The companies were in the early stage of sustainability journey and found it difficult to operationalise their strategy without sufficient resources in the form of tools and methods.

> *"No tools or any standard formula, we don't have it. We are not that far, we want to be there. I hope we come there. We started that discussion what should be our main setup, if to be honest every single project should include one or another element where we take care of sustainability. It might be environmental, health or combination. But we are not there today, but we have several projects going on having environmental elements." (G3 – Soap)*

> *"As it has been so far, it has been mostly about convincing the right people, but what we want to have is to agree to (certain structure). When we choose people to do this (DfS) projects,*

we choose different departments and the relevant ones. Therefore, what we want to do is a sort of 4-5 guidelines that you should always consider in an innovation process or communication or other things, you should always consider that. [..] So, I think that is the starting point. But, when it comes to seeing how we can be more effective, that is where we could be more eager, or have higher expectations on ourselves, to deliver more on being through sustainable choices. So it has been more ad hoc in the way we have introduced these subjects, but what I really believe in is that, we have to write a lot of theses. You don't succeed in doing do it, if you don't have it as part of the structure. What kind of question should you ask when you come this kind of product? Yes, you should ask these, these and these questions and those sustainable questions that should in that level. So that the different departments have to go through that gate. Are we willing to take a kind of reputation risk or do we want to see that X or Y happens? So that we are responsible (in DfS projects). And I think that natural or routine guidelines in that level is important, if not it is more accidental." (E1 – Vitamin)

Thus the level of formalization or lack of it in DfS implementation in companies was found to be an important intrinsic characteristic in defining the company persona.

4.2.4. Sustainability definition

Another important characteristics observed in the companies was the how the term sustainability was defined within the company context. At Company D, the respondent opined that terminologies such as Design for Sustainability or eco-design was not commonly used in the company thus often creating an ambiguity in the usage of the phrase in project teams.

"And we could also continue developing the language that we use about it. Because when you say "eco-design projects", it's not a word we use in here (at the company). So we could work further on a common language because there are many different words flying around in the media, but what is actually a green product or a sustainable product? What is it actually? It is very different what people understand by that." (D1 – Wood)

At Company F, the respondent received requests from units on how to proceed with

"It has been overwhelming for us, taking sustainability on-board. So they (units) are asking me, what do you want us to do? Please tell us there are so many topics, we don't know what to do and what should we focus on. So, that was actually why we tried to develop the common sustainability strategy to try and define all the different topics and make it easier." (F2- Food)

Further, in the interviews with sustainability experts, SE4 opined that there is a difference in between the definition of sustainability and understanding of what it means in a company context. Often well defined and communicated sustainability goals are not understood in the same manner among the employees due to the difference in the educational background or individual perceptions regarding it. This difference was also observed in the case company interviews and is further elaborated in Section 4.2.5.

4.2.5. Sustainability understanding

The interviews showed that most often the way sustainability is defined in the companies can be understood differently by different departments or individuals in the company. Another aspect to this is the awareness surrounding sustainability topics and how it is acknowledged in the product development process. F2 mentioned how it was difficult to convince and talk with colleagues on the need for integrating sustainability a few years ago and how it has changed recently with more clearer goals and increased awareness in the company.

> *"I talked with them (colleagues) four years ago but this (increased awareness) is something new which I think makes it easier now. Because now I know where I am going, I know that I'm going to launch a product with recycled materials. Hence, it's easier to discuss with them, they're already in that area and have a lot of competence, and I need that competence and understanding to make it work.." (F2 – Soap)*

At Company B, sustainability is very much top-down driven and has been successful in imbibing DfS focus in product development practices, however lack the same understanding on sustainability issues among the departments such as sales and marketing that are on the "business side" of the company.

> *"I think we have been, that we have integrated the way (for sustainability), or may be in the past, there wasn't this intensity with the corporate sustainability standing alone, sitting in the ivory tower. I think we are definitely working towards bringing sustainability more out at the practical side in the business. That is where it can be a huge challenge. I think we have managed really well in the PD. May be next step is to manage equally well with the marketing department" (B1 – Microbes)*

At Company E, due to the absence of a common understanding on sustainability topics, it has been difficult to convince and educate departments on the certifications needed and raw material selection criteria pertaining to sustainable sourcing.

> *"So it (sustainability understanding) is more about wider areas to cover. So, if you talk about sustainability in total about the raw materials here, there are many (sustainability) factors (involved). To get them (departments) understand better what is the difference between those and why is it not possible to have one certificate or some raw materials is difficult currently." (E2 – Vitamin)*

4.2.6. Functional goals in DfS

A general trend observed in the case companies was the situational versus planned and systematic improvements on the sustainability activities of the company. Company A resorted to having situational improvements to their products as potentially possible without disrupting the utility of the product. Such an approach was need for the company given its niche business area as explained earlier.

> *"We don't have any formulated target on environmental improvements in the process, other than we want to evaluate it and we want to you can say we want environment to be part of the decisions. But we have not defined that we always want to take the greenest solution per se. And this is our main driver. And if we can combine that with a good environmental solution*

then we would like to do that. But the main driver is the solution. So that is really our passion. So it's actually more the social part you could say. That's the driver. (A2 – Pouch)

While at Company D, a new organisational unit was formed exclusively to source for new raw materials to replace existing ones in their products. Sustainability was also included as one of the evaluation criteria in this new sourcing process.

"This spring, I was changing my position from the development department to a new part of our organization, where we want to be a little more ahead of the development in terms of finding new materials or combinations of materials that can be used for new products" (D1 – Wood)

4.2.7. DfS Chaperoning

Another important intrinsic characteristic was the entity that drives the sustainability activities within the company. We term it DfS Chaperoning, which was found to be either eco-champions in companies, certain departments or indirect stimuli from external actors in the form of NGOs, Environmental activists and consultants. Companies acknowledged that these entities with high motivation plays an important role in establishing, executing and following up sustainability goals in the company. At Company D and A, this was observed to be individuals pushing bottom up for sustainability focus in the company. These eco-champions pursued the sustainability agenda actively in the product development process.

"So I think it's a movement (sustainability focus), it's something that is maturing along as we get more knowledge. Putting the focus on sustainability, building it in in the presentation that we show to the management. Yes I would say that it is individuals, there are also some specialists that have a green focus that contribute so yes I would say it is individuals (chaperoning the process)." (D1 – Wood)

A1 narrated a similar incident in the following quote:

"I try to give a speech in a start-up project, I ask for 5-10 minutes, where I deliver the main issues that could be from our yearly environmental report. But it could also be like mass flows, pointing out the importance of environmental issues. Ok, we produce so much waste, but the waste we produce PD has been the same since 5-10 years ago. That is because we still produce these products and they still involve these waste. So, that is my key point, OK, so we really like to reduce waste and energy consumption is important for our whole CO2 account. It is now that we have to do it." (A1 – Pouch)

While at companies E,F and G, this was found to be external stimuli in the form of international collaborations with environmental agencies or companies themselves acknowledging the need for it along the whole value chain.

"As an administrative body we collaborated with the UNDP. So we developed together a project description, a concept description of the different types of activities that we believed needed to be taken in order to really lift the sector (sustainability in the whole value chain)" (F2 – Food)

5. Discussion and analysis

Persona in design studies helps in bridging the gap between the actual and presumed need of the users. Similarly, it was observed that the 14 dimensions found from the interviews addressed the concerns on bridging the gap between the context of the company and the intended use of various DfS implementation processes [10,18,48] by detailing the different extrinsic and intrinsic characteristics crucial to the companies' sustainability journey. The dimensions can be seen to be a mix of both technical needs in DfS products [49] and the "soft-side" elements of the company [13,23]. While the former can be found in dimensions I3, I5 and I6, the managerial conditions and other soft elements are mapped under the other 11 dimensions. As can be read from the cited quotations in Section 4, all these 14 dimensions were found to be have an influential role at one or other stage of DfS implementation in the case companies. These dimensions in totality helps in defining a complete picture of the company context, which have been otherwise overlooked in company clustering studies. This also follows the embodiment feature of personas explained in Section 2.2, where the extrinsic characteristics define the external factors that influence the company while the intrinsic characteristics will help the researchers and practitioners in understanding the company's internal functioning in the DfS context.

5.1. Extrinsic and Intrinsic

A general trend observed in both extrinsic and intrinsic characteristics were the strong presence of certain dimensions in all the companies. While market conditions and strategic focus of the company were the most observed extrinsic characteristics; senior management approach, DfS implementation approach and sustainability definition were found to be prominent among the intrinsic characteristics. This also follows findings by earlier DfS researchers who emphasized the need for the right market for eco design products [9], the importance of management commitment [48], need for sustainable strategies [10] and level of formalisation in eco-design processes [50]. Thus pointing to the fact that the identified persona dimensions are in congruence to earlier empirical findings in DfS research.

Further, an interesting finding among the dimensions was the risk sensitivity approach of the companies which can possibly help researchers and consultants in understanding the nature of approach companies prefer. Risk averse companies tend to take a defensive approach to their business model with focus on compliance and adjustment in current models [17,51] while risk taking companies would be more proactive and would possibly restructure the whole business to accommodate DfS. Thus, practitioners and researchers helping a company can adapt their solutions in relation to the risk sensitivity of the company. In another observation certain other dimensions were found to have strong interconnections among themselves, for example sustainability understanding within the companies could be closely seen in connection with the strategic focus in the company and the way sustainability was prioritised within the company activities. Market conditions were often influenced by the history of the company, its strategy and management decisions. Such interconnections are crucial to company's context and should be factored in while providing recommendations.

As explained in Section 1, the eco-design tool usage has been relatively low in companies compared to the number of tools created for the purpose. A similar trend can also be observed in the interview results where even though the need for tools are aired in the interviews, the skill set and adaptability of the tools to meet the company environment were more stressed upon. Thus, highlighting the need for understanding the company context better in addition to the technical needs of DfS projects.

5.2. Constructing company personas

Adapting from literature presented in Section 2.2, we propose a three stage process for creating company personas,

(i) Firstly, evaluating and reporting the sustainability proposition of the company which could vary from establishing a sustainability strategy as observed in Companies E and G to a full sustainability integrated future as in Company B.

(ii) Secondly, enumerating and enlisting the status of the company. This stage involve outlining the existing and planned sustainability activities of the companies and mapping the company context along the 14 dimensions.

(iii) Finally, exploring the interconnections between these dimensions and the implications of it in order to foresee the changes in the company due to the customised solutions that shall be provided.

Using this three stage process, the following subsection provides a short description of company personas based on the 16 company interviews.

5.2.1. Pouch

Pouch is a leading Medicare product supplier in its industry branch. The company is a market leader in most of its product categories and caters to customers suffering from serious health conditions. With a stated commitment to user focussed market approach and innovation to provide a comfortable life to their customers, the company has increasingly explored alternatives to replace PVC and other raw materials with a significant environmental footprint. The company has a specific department handling their sustainability issues and in house knowledge to develop Life Cycle Analysis (LCA) results on their products. However, the use of these results are not often standardised or mandated by established practice.

Business opportunities and enhanced customer experience are the prime drivers for the top management at Pouch. The only enforced demand in terms of sustainability in new products is an improved performance compared to the existing ones. Even though sustainability is not yet a main focus in the company, middle level managers are increasingly aware of various elements in their product development activities that have a possible environmental impact.

5.2.2. Vitamin

The company is part of a larger conglomerate in the Fast Moving Consumer Goods (FMCG) industry and has some well performing health care products in its portfolio. The company has undergone some major mergers and name changes leading to a considerable change in its leadership and strategy over the recent years. Vitamin produces health supplements and multivitamins at a large scale and its main environmental impact is from the use of raw materials. A considerable amount of which is sourced from the sea, hence, tries to ensure that the fishing practices of their sources are sustainable and certified according to regulations.

Design for Sustainability has not been a prime concern in Vitamin yet and only includes timely inputs on environmental data from the CSR department to the top management and the larger conglomerate for mandatory environmental reporting. However, the recent change in the overall sustainability strategy and pressure from competitors have necessitated Vitamin to look into their environmental impact and mostly in terms of logistics and sourcing. They are yet to develop on the use of DfS tools or methods for the targeted improvements.

5.2.3. Watt

Watt is one among the leading suppliers of renewable energy technology in their industry branch and acknowledge that their contribution to sustainability is their business itself rather than the sustainability credentials of their products. LCA is used in the product development phase only when demanded by the customers. As a rapidly advancing field of engineering, Watts engineers are often challenged with performance and cost of their products. This often translates to better production methods, lesser waste and increased energy output. Thus indirectly delivering sustainability benefits as mentioned by the interview respondents.

There is a general consensus among the different department in Watts to focus on DfS, however, this is not formalised by standardised DfS tools, methods or procedures. In the recent future the company is also preparing for a merger, thus restructuring their priorities and operational capabilities. This along with a motivated CEO and general acceptance for material use and environmental footprint, sustainability is a focus topic at Watts, though the path to it is not yet well defined.

5.2.4. Microbe

The primary objective of Microbe is to provide bio-based solutions to their customers, who use it to provide superior end products to the users. Thus, sustainability is well rooted in their business as in Watts and assessment tools such as LCA are widely used at Microbe. These tools are formally integrated in the stage gate process of product development and the sustainability department is consulted in various stages of PD.

The clear commitment from top management towards sustainability initiatives plays a key role in translating it into operational goals throughout the organisation. Though there is an overall alignment on sustainability needs, customer demands are often prioritised in PD decision making. There is a considerate effort in Microbe to present make its sustainability goals more visible in management decisions and future activities.

5.2.5. Soap

Soap manufactures some of the well know personal care brands in its market. Subsequently, DfS is increasingly discussed within the company and concerted efforts are underway in the company to make it part of their strategy. However, there is a visible absence of formalised tools and procedures for DfS projects and are often carried out based on guidelines given by the mother company of Soap. The main driver for DfS projects is the consumer demand lower down the supply chain.

Though management acknowledges the need for more sustainable products, they are often risk averse towards changing their well performing products in the market. Sustainability is not part of the organisation yet and Soap is working closely with its sister concerns for improving the situation. However, their smaller size compared to other international competitors is a challenge while demanding more sustainable products from their suppliers.

5.2.6. Wood

The company has a diverse portfolio of lighting and ventilation solutions for building and a global market presence for its products. Similar to Watt, the respondents from Wood also stated that their products provided indirect sustainability benefits through reduced energy consumption in buildings. LCA is integrated in the company’s stage gate model as an informative tool but is not used to arrive at decisions in the PD processes.

Though Wood has in house sustainability experts some project instances demonstrate a lack of awareness among departments on sustainability expertise. Departments had consulted third parties for data already available with the sustainability department in Wood. Sustainability focussed projects are met with initial resistance from the senior management. The interview respondents highlighted the need for this alignment within the company.

5.2.7. Food

The company is one of market leaders in its industry has a dominating role in most of its product categories. A structured sustainability journey is rather recent and new to the company, but it has a well-established sustainability strategy that was formulated with a large stakeholder involvement in the company. Such an approach has also helped the company in creating a consensus on the need for sustainability throughout the company. However, being early in its journey, the company is facing challenges in terms of sustainability knowledge within the company and actively follow its larger competitors’ sustainability activities.

The company has also been involved in international collaboration projects to learn and lead the change along its value chain. The senior management support has helped the company to prioritise on resources within itself and it provides guidance and support to its sub units. Even though welcomed by the departments such an approach has also given raise to ambiguity in the DfS implementation process, and is a big challenge in the company.

5.3. Limitations of this study

The number of interviews conducted for this study was 20 (including 4 interviews with sustainability experts), among this only one interview was conducted at Company B due to practical limitations. This disparity in the number of interviews has been challenging in carrying out cross-comparative studies between different companies during the analysis phase. Additionally, one common criticism attributed to persona in design studies is the static nature of personas which are not updated according to the changing needs of the user [52]. A similar challenge for company persona was also identified from the interview SE1, where the respondent observed that companies, though not so rapid, but do change their characteristics necessitating a different approach to sustainability. The current number of interviews presented in this paper is not sufficient to accommodate for such contextual changes of company's persona and would need more indepth practical studies in close collaboration with case companies to address it. Further, more detailed field testing will be required to increase the robustness of "company persona" as a practical aid in DfS implementation.

6. Conclusion

This explorative paper presented "company persona" as an alternative to take an informed DfS implementation approach in companies. Based on findings from (tabulated in Table 2) 16 semi-structured interviews the paper presents the 14 different dimensions of such a company persona categorised under extrinsic and intrinsic characteristics. Such an approach, we believe, will enable practitioners, academicians and companies in making better informed decisions on the actual requirements of tools, guidelines and consultancies companies require to deliver their stated sustainability goals. Future work will involve empirical testing and improving of the identified company personas through workshops in companies and among researchers who have worked with DfS implementation in companies.

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Appendix A. Themes addressed during the interviews

- DfS implementation process in the companies.
- Different contextual elements influencing the implementation process.

- Interaction within the company and between the company and external actors on sustainability issues.

Appendix B. The interaction mapper used during the interviews.

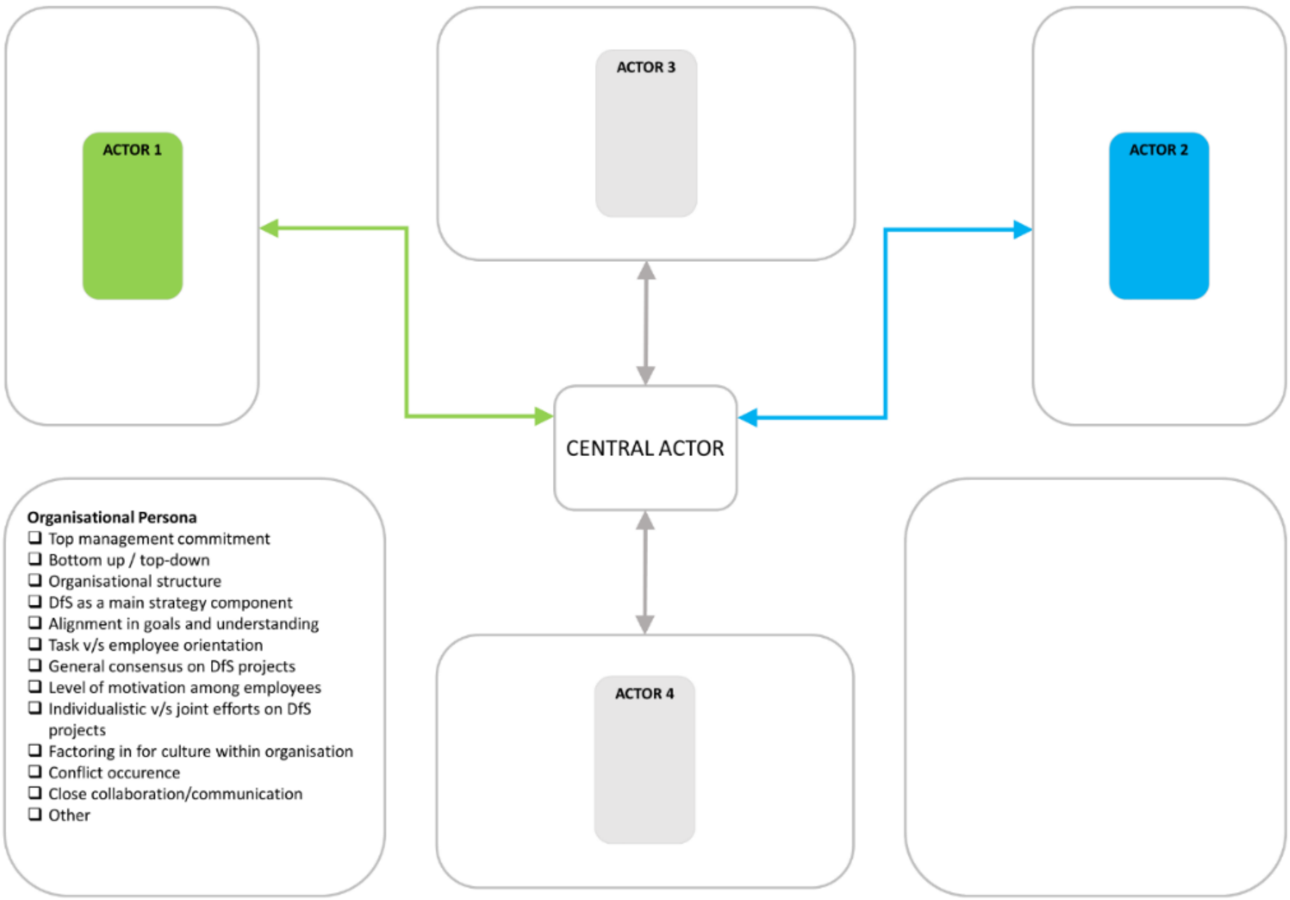

Figure A 1 An illustration of the interaction mapper used during the interviews. The central actor was the interview respondent. The map was used to identify the various contextual elements of the company in relation to DfS implementation and different actors the respondent interacted with.

Appendix C. Definitions of company persona dimensions

Table A1 Description of the dimensions identified from the interviews categorised under extrinsic and intrinsic characteristics. E= Extrinsic and I = Intrinsic

ID	Dimension	Description
E1	Board of Directors	The role of ownership and decision-making bodies in the company.

E2	Value proposition of the company	The main value offered by the company through its activities which could be consultancy, product, PSS or service
E3	Drive of the company on DfS issues	The major driving factor in the company in the form of cost, CSR, legal compliance, philanthropy or total sustainability.
E4	Strategic focus of the company	The extent to which sustainability is part of the company's defined strategy and how it is being emphasised in the decision making process in the company.
E5	Market Conditions	The market readiness, regulatory needs, demand for sustainable alternatives, existing and possible collaborations with actors in the value chain on DfS .
E6	History of the company	The traditional business experience and values that has influenced sustainability activity in the company such as existing product offerings, ownership focus on niche business areas that contribute to sustainability
E7	Risk sensitivity	Willingness of the company to prioritise experiment or launch DfS products, or take actions leading to sustainability goals while disrupting the status-quo.
I1	Senior management approach to DfS	The steps taken by the senior management of the company in establishing, realising and supporting activities that contribute to the overall sustainability strategy of the organisation.
I2	Organisational constitution	The way the departments, personnel and functionalities are organised within the company and DfS projects executed.
I3	DfS implementation	The method in how DfS focussed projects are conceived, planned and implemented with or without the aid of formalised processes such as stage gate models, eco-design tools.
I4	Sustainability understanding	Extent of sustainability awareness/perception in the company and the manner in which it is/not being incorporated in the company's activities at both individual and group level.
I5	Sustainability definition	The way sustainability is defined, communicated and operationalised in the day-to-day activities in the company.
I6	Functional goals in DfS	Realisation of sustainability goals of the company through targeted steps leading to direct sustainability benefits or rather incremental improvements in activities leading to indirect sustainability benefits.

I7	DfS Chaperoning	The anchoring and leading role that drives sustainability in the company, in the form of sustainability champions, departments.

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