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Hanna Salo

IMPLEMENTING GREEN INNOVATIONS AND ECODESIGN IN COMPANIES

Differences among the Nordic textile and IT sectors

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The thesis examines the differences and similarities of green innovation and ecodesign and how they are implemented in textile and IT companies that manufacture and/or design products in the Nordic countries. Green innovations are defined as an approach of developing and implementing product, process, marketing, organisational or institutional innovations that reduce environmental impact in relation to a stated common reference. Ecodesign is a collaborative, proactive and systematic design and management process that integrates environmental issues into product development processes. The thesis looks at innovative targets and mechanisms and their level of radicality to compare the two approaches. It applies this framework in the context of the Nordic countries, which are perceived as forerunners in environmental matters.

The thesis uses mixed methods to form a general overview of the current situation of green innovation and ecodesign implementation: first a broad questionnaire and second, deepening the understanding by interviewing forerunning companies. The questionnaire was conducted in Webropol and sent by the national industrial associations and the researcher to the target population (N=104). Thereafter, six Finnish companies were interviewed. Textiles and IT were chosen to be the target sectors due to concerns about their global environmental impacts.

The findings of this thesis can be summarised into three propositions: 1) Green innovations concern more varied targets than ecodesign by looking at both the technological and non-technological issues. 2) The respondents are fairly mature in terms of how they integrated environmental sustainability into their operations. The main stimulus for environmental proactivity is general willingness, whereas many companies are deterred by cost increases and societal barriers. 3) Companies remain focused on technical product and process innovations and especially functional innovations are lagging behind.

The contribution of this study to existing literature on green innovations and ecodesign is its promotion of understanding of how companies can participate in the required systemic change towards a circular economy. The study indicates the main contributors for green innovations in the product design phase. This thesis suggests that research and development activities related to environmental matters and the use of ecodesign tools to support the information base and communication purposes are very central to the creation and implementation of innovations.

Key words: Green innovation, ecodesign, companies, circular economy, tools, Nordic countries, textile, IT sector

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SALO, HANNA: Vihreiden innovaatioiden ja ekosuunnittelun jalkauttaminen yrityksissä: Pohjoismaisten tekstiili- ja IT-alojen erot

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Tutkielmassa perehdytään vihreiden innovaatioiden ja ekosuunnittelun välisiin eroihin ja samankaltaisuuksiin sekä siihen, kuinka niitä jalkautetaan yrityksissä. Tutkimuksen kohderyhmänä ovat tekstiili- ja IT-alojen yritykset, jotka valmistavat ja/tai suunnittelevat tuotteensa Pohjoismaissa. Vihreät innovaatiot määritellään tapana kehittää ja ottaa käyttöön tuote-, prosessi-, markkinointi-, organisaatio- ja institutionaalisia innovaatioita, joiden ympäristövaikutus on pienempi kuin perinteisellä verrokilla. Ekosuunnittelulla puolestaan viitataan tuotesuunnitteluprosessiin, joka huomioi ympäristöasiat ennakoivasti ja systemaattisesti. Tutkielmassa tarkastellaan näiden kahden lähestymistavan tarkastelukohteita, mekanismeja sekä radikaaliutta ja sovelletaan kyseistä viitekehystä Pohjoismaihin, joita usein pidetään ympäristöasioiden edelläkävijöinä.

Tutkielma edustaa monimenetelmätutkimusta, jossa ensin selvitettiin vihreiden innovaatioiden ja ekosuunnittelun käyttöönoton tilannetta laajan kyselyn avulla ja sen jälkeen syvennettiin tietämystä haastattelemalla edelläkävijäyrityksiä. Kysely toteutettiin Webropolissa, jota Pohjoismaiden kansalliset teollisuusliitot sekä tutkija levittivät kohdeyrityksille (N=104). Tämän jälkeen haastateltiin kuutta suomalaista edelläkävijäksi tunnistettua yritystä. Tekstiili ja IT sektorit valikoituivat tutkimuksen kohteiksi merkittävien globaalien ympäristövaikutustensa vuoksi.

Tutkielman tulokset voidaan tiivistää kolmeen ajatukseen: 1) Vihreät innovaatiot käsittelivät ekosuunnittelua laajemmin erilaisia tarkastelukohteita, joihin lukeutuvat paitsi tekniset niin myös ei-tekniset asiat. 2) Vastaajat olivat sisällyttäneet kestävyyden osaksi toimintaansa varsin laajasti. Tärkein ajuri aloitteelliselle toiminnalle oli yrityksen sisäinen tahtotila. Yritykset puolestaan kokivat kustannusten nousun sekä yhteiskunnalliset esteet haasteiksi toiminnalle. 3) Yritykset keskittyivät pääasiassa teknisiin tuote- ja prosessi-innovaatioihin, ja erityisesti funktionaalisten innovaatioiden kehittämisessä ja käyttöönotossa oli puutteita.

Tutkimus tuo lisäymmärrystä vihreitä innovaatioita ja ekosuunnittelua koskevalle tutkimukselle siitä, kuinka yritykset voivat osallistua systeemiseen muutokseen kohti kiertotaloutta. Tutkimuksessa osoitettiin useita tärkeitä tekijöitä, joilla voidaan edistää vihreitä innovaatioita tuotesuunnittelussa. Erityisen tärkeiksi tunnistettiin ympäristöasioihin liittyvän tutkimus- ja kehitystoiminnan sekä ekosuunnittelun työkalujen käyttöönotto. Niiden avulla voidaan vahvistaa innovaatioiden luomisen ja toimeenpanon mahdollistavaa tietopohjaa sekä viestintää yrityksen ulkopuolelle.

Asiasanat: vihreä innovaatio, ekosuunnittelu, yritykset, kiertotalous, työkalut, Pohjoismaat, tekstiili, IT-ala

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1 Introduction

There is a growing need for solutions promoting more sustainable production and consumption towards achieving a circular economy, which aims at transforming the prevailing linear economy into a circular, closed-loop model (Stock *et al.* 2016; Geissdoerfer *et al.* 2017). Since the beginning of the industrial revolution, people have consumed more products, which have been supported by growing manufacturing industries (Lieder & Rashid 2016). However, the negative sides of the consumption and production patterns are becoming visible, with scarcity of natural resources, emissions to the environment and waste generation. In the circular economy, companies have the opportunity to be bigger actors than their size would indicate - having a small footprint of required resources but a large handprint with positive outcomes. This offers them possibilities to increase competitiveness, improve company image and contribute to the larger development of society, in addition to fulfilling environmental requirements (van Hamel & Cramer 2002; Arundel & Kemp 2009; Horbach *et al.* 2012; Boons *et al.* 2013; Gouvinhas *et al.* 2016). Thus, it is important to find ways and techniques that allow every company to develop new behaviours and modes of operation for supporting the circular economy (Dekoninck *et al.* 2016).

In order to make contemporary society more ecologically sustainable, emphasis is placed on production rather than consumption (Blewitt 2008: 190). Design is a crucial dimension of proactive planning with the aim of improving existing systems and transforming them into or creating completely new ones (Carrillo-Hermasilla *et al.* 2010). It is considered to be the most crucial step when improving the environmental performance of a product (Belmane *et al.* 2003: 19; Byggeth & Hochshorner 2006; Kammerl *et al.* 2016). Traditionally, the design process itself consumes only low resources, approximately 15% of manufacturing costs, but it is considered to be responsible for determining up to 80% of the environmental impacts (Knight & Jenkins 2009; Schwarz *et al.* 2017). According to Ilgin and Gupta (2010), there is a need for environmentally conscious design methodologies that acknowledge the environmental impact of not only products but also of processes. However, marketing organisational and institutional changes should also be added to the list in order to cover the varied changes that are required for achieving systemic change, such as the circular economy (Boons *et al.* 2013; Gault 2018; Korhonen *et al.* 2018).

As design is the most effective stage in the life cycle of a product, multiple ways have been developed to help designers make more environmentally sustainable choices. Green innovation is one of them, as it concerns improving or creating completely new products, processes and methods to reduce environmental impacts (Spangenberg 2001: 26; Chen *et al.* 2006; Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010). Another way to include environmental considerations into product design is ecodesign, which is used to enable designers to design products with environmental issues in mind (van Hemel & Cramer 2002; Directive 2009/125/EC; Pigosso *et al.* 2013; Dekoninck *et al.* 2016; Prendeville *et al.* 2017). It seeks to highlight the role of design and address the wider picture in order to contribute to a balance between the environment and product development (Knight & Jenkins 2009).

Green innovation and ecodesign are firmly interconnected as they share a common goal, although with different emphases and scopes. Despite this, there is not much research that deals with both of them. Exceptions to this pattern include the studies conducted by Santolaria *et al.* (2011), who examined attitudes towards ecodesign in innovation-driven Spanish companies, Cluzel *et al.* (2014), studying the difference between the perceptions of eco-innovations and ecodesign in French organisations and Huang *et al.* (2016), who saw ecodesign as a training method for employees to achieve green innovations. To the best of my knowledge, there is no research that has examined the way ecodesign is practised in companies and combined it with the green innovativeness of an organisation. In addition, the Nordic countries offer a promising context as they have all the prerequisites for being proactive, and in earlier studies by, for example, Tukker *et al.* (2001), Belmane *et al.* (2003) and Marin *et al.* (2015), they have been acknowledged as forerunning areas. Still, there have been no studies focusing on the concrete principles used by Nordic companies and their outcomes.

This thesis aims to supplement the existing literature on ecodesign and green innovations by strengthening understanding of how companies can adopt them and participate in the required systemic change towards the circular economy. According to Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010) and Carrillo-Hermosilla *et al.* (2010), radical innovations are required to achieve sustainability, but ecodesign is mostly considered as an incremental approach. Therefore, ecodesign should be broadened to consider not only small technological changes but to provide for new larger-scale green innovations. The main contributors to promoting different types of green innovations in the product design phase are identified to highlight stimuli that should be supported and identify barriers still preventing change. In addition, this thesis suggests that research and development activities related to environmental matters and the use of ecodesign tools to support the information base and communication purposes would be very central features supporting the creation and implementation of innovations. Furthermore, the study aims to support companies on their way towards more sustainable consumption and production by formulating suggestions for different types of companies, based on the results of the study. Some of them are included in the conclusions of this thesis, but a major part will be sent directly to the respondents to help them to focus their efforts.

The study objectives were answered by using mixed methods, first by conducting a broad questionnaire in the Nordic IT and textile sectors followed by interviews. The combination of general and more detailed data acquisition follows the example of Belmane *et al.* (2003). The questionnaire was sent by the researcher and national industrial associations to almost 1,000 companies that manufacture and/or design textile or IT products in the Nordic countries, and received 104 responses. The mainly nominal and ordinal-scaled data were analysed with statistic cross-tabulations and nonparametric tests. To support the more general data, six interviews with Finnish forerunning companies were conducted to discover the concrete experiences, practices and interpretations of green innovation and ecodesign. The semi-structured interview data was analysed using qualitative content analysis.

In my first research question I will provide a general overview of the relationship between green innovations and ecodesign. This question formulates a background for the used methods and analysis based on a literature review. The second and third questions will be answered by the results of the questionnaire and interviews. The second question builds a more detailed picture of the perceptions of companies on green innovations and ecodesign by examining the observed stimuli and barriers. Lastly, the third question explores the reality of company activities related to promoting sustainable production and consumption. It examines the nature of the targets, mechanisms and tools implemented by the Nordic companies. The research questions are:

1. What is the relationship between green innovations and ecodesign?
2. What stimuli and barriers do Nordic IT and textile companies face when applying green innovations and ecodesign?
3. What specific innovative targets, mechanisms and ecodesign tools do Nordic IT and textile companies use to promote sustainable production and consumption?

The thesis first examines the central concepts of innovation, green innovation and ecodesign - what is considered an innovation and how can it be green? Then it goes on to study existing literature on reducing the environmental impacts of consumption and production and the implementation of green innovations and ecodesign into practice. Chapter 3 introduces the materials and methods, whose results are discussed in Chapter 4. Lastly, Chapter 5 outlines the results and proposes ideas for future research. The central background information related to the relationship between green innovation and ecodesign principles, the questionnaire and interviews are included in the appendices.

2 Theoretical and conceptual framework

2.1 Defining the key concepts

2.1.1 Innovation

A variety of definitions for innovations exist, some concerning product and process innovations while others include organisational and institutional ones (e.g. Chen *et al.* 2006; Brones *et al.* 2017; Gault 2018). The prevailing definition is very broad and sees an innovation as a new or significantly improved product, process, marketing method or organisational method in business practices, workplace or external relations, as stated in the Oslo Manual (2005: 46) (Brones *et al.* 2017; Gault 2018). A common characteristic of all definitions is that they differentiate innovations from inventions (Fagerberg 2005). Here, an invention is considered to be the first occurrence of an idea for a product or a process, while an innovation is the first attempt to put an invention into practice. Thus, a prerequisite for innovation is implementation, meaning that a product is introduced onto the market or processes and methods are brought into actual use in the operations of an organisation (Oslo Manual 2005: 47).

The broad definition of innovation is based on a classification of innovative targets, meaning the specific focus areas (Oslo Manual 2005; Brones *et al.* 2017). Innovations that focus on products and processes are traditionally considered as technological change, while marketing, organisational and institutional methods are non-technological (Oslo Manual 2005: 46; Arundel & Kemp 2009; Sustainable Manufacturing and Eco-Innovation… 2009). These targets follow the classification made by the Austrian pioneer of innovation theory, Joseph Schumpeter (1934/1983: 66), as he concluded that an innovation is a new product, new production methods, exploitation of new markets, new sources of supply and new ways to organise business. Most of the focus of economic research has been on the first two of these (Fagerberg 2005).

Another approach to classify innovations is dividing them into radical and incremental innovations based on the degree of disruption generated (Fagerberg 2005; Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010; Cluzel *et al.* 2014). This division is also based on Joseph Schumpeter's work (Fagerberg 2005). Here, an innovation is compared with existing products, processes and methods in order to evaluate its radicalness. Radical changes refer to discontinuous changes seeking to replace existing components or systems and creating new networks, while incremental innovations are gradual and continuous modifications that maintain the existing production systems and networks and are therefore a more common type of innovation (Fagerberg 2005; Verganti 2009: 46; Carrillo-Hermosilla *et al.* 2010). Some scholars consider novelty and radicalness, being "new to the world", as central elements of an innovation (e.g. Call for Proposals... 2008; Calik & Badurdeen 2016). Schumpeter (1934/1983: 8) also considered radical innovations to be of greater importance. However, the cumulative impact of incremental innovations can have as great or even greater impacts as radical innovations (Fagerberg 2005). Most scholars thus do see innovation as adopting a technique that is novel to the company, even if it has existed for a while and has been developed by someone else (e.g. Bunnell & Coe 2001; Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010; Schiederig *et al.* 2012; Cluzel *et al.* 2014). This view including both radical and incremental innovations is also supported by the Oslo Manual (2005: 46).

Innovations can further been divided into Science, Technology and Innovation (STI) and Doing, Using and Interacting (DUI) modes (Jensen *et al.* 2016). The first focuses on scientific and technological knowledge which is usually supported by different fields of science. The second mode sees innovations as primarily a result of experience-based learning which mainly takes place by finding solutions locally to existing problems in an informal way. To create new innovations, these modes should be intertwined and complement each other to utilise varied knowledge and benefit from each other (Parrilli & Heras 2016). Hence, innovation is seen as an interactive process within and between companies, customers, suppliers and knowledge institutions (Jensen *et al.* 2016).

Measurement of innovations is a complex task because they may take different forms and their conceptual background may be forgotten (Smith 2005: 148–150). Acs and Audrecht (1993: 10) measured corporative innovations based on input, intermediate output and direct output. Firstly, input includes research and development (R&D) expenditures, R&D personnel and innovation expenditures. These investment variables make it possible to measure the technological capacity of an organisation and its actual engagement in innovative activities over a long period of time (Smith 2005; Marin *et al.* 2015; Huang *et al.* 2016). This represents the STI mode of innovation (Jensen *et al.* 2016). However, the use of expenditures underestimates the mainly informal product development done in small businesses, and they do not typically cover marketing organisational or institutional innovations (Smith 2005). Secondly, intermediate output concerns the number of patents and scientific publications (Acs & Audretsch 1993: 10; Arundel & Kemp 2009). Patents are widely used, objective and stable measures to describe the inventive output of an organisation (Smith 2005; Arundel & Kemp 2009; Calik & Badurdeen 2016). A down side is that they depict inventive activity, not real innovations and cannot be used for all types of innovations. Thirdly, direct output contains the number of innovations, descriptions of individual innovations and data on sales of new products (Acs & Audretsch 1993: 10; Arundel & Kemp 2009). Information concerning these may nevertheless be hard to obtain. Arundel and Kemp (2009) added a fourth type to the list by measuring indirect impact derived from aggregate data. Indirect impacts include changes in efficiency and productivity measured using a decomposition analysis. The problem with assessing indirect impacts is the lack of databases with sufficient information. Jensen *et al.* (2016) suggested new indicators for the DUI mode of innovation, including interdisciplinary workgroups, proposal collection systems and cooperation with customers.

Arundel and Kemp (2009) encouraged measuring both direct innovation output and indirect impact to get an overall picture rather than using inputs or intermediate output, which have been the main focus points of green innovation research. These output measures can be collected from publications, but direct innovation questionnaires still probably provide superior indicators for environmental process innovations according to Arundel & Kemp (2009). To cover the range of innovations, they are measured in this thesis with inputs and both intermediate and direct outputs collected in the questionnaire.

2.1.2 Green innovation

Green innovation is a recent phenomenon involving expanding environmental considerations from specific steps of product development to the whole innovation process (Schiederig *et al.* 2012; Luiz *et al.* 2016). The literature study by Schiederig *et al.* (2012) indicated that there was little research conducted on innovations with reduced environmental impact prior to 1990. Since 2005, the concept of green innovation has become increasingly used. Still, it lacks a specific definition, wherefore many kinds of innovations may be called green (Carrillo-Hermosilla *et al.* 2010). However, in general, green innovation is described as reducing the environmental impact caused by consumption and production activities, whether or not the development or deployment is environmentally driven (Chen *et al.* 2006; Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010).

The division between radical and incremental innovations is relevant for green innovations, as they generate different types of environmental benefits on different time scales (Sustainable Manufacturing and Eco-Innovation… 2009; Boons *et al.* 2013). In general, incremental changes result in lower benefits but their impacts are quite predictable compared to larger and radical changes (Sustainable Manufacturing and Eco-Innovation… 2009). They have been criticised for not generating a shift of the required magnitude to promote sustainable development (Boons *et al.* 2013). However, radical green innovations in particular are difficult to achieve because the prevailing system may act as a barrier to the creation and diffusion of a new product, process or system (Carrillo-Hermosilla *et al.* 2010).

Green innovation is closely related to the concepts of sustainable, environmental and eco/ecological innovations (Carrillo-Hermosilla *et al.* 2010; Schiederig *et al.* 2012). Conventional innovations focus on economic aspects, whereas green, environmental and ecological innovations pay attention to both the economic and environmental dimensions of sustainability (Calik & Badurdeen 2016). Sustainable innovations deviate from the three environmentally oriented concepts, as in its original meaning it has taken a broader scope by including the social dimension in addition to the ecological and economic dimensions (Schiederig *et al.* 2012; Boons *et al.* 2013; Calik & Badurdeen 2016; Stock *et al.* 2016). Schiederig *et al.* (2012) found only minor differences between green, environmental and ecological innovations in their quantitative literature analysis. One slight distinction is the level of sophistication of the concepts, as eco-innovation seems to be the most developed and precise one, whereas green innovation is rather shallow. However, in most publications the concepts have been used interchangeably. All of the aforementioned terms are based on a similar understanding and on a holistic view of sustainability. Thus, the concept of green innovation is used in this thesis to encompass all innovations with a reduced impact on the environment.

Building on these observations, green innovation is defined in this thesis as both a radical and incremental change to a conventional approach of a certain company, which improves the environmental performance of a product, process or service. The initial motivation for the innovation can be purely environmental but it does not have to be.

2.1.3 Ecodesign

Ecodesign is a collaborative, proactive and systematic design and management process that integrates environmental issues into product development processes (Brezet & van Hemel 1997; Tischner 2001: 269; Fuad-Luke 2004; Johansson 2006; ISO 14006:2011; Liao *et al.* 2013; Pigosso *et al.* 2013; Dekoninck *et al.* 2016; Prendeville *et al.* 2017). Ecodesign is synonymous with Design for Environment (DfE), green design and environmentally conscious product development and design. Ecodesign can be used to identify environmental aspects of a product by integrating them into product design and product development processes (Belmane *et al.* 2003: 19; Byggeth & Hochshorner 2006). It applies a life-cycle perspective and takes into account the significant environmental impacts of the entire material life cycle of packaging, products, processes, services, organisations and systems (ISO 14006:2011; Liao *et al.* 2013). Ecodesign aims to reduce consumption of resources, prolong the lifespan of a product, use less hazardous materials, optimise production and distribution and ensure the safe disposal of products (Belmane *et al.* 2003: 19). Therefore, ecodesign provides an opportunity to focus on eliminating, avoiding or reducing upstream and downstream environmental impacts with a preventive approach. In addition, trade-offs in the environmental burden from one life-cycle stage to another or from one impact to another should be considered (ISO 14006:2011).

The European Union set out the first Ecodesign Directive for energy-using products (EuPs) in 2005 to guide national efforts towards sustainable production and consumption (Directive 2005/32/EC; Directive

2009/125/EC). The directive set out a framework for ecodesign requirements in order to continuously improve the overall environmental impact of EuPs and thus contribute to sustainable development. This was done by identifying the major sources of negative impacts and avoiding transfers of pollution without creating excessive costs. The directive concerned energy-using products which use, generate, transfer or measure energy, such as freezers and computers (Directive 2005/32/EC; Ecodesign Legislation 2018). The scope of the EU ecodesign regulation was broadened in 2009 when the new Ecodesign Directive for energy-related products was set out (Directive 2009/125/EC). It extended the target group from EuPs to energy-related products (ErPs) and steered environmental performance by setting requirements on their energy-efficiency. ErPs include products like windows and insulation materials, which do not use energy but have an effect on energy consumption. Ecodesign requirements must not be fulfilled at the expense of the functionality of a product, its safety or health (Ecodesign Your Future 2014). They should be beneficial to consumers and other end-users. The directive provides for the setting of requirements that energy-related products must meet in order to access the market and/or be put into service. It also aims to prevent barriers to trade and unfair competition by harmonising national laws (Directive 2009/125/EC)..

As a framework, the Ecodesign Directive does not set mandatory requirements or legislation, but sees organisations and market as the main drivers of sustainability transition (Directive 2009/125/EC). The obligations come in force only when a product group-specific decree has been set. The Directive is executed through either implementing measures or voluntary agreements. The implementing measures are adopted by the Commission and concern those energy-related products with great demand, environmental impacts and potential. The implementing measures apply to products that sell more than 200 000 units a year within the Union, have a significant environmental impact and present significant potential for improvement in their environmental impact without excessive costs. The implementing measures include generic and specific requirements. The generic mandatory requirements do not set thresholds but may demand compliance with relevant European standards or information requirements (like material coding), whereas the specific requirements set limit values on specific technical aspects (e.g. maximum energy consumption). The Directive also takes into account the absence of other relevant legislation, failure of market forces to address the issue and disparities in the environmental performance of products with equivalent functionality. According to the Directive (2009/125/EC), legislation may be needed if market forces fail to develop in the right direction or at an adequate speed. Thus, the main focus should be on voluntary approaches, such as self-regulation, which enable rapid progress, cost-effective implementation and flexibility. Products that fulfil the minimum product group-specific requirements are granted a ‘CE’ marking and are allowed to be sold in the EU market. By April 2019, the Directive covered nine broad product groups and included 35 implementing regulations and three voluntary agreements (Product Groups 2019).

The ecodesign standard ISO 14006:2011 is part of the ISO 14000 family providing tools for companies and organisations to manage their environmental responsibilities (ISO 14006:2011). ISO 14001 sets requirements that enable an organisation to manage its environmental responsibilities in a systematic manner and to meet the objectives of its Environmental Management System (EMS) (ISO 14001: 2015). Through the standard, organisations can make self-declarations, confirm their stakeholders and certificate their EMS, which provide value for the environment, the organisation itself and its stakeholders. Stakeholders include customers, communities, suppliers, regulators, non-governmental organisations, investors and employees. Alongside ISO 14001, organisations may use ISO 14006 to establish a systematic and structured approach to incorporate and implement ecodesign processes as part of an EMS (ISO 14006:2011). ISO 14006 replaced the former standard ISO 14062:2002 which provided guidance for integrating environmental aspects into product design and development. Ecodesign is defined by ISO 14006:2011 as the integration of environmental aspects into product design and development with the aim of reducing harmful environmental impacts throughout a product's life cycle. It applies to those product-related environmental aspects under the control influence of an organisation. The standard aims to help organisations to influence the environmental impacts under their control. It does not establish environmental performance criteria, nor is it intended for certification purposes.

Ecodesign is related to other concepts concerning sustainability and product design (see Figure 1 in Section 2.2.3) (Tischner 2001). Two aspects have been identified to differentiate ecodesign from traditional design: environmental assessment and environmental strategy (Collado-Ruiz & Ostad-Ahmad-Ghorabi 2010; Vallet *et al.* 2012). Environmental assessment is a key step of ecodesign and it is to be obtained by an expert group and typically supported by either a qualitative or quantitative method, such as a Life Cycle Assessment (Vallet *et al.* 2012). By using an environmental strategy suitable for the product, project and company situation, decision-making becomes easier and trade-offs can be avoided. Overall, ecodesign broadens the scope of product design by paying attention to minimising the environmental impacts of a product without compromising other important factors, such as performance, functionality, quality and cost (Tischner 2001: 269; Liao *et al.* 2013; Pigosso *et al.* 2013). Sustainable product design is another concept operating in this field. Sustainable product design includes environmental, economic and social issues, while ecodesign only concerns the two previous ones. Thus, the relationship between sustainable design and ecodesign is similar to the relationship between sustainable innovations and green innovations as presented in Section 2.1.2. However, according to several scholars (e.g. Fuad-Luke 2004; Niinimäki 2006), ecodesign also considers social and ethical needs. This view diminishes the typically identified differences between sustainable product design and ecodesign. In this study, ecodesign is outlined to include environmental concerns related to product design in accordance with Tischner (2001), Byggeth & Hochschorner (2006) and Rousseaux *et al.* (2017) among others.

2.2 Reducing the environmental impacts of production and consumption

2.2.1 The circular economy

The circular economy is a relatively new idea around reducing environmental impacts, especially related to the consumption of virgin raw materials and discarding of the materials after use, while also generating positive economic impacts at the same time (Lieder & Rashid 2016; Geissdoerfer *et al.* 2017). It offers an alternative to the prevailing linear extract-produce-use economic model in which materials and energy are extracted, produced and consumed and from which waste and emissions arise (Stock *et al.* 2016; Korhonen *et al.* 2018). The currently used definitions present the circular economy as an approach including long-lasting design, reuse, remanufacturing and refurbishment which result in a society that demands less resources and energy (Geissdoerfer *et al.* 2017; Korhonen *et al.* 2018). It aims at maximising the life cycle of a material by slowing, closing and narrowing material and energy loops (Geissdoerfer *et al.* 2017). The material is first recovered for reuse, refurbishment and repair, then remanufactured and finally for raw material utilisation, which has been the prevailing goal of traditional recycling (Korhonen *et al.* 2018). By prolonging the life cycle, the value of an extracted material is retained which often leads to both economic and environmental gains compared to a traditional linear model.

Despite the increasing extent of seeing the circular economy as a solution to a series of problems (Lieder & Rashid 2016), the concept remains superficial and disorganised, as stated by Korhonen *et al.* (2018). Therefore they (p. 39) suggested a new scientific definition, “as economy constructed from societal production-consumption systems that maximizes the services produced from the linear nature-society-nature material and energy throughput flow". The means of the circular economy would then include cyclical material flows, renewable energy sources and cascading energy flows on a level that nature can tolerate. This definition is, however, only the beginning of a definition process of what the circular economy stands for in science.

The circular economy has gained official status on the local, regional, national and supranational levels (Geissdoerfer *et al.* 2017). Germany was the first to integrate the circular economy into national laws in 1996, followed by Japan in 2002 and China in 2009 (Lieder & Rashid 2016). EU has also incorporated circular economy considerations, one of which has been the Circular Economy Package to implement the Circular Economy Action Plan that was completed in 2019 (Circular Economy 2019). The package included, for example, material efficiency requirements for ecodesign, increased innovation investments and the EU Strategy for Plastics in Circular Economy.

2.2.2 Sustainable production and consumption

Production and consumption are both very broad concepts (Spangenberg 2001: 32–33). Production means a process of transforming the resources that are not directly disposed of into useful goods, services or also waste. In this process, resources are consumed as they have been extracted from nature. This definition also concerns consumption in a wide sense, as the resources are partly used for economic purposes in production, but a larger share is immediately disposed of as waste and waste water. Still, the most common definition of consumption sees it as an economic transaction where products are produced in order to meet the needs of consumers (Spangenberg 2001: 32–33; Tischner & Cramer 2001). Consumption can be examined as state consumption, household consumption, intermediate use and storage and exports. State consumption produces services, such as education, medical treatment and security, which are eventually consumed by individual citizens. Consumer choices affect only some of the consumption clusters, while many fall beyond the authority of an individual (Spangenberg 2001: 35). Therefore, decision-makers and companies that provide more sustainable products are essential players in this field.

Current ways of producing and consuming exceed the carrying capacity of the Earth, wherefore international actions have taken place (Tischner & Charter 2001; Sachs 2015: 1–3). Achieving a sustainable level requires fundamental changes in production and consumption on a broad and long-term scope, (Sachs 2015: 1–3), i.e. turning the linear economic model into a circular economy (Korhonen *et al.* 2018). A global framework to promote the shift towards sustainable production and consumption was adopted at the United Nations Conference on Sustainable Development in 2012 (The 10 Year Framework… 2017). The framework is called the 10-year Framework of Programmes on Sustainable Consumption and Production Patterns (10YFP) as it takes place during a 10-year period of 2012–2022. It aims to collaboratively build up synergies between existing regional and national initiatives and partners, scaling up and replicating best practices and generating and supporting new activities. The 10YFP is also part of the United Nations Sustainable Development Goals (SDGs) to promote more comprehensive sustainable development following the Millennium Development Goals (MDGs) (UN General Assembly 2015; Sachs 2015: 493). The 17 universal SDGs were introduced in the "Transforming Our World" report, also known as "Agenda 2030" (UN General Assembly 2015). The SDGs steer the promotion of sustainable development in 193 UN member countries between 2016 and 2030. Goal number 12 "Ensure sustainable consumption and production patterns" includes the efficient use of natural resources, the environmentally sound management of chemicals and waste, providing information on sustainable lifestyles for individuals and incorporating sustainability into public procurement and company practices, among other aspects. In addition, the promotion of the 10YFP is one of the standalone targets (number 12.1) of the SDGs.

At the European Union level, the Integrated Product Policy (IPP) has been a prevailing initiative towards sustainable production and consumption by minimising the environmental burden of products (COM/068/2001; COM/0302/2003, Bovea & Pérez-Belis 2012). The IPP focuses on promoting policy instruments that support decision-making leading to the systematic reduction of the environmental burden of products and services throughout their life cycles. It aims to make markets greener on both the demand (consumption) and supply (product development) sides (Niinimäki 2006; Bovea & Pérez-Belis 2012). Because of the IPP, consumers should have the opportunity to choose, use and discard products and services with a lower environmental impact. The multiple methods of the IPP focus especially on ecodesign, the realisation of environmental product innovations, informed consumer choices and the polluter pays principle in product prices (COM/0068/2001; COM/0302/2003; Niinimäki 2006). It also promotes the use of tools that consider the impacts during the whole life cycle of a product.

Ecodesign and green innovations have primarily focused on the environmental and economic dimensions of sustainability (Tischner 2001: 269; Schiederig *et al.* 2012; Boons *et al.* 2013; Pigosso *et al.* 2013; Calik & Badurdeen 2016). However, sustainable production and consumption do not only concern environmental issues but economic and social dimensions are also included in the concept of sustainable development (Tischner & Charter 2001). According to Spangenberg (2001: 45), ecodesign can contribute to these broader sustainability goals by increasing the eco-efficiency of production and the attractiveness of those products, as well as changing consumption patterns by reducing the production costs and contributing to change in the markets. Green innovations, on the other hand, in some definitions include social considerations as they concern equality in terms of pricing of the products, informing consumers and companies and promoting discussion that challenges the status quo (Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010).

2.2.3 Environmental importance of product design

Product design means the act of developing an object before it is made by planning and drawing its potential look, function and operation (What is Product Design? 2019). Design is a crucial dimension of proactive planning with the aim of improving existing systems and transforming them into or creating completely new ones (Carrillo-Hermasilla *et al.* 2010). Traditionally, the focus of product designers has been on improving the design with respect to its cost, functionality and manufacturability (Ilgin & Gupta 2010; What is Product Design? 2019). However, the arising environmental considerations have forced designers to take into account certain environmental criteria during the design process. To help the designers, multiple methodologies have arisen, especially in relation to ecodesign, life-cycle analysis and material selection, according to Ilgin and Gupta (2010).

The product design stage is considered to be the most crucial step when improving the environmental performance of a product (Belmane *et al.* 2003: 19; Byggeth & Hochshorner 2006; Pigosso *et al.* 2013; Kammerl *et al.* 2016). Traditionally, the design process itself consumes only a few resources, approximately 15% of manufacturing costs, but it is responsible for causing the remaining 85% (Knight & Jenkins 2009; Schwarz *et al.* 2017: 33). While a product is the prime determinant of the environmental impacts of an innovation (Blewitt 2008: 134–135; Schwarz *et al.* 2017: 33), it is also the main character of green innovations (Carrillo-Hermosilla *et al.* 2010). Thus, green innovations are firmly interconnected with ecodesign in order to reduce environmental impacts with the focus on product design. In both approaches, the identified effects, benefits and requirements should be integrated early on in order to reach the most optimal solution (Byggeth & Hochschorner 2006). Ideally, each stage of product development should be evaluated with environmental consideration (Charter & Tischner 2001: 17). In practice, however, sustainability efforts concentrate on the later phases of product development and marketing (Kammerl *et al.* 2016). Companies may see environmental issues as a burden in the early phases and are more willing to spend money on, for example, marketing campaigns. Making changes in the later stages is increasingly costly and technically difficult (Byggeth & Hochschorner 2006; Kammerl *et al.* 2016). The cost of product modifications is assessed to increase exponentially along the life cycle. Therefore, ecodesign seeks to highlight the role of design and address the wider picture in order to contribute to a balance between the environment and product development (Knight and Jenkins 2009).

Figure 1 brings together the key concepts of this thesis with the theoretical framework of the circular economy and sustainable production and consumption. The whole thesis is based on an idea of a circular economy with closed material cycles and long-living products, generating both environmental and economic benefits (Lieder & Rashid 2016; Geissdoerfer *et al.* 2017; Korhonen *et al.* 2018). This aim is achieved by sustainable production and consumption, in which ecodesign is a major player (Brezet & van Hemel 1997; Spangenberg 2001: 45). Green innovations, on the other hand, are evaluated to exceed the boundaries of product and process-focused approaches such as ecodesign and aim to contribute to systemic change (e.g. Arundel & Kemp 2009; Sustainable Manufacturing and Eco-Innovation… 2009; Cluzel *et al.* 2014;), as is discussed in Section 2.3, wherefore it overarches Figure 1.

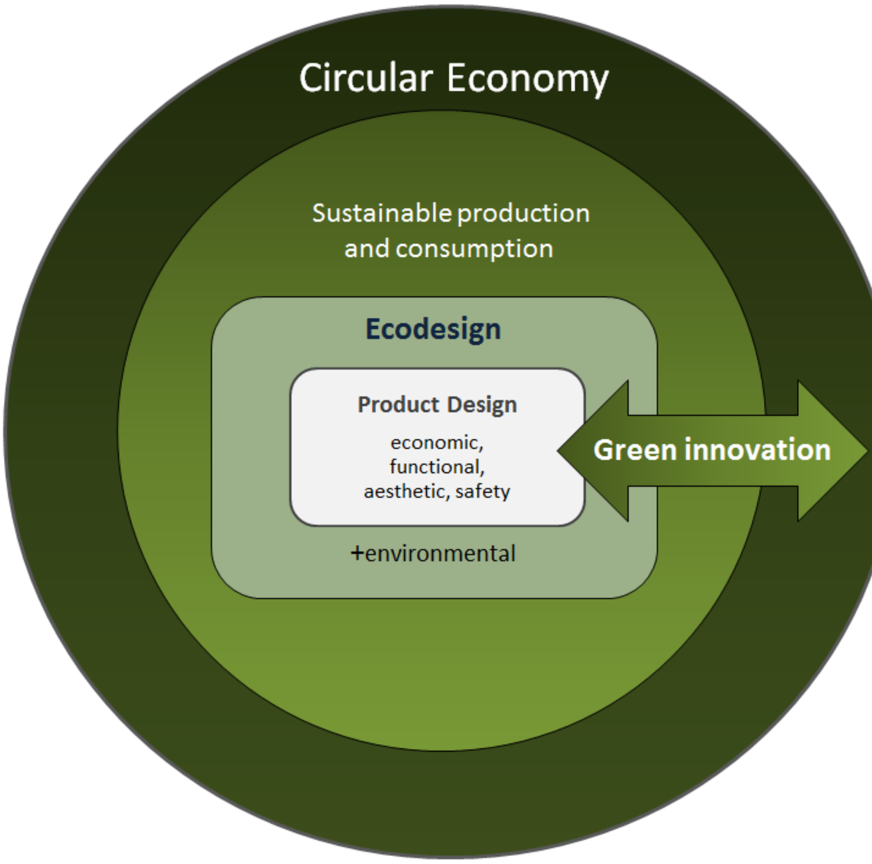

Figure 1. Relationship between circular economy, sustainable consumption and production, ecodesign, product design and green innovations, partly adapted from Tischner (2001).

2.2.4 Corporate environmental responsibility

Sustainability concerns have become increasingly important among organisations and their stakeholders (Byggeth & Hochschorner 2006; Gouvinhas *et al.* 2016; Caiado *et al.* 2017). As part of this, environmentally preferable procurement has also become more common among organisations, producers and customers. According to Kammerl *et al.* (2016), the motivation of organisations for developing sustainable products is often based on legislation and market benefits, but it may well be for reduced costs and goodwill (Byggeth & Hochschorner 2006) among other stimuli that are described in Section 2.3.1.

Different levels of maturity have been identified in terms of integrating sustainability into business activities (e.g. Boks & Stevels 2007; Gouvinhas *et al.* 2016). Willard (2005) introduced five stages, which Hallstedt *et al.* (2010) summarised as:

1. Pre-Compliance: Sustainability is ignored and related regulations are opposed.
2. Compliance: Complying with laws and regulations.
3. Beyond Compliance: Identifying an opportunity to cut costs through higher resource efficiency and reduction of waste. Sustainability is not an integrated part of the core business.
4. Integrated Strategy: Integrating sustainability in the company's vision and business strategies though innovation, design and improved financial risk assessments.
5. Purpose and Passion: Sustainability is the key operation of the company. It is not a next step for most companies but rather for a special type of company.

Hence, companies are expected to develop in terms of sustainability recognition from a level at which they do not perceive sustainability as their responsibility to integrating it as a central part into their strategies and vision on a company or chain level (van Hemel & Cramer 2002; Boks & Stevels 2007; Hallstedt *et al.* 2010). On the lowest level of compliance, companies are immature and do not know how to cope with environmental issues (Gouvinhas *et al.* 2016). They are often pressured externally by different stakeholders and regulations. Following that initial phase, environmental issues can develop to a level in which several departments are involved and have basic information on environmental issues (Boks & Stevels 2007). They start to act more proactively and perceive it as a market opportunity. Lastly, a long-term vision is applied and information is spread throughout the company (Gouvinhas *et al.* 2016). They affect their value chains as well by requiring environmentally sound materials and components, but also customers by educating them and creating new kinds of conscious customer behaviour and demand. Thus, they start a "domino effect". At this stage, companies are ready to use specific tools customised for their operations (Boks & Stevels 2007).

2.3 Implementation of green innovations and ecodesign into practice

2.3.1 Stimuli for change

Many companies have recognised the value of environment-related product responsibility as a vital contributor to sustainable long-term success (Byggeth & Hochschorner 2006; Pigosso *et al.* 2013). Companies can seek to improve their performance through both green innovations and ecodesign because of multiple internal and external stimuli (e.g. van Hamel & Cramer 2002; Arundel & Kemp 2009; Boons *et al.* 2013). The determinants for introducing green innovations and ecodesign at the firm level have been quite vastly examined (Montalvo & Kemp 2008; Huang *et al.* 2016). Several of the characteristics driving innovativeness are the same as or have considerable resemblance to the factors that drive ecodesign.

Internal stimuli are factors that originate within the company itself (van Hemel & Cramer 2002; Arundel & Kemp 2009). They are considered to be a prerequisite for the implementation and realisation of the approaches. Internal stimuli include commitment to reducing environmental impacts and costs, increasing functional quality of products, improving corporate image, higher working motivation among personnel and synergy advantage (Tischner 2001; van Hemel & Cramer 2002; Byggeth & Hochschorner 2006; Chen *et al.* 2006; Niinimäki 2006; Santolaria *et al.* 2011). By acting voluntarily, a company may also expect image improvement that leads to competitive advantage along with increased productivity and higher profits. Ecodesign is also assessed to improve the long-term innovation opportunities of a company (Tischner 2001; van Hemel & Cramer 2002; ISO 14006:2011). A company pioneering in green innovation can enjoy “first mover advantages” by increasing their market share or accessing new markets (van Hemel & Cramer 2002; Chen *et al.* 2006).

Internal stimuli have been found to act as the main drivers for ecodesign implementation (e.g. Santolaria *et al.* 2011), as van Hemel and Cramer (2002) indicated. Reducing environmental impacts and increasing energy-efficiency have been acknowledged to be the prevailing reasons why companies introduce ecodesign into their innovative strategies in Spain (Santolaria *et al.* 2011). The important internal stimuli include opportunities for innovation, expected increase of product quality and potential market opportunities, which have been highlighted for ecodesign in Dutch SMEs (van Hemel & Cramer 2002). These stimuli have been recognised to be more likely to lead to the implementation and realisation of ecodesign practices. However, they were not the most frequently mentioned stimuli. Environmental benefit, cost reductions and image improvement were mentioned more often by companies, but their influence remained modest in earlier studies. However, for green innovations, both internal and external stimuli have been found to be relevant, as the identified main determinants are cost reductions and legislation (e.g. Rennings *et al.* 2002; Horbach *et al.* 2012). Horbach (2008) found environmental management tools important for introducing green product innovations. The introduction of new or significantly improved organisational structures is also relevant in the case of green innovations. Other main internal reasons to implement green innovations include new markets and image, noted by Rennings *et al.* (2002).

External stimuli include those factors outside the company that directly influence the attitude of the company towards the environment (van Hemel & Cramer 2002). External stimuli take account of legislation and governmental regulation, environmental pressure from industrial organisations, demand from customers, negative media attention, suppliers offering new eco-efficient materials or components and catching up with competitors who have already applied ecodesign (Tischner 2001; Rennings 2002; van Hemel & Cramer 2002; Belmane *et al.* 2003; Byggeth & Hochschorner 2006; Horbach *et al.* 2012; Marin *et al.* 2015). Green innovation can help companies to avoid facing environmentalist protests or penalties (Chen *et al.* 2006), whereas ecodesign supports companies to be proactive and improve their legal compliance, which again reduces the potential negative media attention (Tischner 2001; Belmane *et al.* 2003; Byggeth & Hochschorner 2006). External stimuli are considered to be similar between companies, meaning that the customers, government and corporate interests do not differ significantly within a sector (van Hemel & Cramer 2002).

The most important external stimuli concern customer demand and legislation (van Hemel & Cramer 2002; Rennings *et al.* 2002; Horbach 2008; Kammerl *et al.* 2016). Legislation is used to steer product development by, for example, restricting or banning the use of certain chemicals or regulating the recycling of products, which can again spur and enable the use of recycled materials in manufacturing processes or lengthen life cycles. Customers, on the other hand, can influence by preferring certain items that are expected to fulfil their needs and wishes. External stimuli have been noted to have less of an impact compared to internal stimuli in the case of ecodesign (van Hemel & Cramer 2002; Santolaria *et al.* 2016). Only a third of all the realised ecodesign options have been associated with an external stimulus according to a study conducted by van Hemel and Cramer (2002). However, for green innovations, external stimuli have been noticed to matter the most and they are rather policy- than market-driven, although transition is expected to take place (Horbach *et al.* 2012; Marin *et al.* 2015). The improvement of technological capabilities, especially those of suppliers, acts as a driver for both green innovations and ecodesign, as it enables multiple opportunities for improvement (van Hemel & Cramer 2002; Horbach 2008). In addition, supplier development has been frequently mentioned, whereas industrial sector initiatives have been perceived as one of the most influential external stimuli for ecodesign alongside customer demand and legislation (van Hemel & Cramer 2002). Subsidies have also been noted to trigger green innovations. It should also be noted that, according to Schwarz *et al.* (2017), radical innovations are not typically pushed by the market, as the customers are evaluated to be unable to specify their needs and expectations for the properties of a new product.

A stimulus can also be interpreted as both external and internal at the same time (van Hemel & Cramer 2002). To illustrate this, the stimuli of legislation and keeping up with competitors are external, but may result in seeking market opportunities that are considered internal. For example, companies are often pressured to be proactive and go beyond the set regulation and legislation in order to maintain their competitiveness (Sakao & Fargnoli 2010; Gouvinhas *et al.* 2016). Thus, designers have to invest in differentiating properties in order to attract customers and to guarantee that the environmental performance is at least in line with the tightening law. Here the stimuli are interpreted as external ones, as their origin is in legislation and competitors (van Hemel & Cramer 2002). Another example is that changes in values are important for achieving ecodesign, while not only technological achievements are enough. This concerns the company internally but also the surrounding society, including producers and consumers. Producers must provide essential information and functions based on the mutual consensus between producers and customers. At the same time, the functions need to be properly used by customers.

The relevance of stimuli differs between sizes of companies, according to Santolaria *et al.* (2011). Larger companies in particular have been subject to more and stronger stimuli for greening their business than small and medium-sized companies (SMEs) (van Hemel & Cramer 2002). Santolaria *et al.* (2011) stated that large companies are more concerned about legislative adjustments than smaller companies, which are mostly driven by cost reductions. In addition, smaller companies are forced to be innovative and develop new products to beat their competitors (Horbach 2008).

2.3.2 Barriers

Barriers discourage companies from introducing or implementing green innovation and ecodesign tools into their practices (van Hemel & Cramer 2002). The barriers are mostly similar to the stimuli but act in the opposite direction. Barriers include uncertainty of environmental benefits, lack of legislation and market demand, conflict with the functional requirements of a product, lack of proper technical alternatives, finding new investments in redesigning a product worthless, not perceiving the responsibility and lack of time and knowledge (van Hemel & Cramer 2002; Byggeth & Hochschorner 2006; Dekoninck *et al.* 2016). Most of these are considered as initial barriers that can be broken. In van Hemel and Cramer (2002), those SMEs with no interest to implement ecodesign in the future found more barriers than companies which were interested in ecodesign but had not yet realised it or already implemented ecodesign.

Integrating environmental aspects into product development is perceived to lead to synergies with other business interests, such as image improvement, new market opportunities and possible cost reductions, acting as stimuli (van Hemel & Cramer 2002; Byggeth & Hochschorner 2006). However, the integration of ecodesign into product development, management and corporate strategy is still considered insufficient (Baumann *et al.* 2002; Le Pochat *et al.* 2007; Pigosso *et al.* 2013). Product development in particular considers many desirable elements, which cannot all be optimised at once (Byggeth & Hochschorner 2006). In some cases, promoting ecodesign and green innovations may increase the costs of a company, which is an important trade-off (Konar & Cohen 2001). According to van Hemel and Cramer (2002), the most frequently mentioned barrier to ecodesign implementation is that it is in conflict with other product requirements. In ecodesign, trade-offs appear as conflicts between environmental targets, as improvement in one area can give negative effects in another. Therefore, integrating environmental aspects via ecodesign is important in order to find the best compromises to gain the optimal benefit.

Trade-offs are also related to the dedication to communicate with customers (Johansson 2006). Green innovations are often new to the market, either incrementally or radically, and outside the mainstream, and hence their acceptance in the market may be restricted (Konar & Cohen 2001). Without communication with customers, there is a risk that trade-offs are made incorrectly in terms of what customers need (Johansson 2006). Therefore, Schwarz *et al.* (2017) pointed out that, for example, the ecodesign criterion of using renewable materials may not meet technical requirements, streamlining structures may be expensive and marketing may request a component to improve the look of a product.

Van Hemel and Cramer (2002) found three “no-go” barriers for ecodesign that a company cannot overcome. These are not perceiving ecodesign as a responsibility, lack of available alternative solutions and lack of clear environmental benefit. The most influential barrier to ecodesign implementation is that ecodesign is not perceived as a responsibility, as noted by van Hemel and Cramer (2002). This issue relates to values and market demand, and ecodesign is therefore dependent on changes in values within both a company and broader society, as pointed out by Aoe *et al.* (2007). The barrier applies to green innovations as well, because the environmental consciousness of the consumers and the firm itself contributes to the diffusion of environmentally friendly products (Horbach 2008). This process is necessitated by social demands and will. To support the change of values, producers need to provide essential information and functions based on mutual consensus between producers and customers (Aoe *et al.* 2007; Dekoninck *et al.* 2016). By following these guidelines, the barrier of missing alternative solutions can also be avoided (van Hemel & Cramer 2002).

The barrier of market demand, especially when faced by smaller companies, is related to prevailing values and communication, because ecodesign builds on input from stakeholders across product development (Dekoninck *et al.* 2016). New innovations have a better chance of success in the marketplace if their development process has had a greater market focus (van Hemel & Cramer 2002; Santolaria *et al.* 2011). Within a company, marketing departments should be involved in the design process to promote ecodesign and bring it out in the marketplace (Tischner 2001: 265). In addition, taking into account user perspectives is increasingly important for both green innovations and ecodesign (Carrillo-Hermosilla *et al.* 2010). Despite acknowledging this issue, current ecodesign methods have been poor in addressing the customer aspect and have focused more on technical aspects of design and production, according to Sakao & Fargnoli (2010). Market acceptance is also reliant on other than environmental attributes of a product, meaning that style, design, price and performance need to be delivered. SMEs and smaller companies experience customer demand as a stronger stimulus, and lack of it a greater barrier, than legislation (van Hemel & Cramer 2002; Santolaria *et al.* 2011). At the same time, Pigosso *et al.* (2013) and Gouvinhas *et al.* (2016) highlighted the role of consumers, because even a product with greater environmental and economic benefits may be rejected by the public. Thus, dialogue between producers and customers and integrating customers into product development would ease the sustainable fulfilment of needs and create a win-win situation (Knight & Jenkins 2009).

Companies have not adopted ecodesign systematically into their product development processes worldwide over recent decades (Brezet & Rocha 2001; Baumann *et al.* 2002; Johansson 2006; Le Pochat *et al.* 2007; Pigosso *et al.* 2013; Dekoninck *et al.* 2016). Knight & Jenkins (2009) underlined that this may be because the methods for introducing ecodesign are not generic and immediately applicable, but instead require some form of process-specific customisation prior to use. This requirement may act as a barrier to adoption. Developing a strategy that integrates ecodesign is particularly difficult for SMEs, because they often have fewer resources and focus on short-term objectives (Le Pochat *et al.* 2007). The continuous development of new ecodesign tools also makes it harder for a company to choose between different tools and practices (Boks & Stevels 2007; Pigosso *et al.* 2013). In addition, companies have been noticed to lack a roadmap to support them in implementing ecodesign and promoting actions towards higher implementation levels (Brezet & Rocha 2001; Boks & Stevels 2007; Pigosso *et al.* 2013).

2.3.3 Innovative targets

Green innovations and ecodesign both have a common fundamental objective to reduce the environmental impacts related to production and consumption activities (Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010; ISO 14006:2011; Brones *et al.* 2017). In most cases, the different innovation and ecodesign mechanisms eventually contribute to that goal, although in different ways and time frames (Carrillo-Hermosilla *et al.* 2010).

Types of innovative targets, meaning the specific focus areas, range from singular products to broad institutions and from technological to non-technological innovations (Figure 2) (Arundel & Kemp 2009; Sustainable Manufacturing and Eco-Innovation… 2009; Brones *et al.* 2017). Technological innovations in product and process activities were the prevailing types of innovation at the turn of the century (Fagerberg 2005; Oslo Manual 2005; Chen *et al.* 2006). They are also typical targets of ecodesign (ISO 14006: 2011; Cluzel *et al.* 2014). They concern the STI mode of innovations (Jensen *et al.* 2016; Parrilli & Heras 2016). Product innovations include new and improved goods and services (ISO 14062: 2002; Oslo Manual 2005: 48; Sustainable Manufacturing and Eco-Innovation… 2009; Cluzel *et al.* 2014). New products have significantly altered characteristics or usage compared to previous products of the organisation. Improvements of existing products can occur through changes in materials, components or other characteristics enhancing performance, according to the definition of the Oslo Manual (2005: 48). The difference between product improvement innovations and new product innovations is demonstrated by the following example. The first portable MP3 player combining existing technologies was a new product innovation, while breathable fabric and Internet banking services were product improvement innovations. Technological process innovations concern the implementation of a new or improved production or delivery method, which use less resources and generate fewer environmental impacts to provide the same number of products (Fagerberg 2005; Oslo Manual 2005: 49). Production methods include the techniques, equipment and software to produce products. For example, implementing new automation equipment in the production process is a process innovation. The other form of process innovation is delivery, which involves the logistics of an organisation related to sources, supplies within the organisation and delivering final products. Examples of delivery innovations include introducing GPS tracking devices for transport services and new reservation systems for travel agencies.

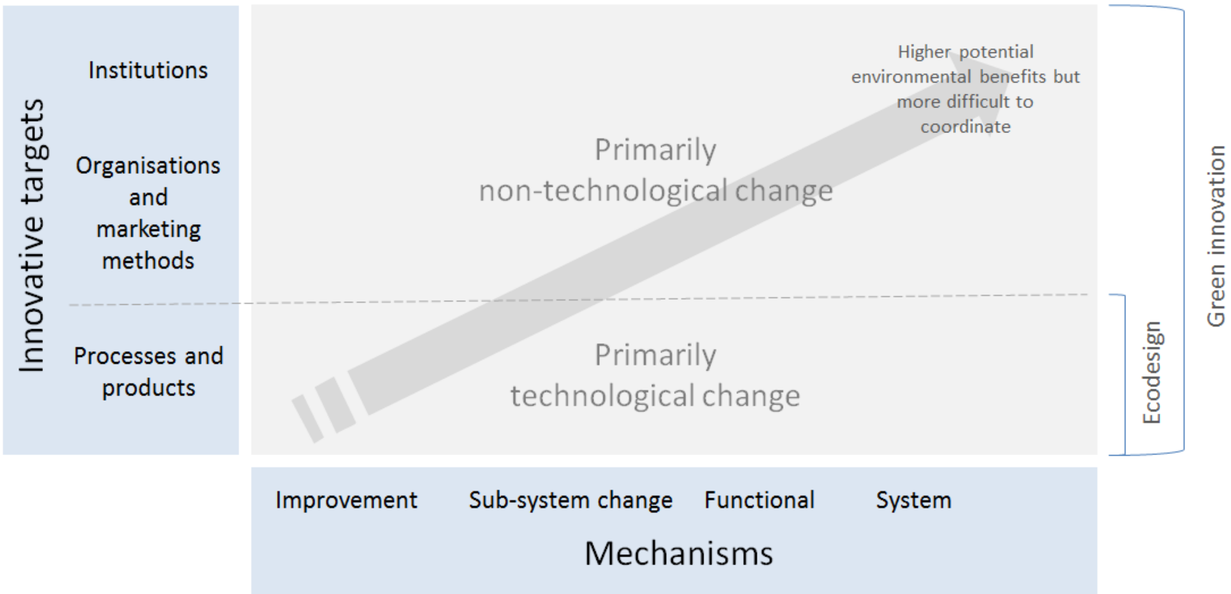

Figure 2. Innovative targets and mechanisms of green innovation and ecodesign. Green innovations are often expected to exceed the typical technological targets of ecodesign. Partly adapted from Sustainable Manufacturing and Eco-Innovation Framework, Practices and Measurement Synthesis Report (2009: 13).

Technological innovations do not fully address the innovations created and implemented in service and low-technology sectors, wherefore the Oslo Manual (2005) included non-technological organisational and marketing innovations within its scope. According to Cluzel *et al.* (2014) the non-technological innovations exceed the expected outcomes of ecodesign. Organisational innovations concern management structure and the distribution of responsibilities, which may aim to increase the performance of the organisation by reducing administrative costs, improving workplace satisfaction or gaining external knowledge (Oslo Manual 2005: 51; Sustainable Manufacturing and Eco-Innovation… 2009). Green organisational innovations concern environmental management systems (EMS) such as EMAS and ISO 14001 and research and development activities which comprise in a formalised way organisational capabilities and practices (Arundel & Kemp 2009; Marin *et al.* 2015). Wagner (2007) noted that implementation of EMS is associated with the probability of the firm to pursue innovations and specifically green innovations. Organisational innovations can be promoted by databases of best practices, greater autonomy of employees in decision-making and collaboration with other organisations, research organisations and customers (Oslo Manual 2005: 51). Marketing innovations involve changes in the appearance of a product, its packaging, placement and pricing (Oslo Manual 2005: 49; Sustainable Manufacturing and Eco-Innovation… 2009). The aim is to better address customer needs, create new markets or reposition a product in the market to increase sales. A new marketing method, developed by the organisation itself or adopted by another organisation, must be applied. In addition, it should be noted that many innovations can have characteristics suitable for more than one type of innovation (Sustainable Manufacturing and Eco-Innovation… 2009).

Green innovations in manufacturing focus primarily on technological innovations (Sustainable Manufacturing and Eco-Innovation… 2009). These green product and process innovations in technologies involve energy saving, pollution prevention, waste recycling and green product design (Chen *et al.* 2006; Arundel & Kemp 2009). Despite the prevailing position of technological innovations, non-technological changes have often acted in their background to drive technological development and complement the technological changes (Sustainable Manufacturing and Eco-Innovation… 2009). Non-technological solutions include organisational and marketing innovations, like the Oslo Manual (2005) declared. Green innovations and their environmental impacts exceed the organisational boundaries of the innovator, wherefore they can affect the institutional arrangements, social norms and cultural values of society (Arundel & Kemp 2009; Sustainable Manufacturing and Eco-Innovation… 2009). Therefore, institutional innovations should be included within the class of non-technological innovations (Arundel & Kemp 2009; Sustainable Manufacturing and Eco-Innovation… 2009; Carrillo-Hermosilla *et al.* 2010).

On the grounds of these observations, this thesis covers product, process organisational, marketing and institutional innovations in order to represent a more comprehensive picture, as Arundel and Kemp (2009) recommended.

2.3.4 Mechanisms

The mechanisms for introducing green innovations and ecodesign have, to a large extent, similar characteristics and potential for creating environmental benefits. Mechanism means the type of progress that is being made (Brones *et al.* 2017). The mechanisms of green innovation creation and introduction are modification, redesign, alternatives and creation, according to the OECD report "Sustainable Manufacturing and Eco-Innovation…" (2009), whereas Carrillo-Hermosilla *et al.* (2010) perceived only three main mechanisms: component addition, sub-system change and system change (see Figure 2). For ecodesign, the methods include product improvement, product redesign, function innovation and system innovation, according to Brezet and Rocha (2001: 247). These mechanisms generate different levels of potential magnitude for reducing environmental impacts (Sustainable Manufacturing and Eco-Innovation… 2009; Boons *et al.* 2013). Product improvement and eco-efficient sub-system changes over which companies have full control are likely to have direct, short-term impacts on environmental performance (Carrillo-Hermosilla *et al* 2010; Boons *et al.* 2013). They can be used when more complete systematic change cannot be achieved quickly enough. The more systematic methods, such as function and system innovations, generally produce higher potential benefits than smaller-scale modifications and redesign. Thus, achieving sustainable development is dependent on these systematic and radical innovations (Boons *et al.* 2013).

The first and easiest way to introduce both green innovations and ecodesign concern small changes to existing products and processes, called either modification, component addition or product improvement in the literature (Brezet & Rocha 2001: 247; Carrillo-Hermosilla *et al.* 2010; Sustainable Manufacturing and Eco-Innovation… 2009). This mechanism includes component-level changes, but the product and production techniques, in general, remain similar (Brezet & Rocha 2001: 247; Carrillo-Hermosilla *et al.* 2010; Sarasini *et al.* 2014). For example, including incineration ashes as new components of cement production, while retaining the same manufacturing method, belongs to this class of innovation mechanisms as well as providing training for employees.

The second method is redesign, maintaining the same product concept but making significant changes to it, as stated by Brezet & Rocha (2001) and "Sustainable Manufacturing and Eco-Innovation…" (2009). In this method, product components are fully improved or replaced, aiming at non-toxic materials, recycling, improved distribution, reuse of parts and energy use reduction (Brezet & Rocha 2001: 247). Carrillo-Hermosilla *et al.* (2010) proposed 'sub-system change' which focuses on producing more goods with fewer resources, i.e. eco-efficiency. Examples of this type of innovation include the increased efficiency of a waste management system to give fewer emissions or changes in company's operations, such as logistics (Carrillo-Hermosilla *et al.* 2010; Sarasini *et al.* 2014). This is a typical mechanism of green innovations and ecodesign as their main goal is to reduce environmental impacts. According to Brezet and Rocha (2001: 247) and supported by Sarasini *et al.* (2014), most environmentally conscious product policies focus on improving and redesigning existing products and processes.

The third mechanism looks for alternative solutions that change the way in which a product's function is fulfilled (Brezet & Rocha 2001: 247; Sustainable Manufacturing and Eco-Innovation… 2009). It takes place through a general shift from physical products to dematerialised services. However, products and services are always linked and mixed, according to Tukker *et al.* (2006), and they cannot exist without one another. Thus, functional changes are included within the concept of product-services. Product-service systems include product-oriented services, such as selling a computer, repairing it and offering consultancy; use-oriented services include renting clothes; and result-oriented services are those where a result is set but there is no predetermined product involved (Tukker *et al.* 2006; Sustainable Manufacturing and Eco-Innovation… 2009; Carrillo-Hermosilla *et al.* 2010). An example of a result-oriented service is an agreement between an office and a company that delivers a 'pleasant climate' rather than cooling equipment.

Lastly, the fourth and most efficient way to introduce green innovation and ecodesign is system innovation (Brezet & Rocha 2001), which is called system change by Carrillo-Hermosilla *et al.* (2010). System innovation replaces the whole technological system (product, product chain and associated infrastructure and institutional structure) by a new system in order to reduce environmental impacts on the ecosystem and society as a whole (Brezet & Rocha 2001; Carrillo-Hermosilla *et al.* 2010). In the "Sustainable Manufacturing and Eco-Innovation…" (2009) report, the most progressive mechanism is considered to be the creation of entirely new products, processes organisations or institutions. However, system innovations are not only technological, but the change has to be associated with organisational and social structures, human nature and cultural values. This definition as represented in the report is somewhat similar to the findings of Brezet and Rocha (2001) and Carrillo-Hermosilla *et al.* (2010). Besides being most difficult to achieve, green system innovations are also the most difficult to measure (Arundel & Kemp 2009). Unlike the other innovation types, system innovations are about evolving systems including multiple changes.

2.3.5 Principles and measurement of ecodesign and green innovations

Innovative targets and mechanisms can be examined in practice by using principles that encompass all the different modes of targets and mechanisms. Many scholars refer to the classification introduced by Chen *et al.* (2006) (e.g. Huang *et al.* 2010; Schiederig *et al.* 2012; Calik & Badurdeen 2016). They divided green product innovations into four principles. The first concerns choosing materials that produce the least amount of pollution for conducting a product. The second includes choosing materials that consume the least amount of energy and resources. The third principle is about using the lowest amount of materials to comprise a product. Lastly, the fourth principle aims at developing products that are easy to recycle, reuse and decompose. Green process innovations, on the other hand, focus on the manufacturing processes to reduce the emissions of hazardous substances and waste, recycle waste and emission, reduce the consumption of water, electricity, coal and oil and reduce the use of raw materials (Chen *et al.* 2006; Chen *et al.* 2008; Calik & Badurdeen 2016).

While Chen *et al.* (2011) focused on products and processes, it is necessary to broaden the scope to include non-technological targets as well in a more holistic manner (e.g. Arundel & Kemp 2009; Calik & Badurdeen 2016). These non-technological, including organisational, marketing and institutional, green innovations primarily exceed the scope of ecodesign (Cluzel *et al.* 2014). The principles of organisational innovations include internal schemes and systems for improving environmental performance, research and development activities and cooperation with other organisations along value chains (Arundel & Kemp 2009; Marin *et al.* 2015). Marketing innovation principles concern the pricing of products and services, packaging and informing customers (Arundel & Kemp 2009; Gouvinhas *et al.* 2016). Lastly, institutional innovations include principles of creating larger, systemic change among society, such as complying with environmental law, providing knowledge and promoting changes in norms and values (Arundel & Kemp 2009; Sustainable Manufacturing and Eco-Innovation… 2009; Carrillo-Hermosilla *et al.* 2010; Promoting better environmental… 2016).

In this thesis, the focus is on the most efficient and versatile ecodesign and green innovation principles based on the literature (van Hemel & Cramer 2002; Chen *et al.* 2006; Niinimäki 2006; Tukker *et al.* 2006; Aoe *et al.* 2007; Arundel Kemp 2009; Carrillo-Hermosilla *et al.* 2010; ISO 14006: 2011; Calik & Badurdeen 2016). Appendix 1 combines the principles of ecodesign and green innovation and indicates their differences, which have then been used in the data collection of this thesis. Thirteen principles applied to both ecodesign and green innovations and there were eight additional green innovation principles. The principles were further divided based on their innovative target and mechanism. The division indicates that products and processes are the most common types of targets and sub-system change is the most common mechanism.

2.3.6 Ecodesign tools

Ecodesign tool does not have an inclusive, formal definition; instead it is defined case by case in the context of a publication (Rousseaux *et al.* 2017). Most often ecodesign tools are described as systematic methods or procedures supporting the practice of ecodesign, helping the integration of environmental concerns and evaluation of the requirements (e.g. Baumann *et al.* 2002; Le Pochat *et al.* 2007; Bovea & Pérez-Belis 2012; Rousseaux *et al.* 2017). Their aim is to facilitate the integration of environmental aspects into the product development processes in a prescriptive, problem-solving way (Baumann *et al.* 2002; Byggeth & Hochschorner 2006). Ecodesign tools, like other indicators, serve to raise awareness, monitor performance, enable the setting of targets and simplify and facilitate communication in the complex systems of sustainability (Byggeth & Hochschorner 2006; Lehtonen *et al.* 2016). Ecodesign tools can be used to highlight potential environmental problems and enable a choice between different environmental aspects. They may also aim to analyse environmental impacts, select potential environmental improvements, assist in designing and brainstorming and evaluate environmental aspects with other important criteria.

2.3.6.1 Classifications

Ecodesign tools can be classified based on multiple criteria (e.g. Byggeth & Hochshorner 2006; Le Pochat *et al.* 2007; Knight & Jenkins 2009; Vallet *et al.* 2012). Researchers have had only a few common features in their classifications (Knight & Jenkins 2009). Nevertheless, Knight and Jenkins (2009) found assessment and improvement tools to be the most frequently used classes in the ecodesign literature. Le Pochat *et al.* (2007) perceived these two as the main categories of ecodesign tools, because they fulfil the basic requirements of an ecodesign project by first assessing the relevant environmental aspects of a product and then designing that product taking into account the environmental issues. Those aspects also distinguish ecodesign from traditional product design (Collado and Ostad-Ahmad-Ghorabi 2010). According to Le Pochat *et al.* (2007), most ecodesign tools fit in these two classes, but there are also complementing tools for communication, decision-making and assisting creativity. Le Pochat *et al.* (2007) pointed out that the tools may be further classified based on, for example, the form of the tool (quantitative or qualitative, software or on paper, database, checklists and tables) or its purpose (e.g. a specialist tool for a given industrial sector, precision and completeness of results), etc.

Environmental assessment tools

Environmental assessment, or analytical, tools provide a systematic vision at a specific level of product development or life cycle (Le Pochat *et al.* 2007; Knight & Jenkins 2009; Vallet *et al.* 2012; Rousseaux *et al.* 2017). They are usually quantitative, which enables detailed measurement (Bovea & Pérez-Belis 2012). Le Pochat *et al.* (2007) saw Life Cycle Assessment (LCA) as the reference tool of this category because it is the most effective for environmental assessment and enables the most advanced analysis. The most common software LCA tools include SimaPro and GaBi (Rossi *et al.* 2016). LCA quantifies the environmental impacts of a product and thus indicates effectively the problematic stages within a life cycle (Le Pochat *et al.* 2007; Collado-Ruiz & Ostad-Ahmad-Ghobari 2010). On the down side, LCA requires a great deal of data, time and expertise. The data needed for the assessment might not be available in the early stages of a product development process and its models always include some level of uncertainty in the results, although the apparent exactness may cause over-confidence.

In order to reduce resource requirements, more user-friendly, simplified LCAs have been applied to use generic databases (Bovea & Pérez-Belis 2012). Simplified or streamlined, an LCA helps to identify the problematic areas of a product's life cycle and is particularly helpful for comparing the environmental impacts of different products. They often provide a good compromise between the relevance of the results and potential for use in a company (Le Pochat *et al.* 2007). Several simplified tools have been developed including Quantis Suite 2.0, Environmental Improvement Made Easy (EIME) and LCA to Go (Rossi *et al.* 2016). Despite the efforts towards easier tools, simplified LCA remains an expert tool because the purchase, use and updating of specialised software require financial resources, and the synthesis of the results, company strategy and regulations must be carried out by an expert (Le Pochat *et al.* 2007).

Footprint indicators, including the 'Footprint Family' of Ecological, Carbon and Water Footprints, have been developed to assess the environmental impacts of human actions on the planet (Galli *et al.* 2012). Ecological Footprint is the broadest mode of footprints, as it measures the area of biologically productive land and water area in the global hectares required to produce the natural resources consumed by a certain population and absorb its waste (Wiedmann & Minx 2008; Ecological Footprint 2018). It is usually expressed on a global, country, region or individual level. By comparing the Ecological Footprint with the carrying capacity of the Earth, the balance between demand and supply of ecological resources can be evaluated. Carbon Footprint, the main contributor to the Ecological Footprint (Ecological Footprint 2018), measures the total amount of carbon dioxide or greenhouse gas emissions directly and indirectly caused by an activity or accumulated over the life cycle of a product, according to Wiedmann and Minx (2008) and Galli *et al.* (2012). Despite the name, Carbon Footprint is measured in mass units, such as kilograms, without an areal conversion. Water Footprint measures the amount of water used in a single process, product, company or sector directly and indirectly (Galli *et al.* 2012; What is a water footprint? 2018). All of these methods belonging to the Footprint Family are easy to communicate, but lack comprehensiveness of all aspects of environmental sustainability (Galli *et al.* 2012). In addition, data for calculations may be hard to collect.

In order to harmonise the various environmental impact assessment methods, the European Commission proposed the use of a Product Environmental Footprint (PEF) (Product Environmental Footprint (PEF) Guide 2012). The PEF was developed to create a common, easy-to-use life-cycle based method to measure the environmental performance of products in order to establish a single market for green products in Europe. The PEF calculates the environmental performance of a product throughout the value chain in 16 impact categories including climate change, toxicity and resource depletion. The method was tested during a pilot phase taking place in 2013–2018. It includes 21 product groups, which have tailored product group-specific rules, called Product Environmental Footprint Category Rules (PEFCRs), to guide the measurement. Thus, the PEF aims to increase the completeness, accuracy and transparency of environmental claims and to strive for comparability between products within the same product group. As a harmonised method, the PEF is expected to ease the adoption and implementation of LCA and to overcome some barriers related to the implementation of ecodesign tools (Rossi *et al.* 2016).

Matrices are other simplified assessment tools, which may be either quantitative or semi-qualitative (Le Pochat *et al.* 2009). They allow specific life-cycle stages or environmental parameters to be emphasised (Bevilacqua *et al.* 2012). Examples of matrix methods are the Material, Energy and Toxicity (MET) Matrix, Environmentally Responsible Product Assessment (ERPA) Matrix and Material, Energy, Chemical and Other (MECO) Matrix (Knight & Jenkins 2009; Bevilacqua *et al.* 2012; Rossi *et al.* 2016). The MET Matrix helps to identify the most important environmental impacts related to materials, energy and toxic emissions of a product during its life cycle, whereas MECO and ERPA estimate impacts at each life-cycle stage. Matrices are designed to be easy to use in terms of data gathering and evaluation of a product, but they still require an expert user with sound environmental knowledge of the industrial sector. However, according to Bevilacqua *et al.* (2012), they are also more liable to subjectivity than quantitative methods because they lack guidelines to rate each element in the matrix. Therefore, matrices providing general results could be enhanced by adding in another, more detailed and quantified tool (Byggeth & Hochschorner 2006; Knight & Jenkinson 2009).

Parametric assessment tools could accompany matrix methods and provide them with specificity (Le Pochat *et al.* 2007). Parametric assessment tools estimate mathematically the environmental impacts of a product using material and process factors (Le Poghat *et al.* 2007; Bevilacqua *et al.* 2012). An example of a parametric tool is the Material Input per unit of Service (MIPS), which measures the mass of input materials in kilograms required to produce a product or service (Bevilacqua *et al.* 2012). Parametric assessment tools aim at providing designers with the best environmental solutions to be used in the early conceptual design phase (Le Pochat *et al.* 2007). However, they require large databases and predefined environmental impacts that a company wishes to control. In addition, they may not be suitable for companies introducing ecodesign for the first time.

Another type of environmental assessment tool is ecolabels, which can be used for evaluating the environmental impacts of an existing product (Vallet *et al.* 2012). Ecolabels have been categorised into three groups based on their nature (ISO 14025:2006; Niinimäki 2006; ISO 14021:2016; ISO 14024:2018). Type 1 ecolabels are voluntary labels awarded by a third party (ISO 14024:2018). In order to be granted use of a label on a product, the product must fulfil a set of criteria in order to prove that the product is, over its life cycle, overall environmentally preferable compared to other products within the same product group. This procedure aims to help customers to choose more sustainable products. In addition, criteria are set to identify environmental impacts and potential for improvement. This group of ecolabels includes, for example, the EU Ecolabel, Nordic Swan Ecolabel, Öko-Tex and Bra Miljöval. Ecolabels can help a company to improve its image and increase sales (Kjeldsen 2014: 10, 27–33, 37–41). Other stimuli for ecolabelling include market demand, catching up with competitors and preparing for future legislation. Problems related to ecolabels concern the costs of participating in the scheme, the time-consuming application process and lack of benefit for a company, because ecolabels might not be well-recognised, trusted or understood (MacDonald 2015). Type 2 ecolabels are self-declared claims made by the company (ISO 14021:2016). These types of ecolabels do not need to be certified by a third party. Type 3 ecolabels again are voluntary programmes that provide quantified environmental data for a product over its life cycle in pre-set categories that are set and verified by a third party (ISO 14025:2006). Type 1 and 3 ecolabels are included in the scope of this thesis, because they assess the environmental impacts of a product in a regulated manner.

Environmental improvement tools

Environmental improvement tools as referred to by Le Pochat *et al.* (2007) and Rousseaux *et al.* (2017) or environmental strategy tools as mentioned by Vallet *et al.* (2012) include guidelines and manuals. They are mainly qualitative tools that are quick and simple to use in the early stages of the product design process, when there is less data about a product (Bovea & Pérez-Belis 2012). Guidelines are collections of general rules of ecodesign to be used in the early phase of product development, such as the Product Investigation, Learning and Optimization Tool (PILOT) and the Ten Golden Rules (Bevilacqua *et al.* 2012). They provide support to improve different products' features flexibly either across the whole development process and life cycle or in a particular area, such as disassembly or recycling (Knight & Jenkins 2009). Guidelines may be used as a reference in order to support engineering design activities and are do not require high levels of environmental expertise (Le Pochat *et al.* 2007; Knight & Jenkins 2009). However, guidelines are too general to provide design solutions and must therefore be accompanied by, for example, material databases (Le Pochat *et al.* 2007; Rossi *et al.* 2016). Ecodesign manuals describe the basic principles of ecodesign and rules for completing product development with environmental considerations (Le Pochat *et al.* 2007; Vallet *et al.* 2012). They act as a reference system for comparing existing products. The Design for Sustainability manual is an example of a basic collection on how to implement ecodesign step-by-step. Nevertheless, manuals are too general to be used by companies.

Checklists present questions which are considered easy for designers to answer and suggest alternatives for companies to remind them about environmental issues and solve problems during the design and development process (Bevilacqua *et al.* 2012; Rossi *et al.* 2016). Therefore, checklists are both assessment and improvement tools according to the classification of Le Pochat *et al.* (2007). They are sufficiently generic and flexible to be applied to different company products quickly, but according to Knight and Jenkins (2009), checklists provide in-depth but narrow information at selected stages. Checklists can be qualitative, like the ABC Analysis and the Philips Fact Five Awareness or semi-quantitative, like Volvo's black, grey and white lists (Byggeth & Hochschorner 2006; Bevilacqua *et al.* 2012). For example, the ABC Analysis groups environmental impacts of a product into A, B and C groups based on 11 environmental impacts, while Volvo's list concerns the use of substances and divides them into black, grey and white substances based on their harmfulness. Problems with checklists concern the formulation of questions and the fact that they do not cover holistically complete life cycles (Le Pochat *et al.* 2007; Knight & Jenkins 2009; Bevilacqua *et al.* 2012).

In addition to the assessment and improvement tools presented by Le Pochat *et al.* (2007), spiderweb diagrams should be included in the classification, as they include important ecodesign tools (Bevilacqua *et al.* 2012; Rossi *et al.* 2016). These diagrams evaluate how well the product is performing against set environmental criteria and visualise them graphically. Examples of spiderweb diagrams include the Lifecycle Development Strategy (LiDS) Wheel, also known as the Ecodesign Strategies Wheel, Econcept Spiderweb and the

Eco Compass (Byggeth & Hochschorner 2007; Bevilacqua *et al.* 2012; Rossi *et al.* 2016). They are particularly used for comparing an assessed product to a reference product in order to identify their differences in environmental terms. They are simple to use and the visualisation of the results eases their interpretation. Therefore, spiderweb diagrams are the best kind of tool for choosing design alternatives in the product planning and development stage. In addition, they are relatively quick to complete. However, they require expertise and are subject to human error (Byggeth & Hochschorner 2007). The diagrams only provide qualitative results and do not have a life-cycle perspective, nor do they assess environmental impacts. The spiderweb diagrams also require a reference product in order to carry out the comparison.

This thesis builds on the classification of tools into environmental assessment and improvement tools, following Le Pochat *et al.* (2007) and Knight and Jenkins (2009). The ecodesign tools that were included in the questionnaire were mentioned in at least two scientific articles included in the framework of this thesis. The articles were Tischner (2001), Byggeth & Hochschorner (2006), Knight & Jenkins (2009), Bovea & Pérez-Belis (2012), Rossi *et al.* 2016 and Rousseaux *et al.* (2017). The list was complemented with tools that are known to be used in the sectors in question (see Appendix 3). These pros and cons also act as drivers and barriers for the use of ecodesign tools in companies. However, the existing ecodesign tools do not fulfil all the requirements of being easy to use and interpret and providing concrete solutions at the same time, wherefore Le Pochat *et al.* (2007) emphasised the need to use different types of ecodesign tools.

2.3.6.2 Barriers for implementing ecodesign tools

Like the reasons for choosing to use a specific ecodesign tool, the barriers related to a tool are also associated with its functions (Le Pochat *et al.* 2007). Dekoninck *et al.* (2016) discovered two types of challenges: finding the right tool for ecodesign implementation and problems with applying the existing tools. Many of the challenges identified decades ago are still valid for today's ecodesign activities, according to Dekoninck *et al.* (2016). The general barriers for implementing ecodesign have been described in Section 2.3.2.

Finding the right tool for ecodesign implementation is associated with a lack of criteria for selecting the most suitable tools, the difficulty of implementing new tools within the development process and a need for new tools (Dekoninck *et al.* 2016). The wide variety of ecodesign tools in the market makes it hard for practitioners to select the most relevant tools for their needs (Boks and Stevels 2007; Rousseaux *et al.* 2017). Most often ecodesign tools are developed in pilot projects among companies and researchers, according to Le Pochat *et al.* (2007). Thus, new tools are developed continuously and at the same time, understanding of how the existing tools could be further developed and more effectively adopted into industrial practice has been forgotten (Bovea & Pérez-Belis 2012; Dekoninck *et al.* 2016). To demonstrate the situation, Rousseaux *et al.* (2017) included 629 ecodesign tools in their classification. Despite the vast amount of tools, the need for new tools for specific issues was pointed out by Dekoninck *et al.* (2016).

Problems with the existing tools relate to the amount of expertise required to implement and adopt ecodesign tools (Baumann *et al.* 2002; Dekoninck *et al.* 2016). Companies lack the knowledge to assess the environmental impacts of a product and to interpret these impact results into practice (Le Pochat *et al.* 2007). The lack of knowledge acts as a barrier to the participation of the company's staff. At the same time, it is also a barrier to integrating ecodesign. Problems with adopting ecodesign tools especially relate to the difficulty of the main environmental assessment tool, LCA (Dekoninck *et al.* 2016). It requires a lot of resources in terms of data, time and expertise and its results are not straightforward to use in a decision-making process. In addition, the LCA approach is very broad, wherefore simplifications are required but at the same time, crucial information may be lost. Therefore, the European Commission has proposed the use of the PEF to provide product group-specific guidance and databases for executing environmental assessments in a harmonised way (Product Environmental Footprint (PEF) Guide 2012; Rossi *et al.* 2016). It should be noted that both Bey *et al.* (2013) and Dekoninck *et al.* (2016) found that problems with tools were a low-ranking challenge for companies with significant experience in ecodesign, when the recurrence of the type of challenge was taken into consideration. However, according to Ilgin and Gupta (2010), many companies lack the necessary environmental knowledge to support ecodesign activities. Other problems concerning the implementation of existing tools include a lack of support for data exchange between different tools and the fact that behavioural and cultural changes are necessary to support tool implementation (Bey *et al.* 2013; Dekoninck *et al.* 2016).

3 Materials and methods

3.1 Context of the Nordic countries and the textile and IT sectors

3.1.1 The Nordic countries

The Nordic countries, meaning Denmark, Finland, Iceland, Norway and Sweden, are well-known for their long traditions of environmental consciousness (e.g. Tukker *et al.* 2001; Nordic cooperation 2018). The Nordic countries were selected as the study area because this thesis was conducted as part of the SCEPEF project funded by the Nordic Council of Ministers. The Nordics refer to a varied group of five countries with populations between 300,000 and 9.1 million, areas ranging from 43,000 to almost 450,000 km^2 and both monarchies and republics as their forms of government (Facts about the Nordic countries 2019). Still, in many terms the Nordics are very similar. They are all considered welfare states that have fairly small inequality, high life satisfaction and reliability of governance – also known as the Nordic model (Andersen *et al.* 2007). In addition, Denmark, Finland and Sweden are members of the European Union, while Norway and Iceland are not. However, Norway and Iceland both participate in the European Economic Area (EEA), European Free Trade Association (EFTA) and Schengen, and therefore they cooperate with the EU members (Iceland and the EU 2016; Norway and the EU 2016).

The Nordics are an essential subject of research due to their perceived forerunner status in environmental matters. According to Marin *et al.* (2015) Sweden and Finland are 'Green champions', meaning that they belong to the group of environmentally leading and top-regulated countries. In an older study conducted by Tukker *et al.* (2001) Sweden and Denmark were acknowledged as forerunners of ecodesign in terms of method development, dissemination and education.

3.1.2 The textile and IT sectors

The IT and textile sectors were chosen to be the object of this study due to their clear sector definitions, dissimilarity from one another, significant environmental impacts, existing PEF Category Rules and the amount of research literature on their ecodesign and innovations (e.g. Chen *et al.* 2006; Niinimäki *et al.* 2006; Aoe 2007; Boks and Stevels 2007; Liao *et al.* 2013; Mattila *et al.* 2014; Andrae *et al.* 2016).

The target group of this study was outlined as companies that currently design and/or manufacture products in the Nordic countries. To assure comparability between countries and sectors, the sectors were defined according to their NACE codes. NACE (Nomenclature générale des Activités économiques dans les Communautés européennes) is an official classification of economic activities used in the European Union (NACE Rev. 2 – Statistical Classification of Economic Activities 2019). The textile sector is here defined to include NACE codes 13 and 14, namely manufacture of textiles and manufacture of wearing apparel (Metadata 2008). Manufacture of textile concerns the preparation and spinning of textile fibres, textile weaving, finishing textiles and manufacture of textile articles. Manufacture of wearing apparel includes manufacture of wearing apparel, articles of fur and knitted and crocheted apparel. The IT sector here is covered by NACE codes 26.1–26.4. These codes include manufacture of electronic components, computers, communication equipment and consumer electronics. The IT sector was limited in this thesis to manufacture of hardware, which left out games and software, programming and repair of IT equipment. The number of companies in the textile and IT sectors within the scope of this thesis varies in the Nordic countries (Figure 3). Sweden stands out from the rest of the Nordics with over 3,800 textile companies (Antal arbetsställen… 2019), followed by Finland with less than half of that (Structural Business… 2018). The number of IT companies is much more even, with fewer than 1,200 companies in each country (General Enterprise

Statistics by Unit… 2016, Number of Enterprises… 2017, Structural Business… 2018, Virksomheter etter region… 2018, Antal arbetsställen… 2019). The lowest number of companies is in Iceland, where there are a little over 600 companies in total, 115 of which work in the textile sector and 34 in the IT sector (Number of Enterprises… 2017). The Finnish statistics did not specify the NACE subgroups, so the data on the IT sector represents the whole of code 26, not only subgroups 1–4 and the number of IT companies is overestimated (Structural Business… 2018).

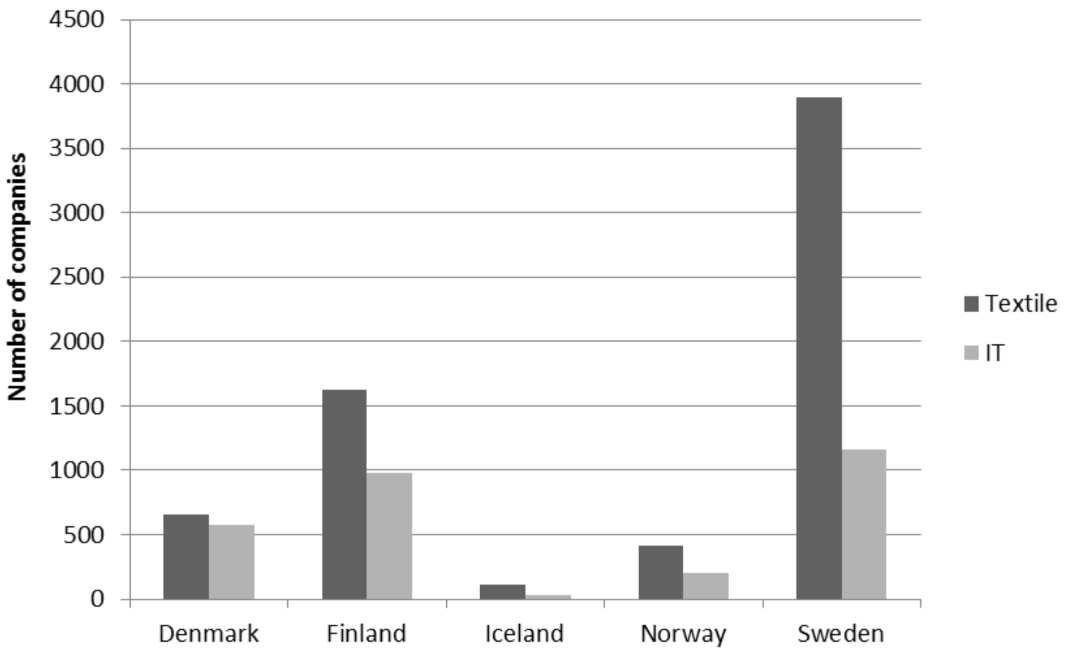

Figure 3. Number of companies working in the textiles and IT sectors in the Nordic countries based on national statistics. Note that these statistics represent the target population, meaning manufacturing and designing companies within NACE codes 13, 14 and 26.1–26.4, not the whole sectors. The Finnish IT sector here covers the whole of code 26 and is therefore overestimated. Data sources: General Enterprise Statistics by Unit… 2016; Number of Enterprises… 2017; Structural Business… 2018; Virksomheter etter region… 2018; Antal arbetsställen… 2019

The textile and IT sectors have been evaluated to be of great importance in terms of both their volume and environmental impacts (e.g. Boks & Stevels 2007; Roos *et al.* 2015, Li *et al.* 2016). At the same time, the life cycles of the products in these sectors have shortened as it has become fashionable to consume more and more often to follow trends and technological advancements (Ahola *et al.* 2010; A New Textiles Economy: Redesigning Fashion's Future 2017). For example, clothing sales doubled between 2000 and 2015, but at the same time the garments are used for a shorter period of time. The textile sector has been estimated to make up up to 3% of the world's carbon footprint and demands high amounts of energy, water, chemicals and pesticides (International Carbon Flows—Clothing 2011, Roos *et al.* 2015). The major environmental impacts of textile products arise from the fibre and fabric production phases of the life cycle. The ICT sector including hardware, software and services has been assessed to make up up to 2% of global CO_2 emissions (Gartner 2009; Hischier *et al.* 2014). The environmental impacts of IT equipment are mostly derived from electricity consumption during operation especially because of the data transfer through the Internet, and from material production (Boks & Stevels 2007; Hischier *et al.* 2014).

3.2 Background for the used materials and methods

The thesis builds on both quantitative and qualitative research approaches. Quantitative research responds to questions concerning frequencies and percentages (Heikkilä 2014). It usually utilises data that has been collected in questionnaires with given answer options. Quantitative research depicts issues with numerical variables and often explores the occurrence, relationships and changes of the phenomenon. However, it cannot usually examine the reasons behind the issues. Hence, a qualitative research approach is needed. Qualitative research explores certain cases, acknowledges the interaction between the researcher and the object and helps the researcher to understand the object (Koskinen *et al.* 2005: 31–32; Heikkilä 2014). To do that, qualitative research usually focuses on a narrow research object but aims for a deeper understanding of the issue. Qualitative research is perceived to be generally inductive, as it does not create a hypothesis based on a theory, but rather alongside the collection and analysis of data. However, sometimes a theory-based hypothesis may be used in qualitative research if it is superior, logical and strong. A single study combining both quantitative and qualitative research techniques, methods and language into a single study represents mixed methods research (Johnson *et al.* 2007; Tuomi & Sarajärvi 2018: 78–79). Mixed methods research is considered to bring together the quantitative and qualitative approaches and their complementary features rather than their contradictions. The strengths of the approach include breadth of knowledge, better understanding and a fuller picture, which enable findings from different sources to be validated and explained, and produce more comprehensive, consistent and valid findings. In this sense, the qualitative findings are supplemented with the quantitative results and vice versa.

The thesis follows a deductive approach which aims to develop, test and refine a framework of green innovation and ecodesign activities (Tuomi & Sarajärvi 2018: 107). The approach develops a theoretical orientation that guides the research (Koskinen *et al.* 2005; Tuomi & Sarajärvi 2018: 107: 110). It builds on previous literature on the subject and applies it to the Nordic textile and IT sectors. The deductive approach is commonly defined to go from general to specific, but the logic must also work in the other direction, meaning that the specific matters generated with deductive reasoning must get back to the general (Tuomi & Sarajärvi 2018: 110).

The materials consisted of a structured web questionnaire and semi-structured interviews. A quantitative web questionnaire with multiple choice, numeric and open-ended questions was sent to Nordic companies to gather a general picture of the current situation of green innovations and ecodesign. The wide sectors and multiple countries enable varied analyses of both the sectoral and spatial features and their heterogeneity (Mazzanti *et al.* 2016). Questionnaires of this kind may provide alternative approaches for empirical analysis according to Mazzanti *et al.* (2016). Narrowing the focus to two sectors and five countries in this thesis is less costly and permits focusing on specific questions with more in-depth information. Following the questionnaire, six semi-structured interviews were conducted to gain a deeper understanding of the issue with front-running companies that have significant experience of environmentally conscious production and design. This combination of general and more specific methods complies with the study of Belmane *et al.* (2003).

3.3 Questionnaire

3.3.1 Questionnaire as a method

A structured web questionnaire was conducted to gather general knowledge on what the Nordic textile and IT companies have done related to green innovations and ecodesign in the past, are doing currently and plan to do in the future. The method was preferred to a less structured questionnaire because of the size of the target group and to ensure reliability and comparability between language versions (Santolaria *et al.* 2011). The questionnaire was sent to all Nordic organisations working in the selected sectors via email and was conducted anonymously in Webropol. Web questionnaires are self-administered and respondents answer the questions without the help of an interviewer (Andres 2012: 47). The respondents are provided with information that they are required to read, thus the questionnaire must be clear, straightforward and unambitious. In a self-administered questionnaire, respondents are able to choose when to complete the questionnaire and can check for additional information if needed. In addition, web questionnaires have the potential to customise the questions based on the responses (Andres 2012: 51). For example, those who answer yes to a question of whether the company uses ecodesign tools get additional questions about the tools. Thus, the questionnaire is shorter and quicker to fill in for companies who do not have much experience on the subject, but whose perspectives are nevertheless important. Other advantages of a web questionnaire are that it is affordable and it conducts data collection automatically.

The limitations of questionnaires as a method include their self-assessment nature (Santolaria *et al.* 2011). In this study the respondents were asked to rate on a Likert scale how well they fulfilled the claims, which reflected a subjective perception. CEOs and directors have been found to label their company's operations more positively than an outsider would. In addition, response rates of web questionnaires remain low due to, for example, technological difficulties, fatigue of online questionnaires among the frame population and uncertainty about anonymity (Andres 2012: 53–55).

3.3.2 Structure of the questionnaire

The questionnaire items were formulated based on past literature on ecodesign and innovations. The phrasing of the questions used in the questionnaire was influenced especially by Chen *et al.* (2006), Dekoninck *et al.* (2016), Calik and Burdedeen (2016) and "Promoting better environmental performance of SMEs. Georgia" (2016). The questionnaire was complemented with knowledge gained from the PEFCRs of IT equipment and T-shirts in order to find out whether the companies had already taken into consideration the issues highlighted in the PEF (PEFCR 2016; PEFCR 2017). These issues included, for example, the energy-efficiency of a product, saving raw materials and using less packaging material.

The basic questionnaire template was allocated to the sectors separately by providing sector-specific response options. For example, the question concerning the company's main field of operations included options like clothing and apparel for textile companies, whereas the template for IT included consumer electronics. Appendix 3 presents the unallocated template in English. The Webropol questionnaire had the questions in the primary official language of each country. To increase validity, discussions with the representatives of the Finnish Technology Industries and Finnish Textile & Fashion were conducted to inform these associations for the IT and textile sectors about the study and to gain their opinions on the questionnaire. Following the discussions, it was decided not to use 'ecodesign' in the questionnaire template for textiles because of the specific vocabulary of the sector and possible misinterpretations of the term. Instead, the wording 'ecological product design' was used.

The questionnaire included 33 questions grouped onto six pages based on the subject of the questions although a majority of them were not aimed to be answered by all respondents. The questionnaire mostly featured closed-ended questions that provided a list of answer choices based on the literature to ease responding and provide readily comparable results between language versions (Dillman *et al.* 2009: 72). In addition, the respondents were allowed to add in an 'other' option outside the predetermined list to allow respondents who do not fit in the provided categories to specify a different category. According to Dillman *et al.* (2009: 75), respondents are more likely to choose a given option, so the list included all the previously identified key aspects, although listed answer options and matters added by respondents are not accurately comparable. One voluntary question concerning thoughts on the PEF was open-ended. In addition, at the end of the questionnaire, respondents were encouraged to give their feedback about the questionnaire. The questionnaire included both objective and subjective questions. The objective questions mainly concerned background information on the company, like number of employees, sector and research and development activities. Subjective questions were related to, for example, satisfying ecodesign and green innovation principles and the benefits and disadvantages of specific ecodesign tools. Other questions concerned reasons and experiences around promoting ecodesign and green innovations and reality, which is depicted by, for example, the number of patents, ecolabelled products and different targets and mechanisms used by the companies.

The scale of the questions was primarily nominal in order to increase the quality of results and minimise the possibility of different interpretations, as noted by Arundel and Kemp (2009). Nominal questions provide a list of options that have no natural ordering (Dillman *et al.* 2009: 124). Questions using the nominal scale included, for example, business type, use of ecodesign tools and experienced stimuli and barriers to promoting environmental issues. There was one ordinal scale question which included a Likert five-point bipolar opinion scale on how well a company satisfies the principles of ecodesign and green innovation (Dillman *et al.* 2009: 135). However, because the categories were set to be equidistant, the scale can be interpreted as interval-scaled. A 'do not know' option was also provided in order to cover responses that did not have previous knowledge on the subject or could not evaluate how well the company satisfied the statement. The used scale was bipolar because it measured both the direction and intensity of the construct (Dillman *et al.* 2009: 137). The five opinion categories from strongly agree to strongly disagree were sufficiently long to let respondents place themselves on the scale but short enough to make categories easily distinctive, answerable and meaningful for analysis. One question concerning companies' year of foundation used an interval scale. The remaining questions about number of employees and the budget for research and development activities used ratio scales, asking exact numbers for each.

3.3.3 Execution of the questionnaire

A letter presenting the questionnaire was sent out to 902 companies by email between 25th June and 30th August 2018 (Appendix 2). Finnish questionnaires were sent a week earlier than others because the Finnish template did not have to wait to be translated and if any problems did emerge, they could be handled prior to delivering it to the other Nordic countries. The companies were given eight weeks to submit their responses.

Special attention was paid to increasing the respondent rates of the questionnaire. Sampling was not done because previous questionnaires concerning ecodesign in companies have had low response rates from 4% to 33% (Dekoninck *et al.* 2016). By using a large population, the data was expected to provide for statistical analysis even if the respondent rate was low. In order to minimise respondent loss, attention was paid to the structure and length of the questionnaire and phrasing of the questions, and motivating the companies through a presentation letter (Dillman *et al.* 2009: 23–25). The presentation letter briefly described the study aims, emphasised the relevance of the responses and provided a link to the questionnaire website. All of these in addition to the questionnaire itself were written in the native language of the country where the company was located in order to ease answering for respondents. The questionnaire was estimated to take 10–15 minutes. The Webropol platform reports the time each respondent spends between the beginning and the end of the questionnaire and the average length was 19 minutes, ranging from 6 minutes to over four hours. The questionnaire included a progress bar indicating the total length of the questionnaire. Furthermore, the platform was set to automatically skip to the next relevant question for the respondent in order to personalise and shorten the questionnaire (Dillman *et al.* 2009: 79). Eleven of the 38 questions were compulsory and the number of other questions depended on the responses. For example, companies who do not use EMS or ecodesign tools or have activities for research and development related to environmental issues had 11 compulsory questions and 18 questions in total.

Two delivery methods were used to spread the questionnaire: National industrial associations sent the questionnaire to 572 companies in total and the researcher sent the questionnaire directly to 330 companies (Table 1). The two deliveries were used because the industrial associations were not allowed to give out the contact information of their members and thus it was an important guarantee that the sample would be extensive and all the significant organisations in both sectors in each Nordic country would have been contacted. The national industrial associations were the Finnish Tekstiili & Muoti, Finnish Teknologiateollisuus, Swedish Textil- & Modeföretag, Swedish IT&Telekomföretagen and Branchkansliet, Norwegian Norsk Industri, Norwegian Virke, Danish Dansk Industri and Icelandic Samtök iðnaðarins. The associations delivered the questionnaire to their environmental groups, which may have affected the results of this study because those companies are expected to be more concerned about the environment than a regular company would be. The Danish Danske Mode & Textil delivered the questionnaire to 16 companies but advised to directly contact the Danish textile companies licensed with a Nordic Swan Ecolabel or EU Ecolabel. The list of licensees included 36 companies in total, 11 of which were Danish and sent the questionnaire. The Norwegian IT sector could not deliver the questionnaire to their members due to their policy.

The directly contacted companies were collected from public lists provided by EuroPages, a European platform for manufacturing companies, and national registers: Finnish Yritysrekisteri, Association of Swedish Fashion Brands, Swedish Svensk Elektronik, Norwegian Brønnøysundregistrene, Norwegian Virke, Danish Centrale Virksomhedsregister and Icelandic Ríkisskattstjóri. In addition, several Google searches with search words “[country]+[sector]+company” were conducted in each Nordic language. Following the identification of relevant companies, their contact information was collected from their websites. These companies were sent a separate link to the questionnaire in order to calculate response rates for both distribution types. A few companies which did not provide any contact information on their website were not included in the study. There were two Finnish, one Danish and one Swedish textile company whose email addresses did not work and the questionnaire could not be delivered. In addition, two Finnish textile, two Finnish IT, one Swedish textile, one Norwegian IT and one Icelandic textile company replied that they were not able to respond to the questionnaire. Some of them referred to company’s policy not to respond to questionnaires. They are not included in Table 1.

A reminder was sent approximately two weeks prior to the expiration of the response time to the companies that had been directly contacted and contacted through the national industrial associations. All but Norsk Industri and Dansk Industri were able to send a reminder. This might have affected the response rate for Norway in addition to the fact that the questionnaire was not delivered by the Norwegian IT association. An additional reminder was sent to the directly contacted companies four days prior to the deadline.

3.3.4 Respondents

3.3.4.1 Response rate

By the deadline, 104 questionnaires had been returned, representing a response rate of 11.3% (Table 1). The textile sector had a higher response rate (16.9%) than the IT sector (6.6%). In addition, most of the respondents of the questionnaire represented the textile sector (69%). The most active respondents were Swedish companies in total, Finnish and Danish textile companies and Icelandic IT companies, all with a response rate over 15%. Quantitatively the respondents were most often Finnish and Swedish companies, who both formulated over a third of the respondents. The respondent companies were relatively young, as more than one-third of them had been established in the 21st century (35%, N=36). Another peak in terms of foundation years was in the 1980s, when 16 had been established. Other decades were represented by 3–7 respondents. The number of employees among the respondents ranged from 1 to 270,000, with an emphasis on companies with fewer than 200 employees. The companies were further classified based on how broadly they operate geographically. They were formulated based on the responses into four classes, who operate mainly (1) nationally, (2) in Europe, (3) in Europe and in some other continent and (4) highly internationally or even worldwide. A majority of the respondents (41%) operated nationally in one country, but other operative areas were also represented.

Table 1. Number of companies to whom the questionnaire was delivered classified based on the contact method and response rates. The number of respondents is indicated in parentheses. The total response rate of the questionnaire was 11.3%. Note that Norwegian IT association did not deliver the questionnaire and associations marked with * did not send a reminder.

	IT companies (# of responding companies)				**Textile companies (# of responding companies)**				**Total**	**Response rate %**
	National association contacted	*Directly contacted*	*Total*	*Sectoral response rate*	*National association contacted*	*Directly contacted*	*Total*	*Sectoral response rate*		
Finland	311 (10)	28 (2)	339 (12)	3.5	48 (5)	65 (25)	113 (30)	26.5	452 (42)	**9.3**
Sweden	42 (12)	33 (1)	75 (13)	17.3	75 (16)	65 (6)	140 (22)	15.7	215 (35)	**16.3**
Denmark	15*(3)	34 (0)	49 (3)	6.1	16 (10)	69 (4)	85(14)	18.4	134 (17)	**12.7**
Norway	-	9 (1)	9 (1)	11.1	45* (3)	24 (3)	69 (6)	8.7	78 (7)	**9.0**
Iceland	10 (0)	4 (3)	14 (3)	21.4	10 (0)	8 (0)	18 (0)	0	32 (3)	**9.4**
Total	378 (25)	82 (7)	486 (32)		194 (44)	231 (38)	425 (72)		911 (104)	
Response rate	**6.6**	**8.5**	**6.6**		**22.7**	**16.5**	**16.9**			**11.3**

Issues affecting the response rates include the timing of the questionnaire, two probably overlapping delivery methods and the inability to identify and contact the correct person. Firstly, the questionnaire was executed during the summer months and many possible respondents were on a holiday at that time. Therefore, the respondents were given eight weeks to submit their responses and were sent at least one reminder during that time. Secondly, there was cross-posting due to two delivery methods of the questionnaire and lack of information on which companies were contacted by the associations. This approach was, however, the only possible approach due to the General Data Protection Regulation and issue of anonymity. Lastly, the questionnaire was aimed to be answered by people responsible for a company's environmental issues. However, in most cases, it was not possible to identify who that was, wherefore the questionnaire was sent to the company's general email address. This might have affected the response rates of the directly contacted companies, as it is not clear whether the questionnaire reached the targeted person. The questionnaire did not ask the title of the respondent, as that question was considered irrelevant in the discussions with the national industrial associations.

3.3.4.2 Representativeness

The background information of the companies was compared with the national statistics to find out how well the sample represented the population (Ronkainen & Karjalainen 2008: 74–76). The comparison used the sizes of companies classified on the basis of their number of employees because of the recommendation of the Oslo Manual (2005). Firstly, the numbers of employees were classified according to the Eurostat (2018) guide and Oslo Manual (2005) into micro (< 10 people employed), small (10-49), medium-sized (50-249) and large (250-) companies (Figure 4). All company size classes were represented quite evenly in the questionnaire with percentages between 20 and 33.

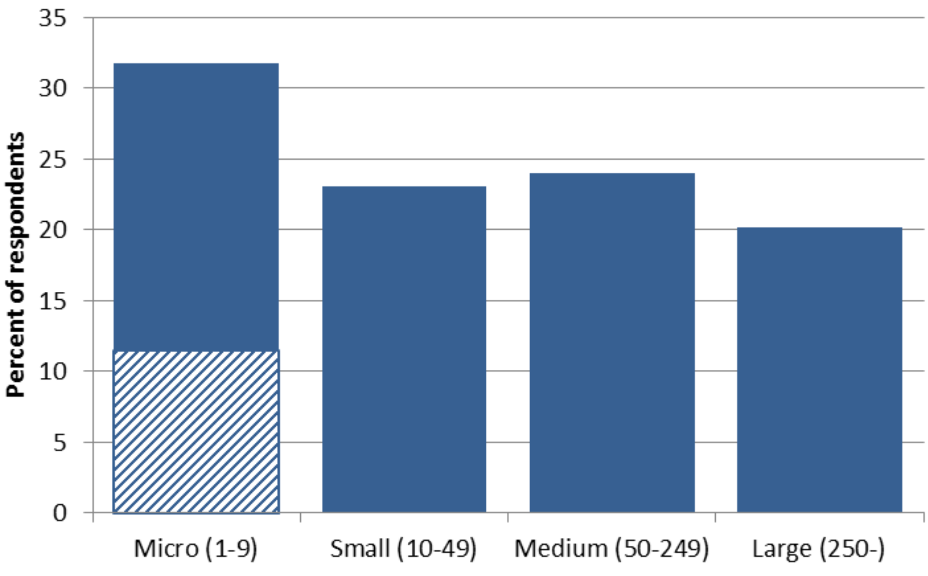

Figure 4. Respondents of the questionnaire (N=104) represented all four classes from micro to large companies based on the number of employees. The class of micro companies indicates separately those companies with 1 employee (striped).

Secondly, the size classes were compared with the national data to find out the representativeness of the respondents (Ronkainen & Karjalainen 2008: 76–78). The comparative data concerned the number of industries operating in the textile and IT sectors based on their sector (NACE codes) and number of employees. In general, larger companies were represented relatively more often than smaller ones. The proportion of respondents in relation to the national statistics varied from 0% to 50%, while the micro companies represented percentages from 0% to 1.5% and the large ones from 13% to 50%. In most cases, sector and size-specific information was provided, but for Danish and Icelandic statistics there was no direct data depicting the sector and the number of employees, wherefore the numbers here are proportions calculated by multiplying the number of national textile or IT companies by the shares of general company sizes. However, the representativeness of Icelandic respondents is not illustrated here because the overall number of Icelandic companies is low and the proportions were misguiding. The most recent and precise data that was publicly available was used to depict the representativeness of each sector and country: this data was from 2016–2018. The national statistics used were the Finnish "Structural Business and Financial Statement Statistics from year 2017" (2019), Swedish "Antal arbetsställen november 2018 fördelat på näringsgren (SNI-kod) och storleksklass" (2019), Danish "General Enterprise Statistics by Unit, Industry (DB07 127-grouping) and time" (2016) and "General enterprise statistics by industry (DB07 19-grouping), Time, Enterprise Size (full time equivalents) and Unit" (2016), Norwegian "Virksomheter etter region, næring (SN2007), antall ansatte, statistikkvariabel og år" (2018) and Icelandic "Number of Enterprises and Operational Information by Industry and Size 2008–2017" (2017).

3.3.5 Analysis

The statistical analysis was done using the SPSS 23.0 programme (IBM Statistical Package for the Social Sciences) to compare the frequencies, percentages, location variables, correlations and significance levels among other statistical characteristics. The raw data from the Webropol platform was imported into SPSS. Every respondent got an ID number and background variables were added. These variables were the country of origin, sector and whether the respondent was contacted directly or by an industrial association. The analysis began by examining the distributions of each background variable. Then the background variables were compared with each other to find out the possible differences and similarities in the distributions.

As noted earlier, most of the questions in the questionnaire were nominal scaled, so the analysis was conducted mainly with cross-tabulation. Cross-tabulation explores the relationships between categorical variables by arranging them into a table and indicating the combination of variables together with frequencies and row percentages (Heikkilä 2014). Alongside the cross-tabulations, Pearson's Chi-Square test was used to test the statistical significances. This tests whether there is a statistically significant difference between the expected counts and the observed counts in one or more categories. The statistical significance is tested in comparison to a null hypothesis, i.e. a situation in which there is no difference at all between the variables. The significance is described by a p-value that represents the probability of getting the perceived result by coincidence. A p-value of 0.05 shows statistically significant and strong evidence against the null hypothesis as it represents a probability of 5% of getting the received result. The Chi-Square test assumes that less than 20% of the cells in the cross-tabulation have an expected count of less than five and every frequency should be more than one. This assumption was in many cases not fulfilled because of the many categories within the variables, for example with five countries and four size classes. Heikkilä (2014) suggested that the original classes can be combined or classes with low frequencies can be left out of the analysis to increase the possibility of meeting the assumptions. However, in this thesis, all classes were separate and relevant for the analysis. Therefore, adjusted standardised residuals were used to explore the difference between the expected and observed counts. They can be used to compare residuals between different cells and because they follow a normal frequency distribution, probabilities of certain values can be evaluated. A value of more than 2.0 indicates a statistically significant difference from the null hypothesis and a probability of less than 5% of getting that result. A positive sign in front of the value shows that the observed count in that cell is significantly larger than would have been expected. A negative sign means the opposite: it shows that the observed count is significantly smaller.

The few ordinal-scaled variables were analysed with nonparametric tests: because the data was not normally distributed and because of the many categories, the minimum number of respondents in each category was not over 100 (Heikkilä 2014). Therefore, instead of a T-test, the Mann-Whitney U-test was used to test the null hypothesis based on the ordinal location of two independent variables. However, many of the grouping variables had more than two categories, so a Kruskal-Wallis test was applied. Kruskal-Wallis uses the same methodology as the U-test and is the nonparametric version of a variance analysis. In these cases, firstly a Kruskal-Wallis test was used to test if any of the multiple groups had differences. Secondly, if there was a statistically significant difference ($p<0.05$) between the groups, for example countries, a Mann-Whitney U-test was used to identify which groups were different, for example Finland and Sweden. After the U-test comparisons, the p-values needed to be Bonferroni corrected. In a Bonferroni correction, the p-value of each U-test is multiplied by the number of comparative pairs. For example, in this study there were five countries and thus 10 comparisons (1–2, 1–3, 1–4, 1–5, 2–3, 2–4, 2–5, 3–4, 3–5 and 4–5). Because of the multiplying, the Bonferroni-corrected U-test p-values might not be statistically significant even though the Kruskal-Wallis test indicates so. In those cases, there are many options for reporting: to report the conflicting results, not report the results at all, report the Kruskal-Wallis test results, report the U-test values with the notification that no Bonferroni correction has been made or conducting only some of the U-test comparisons so that the Bonferroni multiplier remains low. In this thesis only those results that had statistical significance in both the Kruskal-Wallis test and Bonferroni-corrected U-test values are reported.

3.4 Interviews

3.4.1 Interview as a method

Following the questionnaire, several semi-structured interviews were conducted. This division into a general questionnaire and deeper interviews followed the example of Belmane *et al.* (2003). Interviews enable more various and complete responses compared to questionnaires and the interviewer can answer respondents' questions and clarify any ambiguity (Kvale 2007; Andres 2012: 55; Tuomi & Sarajärvi 2018: 85). The semi-structured interview was chosen because it provides predefined themes. The predefined themes including prepared forms and sequences of questions help the interviewer to conduct the interview, as unstructured interviews require broader experience of both the subject and the method (Kvale 2007: 80) Compared to structured interviews, semi-structured interviews allow additional questions to be posed based on the responses of the interviewees, and changes of sequence (Kvale 2007: 52: 12; Tuomi & Sarajärvi 2018: 87–88). It allows the interviewee to be led to a certain theme, ecodesign and green innovations in this case, but not to specific opinions about the theme. At the same time, semi-structured interviews let the interviewees emphasise different issues based on their own perceptions and raise new issues. More versatile information is collected in this way and it yields interpretations and meanings of specific issues.

In this study, the interviews were conducted to gather information on the experiences of front-running companies. They were expected to have more and more varied experiences of improving their operations and thus provide valuable information for promoting ecodesign and green innovations in various companies (Marin *et al.* 2015). The interviews also highlighted the learning processes that companies carry out when facing obstacles during the adoption of ecodesign and implementation of innovations. A disadvantage of using forerunners is that the data does not allow general conclusions on the perception and implementation of ecodesign and green innovations to be drawn (Cluzel *et al.* 2014). However, the used method and sample indicate valuable tendencies with more detailed and in-depth answers, as opposed to a questionnaire. Thus, the semi-structured interviews indicated whether the identified forerunners come up on their own with similar innovative targets, mechanisms, principles, drivers and barriers to the companies in previous scientific studies and those who responded to the questionnaire. The interviews revealed more deeply what ecodesign and green innovations mean for companies in real life, as the interviewees could describe their experiences more freely and provide examples.

3.4.2 Execution of interviews

Prior to sampling the companies for interviews, the sample was decided to concern only Finnish companies due to the limited resources and because it would not have been possible to interview a sufficient amount of both textile and IT companies in every Nordic country to allow comparison between them. At the beginning of the data collection phase, the intention was to interview those companies that gave their contact information on the questionnaire platform. For textile companies, the approach worked well and three companies were sent an invitation for an interview. These three were chosen following familiarisation with their websites and based on the breadth of environmental issues mentioned on the site. However, a similar approach was not possible for the Finnish IT sector as only one company had left contact information. Therefore, the sample of three companies was collected based on recommendations of two researchers, Jáchym Judl and Janne Pesu, from the Finnish Environment Institute, which works closely with the IT sector. In addition to the evaluated front-runner status of the companies, the sample was formulated to include different types of companies in terms of their size, number of operative countries and sector.

The selected companies were sent an interview invitation by email (Appendix 4). The six pre-selected companies were willing to participate in the research. The invitation explained the aims of the research, the use of the results and that the interviews would be recorded and be anonymously reported. The interview outline together with the starting points for the interview and 15 questions was sent one week prior to the interview to enable the interviewees to prepare and reflect on more profound responses. The starting points explained that the interviews were anonymous and voluntary, recorded and transcribed and that the publication would include direct quotations from the interview together with the company identifier (Aineistonhallinnan käsikirja 2018). At the end of the interviews it was asked if the interviewee thought that there were questions that should have been handled in the interview or something they would like to bring up. It was done to provide an opportunity to deal with issues the interviewee could have been thinking about during the interview or had forgotten to bring up earlier (Koskinen *et al.* 2005: 109–110; Kvale 2007: 55–56). The interviews were held either on-site at the company or over the phone in January-February 2019. Only the researcher and one interviewee were present. The interviewees were the CEOs or managers responsible for the design, product development or environmental management of the company.

All the interviewed companies operated mainly in Finland, but they also represented the complete range from national to worldwide (Table 2). The sizes of companies covered all the four classes: micro, small, medium and large companies. Half of the companies were B2C, meaning that their products are sold to consumers and half of them were B2B, meaning that they sell to other businesses. Due to issues of confidentiality, the companies are referred to as companies A, B, C and so on (Cluzel *et al.* 2014; Dekoninck *et al.* 2016). In addition, no detailed or confidential information by which the companies could be recognised is provided here.

Table 2. Information on the interviewed companies.

ID	Sector	Market	Number of employees	Main business type	Mode and date of interview	Length of interview
A	Textile	Europe	10–49	Design, B2B	On-site 7.2.2019	25 min
B	Textile	National	1–9	Design, manufacture and services, B2C	Phone 7.2.2019	20 min
C	Textile	Europe and another continent	50–249	Design and manufacture, B2C	Phone 27.2.2019	20 min
D	IT	Worldwide	> 250	Design, B2B	On-site 30.1.2019	37 min
E	IT	Europe	10–49	Design and manufacture, B2C	Phone 13.2.2019	17 min
F	IT	National	1–9	Design, B2B	Phone 14.2.2019	21 min

3.4.3 Analysis

The interviews were digitally recorded and transcribed. Notes were also taken during the interview but they mainly supported the flow of the interview and helped in the transcribing (Kvale 2007: 102). Transcriptions were done with Microsoft Word verbatim to describe the data word for word and precisely (Koskinen *et al.* 2005: 320–321). Ways of speaking, filler words, pauses or body language were not captured because they are not relevant for this research. The quotes were also cleaned up of filler words and pauses and translated into English. The content of the quotes was assured to remain similar between the original transcriptions and the translated quotes. The 140 minutes of oral recording were transcribed into 26 pages. The transcribed data was handled using qualitative content analysis in the Nvivo 12 Pro programme using the existing literature on green innovations and ecodesign as a framework.

Content analysis is a reflective process, in which the analysis involves continuous coding and categorisation and returning to the raw data (Erlingsson & Brysiewicz 2017). The main aim of the analysis was to formulate different classifications and categories out of the raw data and to test the previous study results in a new context (Tuomi & Sarajärvi 2018: 127). This process began by coding the transcribed interviews following the predefined analysis goals of each interview question but also taking into account the content of the responses (Table 3) (Kvale 2007: 105; Tuomi & Sarajärvi 2018: 104–107). The codes described the meaning of the sentence or sentence fragment. They were defined based on the literature but also complemented by issues that arose from the data following several times reading through the data to cover all relevant issues to answer the research questions. The codes helped to conceptualise the meanings of the statements and enabled quantification of how often certain issues were raised (Kvale 2007: 105). The interviewees did not only respond to the specific question, but often provided answers on other interesting issues as well. For example, a question concerning what services the company provides may have also included responses related to barriers or institutional innovations. The transcribed data was coded with almost 300 references from the data. A few sentences in the transcribed data were found unsuitable for the codes and irrelevant for responding to the research questions and were therefore left out of the analysis. In addition, some initial codes were dropped out of the final coding frame as they did not have any references in the data.

Table 3. Key examples of the content analysis process with pieces of the interview text, their corresponding codes and categories.

Interview text (translated into English)	Code	Sub-category	Category
”We aim to maximise the positive environmental impacts and minimise the negative impacts.”	Handprint is bigger than footprint	General willingness	Internal stimuli
“Only money seems to matter and return on assets is more central than the environment. So, valuations are not encountered in the financing world.”	Money comes first	Societal development	Barriers
”We buy tricot as a material, not a finished product, which has been left over from cutting, and hence the environmental load is almost nothing.”	Excess materials	Material choices	Product Innovations
”We work together with universities and research institutes to develop different methods and calculations.”	Participating in projects	R&D activities	Organisational innovations
”We use different Excel-based methods that are easy for product developers and their teams.”	Own tool	Use of an ecodesign tool	Ecodesign tools

Following the coding, categories were developed around the codes in order to respond the research questions (Erlingsson & Brysiewicz 2017; Tuomi & Sarajärvi 2018: 104–107). Categories were formulated by merging codes and organising them to describe different aspects, similarities and differences of the text’s content that belonged together. A category answers the questions ‘who, what, when or where?’ Furthermore, the data was classified based on the background information on the sector, size and market to help the interpretation of the categories. The Finnish interview texts were translated into English by the researcher insofar as they were found relevant to bring up as quotes into this study. Following the interview and its analysis, the texts were given to the interviewees according to their wish to validate the interpretations made by the researcher (Kvale 2007: 101-102).

It would have been possible to continue the content analysis by defining themes that express the highest level of abstraction of the data and its latent meanings (Erlingsson & Brysiewicz 2017; Tuomi & Sarajärvi 2018: 104–107). However, as Erlingsson and Brysiewicz (2017) highlighted, if the data does not include rich latent meanings and they are not within the study aims, the content analysis can be left at the category level of abstraction. Therefore, it was decided to focus on the category level.

4 Results and discussion

4.1 Setting the scene with background information

Looking at the background information, several differences between the questionnaire respondents can be seen (Figure 5). The textile sector was clearly more represented than the IT sector. Finnish and Swedish companies also made up three-quarters of the respondents. The sizes of the companies were quite evenly distributed, but most of the respondents operated in a national market. In addition, the majority of the respondents did both design and manufacturing of products and their end-products were most commonly sold to consumers or companies. The respondents were also asked about organisational innovations, namely if they had an environmental management system (EMS) or research and development (R&D) activities related to environmental matters. Out of the 104 respondents, 47 of them (45%) used an EMS and 41 (39%) had R&D activities that were specifically related to the environment.

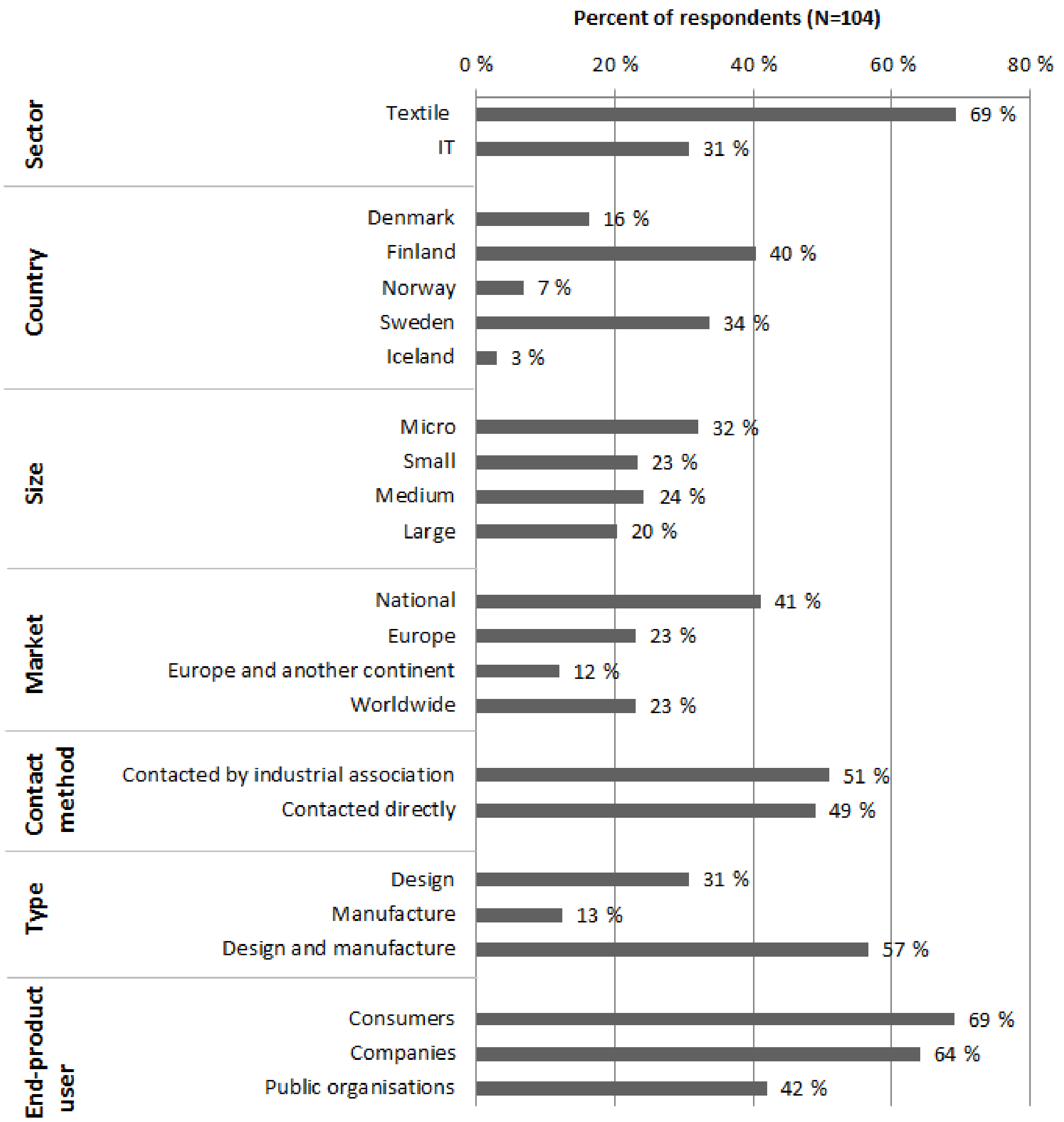

Figure 5. Background information on the questionnaire respondents. Note: Percentages may not add up to 100 because of rounding and multiple responses were allowed for the user of the end-product.

There were clear differences between the textile and IT sectors (Table 4). The textile sector was more interested in responding to the questionnaires and interviews of this study. Most of the respondents to the questionnaire were textile companies (69%, N=72). The response rate of the textile sector (20.4%) was also higher than that of the IT sector (6.6%). In addition, 16 out of 18 companies that left their contact information in the questionnaire were textile companies. This remark was especially valid in Finland, Sweden and Denmark, which also represented the majority of the respondents (Table 5). In Norway and Iceland there was no such difference between the response rates of the sectors. The respondents and their representativeness are described in detail in Section 3.3.4. A similar phenomenon was also present in the case of the interviews. All three Finnish textile companies that were contacted were willing to participate in the interview, but only one of the IT companies responded to the first invitation. The two other IT companies showed their willingness after a second round of invitations. It should be noted that the contacted IT companies had probably not responded to the questionnaire and did not voluntarily leave their contact information in the first place, but were contacted following a recommendation from an expert. The interviewees are described in Section 3.4.2. Based on these observations, it could be assumed that textile companies are more interested in ecodesign and green innovations and in sharing their experiences. In comparison to the results of this study, textile companies turned out to be more active and agree more on questions concerning marketing innovations that are related to promoting oneself and informing others. However, when looking at the rates of how often the companies use EMS, the IT sector was significantly more active. In addition, IT companies operated worldwide more often and were larger in size (Table 4).

Table 4. Statistical associations between background information and organisational innovation variables according to the sectors. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		Country (DEN/FIN/NOR/ SWE/ISL)	Market (National/Europe/ Europe+/Worldwide)	Size (Micro/Small/ Medium/Large)	Use of EMS (Yes)	Environmental R&D activities (Yes)
Textile	Frequency	14/30/6/22/0	33/18/10/11	27/20/16/8	25	29
	AR	1.3/0.4/1.0/-1.0/-2.6	1.4/0.7/0.6/-2.8	1.9/1.7/0.6/-3.4	-3.2	0.3
IT	Frequency	3/12/1/13/3	10/6/3/13	6/4/9/13	22	12
	AR	-1.3/-0.4/-1.0/1.0/2.6	-1.4/-0.7/-0.6/2.8	-1.9/-1.7/-0.6/3.4	3.2	-0.3
Statistical significance (Pearson Chi-square, p-value)		0.044[a]	0.045 *	0.002 *	0.001 *	0.789

Comparison of the Nordic countries indicated that the Finnish and Norwegian companies that responded mainly operated on a national level, whereas all but one Danish company operated on at least a European level (Table 5). None of the comparisons according to countries were statistically significant because the precondition of the Pearson Chi-Square test were not fulfilled due to the many response options and fewer than ten Norwegian and Icelandic respondents. Comparisons between the Nordic countries were also conducted without the Icelandic respondents but those results were similar to the complete data, so all countries were included here. Nevertheless, some differences were noticed in terms of markets and sectors as indicated earlier. In addition, companies that used an EMS were typically Swedish (47%).

Table 5. Statistical associations between background information and organisational innovation variables according to countries. (N=104)
AR=Adjusted Residual
* Statistically significant difference ($p<0.05$) ** Statistically very significant difference ($p<0.001$)
[a] Preconditions for Pearson Chi-Square are not met.

		Sectors (Textile/IT)	Market (National/Europe/ Europe+/Worldwide)	Size (Micro/Small/ Medium/Large)	Use of EMS (Yes)	Environmental R&D activities (Yes)
DEN	Frequency	14/3	1/5/4/7	6/3/3/5	6	7
	AR	1.3/-1.3	-3.2/0.7/1.5/1.9	0.3/-0.6/-0.7/1.0	-0.9	0.2
FIN	Frequency	30/12	22/8/6/6	18/11/8/4	16	15
	AR	0.4/-0.4	1.9/-0.8/0.5/-1.8	2.1/0.7/-0.9/-2.2	-1.2	-0.6
NOR	Frequency	6/1	6/1/0/2	2/2/2/1	3	4
	AR	1.0/-1.0	2.5/0.6/-1.0/-1.5	-0.2/0.3/0.3/-0.4	-0.1	0.2
SWE	Frequency	22/13	14/9/3/9	7/8/10/10	22	14
	AR	-1.0/1.0	-0.2/0.5/-0.9/0.5	-1.9/-0.1/0.7/1.5	2.6	0.1
ISL	Frequency	0/3	0/1/0/2	0/0/2/1	0	1
	AR	-2.6/2.6	-1.5/0.4/-0.7/1.8	-1.2/-1.0/1.7/0.6	-1.6	-0.2
Statistical significance (Pearson Chi-Square, p-value)		0.044[a]	0.024[a]	0.342[a]	0.077[a]	0.872[a]

Many of the respondent companies were relatively young and small. A large proportion of the respondents represented a company that had been founded in the 21st century (35%, N=36). Another peak in terms of foundation year was in the 1980s, when 16 out of the 104 respondents had been established. Other decades were represented by 3–7 respondents. However, the differences in terms of age of the company were mostly statistically insignificant and therefore, no table about the differences was composed. A few differences did arise: Legislation was noticed to be more important a stimulus for older companies and companies established prior to 1970s found more conflicts between ecodesign and other product requirements.

The number of employees among the respondents ranged from 1 to 270,000. The sizes were classified according to the Oslo Manual (2005) and Eurostat (2018) guidance into micro (<10 people employed), small (10–29), medium-sized (50–249) and large (>250) companies. All of these sizes were represented quite evenly as noted in Section 3.3.4, in which the classification and the representativeness of the questionnaire respondents are explained in more detail. The size was statistically significantly associated with the other background information and variables related to organisational innovations (Table 6). General points were that the textile companies were smaller in size, whereas a majority of the IT companies were large (41%). At the same time, micro companies often operated on a national level (70%), while large companies tended to operate worldwide (57%). The strongest difference between the size classes was in relation to the use of

EMS, as few micro companies used an EMS (6%) but most of the large companies did (81%). Larger companies also had more often R&D activities related to environmental matters, but the difference was not statistically significant. These results tie in well with previous literature within the Oslo Manual (2005: 71).

Table 6. Statistical associations between background information and organisational innovation variables according to company sizes. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		Countries (DEN/FIN/NOR/ SWE/ISL)	Sectors (Textile/IT)	Market (National/Europe/ Europe+/Worldwide)	Use of EMS (Yes)	Environmental R&D activities (Yes)
Micro	Frequency	6/18/2/7/0	27/6	24/3/3/3	3	11
	AR	0.3/2.1/-0.2/-1.9/-1.2	1.9/-1.9	4.5/-23/-0.7/-2.3	-5.1	-0.8
Small	Frequency	3/11/2/10/0	20/4	10/6/7/1	11	8
	AR	-0.6/0.7/0.3/-0.1/-1.0	1.7/-1.7	0.1/0.2/2.8/-2.5	0.0	-0.6
Medium	Frequency	3/8/2/10/2	16/9	7/9/1/8	16	9
	AR	-0.7/-0.9/0.3/0.7/1.7	-0.6/0.6	-1.5/1.7/-1.5/1.2	2.1	-0.3
Large	Frequency	5/4/1/10/1	8/13	1/6/2/12	17	12
	AR	10/-2.2/-0.4/1.5/0.6	-3.4/3.4	-3.8/0.6/-0.5/4.1	3.6	1.9
Statistical significance (Pearson Chi-Square, p-value)		0.342[a]	0.002 *	<0.001[a]	<0.001 **	0.287

The largest group of the questionnaire respondents (41%) were those which operated nationally in one country. There was a statistically significant difference between the sectors, as textile companies mainly operated on a national level (46% of textile companies), whereas IT companies operated worldwide (40% of IT companies) (Table 7). The shares varied among the countries, with Norway (86%) and Finland (52%) having the highest shares of nationally operating countries in comparison to Denmark with 6% of respondents operating only there. Another remark is that smaller companies operated more often on a national level whereas large companies operated worldwide. This observation applies to both questionnaire respondents and interviewees. In addition, larger companies acting worldwide used EMS more often.

Table 7. Statistical associations between background information and organisational innovation variables according to the market. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.5) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		Countries (DEN/FIN/ NOR/SWE/ISL)	Sectors (Textile/IT)	Size (Micro/Small/ Medium/Large)	Use of EMS (Yes)	Environmental R&D activities (Yes)
National	Frequency	1/22/6/14/0	33/10	24/10/7/1	15	14
	AR	-3.2/1.9/2.5/-0.2/-1.5	1.4/-1.4	4.5/0.1/-1.5/-3.8	-1.8	-1.2
Europe	Frequency	5/8/1/9/1	18/6	3/6/9/6	14	10
	AR	0.7/-0.8/-1.0/-0.9/0.4	0.7/-0.7	-2.3/0.2/1.7/0.6	1.5	0.3
Europe and another continent	Frequency	4/6/0/3/0	10/3	3/7/1/2	2	6
	AR	1.5/0.5/-1.0/-0.9/-0.7	0.6/-0.6	-0.7/2.8/-1.5/-0.5	-2.3	0.5
Worldwide	Frequency	7/6/0/9/2	11/13	3/1/8/12	16	11
	AR	1.9/-1.8/-1.5/0.5/1.8	-2.8/2.8	-2.3/-2.5/1.2/4.1	2.4	0.7
Statistical significance (Pearson Chi-Square, p-value)		0.024[a]	0.045 *	<0.001[a]	0.005 *	0.669

In general, there were few differences between the companies contacted by the industrial associations and those who were contacted directly. It was somewhat a surprising result, as the companies contacted by the associations are a part of the environmental group of the association. Therefore, they were expected to have greater transfer of information, be more connected with stakeholders and be supported by the associations, which would trigger innovations, as was suggested by Boons *et al.* (2013). Some of the interviewees also brought up that they have participated in lectures about environmental issues, study trips and found partners through the association (Companies A and C). Notably, none of the interviewees representing IT sector mentioned an association during the interviews. The companies contacted directly were often smaller and represented the textile sector. Notably, 57% of the companies contacted by the associations used an EMS in comparison to 33% contacted directly (p=0.017).

Another remark from the analysis of the background variables is that the textile companies did mostly designing and manufacturing (58%) and their products were clothes and accessories (60%). The shares were similar for the IT as 53% of IT respondents did both design and manufacture. Most of the companies provided products for consumers (70%) and other companies (64%). B2B companies selling to other companies used an EMS significantly more often than others (p=0.009, AR=2.6). Other than that, there were no significant differences in relation to background variables.

4.2 Stimuli for acting greener

The respondents were active in indicating what the outlying determinants behind their efforts were towards less harmful production. In total, 433 answer options were chosen, which makes 4.2 options per a respondent on average. General willingness was clearly the most important stimulus among the list of 24 options provided in the questionnaire (64%) but also among the interviewees (Figure 6, Table 8). The internal stimuli were found much more important or at least more frequently chosen and mentioned, than external ones. Four of the six most popular stimuli in the questionnaire are considered internal (i.e. willingness, value and quality of products and company's image). Legislation and customer demand are exceptions to this phenomenon, but they have previously been noticed to be of high importance by Belmane *et al.* (2003: 7) and Horbach *et al.* (2012). Meanwhile all the least important stimuli with a share of less than 3% (e.g. sectoral initiatives, subsidies and request from suppliers) were considered external. This result is in line with the previous studies of van Hemel & Cramer (2002) and Santolaria *et al.* 2011 among others. It could be thus assumed that a majority of the respondents have reached the level of maturity in which they are motivated by internal stimuli and are "beyond compliance", as suggested by Willard (2005).

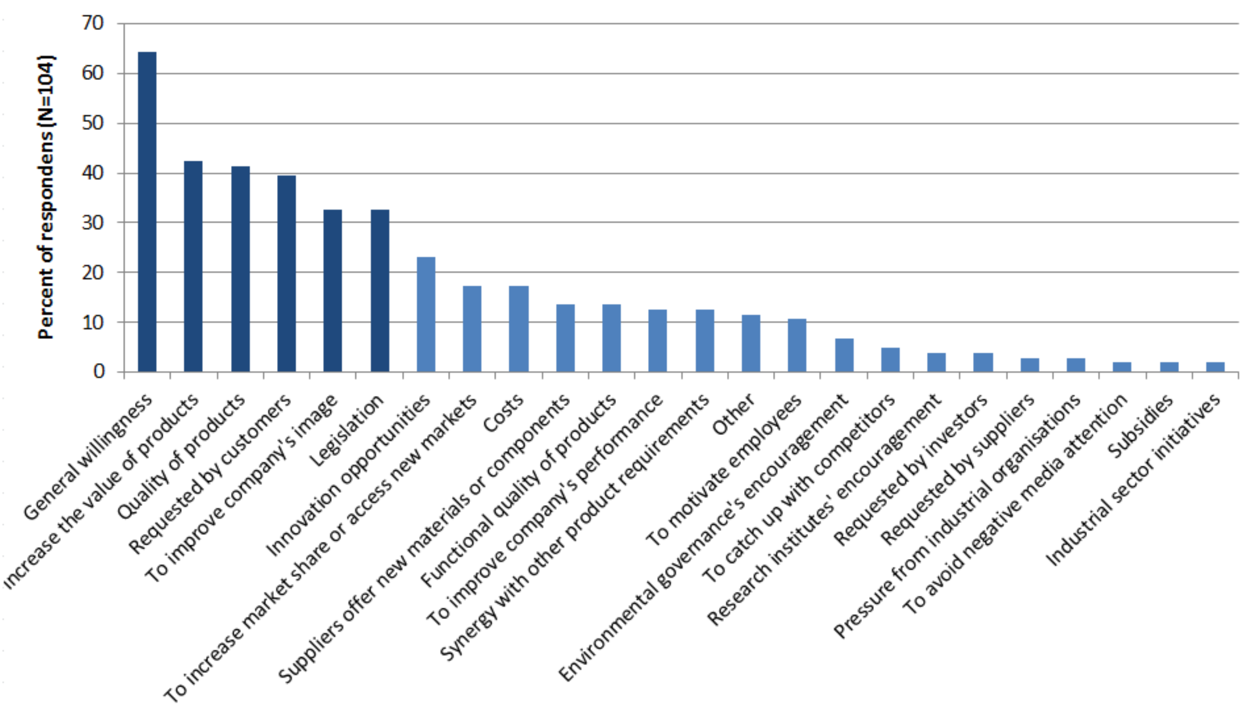

Figure 6. Stimuli for ecodesign and green innovation activities based on the questionnaire responses showcase the importance of internal stimuli and especially general willingness.

Clearly the companies were driven by their internal general willingness to reduce their environmental impacts, which is in line with the results of van Hemel and Cramer (2002) and Santolaria *et al.* (2011). According to van Hemel and Cramer, other internal stimuli originate directly from environmental commitment. More than 60% of the questionnaire respondents and all the interviewed companies mentioned values as one of the reasons behind their environmental friendliness. The respondents of the questionnaire further described their reasons in the open-ended answer option by saying *"Personal values of the entrepreneur"* and *"it's the right thing to do".* These indicated that the companies were strongly driven by internal willingness to act in a way that they morally feel is the right one. This observation was supported by the interviewees, who described it as *"It is worthy for us as a value. It is the main reason why we have begun to do this* [start a company]*".* (Company F), "*It is actually taken for granted; I rarely even think why we do so … It has been built in in the DNA of our company*" (Company D) and "*It has been in our DNA from the very beginning*" (Company A). Interestingly two interviewees mentioned that environmental considerations are in their DNA, which implied that it was in the core of their business and the reason behind it all.

Customer demand and legislation stand out from the rest of the external stimuli (Table 8). A similar phenomenon was also noted by Bey *et al.* (2013), who identified them as the two most important drivers for employing an environmental strategy. Still, in this study, they were only the fourth and sixth most popular options behind the internal stimuli, although the differences are minor between the second and sixth place. In addition, legislation was only mentioned in one interview by company D, which is a large international organisation. This is in line with Santolaria *et al.* (2011) who stated that large companies are more concerned about legislative adjustments than smaller companies.

Table 8. Overview of the top three stimuli in accordance with the number of times they were mentioned in the questionnaire (N=104) and interviews (N=6). All of the three most popular internal stimuli were mentioned more often than any of the external stimuli. Only those stimuli mentioned by at least two interviewees are included.

	External stimuli		Internal stimuli	
	Questionnaire	Interviews	Questionnaire	Interviews
1.	Request from customers (39%)	Request from customers (83%)	General willingness (64%)	General willingness (100%)
2.	Legislation (33%)	Suppliers offer new eco-efficient material or components (33%)	Value of products (42%)	Market opportunities (33%)
3.	Suppliers offer new eco-efficient material or components (13%)	-	Quality of products (41%)	To increase the working motivation of our employees (33%)

Cost reductions and image improvement have been some of the most frequently mentioned internal stimuli in previous studies (e.g. van Hemel & Cramer 2002; Santolaria *et al.* 2011, Dekoninck *et al.* 2016). Those were also among the popular stimuli among the questionnaire respondents. However, their effect on decisions has remained modest according to van Hemel and Cramer (2002). It was also noticed in this study that none of the interviewees mentioned cost reductions or image improvement, supporting the vision of Willard (2005) about different levels of maturity.

The respondents were given the opportunity to choose an 'other' option in the list. This was chosen by 12 respondents, whose responses mainly supported the "General willingness" option. These included answers, such as "*the value base of the company*", "*we want to be the most sustainable one*" and "*personal vision*". Three respondents said that they did not know why they were promoting ecodesign, mainly because it "*takes place at the parent company*".

The stimuli were further analysed statistically in relation to the background information of the questionnaire data to find the underlying differences. Associations were tested in relation to all provided background information, but only the most interesting ones are described here with detailed tables showing the frequencies, adjusted residuals and significance levels. These include the sector, country, size, contact method and use of EMS. Sector, country and size are identified here as the main background variables describing essential information. In addition, contact method and use of EMS both had statistically significant differences in more than four stimuli out of the nine options with shares of more than 15%. Differences based on other variables are described verbally.

There were few statistically significant differences between the textile and IT sectors (Table 9). Legislation and cost reductions were found more important stimuli among IT companies, whereas the value of products was more important for textile companies. Interestingly, legislation was chosen by IT companies even more often (66%) than general willingness (63%). Cost reductions were also more frequently chosen by IT companies. Cost reductions are considered to be mainly related to manufacturing processes and material choices (van Hemel & Cramer 2002; Dekoninck *et al.* 2016), whereas product value is linked to the end-product. Thus, it could be concluded that IT companies are more concerned about fulfilling the legislative requirements and improving the processes to save money, i.e. doing more with less, whereas textile companies see ecodesign and green innovations more as means to improve the product and its perceived value. In addition, it should be noted that outside the list of the nine most frequently mentioned stimuli, the differences in terms of suppliers offering new materials as a stimuli was noticeable. Only respondents from the textile sector chose that option (19% of textile companies) and it was also mentioned by two interviewees, both from textile companies. Based on these observations, it seems that product value and new available materials are very important for textile companies, but not for IT companies. IT in turn was mostly driven by legislation, which again is seen as adding pressure acting as a 'stick' to motivate industries to take the environmental field seriously (Bey *et al.* 2013).

Table 9. Statistical associations between the most important stimuli for promoting ecodesign and green innovations classified according to the sectors. The table includes stimuli with a share of more than 15%. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		GW	PV	PQ	CD	CI	L	IO	MB	CR
Textile	Frequency	47	40	33	26	25	13	20	14	8
	AR	0.3	4.1	1.4	-1.0	0.7	-4.8	1.7	0.9	-2.5
IT	Frequency	20	4	10	15	9	21	4	4	10
	AR	-0.3	-4.1	-1.4	1.0	-0.7	4.8	-1.7	-0.9	2.5
Statistical significance (Pearson Chi-Square, p-value)		0.785	<0.001 **	0.163	0.300	0.508	<0.001 **	0.088	0.388	0.012 *

Stimuli: GW=General Willingness, PV=Product Value, PQ=Product Quality, CD=Customer Demand, CI=Company Image, L=Legislation, IO=Innovation Opportunities, MB=Market Benefits, CR=Cost Reduction

Sweden was an exception among the Nordic countries in relation to many stimuli (Table 10). Notably, Swedish companies selected general willingness, product value and innovation opportunities less often. Still, general willingness was the most selected stimulus among Swedish companies (49%), but it was less evident and clear than in the case of Denmark, Finland and Norway, all with more than two-thirds choosing the option. On the contrary, Swedish respondents mentioned legislation as the second main stimulus for ecodesign, together with customer demand. Product value was also less frequently chosen by Swedish companies, but more among Finnish companies. This together with the cost reduction shares indicates that Swedish companies are less concerned about money than Finnish companies. Innovation opportunities were important for Norwegian and Icelandic companies. Another observation from the statistics is that Danish companies less often perceived improvement of company image as a stimulus.

Table 10. Statistical associations between the most important stimuli for promoting ecodesign and green innovations classified according to country. The table includes stimuli with a share of more than 15%. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		GW	PV	PQ	CD	CI	L	IO	MB	CR
DEN	Frequency	13	7	6	7	2	3	4	4	2
	AR	1.1	-0.1	-0.6	0.2	-2.0	-1.4	0.0	0.7	-0.7
FIN	Frequency	29	24	17	13	17	12	10	3	9
	AR	0.8	2.5	-0.1	-1.5	1.4	-0.7	0.1	-2.3	0.9
NOR	Frequency	6	1	3	3	4	2	5	1	2
	AR	1.2	-1.6	0.1	0.2	1.4	-0.2	3.1	-0.2	0.8
SWE	Frequency	17	10	15	16	10	16	2	9	4
	AR	-2.4	-2.0	0.2	0.9	-0.6	2.0	-3.0	1.6	-1.1
ISL	Frequency	2	2	2	2	1	1	3	1	1
	AR	0.1	0.9	0.9	1.0	0.0	0.0	3.2	0.7	0.7
Statistical significance (Pearson Chi-Square, p-value)		0.153[a]	0.050[a]	0.894[a]	0.587[a]	0.152[a]	0.306[a]	<0.001[a]	0.214[a]	0.580[a]

Stimuli: GW=General Willingness, PV=Product Value, PQ=Product Quality, CD=Customer Demand, CI=Company Image, L=Legislation, IO=Innovation Opportunities, MB=Market Benefits, CR=Cost Reduction

The results demonstrated few significant differences between company sizes, namely in terms of requests from customers and legislation (Table 11). For micro companies, the most considered driving elements were general willingness and value of product. On the other hand, the least driving elements were legislation and customer demand, as has also been noted by Santolaria *et al.* (2011). In the case of small companies, there were no clear preferences, but mainly constant shares between the options. The main difference between medium-sized companies and others were that they did not find product value an important driver. The main stimuli for the medium-sized companies were legislation and market benefits, likewise for the large companies. Legislation was also only mentioned by one interviewee, Company D, was the largest and most international of them all, also supporting the results of Santolaria *et al.* (2011). This observation is explained partly by the results of Belmane *et al.* (2003), who found out that regulations are important for exporting companies, which also tend to be larger. In addition, customer demand was one of the main drivers for large companies.

Table 11. Statistical associations between the most important stimuli for promoting ecodesign and green innovations classified according to company sizes. The table includes stimuli with a share of more than 15%. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		GW	PV	PQ	CD	CI	L	IO	MB	CR
Micro	Frequency	26	17	16	8	9	3	7	2	6
	AR	2.1	1.4	1.1	-2.2	-0.9	-3.5	-0.2	-2.1	0.1
Small	Frequency	13	12	10	8	10	5	6	3	6
	AR	-1.2	0.9	0.1	-0.7	1.0	-1.4	0.4	0.7	0.5
Medium	Frequency	16	6	9	11	10	12	6	7	6
	AR	0.0	-2.1	-0.6	0.5	0.9	1.8	-0.2	1.6	0.4
Large	Frequency	11	8	7	14	5	14	4	6	2
	AR	-1.3	-0.4	-0.8	2.8	-1.0	3.7	0.4	1.5	-1.1
Statistical significance (Pearson Chi-Square, p-value)		0.146	0.150	0.674	0.016 *	0.447	<0.001 **	0.961	0.069[a]	0.746[a]

Stimuli: GW=General Willingness, PV=Product Value, PQ=Product Quality, CD=Customer Demand, CI=Company Image, L=Legislation, IO=Innovation Opportunities, MB=Market Benefits, CR=Cost Reduction

Contact method was related to surprisingly many of the most frequently mentioned stimuli (Table 12). The most significant difference between companies contacted by the industrial associations and those contacted directly was that legislation was perceived as a stimulus much more often among companies contacted by the associations. The outlying explanations can be related to the differences in sectoral and size distributions, as the companies contacted by the associations were more often IT companies and larger. Other statistically significant differences were that the directly contacted companies were more often driven by product value and quality as well as innovation opportunities. There is no direct explanation for these differences, as they were linked to multiple background variables but in different ways. For example, the value of products has been highlighted by textile companies, which could explain why the directly contacted companies, who mostly represented the textile sector, found value a more important determinant. However, the same does not apply to innovation opportunities, which were mostly selected by IT companies. Thus, it is hard to evaluate what the underlying reasons behind the differences in contact methods could be, because the variable distributions did not go hand in hand.

Table 12. Statistical associations between the most important stimuli for promoting ecodesign and green innovations classified according to the contact methods. The table includes stimuli with a share of more than 15%. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		GW	PV	PQ	CD	CI	L	IO	MB	CR
National industrial association	Frequency	32	16	17	24	17	27	7	10	7
	AR	-0.9	-2.6	-2.0	1.2	-0.1	4.0	-2.4	0.4	-1.1
Direct	Frequency	35	28	26	17	17	7	17	8	11
	AR	0.9	2.6	2.0	-1.2	0.1	-4.0	2.4	-0.4	1.1
Statistical significance (Pearson Chi-Square, p-value)		0.380	0.011 *	0.050 *	0.213	0.891	<0.001 **	0.015 *	0.668	0.260

Stimuli: GW=General Willingness, PV=Product Value, PQ=Product Quality, CD=Customer Demand, CI=Company Image, L=Legislation, IO=Innovation Opportunities, MB=Market Benefits, CR=Cost Reduction

Companies who used an EMS saw legislation as a stimulus more often than those who did not use an EMS on a very statistically significant level (p<0.001) (Table 13). The outlying reasons could be that the EMS users are typically larger companies with solid functions, which are associated with legislation as one of their main stimuli, as stated by Santolaria *et al.* (2011). On the contrary, respondents with an EMS were less driven by increasing the quality or price of their product. A remarkable observation is that innovation opportunities were perceived as less of a stimulus by EMS users. Based on these remarks, EMS users tend to focus on meeting the legislative requirements rather than acting as a forerunner and developing new innovations. This view was for its part supported by the interviewees, who were considered to be forerunners and challenging the status quo, but only one of them used an EMS.

Table 13. Statistical associations between the most important stimuli for promoting ecodesign and green innovations classified according to the use of EMS. The table includes stimuli with a share of more than 15%. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		GW	PV	PQ	CD	CI	L	IO	MB	CR
EMS	Frequency	26	11	14	23	13	24	6	11	8
	AR	-1.8	-3.5	-2.2	1.8	-1.0	3.6	-2.3	1.5	-0.1
No EMS	Frequency	41	33	29	18	21	10	18	7	10
	AR	1.8	3.5	2.2	-1.8	1.0	-3.6	2.3	-1.5	0.1
Statistical significance (Pearson Chi-Square, p-value)		0.078	<0.001 **	0.030 *	0.071	0.320	<0.001 **	0.023	0.136	0.944

Stimuli: GW=General Willingness, PV=Product Value, PQ=Product Quality, CD=Customer Demand, CI=Company Image, L=Legislation, IO=Innovation Opportunities, MB=Market Benefits, CR=Cost Reduction

The relationship between the stimuli and other background data was also tested. The distribution of a company's operations in the market was statistically significantly related to legislation and customer demand. Nationally operating companies found legislation as their stimulus less often (p=0.028, AR -3.0), which is in line with the finding that micro companies, which typically operate nationally, are less concerned about legislation. This applies especially to those companies who export their products and need to take into account the environmental product regulations of the export market, as noted by Belmane *et al.* (2003) and Horbach *et al.* (2008). The same finding applies to customer demand as well: national companies chose it less often as their stimulus whereas companies with worldwide operations chose it more often (p=0.042, AR -2.4 and 2.2). This may be related to the highly competitive international markets which force companies to try to meet customer demand and be innovative (Horbach *et al.* 2008). Companies whose end-product was used by companies (B2B) were more often driven by legislation (p=0.011, AR 2.5) which is related to size, as B2B respondents tended to be larger. At the same time, B2C companies found the increase in product value important on an almost statistically significant level (p=0.051, AR. 2.0). Surprisingly, general willingness was less popular among B2B companies (p=0.038, AR -2.1). In relation to R&D, companies with R&D activities related to environmental matters found cost reductions less often as stimuli but were more driven by innovation opportunities on statistically significant levels (p=0.007, AR -2.7 and p=0.008, AR 2.6).

The most frequently mentioned stimuli were also compared with each other to find out if they were related. The stimulus of increasing the value of products was negatively related to legislation (p<0.001, AR -3.5) and customer demand (p=0.018, AR -2.4) on a statistically significant level. Hence, companies who are motivated by an increase in value chose legislation and customer demand as other stimulus options less often. In addition to the negative association with product value, legislation was also negatively related to product quality (p=0.032, AR -2.1). Therefore, it seems that companies driven by legislation were less concerned about their products. As noted earlier, they were also more likely to be larger, worldwide-operating B2B companies. The negative relationship between product value and customer demand was somewhat unexpected, as it indicates that companies who work on meeting the environmental requests coming from their customers less often consider environmental matters as a means of increasing product value. This kind of comparison between the stimuli was not found in the previous literature. Customer demand and legislation were both found to be popular stimuli among large companies and to have a strongly positive association (p=0.001, AR 3.2).

4.3 Barriers standing in the way of ecodesign and green innovations

Half of the questionnaire respondents were concerned that ecodesign would increase their costs (Figure 7). In comparison to stimuli, the respondents chose fewer answer options on barriers, 321 in total and approximately 3.1 per respondent. Here the respondents were given the opportunity to choose up to five out of 15 pre-given options. Costs were as expected the barrier regularly mentioned following the results of Belmane *et al.* (2003: 7), Bey *et al.* (2013) and Dekoninck *et al.* (2016) as they pointed out their importance for companies. This is because an increase of costs can negatively affect the firm's performance or drive away customers due to higher prices. However, only one interviewee mentioned costs as their barrier, stating that *"our visibility is quite limited for doing online campaigns because we do not really have the resources,* *money, to do so"* (Company F). This statement was related to costs but not directly as a barrier for employing ecodesign or green innovations but rather for their marketing, which is a vital characteristic dividing innovation from invention (Fagerberg 2005; Oslo Manual 2005: 47). After the increase of costs, the other barrier options were quite evenly distributed among the questionnaire respondents. This distribution indicates that the respondents may perceive fewer barriers than stimuli or that the barriers could be stronger than

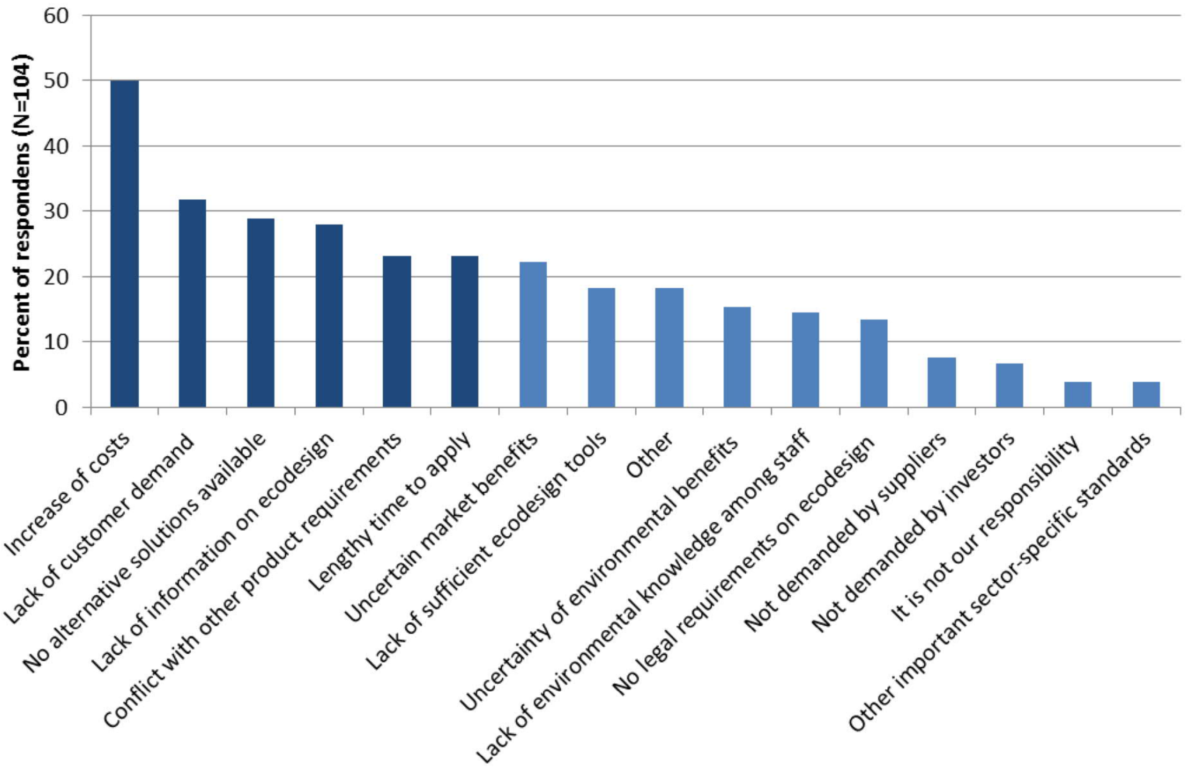

Figure 7. Barriers for promoting ecodesign include costs, lack of customer demand and alternative solutions and lack of knowledge, based on the questionnaire.

stimuli and therefore they chose fewer options in this question. Unfortunately, this cannot be evaluated as the respondents were not asked to rate how strong they perceive each barrier or stimuli to be.

In contrast to the questionnaire responses, the interviewees brought up many more barriers than stimuli and those barriers were diffused. This observation follows the initial idea of interviewing forerunners which are expected to face more and more varied barriers, as acknowledged by Marin *et al.* (2015). In total, nine barrier types were mentioned in the interviews, all but one similar to the questionnaire categories. However, the one added category – namely "development of society" proved to be the most important one (Table 14). It includes issues such as that money comes first, the norms are against change and the basic infrastructure is not developed enough to acknowledge and support sustainable production. Thus, these institutional challenges proved to be of great importance. Five interviewees felt that the current society is too focused on money and financing and stated that *"Only money seems to matter and return on assets is more central than the environment"* (Company F), *"they do not support these kind of issues"* (Company B) and *"There is request for a product like this, but it is hard to get financing for an alternative product"* (Company E). A few interviewees acknowledged some kind of change in a positive direction, for example *"things change slowly but the main thing is that they change"* (Company A) and *"we are in quite a different state* *when compared to the situation 10 years ago both in terms of attitude and understanding*" (Company B). Still, the change was not concrete enough: *"Actually, nothing has happened"* (Company E). Based on the interviews, change towards sustainable consumption and production seems to have taken place in the textile sector but not in IT. Lack of customer demand and alternative solutions were also mentioned more often in the interviews than they were in the questionnaire.

Lack of alternatives has been acknowledged by van Hemel and Cramer (2002) as a no-go barrier that a single company cannot overcome but which can be broken up by a systemic change. The strength of lack of alternative solutions and customer demand imply that the forerunning companies mostly suffer from external barriers that are hard to affect. This problem was not raised in any of the ecodesign or green innovation literature reviewed for this thesis, although the need for changes in norms and values was acknowledged by Arundel and Kemp (2009) and Carrillo-Hermosilla *et al.* (2010). The previous studies have focused more on barriers that are directly faced by companies, such as lack of information, increase of costs or lengthy time to apply.

Table 14. Overview of the top three barriers in accordance with the number of times they were mentioned in the questionnaire and interviews. The barriers were quite similar except for the most frequently mentioned ones.

	Questionnaire (N=104)	Interviews (N=6)
1.	Increase of costs (50%)	Development of society (83%)
2.	Lack of customer demand (32%)	Lack of customer demand (50%)
3.	Lack of alternative solutions available (29%)	Lack of alternative solutions available (50%)

The "other" answer option in the questionnaire was chosen by 19 respondents who articulated that they were "*not supported educationally*", they faced a "*lack of applicable, truly ecological raw materials*" and that "*customers lack knowledge and understanding* ". Most of the other responses were categorised to existing options; for example, the example of raw materials was recoded into "Lack of alternative solutions". One group of three respondents who said that there was a "*lack of technical data to evaluate different options objectively*" and it's "*hard to find information about how ecological mohair is*" and "*research in recycled nylon is lacking*" had in common the barrier of one not having enough information, but also that there was no information available. These examples showcase a growing need for research in this field to provide reliable information on how to do things in a more sustainable way.

The barriers were analysed similarly with the stimuli in relation to the background information of the questionnaire data. All associations were tested, but only the statistically relevant ones are reported here in detail. All in all, few background variables were statistically significantly related to barriers. Thus, barriers seem to be fairly shared by all the respondents. Sector, country and size were here again the main variables with which the barrier data was analysed. Other differences are described verbally.

There were only minor differences between the sectors in relation to barriers (Table 15). The only statistically significant difference was that textile companies were more concerned about increase of costs (57%)

than IT companies (28%). This observation is opposite to the case of cost reductions as a stimulus, as IT companies were statistically more often driven by cost reductions. Hence, it seems that IT companies try to lower their expenses while textile companies try to minimise their increase.

Table 15. Statistical associations between the most important barriers for promoting ecodesign and green innovations classified according to sector. The table includes barriers with a share of more than 15% (excluding other). (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		IC	CD	LS	LI	CPR	T	MB	ET	EB
Textile	Frequency	41	21	19	20	14	19	14	12	13
	AR	2.1	-0.8	-0.8	0.0	-1.3	1.2	-1.0	-0.6	1.1
IT	Frequency	11	12	11	9	10	5	9	7	3
	AR	-2.1	0.8	0.8	0.0	1.3	-1.2	1.0	0.6	-1.1
Statistical significance (Pearson Chi-Square, p-value)		0.034 *	0.399	0.407	0.971	0.187	0.229	0.325	0.526	0.257[a]

Barriers: IC=Increase of costs, CD=Not demanded by customers, LS=Lack of alternative solutions, LI=Lack of information on ecodesign and its benefits, CPR=Conflict with other product requirements, T=Lengthy time to apply, MB=Uncertain market benefits, ET=Lack of sufficient ecodesign tools, EB=Uncertainty of environmental benefits

Sweden differed from the Nordic countries the most, as Swedish companies were statistically different from the rest in terms of three barrier options (Table 16). Based on the analysis, Swedish companies lacked customer demand more, but did have alternative solutions available and saw the market benefits of ecodesign. Danish companies had problems with customer demand. On the contrary, Finland was the opposite in both customer demand and market benefit, as Finnish companies were less likely to face lack of customer demand, but were uncertain of the market benefits.

Table 16. Statistical associations between the most important barriers for promoting ecodesign and green innovations classified according to country. The table includes barriers with a share of more than 15% (excluding other). (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		IC	CD	LS	LI	CPR	T	MB	ET	EB
DEN	Frequency	10	9	7	4	3	4	2	5	5
	AR	0.8	2.1	1.2	-0.4	-0.6	0.0	-1.1	1.3	1.8
FIN	Frequency	23	7	13	12	9	6	14	5	6
	AR	0.8	-2.7	0.4	0.1	-0.3	-1.8	2.3	-1.4	-0.3
NOR	Frequency	4	1	3	3	0	3	3	0	1
	AR	0.4	-1.0	0.8	0.9	-1.5	1.3	1.4	-1.3	-0.1
SWE	Frequency	13	16	5	9	12	11	3	9	4
	AR	-1.9	2.2	-2.3	-0.4	1.9	14	-2.4	1.4	-0.8
ISL	Frequency	2	0	2	1	0	0	1	0	0
	AR	0.6	-1.2	1.5	0.2	-1.0	-1.0	0.5	-0.8	-0.7
Statistical significance (Pearson Chi-Square, p-value)		0.448[a]	0.009[a]	0.102[a]	0.898[a]	0.213[a]	0.227[a]	0.044[a]	0.193[a]	0.466[a]

Barriers: IC=Increase of costs, CD=Not demanded by customers, LS=Lack of alternative solutions, LI=Lack of information on ecodesign and its benefits, CPR=Conflict with other product requirements, T=Lengthy time to apply, MB=Uncertain market benefits, ET=Lack of sufficient ecodesign tools, EB=Uncertainty of environmental benefits

Different sized companies were fairly similar in relation to barriers (Table 17). The only statistically significant difference was between micro and medium companies, the first of which perceived the time-consuming nature of applying ecodesign less of a barrier than medium-sized respondents. This is a remarkable finding, as it was assumed that smaller companies have fewer resources and thus less time to apply excessive means of product development based on the results of Le Pochat *et al.* (2007) and Dekoninck *et al.* (2016) among others. Two interviewees mentioned time as a barrier by saying that, *"the substance is very interesting but it requires familiarisation and because we do not have that much expertise, we need to find out a lot of things and lack of time is a problem in a small company"* (Company C) and *"everyone is so busy, there is a lot to do"* (Company D). Surprisingly, none of the micro companies mentioned time-related problems, but the medium and large companies did. Therefore, it seems that larger companies have a lot of operations to handle at the same time and environmental issues might not be on the priority list at that point, and they are also face lack of knowledge among the company's staff.

Table 17. Statistical associations between the most important stimuli for promoting ecodesign and green innovations classified according to company size. The table includes stimuli with a share of more than 15%. (N=104)
AR=Adjusted Residual
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		IC	CD	LS	LI	CPR	T	MB	ET	EB
Micro	Frequency	14	8	8	10	6	2	8	3	5
	AR	-1.0	-1.2	-0.7	0.3	-0.8	-2.8	0.3	-1.7	-0.1
Small	Frequency	13	10	6	9	3	7	6	6	3
	AR	0.5	1.2	-0.5	1.2	-1.4	0.8	0.4	0.9	-0.5
Medium	Frequency	16	7	7	7	7	10	4	7	3
	AR	1.7	-0.5	-0.1	0.0	0.6	2.3	-0.3	1.4	-0.6
Large	Frequency	8	8	9	3	8	5	4	3	5
	AR	-1.2	0.7	1.6	-1.6	1.8	0.1	-0.4	-0.6	1.2
Statistical significance (Pearson Chi-Square, p-value)		0.254	0.478	0.473	0.375	0.177	0.020 *	0.945	0.225[a]	0.681[a]

Barriers: IC=Increase of costs, CD=Not demanded by customers, LS=Lack of alternative solutions, LI=Lack of information on ecodesign and its benefits, CPR=Conflict with other product requirements, T=Lengthy time to apply, MB=Uncertain market benefits, ET=Lack of sufficient ecodesign tools, EB=Uncertainty of environmental benefits

Other tests were done in relation to the contact methods, use of EMS, customers and R&D activities. Most notably there were differences in terms of conflicting product requirements and lack of customer demand. Respondents who used an EMS (p=0.004, AR 2.9) and were B2B (p=0.009, AR 2.9) experienced these conflicts more often. They were also identified to be larger companies, which was the underlying variable explaining the distribution of the barriers. Lack of customer demand was faced especially by respondents who were contacted by the associations (p=0.001, AR 3.4). This finding is partly explained by the share of Swedish companies contacted by the associations, as 53% of those were Swedish, which also faced lack of customer demand more often. Respondents with R&D activities related to environmental matters faced lack of information on ecodesign and its benefits significantly less frequently (p=0.047, AR -2.0), which was also expected, as R&D activities have been found to be relevant for knowledge creation and building technology capabilities (e.g. Horbach *et al.* 2012; Huang *et al.* 2016).

The most popular barriers were related to each other and the stimuli. Positive associations between barriers were lack of alternative solutions and conflict with other product requirements (p=0.011, AR=2.5). Other associations were found in relation to lack of information on ecodesign and its benefits, which was negatively associated with lack of alternative solutions (p=0.024, AR=2.3) and conflict with other product requirements (p=0.015, AR=-2.4). Hence, companies without knowledge on ecodesign have rarely faced problems in relation to finding alternative solutions and harmonising the existing product requirements with ecodesign principles – they do not know what ecodesign means in general, what it would mean in their case and what solutions they would need to contribute to ecodesign.

Comparison of barriers and stimuli showed that there were both positive and negative associations. Conflict with other product requirements was positively related to both customer demand (p=0.041, AR=2.0) and legislation (p=0.039, AR=2.1). Based on these observations, companies that were driven by customer demand and legislation, which typically were large B2B companies who used an EMS as noted earlier, tended to see ecodesign as being in conflict with other product requirements. Both of these stimuli are considered external, wherefore it would seem that when a company is driven by external factors instead of internal ones they face more problems in harmonising different requirements. In terms of negative associations, only one relation was statistically significant. Lack of customer demand was found to be negatively associated with increase of product value (p=0.047, AR=-2.0). Hence, companies that are driven by a possible increase in the value of their products have less often had problems with customer demand.

4.4 Innovative targets and radicalness of innovations

The innovative targets of the textile and IT companies were studied by using multiple types of questions. In the questionnaire, the respondents were asked to choose if they had applied for patents, brought eco-labelled products to the market or taken into use new or improved products or manufacturing techniques during the last two years. These questions concerned product and process innovations. In addition, the respondents were asked to evaluate how well they fulfilled the 24 different claims on ecodesign and/or green innovation principles (Appendix 3) that had been identified based on the previous research literature (see Section 2.3.3 for more information and Figures 8–10 in this chapter). The claims mostly concerned product innovations, but also processes, marketing and institutional innovations. Marketing innovations were depicted by claims on informing customers and suppliers and packaging as well as items on ecolabels. Organisational innovations were covered in the questionnaire by questions concerning use of an environmental management system, ecodesign tools and activities for research and development related to environmental matters. The question concerning how the companies see the requirements of environmental legislation as a target level handled institutional innovations. As can be seen, many of the questionnaire items concerned products and processes as innovative targets, and therefore the interviews focused more on other targets (Appendix 5). This was done by adding three questions considering organisational innovations (Q3, Q4 and Q5), three on marketing innovations (Q10, Q11 and Q12) and two on institutional innovations (Q13 and Q14). In addition, the general question about how the company takes into account environmental matters allowed them to speak broadly about their focus points (Q1).

An overview of groups of claims based on their innovative targets showed that product innovations had the lowest mean value and institutional innovations the highest, but in terms of standard deviation the situation was the opposite (Table 18). Grouping was made by recoding the means of each claim into five classes where 1–1.49=1, 1.50–2.49=2, 2.5–3.49=3, 3.5–4.49=4, 4.5–5=5. The “do not know” responses were left out of the analysis as they would distort the calculations of mean values. It should be noted that institutional innovations were covered by only one claim and therefore the mean and standard deviation depict its value, which is not a suitable measure for an ordinal variable (Heikkilä 2014). However, by summing together several related claims, the result can be treated as an interval and thus means and standard deviations can be used as descriptive of a distribution for claims with a similar direction. Direction meant that all claims were considered positive if the respondent chose to agree. The means indicated that, in general, all the innovation targets were agreed with more often than disagreed with. The differences between the mean values were relatively small and did not address that one type of target would be neglected or favoured. The standard deviations indicated the same, although targets with higher means had slightly more divided responses. The statistical differences between target groups showed that companies that had R&D

activities related to environmental matters more often agreed with the process-related claims, whereas medium-sized companies disagreed more often with product claims. In addition, textile companies were more active in marketing innovations than IT companies. The results are described in more detail in the following sections.

Table 18. Innovative target groups of the questionnaire and interviews with a special focus on claims concerning the targets. Organisational innovations were not handled in the claims wherefore no descriptive statistics were calculated here.
[a] Preconditions for Pearson Chi-Square are not met.
[b] Not comparable because of the ordinal scale

	Questionnaire items	Number of interview questions	Mean of claims (scale 1–5)	Standard deviation of claims	Statistically significant differences in claims compared to background variables
Product	13 claims 12 ecolabel/patent 5 implementation/ creation	1	3.5	0.68	Medium-sized companies disagree more often (p=0.009[a], AR 3.2)
Process	6 claims 3 implementation/ creation	1	3.66	0.79	Those with R&D activities agree more often (p=0.001[a], AR=2.1)
Marketing	4 claims 12 ecolabel/patent	3	3.63	0.79	Textile companies agree more often (p=0.009[a], AR=2.0)
Organisational	0 claims 3 background questions and their 4 sub-questions 1 question on tools and its 6 sub-questions	3	-	-	-
Institutional	1 claim 1 background question	2	3.93[b]	1.2[b]	-

When compared with the most popular stimuli and barriers, a few differences were acknowledged. Respondents driven by legislation disagreed more often with process- ($p=0.010$) and marketing-related ($p=0.014$) claims. The observation of a negative association between process innovations and legislation supports the results of Horbach *et al.* (2012). Those who were determined because of general willingness and customer demand, on the other hand, were more likely to agree with the institutional claim ($p=0.012$, $p=0.033$), whereas companies stimulated by improving their company image agreed less with marketing innovations ($p=0.010$). Therefore, it seems that companies driven by internal stimuli are more likely to promote discussion and challenge the status quo, whereas companies driven by external stimuli, especially legislation, have process-related innovations less often. Instead, none of the most popular barriers was statistically significantly related to the grouped claims.

4.4.1 Product innovations focus on materials

Product innovations were covered in the questionnaire with the highest amount and most varied claims because they had been formulated according to the previous literature and aimed to cover different types of product innovations inclusively. Thus, many differences were also noticed during the analysis. Mechanisms from improvement to functional innovations were covered and were, in general, rated positively. However, a functional innovation of renting products instead of selling them was strongly opposed by more than half of the respondents. Mechanisms are discussed in detail in Section 4.5. The claims that were evaluated the most positively on a scale from totally disagree to totally agree were mostly related to materials, such as selecting materials whose production pollutes less emissions, producing the product with less materials or using recycled materials. The phenomenon was also acknowledged in the interviews, in which all the textile companies told that they focused on material choices, such as *"selecting the most environmental option*" (Company A), *"using materials that have at least been recycled or possibly classified as a textile waste"* (Company B) and *"using recycled materials"* (Company C). According to Roos *et al.* (2015), the majority of the environmental impacts of textile sectors are derived from materials, hence the respondents had been focusing on the appropriate issues. Notably, none of the IT companies mentioned materials during the interviews, although material production contributes greatly to the environmental impacts of IT products (Boks & Stevels 2007; Hischier *et al.* 2014).

In line with the results of Belmane *et al.* (2003), in Baltic industry, many companies consider reliability and durability of products essential. In this study, as many as 73% of the questionnaire respondents evaluated that they totally agreed with the claim. This share was exceptionally high. However, according to Belmane *et al.*, improving quality and longevity are not primarily done for environmental reasons. The interviewees also mentioned longevity as one of their process-related innovations. According to the interviewees, the life cycle is prolonged by focusing on *"design"* (Company A), *"quality, classic and fitting products … and testing materials to make sure they are comfortable and functional"* (Company C) and lastly "*reparability and modularity*" (Company E). In both sectors, the appearance of products is highly important and therefore it is relevant to design products that are timeless and reparable (Ahola *et al.* 2010; Sakao & Fargnoli 2010; A New Textiles Economy: Redesigning Fashion's Future 2017).

Looking at the "do not know" rates revealed that most of the product-related claims were fairly easy for the respondents as the shares were mainly under 6% (Figure 8). However, over 10% of the respondents chose the "do not know" option on three claims: "Our products use less energy in usage than usual", "We create different service-based business models instead of traditional supply of goods" and "Our products fulfil the various environmental criteria of a type 1 ecolabel (e.g. EU Ecolabel, Nordic Swan)". The last-mentioned had almost a third of the respondents selecting the "do not know" option. This indicates that a great share of companies were not familiar with ecolabels. The only statistically significant difference in relation to the claim was in accordance with the company size, as micro companies had a higher share of those who chose the "do not know" option (40%) than medium-sized companies (16%), but the medium-sized companies also disagreed more with the claim (p=0.012).

This observation of a low recognisability is partly supported by the responses in the question concerning patented, ecolabelled and energy labelled products that companies have applied for or brought to market during the last two years (Table 19). The question handled both direct and intermediate outputs of innovations. By looking at the background variables, Danish companies were the most active in responding to this voluntary question, as more than 82% of Danish respondents answered, whereas the other countries had response rates between 50% and 70%. Textile companies were more active in responding (69% vs. 47%) to the question, which is in line with the overall observations of this study that textile companies were more active respondents. These distributions reflect the recognisability among companies as well. The results are depicted in detail in Section 4.4.3 and Table 19. More than half of the given response options were valid for both textile and IT companies but some, for example the Öko-Tex and Energy Label, were sector-specific. The EU Energy label was indeed the only IT sector-specific label that was selected by more than four respondents. However, this observation is in contradiction with previous results that ecolabels are well-known among the Nordics, as was noticed in studies conducted by Valeur (2013), Kjeldsen *et al.* (2014) and YouGov (2015). The studies focused on consumers and recognising the label rather than its specific requirements, wherefore the results are not comparable. Still, they reflect a different level of awareness and knowledge of ecolabels.

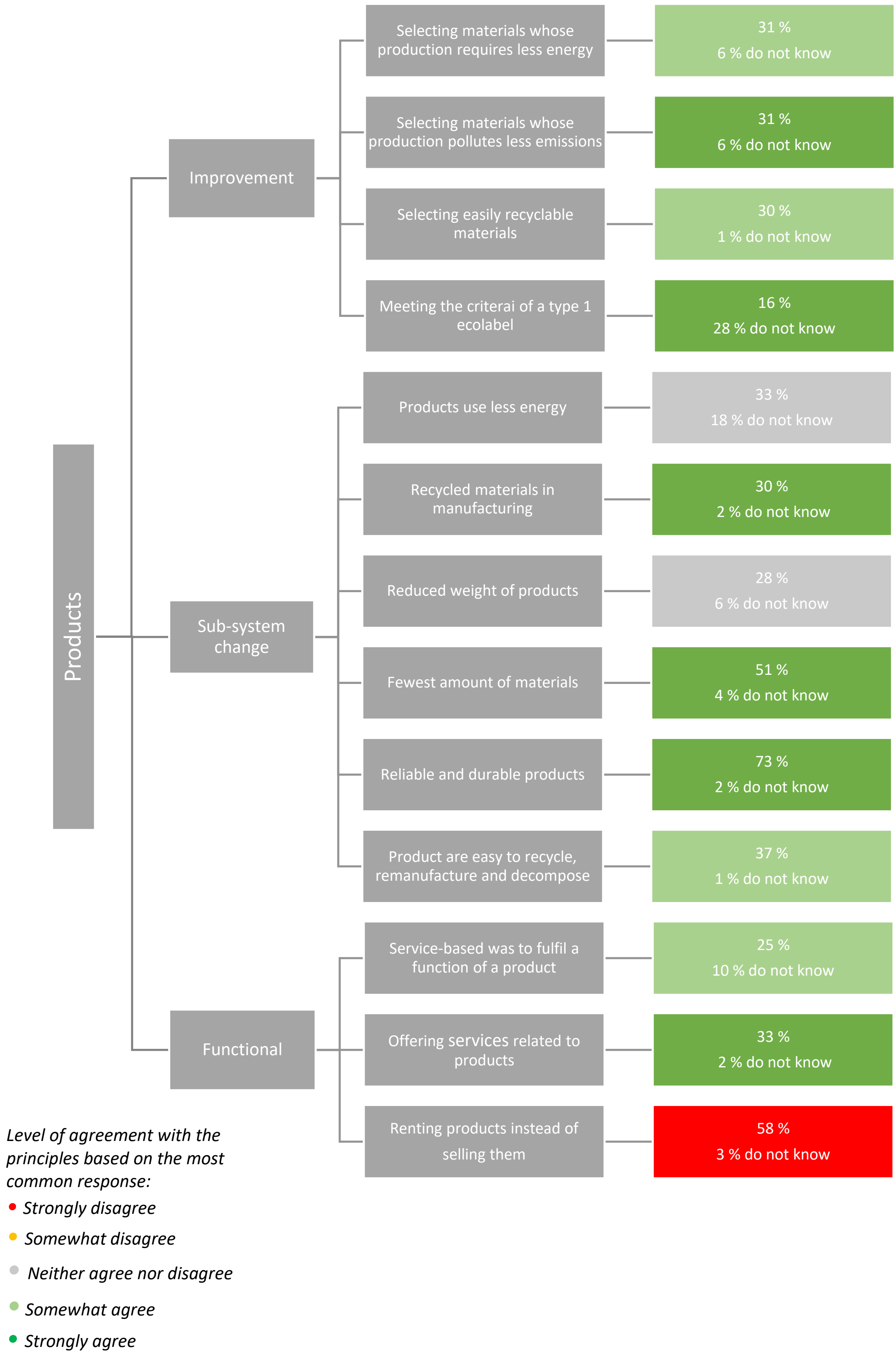

Figure 8. Product-related principles of ecodesign and green innovations classified based on their mechanisms. The most popular responses to the questionnaire and their 'do not know' shares.

Multiple differences were noticed between the respondents in relation to product innovations. The most varied claim was choosing materials whose production pollutes fewer emissions. This was more often agreed with by micro or small (Bonferroni-corrected p=0.012, p=0.030) textile companies (p=0.037) which did not use an EMS (p=0.003). In addition, many claims differed in terms of two variables. The selection of materials whose production required less energy was typically agreed with by small companies (p=0.048) and those who did not use an EMS (p=0.024). Based on the previous literature, energy consumption during use is the major contributor to the environmental impacts of the IT sector, wherefore it would have been expected that IT companies would be more active in affecting the energy use of their products (Boks & Stevels 2007; Hischier *et al.* 2014). Easily recyclable materials were most often agreed with by Finnish companies than Swedish ones (Bonferroni-corrected p=0.050) and micro companies (Bonferroni-corrected p=0.006). Respondents that agreed with the much-disagreed claim of renting products were mostly IT companies (p=0.002) and contacted by associations (p=0.039). Other claims had statistically significant differences only in relation to one background variable. The claim on easily recyclable, reusable and decomposable products was most often agreed with by micro companies (p=0.012), whereas large companies offered services more than small companies (Bonferroni-corrected p=0.018). Still, most of the claims were not statistically related to any of the background variables. It was quite unexpected to notice that none of the product-related claims was statistically related to R&D activities, although product development is one of its key aims. Based on these observations, the product-related claims were more often agreed with by smaller companies which did not use an EMS, which are also related to each other as noted earlier. Contrary to the findings of Chen *et al.* (2006), the IT sector was not found to be focused more on green product innovations than textile companies.

The types of product innovations varied quite a bit. The shares of radical and incremental product innovations were shown to be similar as 51% of the respondents stated that they had developed new products with environmental improvements compared to alternative products during the last two years and 55% had improved or switched materials or components of products in order to reduce environmental impacts (N=67). Based on the previous literature, incremental product innovations were expected to be much more common than radical innovations in the IT and textile sectors (e.g. Tukker *et al.* 2001; Verganti 2009: 46; Li *et al.* 2016), as radical innovations are considered to have strong barriers and involve systemic innovations as they lead to changes in the way the system operates (Fagerberg 2005; Carrillo-Hermosilla *et al.* 2010; Gault 2018). The nature of these radical product innovations and their actual radicalness, however, cannot be evaluated as the respondents were not asked to describe their innovations. As was noted by Bunnell & Coe (2001), Oslo Manual (2005) and Huang *et al.* (2016) among others, R&D activities are related to new product innovations especially in high-technology sectors such as IT, although Verganti (2009: 4) reminded that radical innovations are not considered a subject of R&D. In this study, the association was almost statistically significantly (p=0.062, AR=1.9). In terms of other background variables, notably, only a third of Finnish respondents had undertaken product redesign changes in comparison to the shares of more than 50% of other respondents (AR=-2.2). In addition, only 9% had implemented a product that had been developed outside the company.

4.4.2 Process innovations

Process innovations were the second most frequently measured target type in the questionnaire after products. All the process-related claims were, in general, evaluated neutrally or positively (Figure 9). The most strongly agreed-with claim concerned the reduction of hazardous substances in the manufacturing process. In line with the findings of Belmane *et al.* (2003), it can be concluded that replacing hazardous substances has been popular in both Baltic and Nordic countries for almost two decades. Surprisingly, almost none of the background variables were statistically significantly associated with the process-related claims. Thus, process innovations seem to be well-shared among companies despite their differences. To prove the point, only R&D activities were found to be statistically related to the claims, namely handling of waste and renewable energy. Respondents who had R&D activities related to environmental matters were much more likely to strongly agree with claims concerning handling the waste coming from their manufacturing process to enable its better utilisation (p=0.007) and the usage of renewable energy (p=0.026).

The 'do not know' rates were fairly similar in all process-related claims, varying by only two percentage points. Still, the rate is relatively large, as a majority of the product-related claims had a corresponding rate of less than 6%. Thus, it seems that issues related to the manufacturing processes are hard to perceive for the respondents and probably the responding person was not as familiar with their manufacturing processes as they were with their products or marketing. Remarkably, there were no significant differences between companies that designed, manufactured or did both, although it was expected that manufacturing companies would more rarely choose the 'do not know' option because manufacturing processes were their main function.

It is notable that all of the claims used to depict process innovations had sub-system changes as their mechanism. This is somewhat natural because the processes are a part of the system, namely a sub-system that process innovations change. According to Carrillo-Hermosilla *et al.* (2010), component-level changes, namely improvement mechanisms, do not necessarily change the process or system that generates the impacts in the first place. Therefore, improvements, such as adding a filter to a factory, were not specifically treated in this study. The focus was on approaches that aim at doing more with less in an eco-efficient way rather than on component changes. However, improvements and system-level innovations on processes should have been included in the study from the beginning. The issue was handled in the interviews, in which the interviewees were given the freedom to express their viewpoints. Still, the responses were on a quite general level, not indicating specific improvements to the manufacturing process, for example "*using European manufacturers*" (Company F) and "*reducing the amount of cutting waste*" (Company A). In comparison, the product-related comments by the interviewees were very specific about certain material choices or added components, such as *"reusing jean zippers"* (Company B). Thus, it seems that the improvement-type process innovations were less important for the companies, even acknowledging the insufficiency of questionnaire items.

A few respondents had created new manufacturing techniques, improved an old technique or implemented a technique that had been created elsewhere. The shares differed between 15% and 25%, indicating relatively small variations and low shares compared to product-related innovations of a similar kind that had been performed by 9% to 55% of the respondents (N=67). The most popular type of process innovation was improving an old manufacturing technique, which had been done by 25% of respondents, most often by Danish companies (AR=2.3) and those with R&D activities (p=0.008, AR=2.7). Norwegian companies were significantly more active in creating new manufacturing techniques that counted as radical, system innovations (AR=2.7). The analysis of the relationships between product- and process-related innovations implicated that new product innovations are associated with new process innovations and implementing of existing process innovations (p=0.014, AR=2.5; p=0.024, AR=2.4). However, the process-related responses were not related to each other. Based on these observations, the same respondents tend to do both product and process innovations, especially creating new-to-the-world innovations.

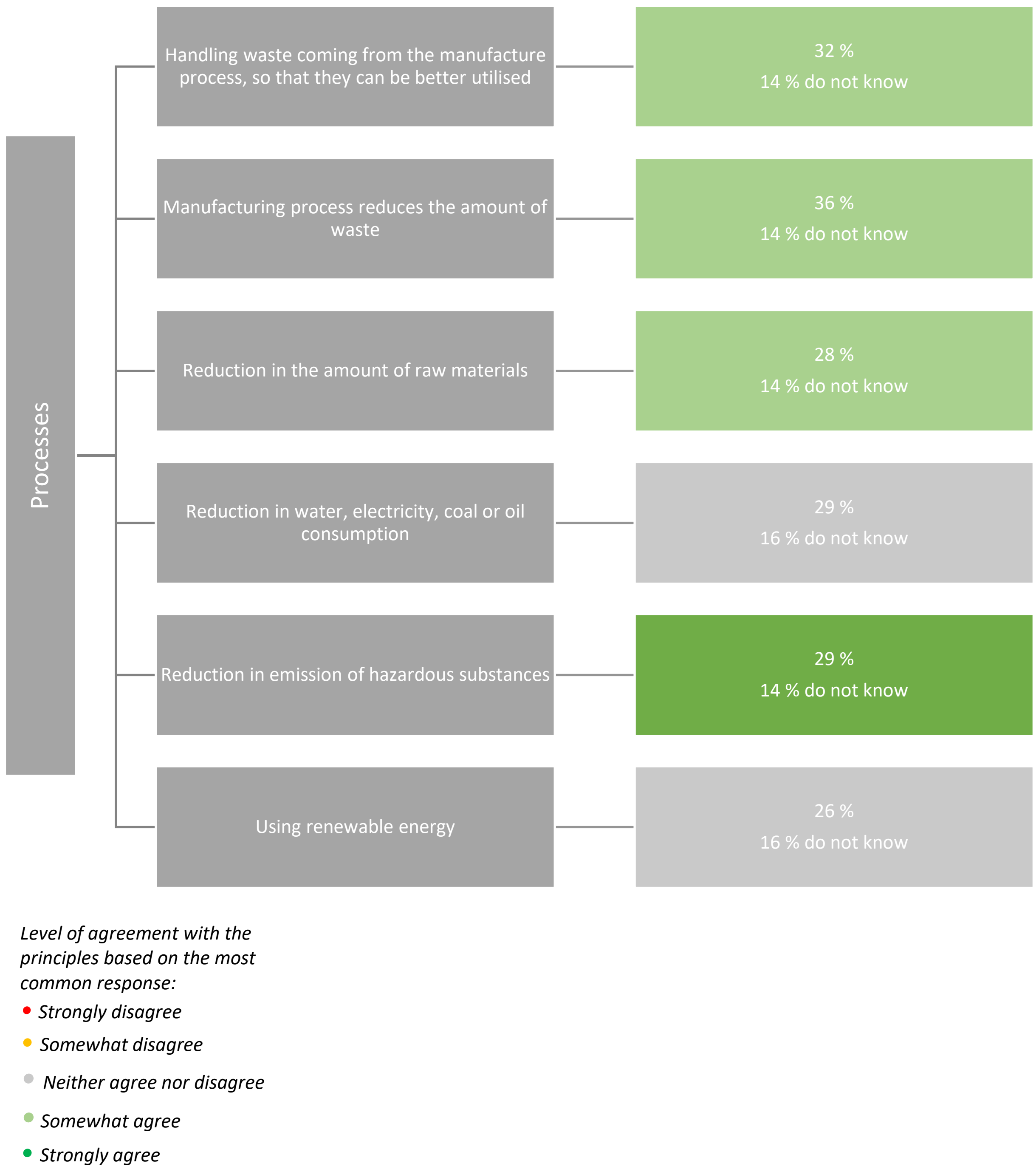

Figure 9. Product-related principles of ecodesign and green innovations classified are all related to sub-system change because the process itself is considered as a sub-system. The most popular responses of the questionnaire and their do not know shares are shown.

4.4.3 Marketing innovations

Marketing innovations were agreed with by the respondents on a general level, but there were evident differences between and within the claims (Figure 10). The questionnaire claim on reducing the amount of packaging materials was somewhat agreed with by one-third of the respondents and no background variable was associated with it. Based on the results of Belmane *et al.* (2003), packaging materials were expected to be more agreed with than they ended up being. In addition, companies A and C mentioned that they had made changes in their packaging to reduce the environmental burden. Company A said that they *"no longer use plastic bags as a packaging material and have begun to use bags made of sugarcane. We aim to challenge the customer to think that products do not need to be single packed."* Based on these observations, norms about the need for packages are beginning to change. Company C had also *"avoided using packages … and began to use durable bags made of fabric"*. Thus, among the interviewees, only textile companies mentioned more sustainable packaging as one of their actions.

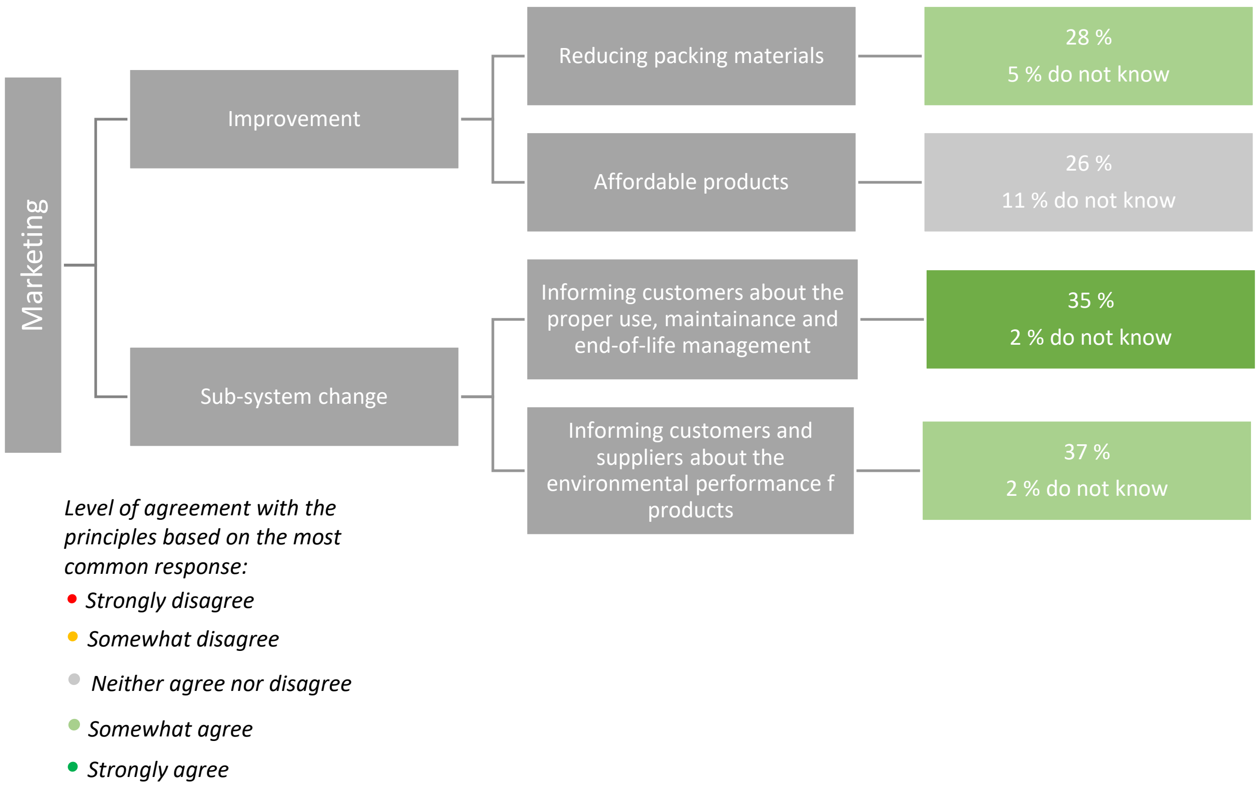

Figure 10. Marketing-related principles of ecodesign and green innovations classified according to their mechanisms. The most popular responses of the questionnaire and their do not know shares together with the responses of the interviews are also shown.

The other marketing-related claims, however, differed in relation to several background variables. The affordability of products was found to be more disagreed with in Finnish and Norwegian companies compared to Swedish ones (Bonferroni-corrected p=0.010, <0.001), non-EMS-users (p=0.010) and those contacted directly (p=0.005). In addition, companies whose end-product was sold to public organisations less often disagreed with the claim than B2B or B2C companies (p=0.003). Based on these observations, it could be claimed that Swedish textile and IT products are perceived as relatively affordable. The same applies for companies that were less organised internally and externally, as they did not use an EMS to handle their in-house environmental matters or belong to an association, most likely.

Addressing customer needs and making customers better aware of the differences in the environmental performance of products are vital characteristics of successful green innovations (Arundel & Kemp 2009). According to Gouvinhas *et al.* (2016), more mature companies educate their customers and suppliers towards a socially and environmentally conscious value chain. Those companies also integrate the demands into their own marketing. Marketing innovation claims related to providing information to customers and suppliers were more often agreed with by textile companies ($p=0.003$ and $p<0.001$), companies headquartered in Denmark ($p=0.006$ and 0.023) and those with R&D activities ($p<0.001$ and $p=0.002$). In relation to other variables, informing about the environmental performance was agreed with more by those whose end-products were sold to public organisations ($p=0.001$). All the interviewees informed their customers and stakeholders regardless of their sector, size or R&D activities. Companies A, C and D informed consumers specifically about the product by stating *"all the environmental matters related to the product, its electricity consumption, material content and instructions to recycle the product"* (Company D), *"about features of the fabric"* (Company C) and *"all the ecological messages that the product has"* (Company A). Informing customers about proper use, maintenance and end-of-life management was positively associated with micro and large companies (Bonferroni-corrected $p=0.040$ and $p=0.030$) and non-EMS users ($p=0.011$). Some interviewees also provided information on how to take care of the product by, for example, *"creating instructions for the user based on our tests"* (Company C). A few interviewees also informed their customers about the manufacturing process, for example, by *"providing a QR code that tells the whole life cycle of the product: Where fabric has come from, where it has been manufactured, where the accessory is from, where the product has been made and what route it has been transported"* (Company A). It seems that companies that had undertaken environmental product development were also enthusiastic about informing about them and helping consumers take care of their products to prolong their life cycles. This observation supports the results of Gouvinhas *et al.* (2016)

Meeting the criteria of an ecolabel is also a marketing method for which a company must improve or redesign its products and processes (Kjeldsen 2014; Calik & Badurdeen 2016). An ecolabel attached to the product addresses its environmental friendliness and superiority in the case of the EU Ecolabel and the Nordic Swan, for example. They also count as innovation outputs according to Calik and Badurdeen (2016). However, only four out of 65 respondents to the voluntary question had Nordic Swan ecolabelled products and nine had EU ecolabelled products (Table 19). In terms of other outputs, many differences were noticed. Most considerably, larger companies tended to have more patents and EU Energy labelled products. Another observation was that Danish IT companies were much more active in having EU Energy labelled products. It is notable that both of these observations are related to the IT sector, wherefore it seems that large IT companies in particular have more patents and EU Energy labels than smaller companies. The same size difference does not apply to the textile sector, as small textile companies were more likely to have GOTS certified products and medium-sized ones to have Öko-Tex 100 labelled products. In addition, Finnish textile companies had significantly more GOTS certified products, whereas Swedish ones had relatively fewer of those in relation to the other Nordics. Another interesting observation was that internationally operating companies were less likely to have Öko-Tex 100 labelled products than European companies and those operating in Europe and some other continent were the most likely to have GOTS.

Table 19. Marketing-related product innovation outputs with a response rate of more than 10% of the respondents (N=65). Note: There were no Icelandic textile respondents and therefore the textile sector-specific labels only have four country classes.
* Statistically significant difference (p<0.05) ** Statistically very significant difference (p<0.001)
[a] Preconditions for Pearson Chi-Square are not met.

		Total	Sectors (Textile/IT)	Countries (DEN/FIN/ NOR/SWE/ISL)	Size (Micro/Small/ Medium/Large)	Market (National/Europe/ Europe+/Worldwide)
Patents	Frequency	12	5/7	1/4/0/6/1	2/0/3/7	3/4/0/5
	AR		-3.2/3.2 **	-1.2/0.1/-1.0/0.9/2.1[a]	-0.5/-2.4/-0.2/3.2[a]	-0.6/0.2/-1.6/1.9[a]
EU Ecolabel	Frequency	9	6/3	3/1/1/4/0	0/1/4/4	1/4/0/4
	AR		-0.8/0.8	0.9/-1.5/0.7/0.4/-0.4[a]	-1.7/-1.2/2.2/1.6[a]	-1.5/1.0/-1.4/1.8[a]
Company's own environmental declaration	Frequency	18	18/0	4/5/3/6/0	6/6/3/3	6/4/5/3
	AR		1.5/-1.5	-0.9/-0.3/0.2/1.8/-0.4[a]	1.1/0.1/-1.2/0.0[a]	-0.3/-1.3/1.8/0.2[a]
Öko-Tex 100	Frequency	20	Only textile	4/9/0/7	1/8/9/2	7/10/3/0
	AR			-0.3/1.6/-1.7/-0.4[a]	-2.6/0.7/2.2/-0.7[a]	-0.4/2.2/-0.2/-2.3[a]
Global Organic Cotton Standard (GOTS)	Frequency	20	Only textile	5/11/0/4	3/12/3/2	5/8/6/1
	AR			0.4/2.8/-1.7/-2.1[a]	-1.2/3.2/-1.7/-0.7[a]	-1.5/1.0/2.2/-1.5[a]
Fair Trade	Frequency	5	Only textile	1/2/0/2	2/2/1/0	0/2/1/2
	AR			-0.1/0.4/-0.7/0.1[a]	0.9/0.3/-0.4/-1.0[a]	-1.8/0.4/0.3/1.8[a]
EU Energy Label	Frequency	5	Only IT	3/1/0/1/0	0/0/1/4	1/0/1/3
	AR			4.2/-0.9/-0.4/-1.0/-0.8[a]	-1.2/-0.9/-0.4/2.0[a]	-0.6/-1.2/0.9/1.0[a]

4.4.4 Organisational innovations

Organisational innovations, namely EMS and R&D activities, were found to be significantly related to many claims and other questionnaire items, as has been briefly noticed in the previous sections.

Almost half of the respondents used an environmental management system (EMS) (45%) and only one of the interviewees used one. This was clearly divided in the questionnaire among the sectors, as IT companies were more likely to use an EMS (69%) than textile companies (39%). The difference was statistically very significant (p=0.001). The users were also bigger companies on a statistically very significant level, with

81% of large companies and 9% of micro companies using EMS ($p<0.001$). Moreover, the interviewee using EMS was a large, international company (company D). There was also a statistically significant difference between contact methods, as 57% of the respondents contacted by the industrial associations used an EMS ($p=0.017$). This difference might be related to the fact that they were a part of the environmental group of the industrial association and were thus more conscious about the formalities of environmental issues (Arundel & Kemp 2009; Boons *et al.* 2013). Another formal type would be R&D expenditures, but those were not found to be related to the contact method in this study. Almost all of the respondents stated that they used ISO14001 instead of EMS. In addition, five respondents stated that they used another type of EMS, such as ecolabels or product certificates.

Environmental management tools were found to be important for introducing green product innovations by Horbach in a German context (2008). These tools include both EMS and ecodesign tools that are used to assess the environmental impacts of products and their life cycle. Wagner (2007) stated that the implementation of EMS is associated with the probability of pursuing green innovations, and according to Barbieri *et al.* (2016), EMS stimulates green innovations that alter production processes rather than products. However, in this study, no statistically significant relations were noticed between the use of an EMS and process innovations or product innovations such as patents, ecolabels, development of new products or processes, improving existing ones or implementing new one. In addition, EMS users disagreed more often with the product-related claims as noted in Section 4.4.1. The use of ecodesign tools was found to be greatly relevant for many types of innovations, especially those related to processes and marketing. These results are shown in Section 4.6.

Another type of organisational innovation is research and development (R&D) activity, which measures the engagement of companies in innovation activities (Smith 2005; Marin *et al.* 2015). A little less than 40% of the questionnaire respondents had activities for R&D specifically related to environmental matters. There were no statistically significant differences in relation to background variables. This finding is the opposite of the Oslo Manual (2005: 71) which says that R&D activities are not widely performed by small- and medium-sized companies, wherefore they were expected to have a relatively lower share of R&D activities. Respondents who answered that they had R&D activities related to environmental matters were further asked how many of their employees took part in it and, if they had a specific budget for that, what percentage of the budget was allocated to it. The responses varied widely from 1 to over 100 employees. A majority (78%) of the respondents with R&D activities related to environmental matters did not have a specific budget. Four respondents gave the allocated percentages, which varied from "very small" to 50%. In the interviews it was noted that many of the companies did not do in-house R&D activities, but rather took part in research projects led by research institutes and universities (Companies A, D, E and F). This was especially convenient for smaller companies with fewer resources: *"As a small company we cannot do research on our own and our development activities are in a quite small scale. It is most reasonable to combine efforts."* (Company A). Participating in research projects was found as an easy option for smaller companies to develop their skills as well as products, processes and the organisation, market themselves and promote discussion on an institutional level. In fact, only company D had its own R&D activities.

Companies that had environmentally related R&D activities more often agreed on process, marketing and institutional innovations (AR=2.2, 1.8 and 2.7). This applied especially to the processing of waste coming from their manufacturing processes ($p=0.007$), usage of renewable energy ($p=0.026$), informing about the environmental performance of products ($p<0.001$) and how to prolong the life cycle of their products (p=0.002), as well promoting discussion and challenge the status quo surrounding existing products, materials or processes (p=0.023). Arundel and Kemp (2009) proposed that R&D cannot cover non-technological innovations, such as marketing and institutional innovations, but based on the results of this study, there is a significant connection between R&D and non-technological green innovations. Companies with R&D activities also made more improvements to existing manufacturing techniques to make them more environmentally friendly (p=0.008). In addition, companies with R&D activities were more likely to have their own environmental declaration (p=0.016) or other than a given ecolabel (p=0.027). Thus, it could be stated that R&D activities related to environmental matters are extremely important for all types of green innovations, although they have previously been acknowledged to be important only in relation to technological innovations (e.g. Oslo Manual 2005; Arundel & Kemp 2009).

4.4.5 Institutional innovations

Institutional innovations were measured in the questionnaire by asking how the respondents saw environmental legislation and how they evaluated their participation in public discussions to challenge the status quo (Carrillo-Hermosilla *et al.* 2010; Promoting Better Environmental… 2016). The interviewees were asked about participating in discussions but also about informing customers about sustainable lifestyles to see if the companies were working towards changing the norms and values of society (Arundel & Kemp 2009; Carrillo-Hermosilla *et al.* 2010). Furthermore, renewed cooperation with stakeholders in several R&D projects or in public-private collaboration can be seen as institutional innovations.

Almost half (46%) of the respondents aimed to exceed the legislative requirements on environmental matters. This observation reflects that respondents were fairly environmentally oriented to begin with and had passed the preliminary, immature levels of sustainability integration (Hallstedt *et al.* 2010; Gouvinhas *et al.* 2016). The second biggest respondent group represented those who complied with the requirements but did not aim to exceed them (36%), which reflects a compliance level of maturity. A minority of the respondents complied with the requirements but they were not their priority (17%). In addition, one micro company felt that the requirements were oversized, indicating that it was on the pre-compliance level of maturity. No statistically significant differences in relation to background variables were noticed.

Institutional innovations of participating in public discussions to change the status quo were supported by many questionnaire respondents and all the interviewees. The claim on participating in discussions to change the status quo was strongly agreed with by 37% of the respondents. Only one significant difference between respondent groups was acknowledged. This was in terms of R&D activities (p=0.023) as more than half of the respondents who had R&D activities agreed strongly with the claim compared with 25% of those without R&D. Interviewees stated that participating in public discussions was an essential part of the business to promote change in consumption and production patterns, as their business idea was to act sustainably and differently compared to prevailing customs. Thus, the reasons included "*affecting the stereotypes*" (Company F), "*showing what we are interested in and what we want to communicate about*" (Company C) and "*because it is business-wise important to be seen"* (Company F). The interviewees participated in many different ways, including participating in workshops, seminars, research projects and social media. Many of them also gave their own lectures and consultation (Companies A, B, D and E). Hence, active participation was a central part of the companies' operations and they profited from it either directly or indirectly. Companies acting this way are perceived to be mature in the environmental sense as they educated their value chain on both the supplier and customer sides and thus were creating new behaviour. However, many interviewees felt unable to tell customers how they should consume and live in general, but they could educate them by showing a good example: *"It comes over in our actions but we do not have a specific agenda"* (Company E).

R&D activities have been observed to be important for all types of green innovations, especially process, marketing and institutional innovations, as noted earlier. R&D activities are, however, themselves an institutional innovation if they take place by changing the way companies cooperate with each other and the public to promote changes in norms and values (Carrillo-Hermosilla *et al.* 2010). For example, Company B stated that it was important for them to participate in a governmental working group, in which the respondent felt that *"I am in an organ that is being heard and has been created to give authentic information from the working life and companies to larger organisations"*. In this way, companies can provide for the 'common good'.

4.5 Mechanisms

Differentiating between mechanisms proved to be quite a challenging task in this study. Claims and other questionnaire items were categorised into different mechanism classes but some adjustments had to be made later during the process as false categorisation was acknowledged. The difference between improvements and sub-system changes was particularly troublesome, as the difference between them can be minor and the actual effect of whether a change of component, i.e. improvement, results in changes in the manufacturing process or not is hard to distinguish. In addition, measuring system-level changes is hard to depict, especially in a questionnaire (Arundel & Kemp 2009). Thus, the questionnaire items on different mechanisms were somewhat unbalanced and the majority represented sub-system change (Table 19). The interviews aimed to compensate for the uncertainty and analyse the mechanism mentioned by the interviewees.

An overview of groups of claims based on their innovative mechanisms showed that sub-system innovations were evaluated with the highest mean and lowest standard deviation (Table 20). The grouping of mechanism-related claims was made similarly with the recoding of target-related questionnaire items in Section 4.4. At the same time, improvement-related claims had no statistically significant differences in relation to the background variables, whereas functional and sub-system innovations had several. Background variables that strengthened the agreement on sub-system innovations were 'Danish' and 'R&D activities related to environmental matters'. Functional innovations, on the other hand, had the lowest mean of the mechanisms, indicating that they were more often disagreed with. In addition, the standard deviation was the highest for functional claims. EMS users especially disagreed with the functional claims, whereas IT companies were more likely to agree with them.

Table 20. Innovative mechanism groups of the questionnaire with a special focus on claims concerning mechanisms. System innovations were not handled in the claims wherefore no descriptive statistics were calculated here.
[a] Preconditions for Pearson Chi-Square are not met.
[b] Not comparable because of the ordinal scale

	Questionnaire items	Mean of claims (scale 1–5)	Standard deviation of claims	Statistically significant differences in claims compared to background variables
Improvement	6 claims 2 implementation/ creation	3.59	0.80	No differences
Sub-system change	16 claims 3 implementation/ creation	3.70	0.67	Danish companies and those with R&D activities agreed more often (AR=2.7 and AR 2.7)
Functional	3 claims 1 implementation/ creation	3.00	1.03	IT companies strongly agree more often (AR=2.2). EMS users disagree more often (AR=2.0)
System	2 implementation/ creation	-	-	-

Improvements were quite evenly agreed with by the questionnaire respondents, although some differences were noticed. Most of the significant differences were in relation to material choices in terms of company size and use of EMS. The interviewees mentioned that they had made improvements such as *"minimised the amount of components that complicate recyclability like leaving out the zippers"* (Company A), "*selecting materials likes lyocell and recycled fabrics"* (Company C) and *"using specific cables and accumulators"* (Company D). Here the system remained the same, although the component-level changes did lead to reduced environmental impact (Brezet & Rocha 2001: 247; Carrillo-Hermosilla *et al.* 2010; Sarasini *et al.* 2014). In the questionnaire, smaller companies were more likely to agree with the improvement-related claims concerning the selection of materials whose production requires less energy (p=0.012), pollute fewer emissions (p=0.002) and are recyclable (p<0.001). On the other hand, respondents who used an EMS disagreed more often with the two above-mentioned claims (p=0.024 and 0.003) but agreed more often with the claim on the affordability of their products (p=0.010). Improvements such as the above-mentioned material choices can primarily be expected to optimise existing products and processes (Carrillo-Hermosilla *et al.* 2010). Other differences were that less energy-consuming materials were most often selected by textile companies (p=0.037). The multiple differences related to the affordability of products have been described in Section 4.4.3. In the two other questionnaire items about improvements, Icelandic companies were found to be more active in improving their products incrementally (AR=2.6) and Danish companies on improving processes (AR=2.3). In addition, R&D activities were positively related to process improvements (p=0.008).

In moving towards a closed-loop system such as the circular economy, performing eco-efficient actions is crucial (Carrillo-Hermosilla *et al.* 2010). Hence, sub-system innovations are perceived to be of high importance and they were the most inclusively described innovation mechanism in the questionnaire. Respondents, however, saw different sub-systemic changes in very different ways. The evaluations of claims differed from those agreed with strongly by 63% of the respondents (claim on reliable and durable products) to many claims that were neither agreed nor disagreed with by one-third of respondents. Many significant differences were acknowledged but no single variable was found to be related to several sub-system claims. Then again, concerning the redesign of products and processes, Finnish companies were found to do less product-related redesign (AR=-2.2) which was the only statistically significant difference concerning sub-system innovations. The interviewees had also done many type of sub-system changes, for example, "*designing a modular product with each module acting as a product itself*" (Company E), "*using intelligent software to shut down operations to reduce energy consumption when operations are not needed*" (Company D) and "*minimised the need for transportation*" (Company A). Thus, it seems that sub-system innovations were being quite well addressed within companies in general due to the highest mean value and lowest standard deviation compared to other target types. However, this is a varied group of innovations which might reflect that many companies are still facing problems conducting them.

Although almost two decades have passed since the research of Tukker *et al.* (2001), the lack of functional innovations seems to remain a notable shortage. In this study, only 11% of respondents had replaced products with services (N=67), 58% strongly disagreed with the claim on renting products (N=104) and only a third offered services related to their products. Disagreeing with the functional claims was associated with barriers related to time shortage (p=0.006) and ecodesign being in conflict with other product requirements (p=0.025). Based on the literature, the lack of functional innovations can be attributable to the scarcity of interplay between many sectors within a company and its stakeholders and the absence of long-term strategies (Tukker *et al.* 2001, 2006). In the interviews, however, one of the forerunner companies had evolved around an idea of offering services that reduce the need for resources and thus could be portrayed as offering result-oriented services (Company F). In addition, four other interviewees admitted having additional services, which they described, for example, as *"maintenance and repair"* (Company B), *"helping our partners to find solutions for their own problems related to circular economy"* (Company A) and, lastly, *"when the product is used for the last time and you don't do anything with it, then we offer a take-back programme"* (Company E). Only one interviewee said that including services was on their strategy at the moment but they did not yet offer any services. These examples showcase that services are a relevant part of the operations of environmentally mature companies, and their strategy and services involve multiple actors.

System innovations are completely new ways of acting, whether in a shape of a new product, process organisation or institution (Brezet & Rocha 2001; Sustainable Manufacturing and Eco-Innovation… 2009; Carrillo-Hermosilla *et al.* 2010). In addition, Arundel and Kemp (2009) stated that system innovations are the most difficult type of innovation to measure. In this study, system innovations were covered by two questionnaire items concerning the creation of new products and processes. Surprisingly, these radical, system innovations related to products and processes had relatively high rates among other type of innovations with the same targets, namely 51% and 14% (N=67). Here, new product innovations were much more popular than new process innovations. No statistically significant differences in relation to new product innovations were observed but in the case of processes, large companies were much more likely to create new process innovations (AR=2.1). System innovations can also be measured as establishing a company on an idea that the current status quo of the sector is not sustainable (Companies B and E) (Sustainable Manufacturing and Eco-Innovation… 2009). One of them discussed the sorrowful reality of a waste treatment plant with huge amounts of usable material and another about the unprofitable repair of a used product which could have had a lot longer life cycle but had to be thrown away because of a repairable malfunction. In addition, as mentioned earlier, company F was established as a result-oriented service company. These findings suggests that even though system innovations are hard to make and even harder to get to market (Konar & Cohen 2001; van Hemel & Cramer 2002; Chen *et al.* 2006; Carrillo-Hermosilla *et al.* 2010), those who succeed are more likely to provide for a larger societal change (Boons *et al.* 2013).

4.6 Ecodesign tools promote almost all kinds of innovations

Ecodesign tools were used by 27% of the questionnaire respondents (N=104) and four out of six interviewees. In addition, three respondents had made plans for using a tool. Still, 70% of the questionnaire respondents did not use tools and 16% were not even interested in or concerned about ecodesign tools. A majority, nonetheless, were interested in using a tool but had not taken action (54%). No significant differences were seen, however, among the interested respondents. It was somewhat unexpected to notice that none of the tool category was statistically associated with sector, size or using EMS, which were found important for stimuli, barriers, targets and mechanisms. This observation was supported by the interviews, because both textile and IT companies varying from micro to large used ecodesign tools (Companies B, D, E and F), although they mainly represented the IT sector. However, only two interviewees specified that they had used well-established tools, namely LCA and MIPS. In addition, all of the tool-using interviewees used in-house tools such as their own Excel sheets, documents and criteria.

According to Boks and Stevels (2007), practices and needs for tools relate to the maturity level of environmental awareness within companies. They stated that most developed companies use and need more advanced tools. The results of this study comply with Boks and Stevels, as using a tool was associated with more positive evaluations on different innovation claims and other questionnaire items, as noted earlier in this chapter. Tool users were most often Danish companies, as 53% of Danish respondents used an ecodesign tool, followed by Swedish (35%), Finnish and Norwegian companies (14%) (p=0.020). Companies with a larger market area were more likely to use ecodesign tools than smaller companies (p=0.021). To support this observation, 42% of worldwide companies and 33% of European companies used a tool, whereas 21% of nationally operating respondents used one. Respondents which operated in Europe and some other continent were, however, an exception to this pattern, as only 8% of them used a tool.

In total, 64 tools were used by 28 respondents, meaning that most of the users applied several tools at the same time. Tools have, in general, been used for 10–20 years and by groups of employees or a single employee. Only one respondent with a type I ecolabel stated that their tool had been used by a consultant. Benefits of the tools included suitability for communication (36%) and being detailed (32%) and extensive (32%). Thus, it seems that companies look for tools that offer a vast amount of quite specific information that can be used for communication purposes, which has also been noticed by Le Pochat *et al.* (2007), Bey *et al.* (2013) and Dekoninck *et al.* (2016). However, combining all the desirable characteristics into one tool is almost impossible and therefore multiple tools with different purposes could be used to supplement each other (Le Pochat *et al.* 2007, Rousseaux *et al.* 2016). The least popular benefit was being quick to apply (4%). On the other hand, all tools were associated with disadvantages that mainly related to the requirement of a lot of data (36%) and environmental expertise (32%). Many disadvantages were selected by none of the respondents. There was lack of clarity on when to use a tool, and the tool being not detailed and extensive enough. The respondents somewhat felt that ecodesign tools have high implementation and certification costs (43%), and take a long time to apply (29%). It was also felt that it was hard to find a proper technical alternative to replace the current material/product (24%) (N=21). At the same time, seven respondents (33%) had no problems in using an ecodesign tool. All of the respondents with no problems were textile companies.

The used tools were mainly type I ecolabels, LCA and carbon footprint assessment (43%, 25% and 25%) (N=28). Other tools were used by 0 to 4 respondents. Notably, all of them were environmental assessment tools, not improvement tools (Bovea & Pérez-Belis 2012; Vallet *et al.* 2012). Type I ecolabels, such as the Nordic Swan Ecolabel or the EU Ecolabel, were used by ten textile companies (48% of textile respondents) and two IT companies (29% of IT respondents). They were especially evaluated to be suitable for communication (58%) but to demand expertise, time and a lot of data (58%, 50% and 50%). LCA, on the other hand, was used by four Danish companies (44% of Danish respondents) and mostly by IT (58% of IT respondents) rather than textile companies (14% of textile respondents). In addition, company D stated they had been using LCA. LCA was seen as a detailed and systematic tool (71% each) that supported product development (43%). However, it requires a lot of data according to 43% of respondents. Carbon footprint again was used quite evenly in relation to the background variables. It was described as a detailed and systematic tool (57% and 43%) that demanded a lot of expertise (71%), time and money and was also hard to use (all with 43%). Company B had been using MIPS but they stated, *"it is an excellent tool for marketing and communications but not for supporting design processes".* In addition, 14 respondents stated that they used a tool that had not been listed. These included the ecolabels Öko-Tex 100 and GOTS, EU regulation for chemicals REACH, companies' own certifications and their own checklists. Two respondents said that they did not know what tools they applied.

Respondents who were uninterested in using tools complied with the results of Boks and Stevels (2007) and their first maturity level of environmental awareness. The first level concerns companies who are ignorant of environmental concerns and need generic solutions and knowledge rather than specific assessment tools. Those who were not interested in using ecodesign tools were most often Finnish (26%) or Norwegian (29%). The difference was statistically significant between Finnish and Danish (p=0.003) as well as Finnish and Swedish companies (p=0.016), indicating that companies headquartered in Sweden or Denmark were much more likely to use tools than Finnish companies, which opposed tools relatively more often. Otherwise, no statistically significant relations were noticed.

The results in relation to ecodesign tools supported Horbach's (2008) results. The users of tools agreed more often with the grouped product-related claims on a statistically significant level (p=0.003), but the preconditions for Pearson's Chi-Square test were not met. The relation was strong, especially in claims concerning fulfilling the requirements of type I ecolabels (p=0.017, AR=3.5) and that their products use less energy than usual (p=0.017, AR=2.6). The phenomenon was notable in also other claims, although the difference was not statistically significant based on Pearson's Chi-Square test. However, the adjusted residuals were over two and exceeded the significant level. The claim on using recycled materials was more often agreed with by tool users (AR=2.1), whereas the users disagreed less often with the claim of manufacturing products that are easy to recycle, reuse and decompose (AR=-2.7) and their products being affordable (AR=-3.1). Those respondents who were not interested in using a tool disagreed more with the claim on renting products (AR=2.6). Thus, it seemed that those who used an ecodesign tool felt that their products used less energy, were made of recycled materials and were recyclable and affordable, in addition to meeting the ecolabel requirements. The differences were significant in relation to those who were still planning to implement a tool, were interested in tools and especially those who were not interested in using a tool. Respondents who were not interested in tools mostly disagreed with the product-related claims. Still, the relationship between the users of ecodesign tools was not as significant as it was in relation to process-related claims.

A strong relationship between the use of ecodesign tools and process innovations was found in this study, also supporting the results of Horbach (2008) on tools being very important for cleaner technologies ($p<0.001$ but the preconditions for Pearson's Chi-Square test were not met). In general, half of the tool users strongly agreed with the process-related innovation questions and 34% somewhat agreed. At the same time, those who were not interested in using an ecodesign tool strongly disagreed with the grouped claims on process innovations. Respondents using ecodesign tools agreed more often especially on claims concerning the reduced use of water, electricity, oil and coal (AR=3.0), use of renewable energy (AR=3.6) and polluting fewer emissions (AR=2.7). No similar distinction arose in the interviews as there was no clear difference between companies that used an ecodesign tool and those who did not.

Ecodesign tools were also related to marketing innovations, as more than half of the users strongly agreed with the grouped marketing-related claims and almost a third somewhat agreed (AR=3.1 and 2.3), whereas those uninterested in tools strongly disagreed more often (AR=2.4) ($p<0.001$, preconditions were not met). Thus, respondents who used an ecodesign tool were much more likely to evaluate their marketing positively. It seems that attitude is also crucial, especially when it comes to informing customers and suppliers, while the uninterested respondents disagreed with these claims very strongly (AR=2.3 and 3.0) but such a difference was not distinguishable among respondents who had not used a tool but were interested in doing so in future. However, a similar phenomenon was not depicted in the interviews with the expected forerunners.

Based on these results, it seems that implementing an ecodesign tool is positively associated with several types of innovations. Therefore, it would be important for companies that do not yet use a tool to plan a roadmap to support their own operations as well as contributing to a larger societal change towards the circular economy. This recommendation is in line with the previous studies by Boks and Stevels (2007) and Pigosso *et al.* (2013).

5 Conclusions and future research ideas

The relationship between green innovations and ecodesign (Research Question 1) proved to be divided into technological and non-technological targets, even though openings towards a more comprehensive definition of ecodesign have been offered. Both approaches focused highly on products and processes as means of change, but green innovations were acknowledged to aim for a broader type of change. Instead of concentrating solely on technological innovations, concerning products and processes, green innovations were found to shed light on non-technological aspects as well. These included innovations related to marketing organisation and institutional transformation. Thus, promoting the circular economy requires different types of innovations that together contribute to a systemic change. Surprisingly, both radical and incremental product innovations were fairly common among the respondents, even though incremental ones were expected to be more frequent. New product innovations were found to be connected to the introduction of process innovations that were either new to the world or to the company. Patents were most often held by large IT companies, whereas the most common ecolabels, Öko-Tex 100 and GOTS, were held by small and medium-sized textile companies.

Overall, the Nordic respondents were fairly mature in terms of integrating sustainability into their operations based on the stimuli and barriers they perceived (Research Question 2). This was probably due to mature firms being more interested in sharing their opinions and experiences and others not perceiving it as their responsibility. The respondents were most commonly driven by internal stimuli and especially by a general willingness to act proactively and according to their own values in relation to sustainable consumption and production, supporting the interpretation of a mature level. Those companies were also more likely to contribute to societal change by informing their customers and suppliers actively about their environmental activities and how their products should be taken care of and participating in public discussions to change the status quo. External stimuli breaking up the pattern of the prevailing internal stimuli were customer demand and legislation, which were especially strong for larger companies operating worldwide and also for IT companies. Therefore, the tightening of requirements seems to be a pushing element for several companies and the criteria should be revised regularly. Then again, barriers acting against the companies related strongly to costs and restrictive institutions. Notably, IT companies were more driven by the possibility of lower expenses with environmental considerations thus promoting their profitability whereas textile companies were afraid of increase of costs. This observation showcases the different approaches between the sectors in relation to costs. A highly remarkable finding was that the forerunners faced great problems related to the development of the surrounding institutions and facilities. They felt that money still runs the world and change towards a society in which sustainability is supported is taking place slowly. Textile companies were more positive in this sense and they felt that during the last decade understanding and valuing of environmental concerns have grown, which has also been visible in their sector. However, the IT interviewees did not mention such a development. Thus, based on this study, it seems that forerunning companies have to face external barriers that are very hard for single companies to affect and require a system-level transformation.

Despite the perceived maturity of the Nordic companies based on the previous literature and the stimuli and barriers, in reality their actions remained focused on mainly technological changes (Research Question 3). The respondents focused primarily on products and sub-system change, which should have been addressed in a more balanced way in the questionnaire. The findings, though, indicate that despite the bias of the options given, product-related innovations were also described in more detail in the interviews than processes or other target types of innovations. Product innovations focused especially on material choices and prolonging life cycles, especially by textile companies, although based on studies, IT companies should pay attention to material choices as well. Some of the questionnaire respondents stated that they had had difficulty finding information on the environmental performance of different options, for example, in materials, which indicates a growing need for research in this field to provide reliable information on how to operate more sustainably. In addition, manufacturing processes were revealed to be hard to perceive for the respondents: probably the responding person was not as familiar with their manufacturing processes as they were with their products or marketing, showing a lack of internal flow of information. It also seems that companies that were less formally organised by not belonging to an industrial association or having an environmental management system were more active in many other areas such as informing customers about handling the product. An area where innovations were lacking was revealed to be the functional change of developing product-service systems, although the forerunning companies had all started or planned to offer several services that replaced products and prolonged their life cycles. Still, no remarkable change had taken place based on these results in comparison to the previous studies from the beginning of the 21st century. In addition, ecodesign literature from this era proved to be relevant in today's context. Overall, the findings suggest that more systemic innovations are hard to make and even harder to make successfully, but they are required for promoting the circular economy and enabling development on a broad basis.

Organisational innovations proved to be of high importance when aiming for different kinds of innovations, in contrary to previous literature stating its importance only for technological change. R&D activities were found to be undertaken by almost half of the respondents from diverse companies in all the Nordic countries, in both sectors and ranging from micro to large companies operating nationally or internationally, despite the expectations that IT would be more active and SMEs would be less represented. Smaller companies found research projects a suitable way of participating to develop their skills and innovations, build co-operation networks, educate their value chains and promote public discussion or change the status quo. Surprisingly, the use of an environmental management system was often negatively associated with innovations, although they were expected to have similar associations to R&D. The majority of the respondents were interested in using an ecodesign tool and based on the results they should take action in applying tools. Tool users were found to have significantly more product-, process- and marketing-related innovations. The most promising tools are suitable for assessing environmental performance specifically and provide for communication at the same time. No single, superior tool was found, but instead, companies used different tools for different purposes, for example LCA for assessment and ecolabels for communication. These tools helped the companies to choose alternatives, focus their environmental concerns on the most meaningful solutions and rationalise their preferability to their stakeholders. Thus, it would be recommended for companies to make long-term roadmaps concerning their future and include the application of ecodesign tools and R&D activities in that to support their operations and innovativeness.

This study acknowledged several fields for future research. First, a need for systemic change in governance, financing and values was acknowledged in this study, and ways to promote system innovations should be examined, evaluated and promoted more. Second, some respondents were deterred by a lack of information on environmentally preferable materials, which showcased a growing need for research that provides reliable information on how to do things in a more sustainable way. Third, smaller companies in particular could benefit from participating in external research projects, and more focus should be placed on taking them along. Fourth, the data collected for this thesis offers many possibilities for future research. It could be used for formulating company groups with different preferences and maturity levels among other aspects which were not in the scope of this study. Furthermore, it would have been interesting to interview more companies in other Nordic countries to develop a more thorough comparison of features of forerunners as well as those who have not taken environmental matters into account. The proven methodology combining general questionnaires and more specific interviews could also be used in examining other sectors and countries.

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Appendices

Appendix 1. Ecodesign and green innovation principles

Ecodesign principle	Green innovation principle	Innovative target	Mechanism
Recycled and clean materials. Using more sustainable raw materials (e.g. recycled organic)	Using recycled materials in manufacturing; Choosing materials whose production requires less energy than usually; Choosing materials whose production pollutes less emissions than in general	Product	Sub-system change
Reduction in weight	Reducing the weight of products	Product	Sub-system change
Doing more with less; Saving raw materials	Using the fewest amount of materials possible for producing a product	Product	Sub-system change
Low energy consumption, developing products that are more energy efficient	Products use less energy in usage than usual	Product	Improvement, sub-system change
High reliability/durability	Reliable and durable products	Product	Improvement
Remanufacturing/refurbishing, enhancing the remanufacturing of our products	Using materials that are easy to recycle; Products are easy to recycle, remanufacture, reuse and decompose;	Product	Improvement, sub-system change
Dematerialisation, shared use of products	Service-based ways to fulfil a function of products; Offering services related to products, renting	Product	Function innovation
Recycling of materials	Recycling waste and emission coming from manufacturing process	Process	Sub-system change
Less production waste	Manufacturing process effectively reduces the amount of waste	Process	Sub-system change
Clean production techniques, using efficient manufacturing technologies; Minimising the use of chemicals	Manufacturing process reduces the use of raw materials; Manufacturing process reduces the consumption of water, electricity, coal or oil; Manufacturing process	Process	Sub-system change

	effectively reduces the emission of hazardous substances		
Cleaner energy source	Using renewable energy	Process	Sub-system change
Using less/clean/reusable package materials	Reduce the amount of used package materials	Marketing	Sub-system change
Changing the traditional mind-set	Promoting discussion and challenging the status quo surrounding existing products, materials or processes	Institutional	Sub-system change
	Meeting the environmental criteria of a type 1 ecolabel	Product	Improvement and sub-system change
	Replacing products or production chains with completely new ones	Product, process	System innovation
	Affordable products	Marketing (sustainable innovation)	Sub-system change
	Informing customers about environmental performance of products and their proper use, maintenance and end-of-life management	Marketing	Sub-system change
	Informing customers and suppliers about the environmental performance of products	Marketing	
	Training employees about the environmental matters	Organisational	Improvement
	Schemes and systems for improving environmental performance of an organisation (EMAS, R&D activities, cooperation)	Organisational	Sub-system change
	Choosing partners that are located near to reduce the need of logistics	Organisational	Sub-system change

Appendix 2. Presentation letter of the questionnaire (English version)

Title: Survey on ecological product design/ecodesign and environmental innovations

Hello,

* Apologies for possible cross-posting*

I invite you to respond to a survey which is a part of my master's thesis and a study financed by the Nordic Council of Ministers. The results will help us advise companies to better consider environmental issues in their operations and identify the most suitable ecological product design/ecodesign tools. In addition, if you so wish, you can also present your best practices in a video that shows consumers the operations of your company.

The survey will examine how the Nordic textile and IT companies promote ecological product design/ecodesign and environmental innovations in their activities. Your response is very important in order for us to get a correct impression of the situation and I hope you can answer the survey even if you do not yet have knowledge about the topic.

Responding takes approximately 10-15 minutes. Responding is completely anonymous, data is handled confidentially and no single respondent can be recognised.

Please answer the survey by using this link:

I request that you answer the survey as soon as possible, yet no later than x.x.

I am happy to answer any questions concerning the study or the survey. If you wish to participate in our study in the future, hear about its results and receive instructions for making a video, you can leave your contact information to me at hanna.h.salo@ymparisto.fi. Your contact information will not be associated with the survey.

Thank you very much for your time and precious responses!

Hanna Salo
Trainee, University student
Finnish Environment Institute
+358 295 251 944
hanna.h.salo@ymparisto.fi

Ari Nissinen
Development manager
Finnish Environment Institute
+358 295 251 457
ari.nissinen@ymparisto.fi

More information about the project: http://www.syke.fi/projects/scepef

Appendix 3. Questionnaire (English version, both sectors included)

Countries where company has operations*: ______________________

Year of foundation: ______

Number of employees*: _______

What is your company's main field of operation? You can choose multiple options.

- Clothes and accessories (textile)
- Home décor textiles (textile)
- Technical textiles (textile)
- Fibre (textile)
- Other textile (textile)
- Consumer electronics (IT)
- Industrial electronics (IT)
- Telecommunication electronics (IT)
- Other, please specify:

Who use the end product of your company? You can choose multiple options.

- Consumers
- Companies
- Public organisations

Are you a designing and/or manufacturing company?

- Designing
- Manufacturing
- Both designing and manufacturing

Among these statements, which one applies best to your company?*

- We meet the requirements of environmental legislation which is a suitable target level for us.
- We find environmental targets to be very important and aim to significantly exceed the requirements of environmental legislation.
- We comply with environmental legislation but it is not one of our priorities.
- We find the requirements of environmental legislation to be oversized.

Does your company use an Environmental Management System (EMS)?*

- Yes
    - ISO 14001
    - EMAS
    - Other, please specify: _______
- No

Does your company have activities for research and development specifically related to environmental matters?*

- Yes
    - If yes, how many employees take part in it? _____ / Do not know
    - Do you have a specific budget for supporting research and development related to environmental matters?
        - Yes / No / Do not know
    - If yes, what approximate percentage of your total budget for research and development has been allocated for environmental matters during the last two years? ________________ / Do not know
- No

Ecodesign/ecological product design is a design and management process that integrates environmental issues into product development. Ecodesign/ecological product design provides an opportunity to focus on eliminating, avoiding or reducing upstream and downstream environmental impacts with a preventive approach. It aims to reduce the consumption of resources, prolong the lifespan of a product, use less hazardous materials, optimise the production and distribution and ensure the safe disposal of products. Ecodesign/ecological product design is synonymous with Design for Environment (DfE), green design and environmentally conscious product development and design.

References: Tischner 2001; Belmane *et al.* 2003; Byggeth & Hochshorner 2006; Johansson 2006; ISO 14006:2011; Liao *et al.* 2013; Pigosso *et al.* 2013; Dekoninck *et al.* 2016; Prendeville *et al.* 2017

Please evaluate how your company promotes ecodesign/ecological product design and environmental matters in its activities.*

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree	Do not know
We choose materials whose production requires less energy than usual						
We choose materials whose production pollutes less emissions than the ones that are usually used						
We use the fewest amount of materials possible for producing a product						
We use materials that are easy to recycle						
We manufacture products that are easy to recycle, reuse and decompose						
We manufacture products that are reliable and durable						
We use recycled materials in our manufacturing						
We reduce the weight of our products						
We reduce the amount of used package materials						
Our manufacturing process reduces the consumption of water, electricity, coal or oil						

Our manufacturing process reduces the use of raw materials						
Our manufacturing process effectively reduces the emission of hazardous substances						
Our manufacturing process effectively reduces the amount of waste						
We handle the waste coming from our manufacturing process, so that they can be better utilised						
We use renewable energy instead of non-renewable						
Our products use less energy in usage than usual						
Our products fulfil the various environmental criteria of a type 1 ecolabel (e.g. EU Ecolabel, Nordic Swan)						
Our products are affordable						
We create different service-based business models instead of traditional supply of goods						
We offer services related to our products (e.g. repairing, consulting or taking back worn-out products)						
We rent our products to customers instead of selling them						
We promote discussion and challenge the status quo surrounding existing products, materials or processes						
We inform our customers and suppliers about the environmental performance of our products						
We inform our customers about the proper use,						

maintenance and end-of-life management of our products						

What are the main reasons for you taking action to promote ecodesign/ecological product design?*

- Legislation or regulation
- Subsidies or other government support
- Tax incentives
- Cost reduction
- It is requested by customers
- It is requested by investors
- It is requested by suppliers
- Public environmental governance encourages to do so
- Research institutes and universities encourage to do so
- Suppliers offer new eco-efficient materials or components
- To increase the working motivation of our employees
- To increase the quality of our products
- To avoid negative media attention
- To improve the company's image
- To improve the company's performance
- Synergy with other product requirements
- To increase the functional quality of our products
- Synergy with other product requirements
- Industrial sector initiatives
- Due to environmental pressure from industrial organisations
- To increase market share or access new markets
- To increase the value of our products
- To catch up with competitors who have already applied ecodesign/ecological product design
- Innovation opportunities
- To reduce our environmental impacts
- Other, please specify:

What are the main problems your company has faced when promoting ecodesign/ecological product design?*

- Lack of information on ecodesign/ecological product design and its benefits
- Lack of environmental knowledge and skills among the company's staff
- No legal requirements on ecodesign/ecological product design for our product groups
- Uncertainty of environmental benefits
- Lengthy time to apply
- Lack of sufficient tools
- Cost increase
- Not demanded by customers
- Not demanded by investors

- Not demanded by suppliers
- Lack of alternative solutions available
- Uncertain market benefits
- It is not our responsibility
- It conflicts with other product requirements
- There are more important sector-specific standards
- Other, please specify:

Among these statements, which one applies best to your company?*

- We already use an ecodesign/ecological product design tools
- We have made plans to use an ecodesign/ecological product design tool
- We are interested in using an ecodesign/ecological product design tool, but have not taken action
- We are neither interested in nor concerned about ecodesign/ecological product design tools

➔ If chose the first option:

Which tools does your company use?

How many years have you used the tool that has been used for the longest period?

Who uses the tool(s) in your company?

What benefits and disadvantages do the tool(s) that you use have?

<table>
<tr><th>Tool</th><th></th><th>Benefits</th><th>Disadvantages</th></tr>
<tr><td>ABC analysis</td><td rowspan="6">Employee
Group of employees
Consultant
Other, who:</td><td rowspan="6">Simple to use
Effective
Systematic
Detailed
Extensive
Quick to apply
Affordable
Supports product design and development
Does not require environmental expertise</td><td rowspan="6">Difficult to use
Requires environmental expertise
Expensive
Time consuming
Requires a lot of data
Lack of clarity when to use the tool
Not detailed
Scope is too narrow
Scope is too broad</td></tr>
<tr><td>Type 1 ecolabel (e.g. Nordic Swan, EU Ecolabel)</td></tr>
<tr><td>Type 3 ecolabel, ISO 14025, i.e. environmental declarations (e.g. EPD)</td></tr>
<tr><td>LCA (e.g. SimaPro, GaBi, OpenLCA)</td></tr>
<tr><td>Streamlined LCA (e.g. EIME, LCA to Go)</td></tr>
<tr><td>Econcept Spiderweb</td></tr>
</table>

LiDS Wheel		Data is easily available Flexible to be applied for different products Suitable to be used in different product development stages Results are easy to utilise Suitable for communication Other, please specify:	Does not provide practical guidance Subject to subjectivity The results are not concrete Does not work in communication purposes Other, please specify:
ERPA			
MIPS			
MET-matrix			
MECO			
Philips Fast Five Awareness			
Ten Golden Rules			
PILOT			
EcoDesign Checklist			
Black, Grey and White List			
Design for Sustainability			
Carbon Footprint			
Water Footprint			
Other, please specify:			

What problems has your company faced when using an ecodesign/ecological product design tool?

- Difficulty to choose a suitable tool
- Difficulty to implement a new tool in product development
- The existing tools do not sufficiently support our specific situations
- Lack of environmental knowledge and skills among the company's staff
- Lack of a proper technical alternative to replace the current material/product, etc.
- Lengthy time to apply
- High implementation and certification costs
- Ecodesign is not integrated into any general product design software
- Exchange of data between tools is not possible
- Other, please specify:
- None

➔ If chose the second option:

Which tool have you planned to use?

When did you plan on using the tool?

In your opinion, what benefits and disadvantages does the tool that you planned to use have?

<table>
<tr><th>Tool</th><th></th><th>Benefits</th><th>Disadvantages</th></tr>
<tr><td>ABC analysis</td><td rowspan="14">less than 6 months ago
6-12 months ago
1-2 years ago
3-5 years ago
more than five years ago
Do not remember</td><td rowspan="14">Simple to use
Effective
Systematic
Detailed
Extensive
Quick to apply
Affordable
Supports product design and development
Does not require environmental expertise
Data is easily available
Flexible to be applied for different products
Suitable to be used in different product development stages
Results are easy to utilise
Suitable for communication</td><td rowspan="14">Difficult to use
Requires environmental expertise
Expensive
Time consuming
Requires a lot of data
Lack of clarity when to use the tool
Not detailed
Scope is too narrow
Scope is too broad
Does not provide practical guidance
Subject to subjectivity
The results are not concrete
Does not work in communication purposes
Other, please specify:</td></tr>
<tr><td>Type 1 ecolabel (e.g. Nordic Swan, EU Ecolabel)</td></tr>
<tr><td>Type 3 ecolabel, ISO 14025, i.e. environmental declarations (e.g. EPD)</td></tr>
<tr><td>LCA (e.g. SimaPro, GaBi, OpenLCA)</td></tr>
<tr><td>Streamlined LCA (e.g. EIME, LCA to Go)</td></tr>
<tr><td>Econcept Spiderweb</td></tr>
<tr><td>LiDS Wheel</td></tr>
<tr><td>ERPA</td></tr>
<tr><td>MIPS</td></tr>
<tr><td>MET-matrix</td></tr>
<tr><td>MECO</td></tr>
<tr><td>Philips Fast Five Awareness</td></tr>
<tr><td>Ten Golden Rules</td></tr>
<tr><td>PILOT</td></tr>
</table>

EcoDesign Checklist		Other, please specify:	
Black, Grey and White List			
Design for Sustainability			
Carbon Footprint			
Water Footprint			
Other, please specify:			

What problems with ecodesign/ecological product design tools did you face, so that you did not apply a tool?

- Lack of potential benefits
- Difficulty to choose a suitable tool
- The existing tools do not sufficiently support our specific situations
- Lack of environmental knowledge and skills among the company's staff
- Lack of a proper technical alternative to replace the current material/product, etc.
- Lengthy time to apply
- High implementation and certification costs
- Ecodesign is not integrated into any general product design software
- Exchange of data between tools is not possible
- Other, please specify:
- None.

Product Environmental Footprint (PEF)

Product Environmental Footprint (PEF) is a measure of product environmental performance under development for creating a single market for green products in Europe, proposed by the European Commission. It is based on Life Cycle Assessment, but defines stricter rules for making the analysis (so-called Product Environmental Footprint Category Rules, PEFCRs) than LCA standards and by this strives for comparability of product-specific PEF results. The pilot takes place in 2013–2018 and includes 21 product groups. After the pilot phase, there will be a transition phase of a few years, after which it will be decided whether PEF will be a mandatory or a voluntary method and how it will be used in policy instruments.

Have you heard of PEF before?*

- Yes and I have searched for more information about it
- Yes, but I have not explored it more specifically
- No

What would be your company's opinion towards PEF?*

- PEF would complement the ecodesign/ecological product design tools that we are already using
- PEF would replace the tool we are currently using
- We don't know yet how to use it but we are eager to get more information about PEF
- We would not be interested in using PEF
- Cannot say.

What kind of a policy instrument do you see PEF to primarily be?*

- Strengthening the existing EU product policy instruments
- Supporting ecolabels
- Evaluating the accuracy of environmental claims of products
- Cannot say.

Free comments:____

Please mark down if your company has applied for patents or brought energy labelled or ecolabelled products to the market during the last two years.

Patents in general □
Patents which you consider to be linked with environmental goals □
EU Ecolabelled products □
Nordic Swan Ecolabelled products □
Bra Miljöval labelled products □
Blaue Engel labelled products □
Öko Tex 100 labelled products □ (textile)
Öko Tex 1000 labelled products □ (textile)
Global Organic Textile Standard labelled products □ (textile)
Fair Trade products □ (textile)
EU Energy Labelled products □ (IT)
EPET labelled products □ (IT)
Energy Star labelled products □ (IT)
TCO certified products □ (IT)
Products with other ecolabels, please specify: __________
Products with company's own environmental declaration □

Please mark down if your company has taken the following objects into use or brought them to the market during the last two years.

Completely new products developed with environmental improvements compared to alternative products □
Products that we have improved by adding in a component □
Products whose materials or components we have improved or switched to reduce environmental impacts □
Products have been replaced by services □
New products created outside of our company, but which we have implemented □

Completely new environmentally friendly manufacturing techniques that we have developed to reduce environmental impacts □
Environmentally friendly manufacturing techniques we have improved □
New manufacturing techniques created outside of our company, but which we have implemented □
Other, please specify: ____________________

Thank you very much for your time and valuable answers!

If you would like to participate in the research in the future and receive information on the results, please leave your e-mail address here _____________ or send it to Hanna Salo, hanna.h.salo@ymparisto.fi. Your contact information will not be associated with the survey.

The results of the study will help companies to better consider environmental issues. At the same time, the study identifies tools that companies can use to promote ecological product design/ecodesign and environmental innovations in their operations as easily as possible. Thus, the results can enhance the environmental performance of companies, reduce costs and improve the company's image. In addition, if you so wish, you can present your best practices in a video that shows consumers the operations of your company.

If you have any additional thoughts about the topic or the survey, please share them here:

Appendix 4. Interview invitation (in English)

Dear x.x.,

I am studying in my Master's thesis how companies implement environment-related innovations and ecodesign. The thesis is part of the SCEPEF project funded by the Nordic Council of Ministers. A broad Nordic questionnaire was conducted prior to the interviews to find out how textile and IT companies promote environmental issues in their operations and how they use ecodesign tools in helping them. (Textiles: Thank you for responding to the questionnaire and leaving your contact information!)

The interviews with forerunning companies will deepen and broaden the knowledge gained from the questionnaire. (IT: My colleague Jáchym Judl/Janne Pesu recommended contacting you). It is highly important to hear precisely your experiences on taking the environment into account in your business. The results will be published in my Master's thesis. The respondents will be provided with recommendations on how to develop their operations to be even more environmentally friendly, improve company image and lower expenses.

The interview takes less than an hour and can be executed in a certain place or by phone according to your wishes. The interviews will be recorded and transcribed into a text file for analysis. They are anonymous and confidential and no single respondent can be recognised from the published results.

Please let me know about your willingness to participate in the interview by 24.1. and provide information on times that would suit you best. I am happy to answer all questions concerning the study and interviews.

Best regards,
Hanna Salo

Trainee, university student
Finnish Environment Institute
+358 295 251 944
hanna.h.salo@ymparisto.fi

Ari Nissinen
Development manager
Finnish Environment Institute
+358 295 251 457
ari.nissinen@ymparisto.fi

Appendix 5. Interview outline (in English)

Starting points for the interviews:

- Participating in the interview is voluntary.
- The interview takes approximately 30 minutes. It is recorded and will be transcribed into a text file. The recording will be destroyed after transcription.
- The interview is anonymous and no single respondent can be recognised from the published results. Companies will be referred to as “Company A”, “Company B”, et cetera. The published information includes sectors, operative countries, number of employees (note: roughly classified) and main operations that have been collected from the company websites and interviews.
- The publication will include direct quotes from the interviews with the identifier of the company.

To begin with, please tell me about your company.

1. How does your company take environmental matters into account?
2. Why does your company promote environmental matters?
3. Are there employees responsible for developing the environmental performance of your company?
4. Does your company practice product development? Is yes, how is it organised?
5. Do you have research and development activities related to environmental matters?
6. How have you decreased environmental impacts related to your products?
7. Have you developed your manufacturing processes to be more environmentally friendly? If yes, in what way?
8. Have you used an ecodesign tool to promote environmental matters?
9. Does your company offer services? If yes, what kind of services?
10. How do you market your environmental friendliness?
11. Do you inform your customers about the environmental impacts of your products?
12. Do you inform your customers about your manufacturing techniques?
13. Do you tell your customers about sustainable lifestyles? If yes, how?
14. Do you take part in public conversations to promote environmentally sustainable production and consumption?
15. What challenges have your faced in promoting environmental matters?

Lastly, was there anything missing from these questions from your point of view?