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Evaluating approaches to resource management in consumer product sectors - An overview of global practices

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ABSTRACT

Addressing global sustainability challenges associated with natural resource security and climate change requires new perspective on waste and resource management. Sustainability-driven business model innovations have a crucial role in transforming current, unsustainable, production and consumption patterns by slowing product replacement and closing material cycles. This study identifies best practice across a range of consumer product sectors. The study developed a novel methodology to identify and evaluate practical approaches to resource efficiency and the circular economy in order to reduce energy and material demand in these product sectors. These approaches include durable product design, enhanced repair and upgrade services, and product take-back. The study analysed 519 products and identified a total 145 examples of best practice within their respective product sectors that provide important insights into planning more circular business models in a range of product sectors. The paper highlights major barriers to, and opportunities, for wider implementation of these practices.

1. Introduction

In recent decades, rapidly growing resource consumption around the world has raised multiple global sustainability challenges associated with climate change and future access to natural resources (United Nations Environment Programme, 2011). Increased global demand for products and services has escalated resource extraction rates (United Nations Environment Programme, 2016) while shorter product replacement cycles, due to technological innovation and other factors, have increased global waste generation. These have further escalated demand for the energy required for resource extraction and processing, product manufacturing and waste management, energy which is 'embodied' in products (Allwood and Cullen, 2012). Thus, addressing the global sustainability challenges requires a slower and circular management of resources, while minimising the generation of solid wastes, and liquid and gaseous emissions (Ellen MacArthur Foundation, 2014; 2012; Singh, 2016).

In the past, companies' efforts to address the sustainability challenges to their business practices have predominantly focused on incremental environmental approaches to resource efficiency, cleaner production and eco-design (Laurenti et al., 2016; Singh et al., 2014). However, addressing the global sustainability challenges to increasing resource consumption requires radical systemic solutions (Klewitz and Hansen, 2014). Indeed, in order to proactively address the root causes of the sustainability challenges, some organisations have changed their business strategies to pursue more sustainable business practices by adopting sustainable innovations (Bae and Smardon, 2011; Charter et al., 2008). Sustainable innovations differ from regular eco-innovations that have focused on isolated product-, process-, and function-oriented innovations (Boons and Lüdeke-Freund, 2013; Carrillo-Hermosilla et al., 2010; Charter et al., 2008). Sustainable innovations are future-oriented and more radical than the regular innovations (Boons et al., 2013a; Charter et al., 2008).

Based on the theoretical foundations of the field of industrial ecology, the concept of the circular economy offers a new framing of waste and resource management in order to transform the

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current predominant linear 'take-make-dispose' production and consumption systems into more circular ones (Blomsma and Brennan, 2017). Further, in order to facilitate transition towards a circular economy various design and business strategies on slowing and closing the material cycles in a product system have been proposed (Bocken et al., 2016; Bocken and Short, 2016).

A business model is defined as "*a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm*" (Osterwalder et al., 2005, p. 10). Boons and Lüdeke-Freund (2013) distinguish four elements of a generic business model concept – value proposition, supply chain, customer interface and financial model. Sustainability-driven business model innovations create positive and/or reduced negative impacts for the environmental and/or society by changing in the way the organisation create economic value (Bocken et al., 2014). In business models, the central concept of value varies in meaning. Indeed, recent research has highlighted a need for a better understanding of the concept of value in the context of sustainability-driven business model innovations (Bocken et al., 2013; Evans et al., 2017; Sauvé et al., 2016; Schaltegger et al., 2016a; Yang et al., 2014). In order to illustrate the concept of value, several new concepts have been proposed, such as value captured (Osterwalder et al., 2005; Seddon et al., 2004; Teece, 2010), value uncaptured and sustainable value (Evans et al., 2017; Yang et al., 2014).

This paper recognises the crucial role of sustainability-driven business model innovations in reducing the overall material and energy demand in the current unsustainable production and consumption systems (Schaltegger et al., 2011; Stubbs and Cocklin, 2008). Sustainability-driven business model innovations can contribute to a slower and circular management of resources by promoting sustainable business approaches to: (i) prolong product life-spans (Cooper, 2010, 2005); (ii) facilitate product-service systems for enhanced product reuse, repair, remanufacturing and/or end-of-life product collection (Mont, 2002; Roy, 2000; Tukker, 2015); (iii) offer lengthy or renewable product warranties (Alqahtani and Gupta, 2017); (iv) provide contracts for supplying spare parts and/or upgrading the product's functionality (Bakker et al., 2014a; Sabaei et al., 2015); and (v) promote collaborative consumption or the sharing economy (Martin, 2016; Perren and Grauerholz, 2015).

However, despite growing theoretical literature on sustainability-driven business model innovations in recent years (Bocken et al., 2014, 2013; Bocken and Short, 2016; Boons and Lüdeke-Freund, 2013; Evans et al., 2017; Schaltegger et al., 2016b, 2016a; Yang et al., 2017), there is still a lack of studies identifying gaps in current industrial practices to slow and close material cycles in consumer product sectors. In a policy context, it is imperative to analyse the progress and gaps in current practices in order to assist organisations towards better planning and implementation of sustainability-driven business model innovations. This paper addresses this gap in knowledge of current industrial progress in slowing and closing material cycles by providing an overview of the current practices across consumer product sectors and identifying best practices across a range of product sectors. In this study, the best practice within a product sector is defined on the basis of the offering's potential to slow and close material cycles. These offerings are generally 'the best' within the sector from an environmental point of view in terms of the length of guarantees and provisions for maintenance or repair and recovery of products at end-of-life.

In order to achieve this aim, the study devised a novel methodology to identify and evaluate practical approaches to resource efficiency and the circular economy to reduce energy and material demand across product sectors, including clothing, footwear, furniture, floor coverings, household appliances, kitchenware, vehicles, electronic goods, sports equipment, and other personal effects, such as jewellery, watches and travel bags. The paper analyses these approaches to: (1) present an overview of the product sector norm; and (2) identify some key business practices that could lead to sustainable innovations.

The paper is organised as follows: Section 2 provides the theoretical background of the paper; section 3 describes the methodology adopted for data collection and analysis; section 4 presents key results; section 5 discusses the results; and section 6 presents the conclusion.

2. Theoretical background

This section provides a brief theoretical background of various concepts utilised in this paper, and their relevance to slowing and closing material cycles in production and consumption systems.

2.1. Product life-spans

One way to secure slower material cycles is by increasing product life-spans (Cooper, 2005) by: (1) enhancing products' intrinsic durability[1] and, (2) securing opportunities for maintaining the designed life-span, as well as extending the life-span beyond one lifecycle, such as by providing better services for the products' maintenance and reuse (Cooper, 2010). This demands a broader, systems approach to sustainable resource management that goes beyond product design and includes consumption and waste management aspects of socio-technical system (Ceschin and Gaziulusoy, 2016; Singh, 2016, 2014). Within such an approach, business models play an important role (see Section 2.2).

Product durability is one of the most important strategies to reduce resource consumption, by reducing waste (Cooper, 1994) and increasing material productivity (von Weizsäcker et al., 1998). Product durability has also been associated with the quality of products (Cooper, 2012; Mahajan et al., 2018; Salvia et al., 2016). Intrinsic durability of products could be improved by designing products with better technical, functional and aesthetic qualities that resist damage and wear and encouraging users to maintain them in use.

Several definitions of product life-spans are found in the academic literature (see Table 1). Cooper (2010) distinguishes different definitions of product life-span (or 'lifetime') based on the product functionality – technical, service, replacement and economic. Gnanapragasam et al. (2017) explore differences based on consumers' expectations for products' use-time and their understanding of how long a product should last – intended, ideal and predicted life-span (Oguchi et al., 2016). However, den Hollander et al. (2017) argue that product functionality is an insufficient criterion to define product lifetimes because perfectly working products can get discarded, and products that are temporarily out of order or not in use may not immediately be discarded. They propose new definitions of product life-span based on obsolescence – product use cycle and product lifetime (cf. *Table 1*).

In this study, the intrinsic durability of a product is referred to as the technical life of the product, that is, the maximum period during which it has the capacity to function without excessive expenditure on maintenance and repair (Cooper, 1994). The extended life-span beyond one use cycle, through maintenance and repair, is referred to as the service life of the product. Products can

[1] Durability is "the ability of a product to perform its required function over a lengthy period under normal conditions of use without excessive expenditure on maintenance or repair" (Cooper, 1994, p. 5, p. 5).

Table 1
Typology of product life-spans based on product durability and consumers' expectations.

Typology based on	Product life-span	Definition
Product functionality	Technical life	The maximum period during which a product has the capacity to function.
	Service life	The total period in use from initial acquisition to final disposal as waste.
	Replacement life	The period from initial sale to the point at which the owner purchases a replacement, regardless of whether or not the original product still functions.
	Economic life	The point at which maintaining a product becomes more expensive than replacing it.
Consumers' expectations	Intended life-span	The period of time the consumer plans to use the product for.
	Ideal life-span	The period of time the consumer wants the product to last.
	Predicted life-span	The period of time the consumer anticipates the product will last.
Product obsolescence	Product use cycle	The period from when a product is released for use after manufacture or recovery to the moment the product becomes obsolete, where recovery means any operation that reverses obsolescence e.g. through design for recontexualising, repair, refurbishment or manufacture (for more details, see den Hollander et al. (2017)).
	Product lifetime	The period from when a product is released for use after manufacturing and when it becomes obsolete beyond recovery (at product level cf. components).

Source: Own formulation based on Bakker et al. (2014b), Cooper (2010, 1994), den Hollander et al. (2017), Gnanapragasam et al. (2017) and Oguchi et al. (2016).

therefore have more than one use cycle or lifecycle, but only one life-span (or lifetime) (see den Hollander et al. (2017)).

This study evaluates the product offerings based on: (1) the length of guarantees (slower material cycle); (2) provision of repair or maintenance (slower material cycle) and; (3) post-consumption or end-of-life product recovery (closed material cycle). A product offering is the value that a manufacturer or supplier of the product is seeking to offer to customers in its marketplace offering (Bowman and Ambrosini, 2000; O'Cass and Ngo, 2011). A product offering may include a range of the value aspects of the product; however, this study focuses only on the product offerings that relate to slowing and closing of the material cycles.

2.1.1. Product guarantees

In the absence of access to information about technical life of products, the closest proxy for intrinsic durability is the length of its guarantee. A guarantee (or warranty[2]) is an obligation that *"establishes liability on behalf of the manufacturer should the item sold prematurely fail or prove incapable of performing the intended function"* (Alqahtani and Gupta, 2017, p. 1295). Guarantees define product performance expected by consumers, insurance and protection in case consumer expectations are not met (Alqahtani and Gupta, 2017; Blischke and Murthy, 1996). In this study, the duration of a warranty or guarantee is taken as an appraisal of the products' durability (or technical life) and thus an indication of measures taken at the product design phase to improve the length of the material cycles. However, this may not be true for some products: for example, high quality premium range products are not necessarily differentiated in this way since companies offering such products do not always use guarantees to differentiate their products.

2.1.2. Provision of repair or maintenance

The life-span of a product beyond its first use cycle or lifecycle largely depends on, *inter-alia*, the availability of repair or maintenance services. In this study, therefore, data was collected on post-sale provision of repair or maintenance services for products for at least the guaranteed period or beyond. The provision for repair or maintenance of products was taken as a measure of ensuring the product life-span for the designed period (technical life) or beyond the first lifecycle (service life). We recognise that product lifetimes are also greatly influenced by the consumers' expectations for products' use-time (as highlighted in Gnanapragasam et al., 2017); however, this aspect was not included in this study.

2.1.3. Post-consumption or end-of-life product recovery

Sustainable management at the end-of-life phase of products requires an efficient recovery of components (or parts) and recycling of the resources. Separate collection of post-consumer products is, therefore, imperative to achieve this. However, in the current linear economy, the material collection systems in practice are predominantly waste management oriented rather than manufacturing-centred take-back systems (Cole et al., 2019; Singh and Ordoñez, 2016).

The extended producer responsibility principle to collect post-consumer products was devised to motivate design for environment through administrative, economic and information policy instruments (Lindhqvist, 2000; Walls, 2006). This principle was initially introduced for packaging materials in developed countries such as Germany and Sweden (Lindhqvist, 2000). However, over the years, under the same principle post-consumer collection has included other products, through enforced or voluntary measures. For instance, post-consumer collection of electronic goods is now required by law in several countries, and voluntary post-consumer collection of clothing is undertaken by brands such as H&M and Patagonia. However, the effectiveness of these measures is largely unknown due to unavailability of recycling technologies or lack of value chains for the re-use of the recovered resources (Cole et al., 2019; Singh et al., 2014; Singh and Ordoñez, 2016). Despite this, such product 'take-back' initiatives show that some producers are concerned towards addressing environmental problems related to their products or business practices (Cole et al., 2016, 2018a). In this study, provision for post-consumer discard care or 'take-back' is taken as a positive step towards closing material cycles.

2.2. Sustainable innovations and business models

Academic literature employs several typologies to describe innovations. Specifically, innovations that focus on environmental sustainability (such as eco-innovations/environmental innovations) are defined as "*the innovations that improve environmental performance*" (Carrillo-Hermosilla et al., 2010, p. 1075). Some of the basic typologies of such innovations are based on the 'radicalness' of the innovation (the extent of change), such as incremental and radical innovations (Arrow, 1962; Henderson and

[2] In this study, the terms "guarantee" and "warranty" are interchangeably used.

Table 2
Various typologies of innovations.

Basis of typology	Characteristics	Description
The extent of change	a Incremental	Improvements in products' environmental performance through eco-design
	b Radical	New to company, country or world, and disruptive for both consumers and producers
The object of change	a Product/process-oriented	Eco-design and cleaner production processes
	b Function-oriented	Fee-based or free shared usage
	c Systems-oriented	Alternative business systems engaging with the larger parts of socio-economic system to manage system innovation or transition

Source: Own formulation, based on Arrow (1962), Boons et al. *(2013)*, Carrillo-Hermosilla et al. (2010), Charter et al. (2008) and Henderson and Clark (1990)

Clark, 1990) and 'system-ness' of the innovation (the object of change); for example, product/process- oriented, function-oriented and systems-oriented innovations (Boons et al., 2013b) (see Table 2). Although it may be difficult to differentiate innovations based on these typologies, Boons et al. (2013b) distinguish 'sustainable innovations' from 'eco-innovations' as ones that focus on sustainable development i.e. they go beyond incremental improvements and include broader objectives of ecological, economic and social performance (Charter et al., 2008). Further, they are more radical, systems-oriented and normative, and expected to deliver 'win-win' solutions with economic success and sustainable development (cf. Boons et al. (2013b)). Unlike eco-innovations, sustainable innovations - being engaged with the larger socio-economic system - are generally not in the full control of a single stakeholder (Boons et al., 2013a). Thus, successfully managing and guiding sustainable innovations requires policy measures and institutional mechanisms to establish collaboration and participation among key stakeholders in society such as producers, consumers, governmental institutions, academia and non-governmental organisations (Horbach, 2016).

The concept of a business model was popularised in the 1990s due to the rise of new kinds of internet-based businesses defying the dominant business logics of that time (cf. Boons et al., 2013a; Boons and Lüdeke-Freund, 2013). Business model refers to a holistic representation of strategic management of elements within an organisation in order to: understand how an organisation does business (Beattie and Smith, 2013); materialise its resources and capabilities into economic value (Teece, 2010); and become competitive (Dagnino, 2012). Rauter et al. (2017) view the business model as an embedded layer between strategy that defines the overarching goals and the operational activities that put the strategy in practice (see *Fig. 1*).

Business models were associated with sustainable innovation through: the concept of natural capitalism (Hawken et al., 1999; Lovins and Lovins, 2001); product-service systems as means to reduce environmental impacts (Mont, 2000); and corporate sustainability (Stubbs and Cocklin, 2008). In the past two decades, emerging discussions on sustainability offered new contexts to the concepts of business model and value (Schaltegger et al., 2016a). Indeed, recent literature (Bocken et al., 2013; Evans et al., 2017; Sauvé et al., 2016; Schaltegger et al., 2016a; Yang et al., 2014) highlights a need for a better understanding of value in order to promote business model innovations for sustainability. A plethora of terms have been used to describe sustainability-driven business model innovations, such as new/alternative/novel business model, sustainable business model, circular business model, sustainable entrepreneurship, social entrepreneurship, to name a few (Bakker et al., 2014a; Bocken and Short, 2016; Boons et al., 2013b; Del Baldo and Baldarelli, 2017; Halme et al., 2007; Kiørboe et al., 2015; Muñoz and Cohen, 2017; Schaltegger et al., 2016a, 2011; Smith et al., 2010; Stubbs and Cocklin, 2008; Yang et al., 2017). These significantly influence existing value-propositions through establishing, *inter-alia*, new material pathways, stakeholder interactions and economic flows and aim towards normative visions of sustainability using different temporal and spatial scales. Sustainability-driven business models "have the potential to bridge the gap between radical and systemic sustainable innovation and firm strategies, including the issue of economic performance at several levels" (Boons et al., 2013a, p. 3) and provide a normative vision to address the social, economic and ecological challenges. Fig. 2 illustrates a sustainable production and consumption system where natural resources (material and energy) are managed through sustainable business models (focusing on sustainable product design and multiple product lifecycles) and end-of-life product management (focusing on recovery of parts/components and materials).

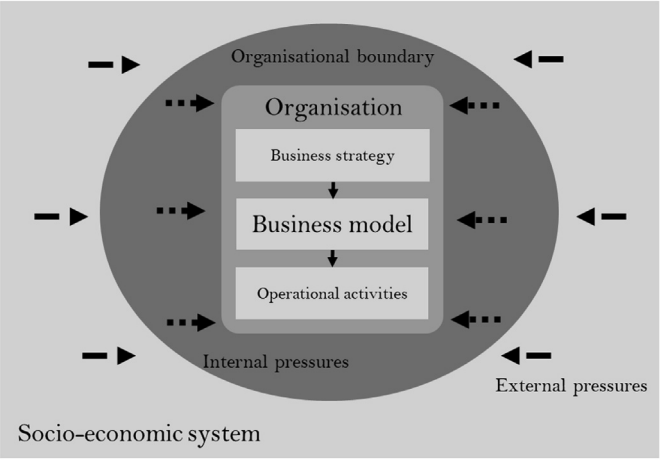

Fig. 1. Relationship between business strategy, business model and the operational activities. Own formulation, based on Osterwalder et al. (2005) and Rauter et al. (2017).

The study therefore recognises a key role of business models in transforming or re-shaping the material cycles (i.e. slowing and/or closing) by promoting product offerings that acknowledge and address the social, economic and ecological challenges (Fig. 2). It identifies and evaluates the product offerings (based on marketing claims), as part of business models, across product sectors relating to: (1) the durability of the product measured as the length of warranty offered at the time of the sale (slower material cycles); (2) provision of repair or servicing (slower material cycles); and (3) post-consumption product recovery (closed material cycles), in order to provide an overview of current norms and identify current best practices in each product sector that could lead future sustainable innovations. However, product offerings in which businesses retain ownership such as pay-per-use, leasing or renting are out of the scope of this study.

3. Methodology

The aim of this study is to identify current best practices focusing on slowing and closing material cycles across product sectors. Considering the myriad of products within these product

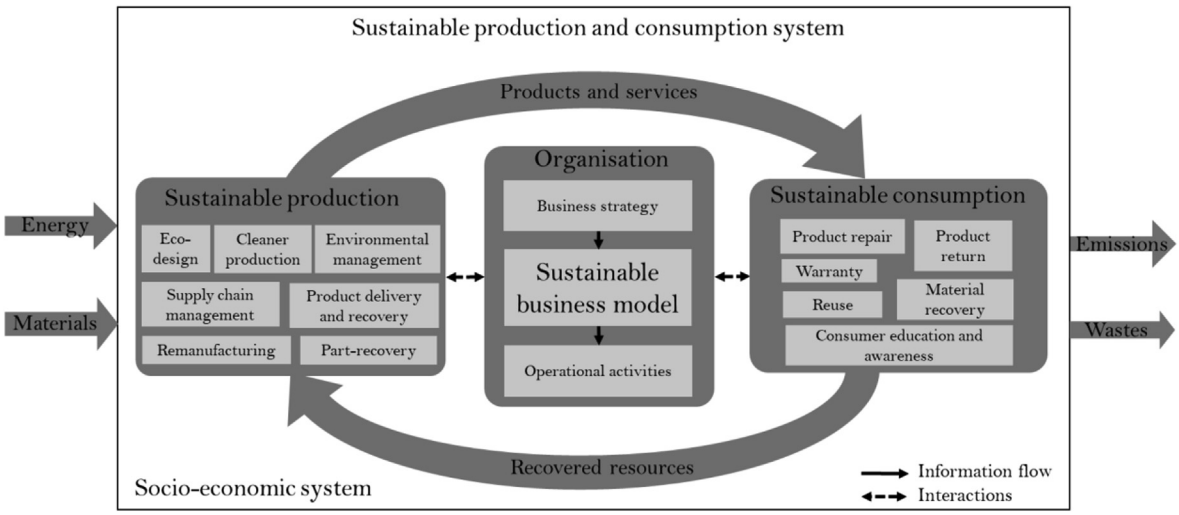

Fig. 2. The role of sustainable business models in a sustainable production and consumption system. Adapted from Singh (2016) and Singh et al. (2014).

sectors, a potent source of data was needed in order to gather the required information. Academic databases for literature search such as Scopus and Web of Knowledge are not particularly suited for this task due to the limited number of products or business models analysed in academia. Indeed, Bocken (2014, p. 47) notes that *"industrial practice appears to be ahead of academia in exploring and developing novel business models"*. Thus, the methodology employed in this study included a systematic and rigorous method to collect, analyse and evaluate data on practical examples of products utilising resource management approaches that enable slower or closed material cycles. Various steps of the methodology are illustrated in Fig. 3.

3.1. Data collection (steps 1 and 2)

The data collection method involved keyword searches on the internet to identify virtual documents (Bryman, 2012) on practical examples of products within the scope of the study. Virtual documents are *the documents that appear on internet* (Bryman, 2012, p. 554). The analysis was limited to the corporate websites or webpages of producers, manufacturers and retailers on their product offerings. These served as sources of information on the approaches employed during the production, consumption and end-of-life phases of products that reduce overall energy and material consumption. The approaches focusing on closing and slowing material flow loops were the main focus of the study. These included design-phase strategies such as design for longevity and design for environment, provision of guarantee/warranty at time of sale, after sale repair/upgrade and end-of-life management of discarded products (see *Table 3*).

An initial set of keywords was chosen to conduct trial searches on the Google™ online search engine in order to identify websites on products within the scope of this study. These were further analysed to understand the varied use of terminology utilised to describe these approaches and the initial set of keywords was systematically updated. Using the COICOP (Classification of Individual Consumption According to Purpose) product categories as a framework (United Nations Statistics Division, 1999), a variety of durable and semi-durable consumer products including vehicles, household appliances and tools, consumer electronics, textiles, and industrial equipment were included in these initial searches (see Appendix A for detailed list of products). Based on the frequency of the use of typical keywords related to the approaches (see Table 3),

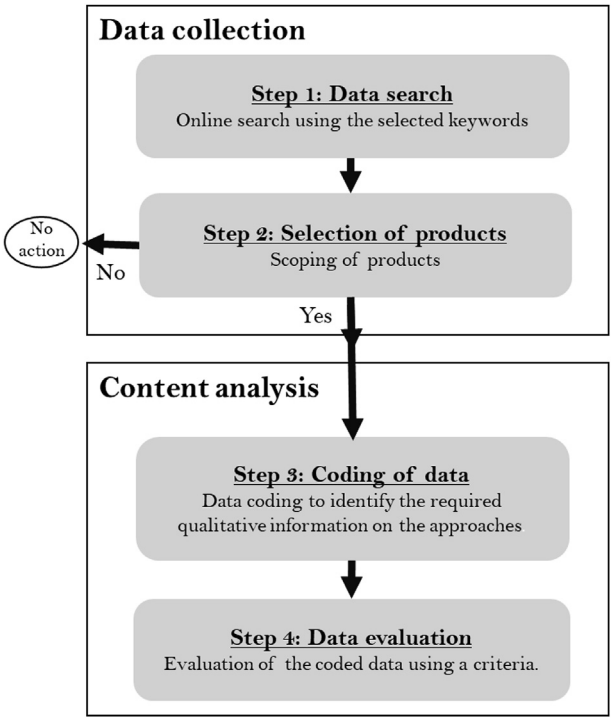

Fig. 3. Various steps of the methodology devised in the study.

three sets of keywords were selected to conduct the online searches for the products and associated services (Table 4). These were used in combinations[3] (see Appendix B). For each combination of keywords, the online searches provided a large number of items relevant (as well as irrelevant) to the products. Recognising this, a filter process was undertaken to remove products outside the scope of

[3] Example combinations of keywords used for online searches included "Guarantee", "Guarantee lifetime", "Guarantee infinite", "Guarantee lifetime repair" and "Guarantee infinite repair" etc. The keywords were used in combinations in order to optimise the search results. The data was collected/analysed over a period several months (between Feb 2017–September 2017). The 'Date Accessed' mentioned in the supplementary material is the date when the website link was last checked.

Table 3
Approaches employed within the product- and process-oriented innovations to manage different life phases of a product.

Approaches		Description
Slower material cycles:		
1	Design for longevity	Marketing claim relating to durability of the product associated with length of guarantee offered at time of sale
2	Repair or servicing strategies	Provision of repair or servicing from the manufacturer/retailer (either directly by manufacturer or authorised repairer)
Closed material cycles:		
3	Post-consumption product recovery	Manufacturer/retailer offers post-consumer product collection

Table 4
Keywords used in the online data searches (Step 1).

First set of keywords	Second set of keywords	Third set of keywords
1. Guarantee	a. Lifetime	i. Repair
2. Warranty	b. Infinite	ii. Part
		iii. Material
		iv. Performance
		v. Limited
		vi. Care
		vii. Maintenance
		viii. Satisfaction*

* This keyword was frequently found during the initial search to describe guarantees in some of the product sectors, such as 100 percent satisfaction guarantee or warranty.

the study which involved checking the product category and sub-category as per the COICOP framework. Further, during initial searches, it was noticed that there were repetitions and/or irrelevant webpages in the later search pages. Therefore, in order to limit the search effort, while not compromising the systematic data search, for each combination of keyword searches only the first five pages were checked for the scoped products. The products identified were sorted according to product sectors and sub-categories adapted from COICOP (Step 2) (see Appendix B and supplementary material).

3.2. Content analysis (steps 3 and 4)

Content analysis (Bryman, 2012) or, more specifically, a direct content analysis approach (Hsieh and Shannon, 2005) was utilised to analyse the qualitative information provided on the websites of the products' manufacturer or retailer. Content analysis method used in this can be defined as "*a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns*" (Hsieh and Shannon, 2005, p. 1278). Content analysis is one of the most prevalent approaches to analysing qualitative data. The main research questions guiding this phase of the study were:

(1) what are the norms in each product sector for offering product warranties/guarantees, providing repair or servicing and post-consumer discard; and
(2) what represents best practice in each product sector?

3.2.1. Data coding (step 3)

A coding scheme was devised that used codes derived from existing research on life cycle thinking (Heiskanen, 2000) and design for sustainability (Ceschin and Gaziulusoy, 2016) in the context of closing and slowing material cycles (Step 3). These were focused on: (1) guarantees/warranties offered at time of sale as an indication of the design-phase strategies focusing on durable products; (2) product repair/upgrade; and (3) end-of-life management of discarded materials/products (see Table 5). The codes for guarantees were based on their length. The data was collected and compiled by manually analysing the product webpages (rather than using qualitative text analysis tools such as RapidMiner© (https://rapidminer.com/products/studio/)). This is because the terminology used to describe product offerings varied across the product sectors, and the required information was accessible only through a detailed analysis of guarantee documents that were often accessible only through manually checking the product offering websites or webpages.

Guarantees vary across product sectors. Some guarantees on products' functionality and repair are required by law (Twigg-Flesner, 2010). These often relate to, for example, quality standards implied in contracts for the supply of goods (Ervine, 2010). Some include only a part of the product's functionality or quality; for example, longer guarantees on motors for electrical appliances and guarantees on colour fading for clothing (see Table 5).

3.2.2. Evaluation (step 4)

Since the product offerings (or marketing claims) for guarantees, repair/maintenance and post-consumer discard vary significantly within and across the product sectors, criteria were developed in order to carry out a consistent and rigorous assessment. The process involved assigning three scores (A, B and C) to the product offerings for guarantees, repair or servicing, and post-consumer product care, respectively (see Table 6). A similar quantitative evaluation method has been used by other researchers to evaluate environmental management policies and plans (Eagles et al., 2014; Fu and Tang, 2013; Norton, 2008; Zhou et al., 2015).

Weighting factors were then applied to these three criteria, to acknowledge the variations in: (1) the relative importance of a particular life-phase of a given product in terms of overall energy and material consumption; and (2) the technical or designed life-span across product sectors (*Table 7*). For example, the end-of-life phase is more significant for semi-durable products with relatively short life-spans and, thus, faster material cycles (Ellen MacArthur Foundation, 2013). Similarly, the design phase is more significant for products with highly material-intensive production processes (Schreiber et al., 2012). Further, relatively simple products (e.g. cooking pots) can be designed for very long life-spans, but more complex products (e.g. electrical and electronic products) may be designed for relatively short life-spans due to technological advance. Based on this, the highest weighting was given to approaches to slow material cycles through design for durability, as measured by the length of guarantees.

The total of the three weighted scores was taken as an overall performance indicator[4] of the product offering and used to represent the relative performance of a product within its product sector (see Table 8). Based the total score, the analysed products were classified into four groups representing the sector norm, slightly better than the sector norm, much better than the sector norm and the best practice within the sector. The product offerings representing the sector norm (with a total score of 1 or 2) were: the

[4] This should not be taken a measure of the product's overall sustainability performance in practice, since this also depends on factors not included in the study.

Table 5
Data collection and compilation for products utilising product- and process-oriented innovations (Step 3).

Data codes	Comments
1 Design for longevity (guarantee offered at time of sale)	
i 1–2 years guarantee	Legally required guarantee as observed in most of the product sectors
ii 3–5 years guarantee	Guarantees for more than 2 years were subdivided, based on trends observed across the product sectors
iii 6–10 years guarantee	
iv 11–20 years guarantee	
v More than 20 years	
a) 21–30 years guarantee	
b) More than 30 years guarantee	
vi Lifetime/Lifetime Repair/Infinite/100 years guarantee	Longer guarantees termed as “lifetime”, “infinite” or “100 years”. Definitions for guarantees termed “lifetime”, “infinite” or “100 years” vary significantly across product sectors. These were further classified as follows:
a) Lifetime of the product	Lifetime defined as the lifetime of the product
b) Life of the owner or buyer	Lifetime refers to the life of the (original) buyer
c) As long as the owner owns the product	Lifetime means as long as the (original) owner owns the product
d) 100 years/Infinite	Lifetime defined as 100 years or infinite
vii Not Applicable	Product not sold (i.e. rented out)
2 Provision of repair or servicing from the manufacturer/retailer	
i Yes (Complete)	Guarantee for the entire product's functionality (rather than a particular component)
ii Yes (Component or attribute)	Guarantee for only an attribute (for example, stains on carpets or colour fading on clothing) or a component (or part) (for example, products with complex components (or parts), such as guarantee for repairing washing machine motors only)
iii No	No provision for repairing/servicing the product
iv Not Applicable	Product not sold (i.e. rented out)
3 Post-consumption product recovery (end-of-life phase)	
i Collection	For example, collection of old clothes or waste electrical and electronic equipment by the manufacturers or retailer
ii Free replacement	For example, underwear with a lifetime free replacement warranty
iii Trade in (Return for discount on new purchases)	Trade in for a discount (cash or coupons)
iv No collection	Collection is not provided for post-consumer product

Table 6
Scoring criteria for the evaluation of product- and process-oriented innovations (Step 4).

Criteria		Scoring criteria*			
		Semi-durable		Durable	
		Simple**	Complex	Simple	Complex
Criterion 1. Indicator for slower material cycles measured as length of guarantee		*Score A = 0,1,2,3,4*			
i	1–2 years guarantee	0	1	0	1
ii	3–5 years guarantee	1	2	1	2
iii	6–10 years guarantee	2	3	2	3
iv	11–20 years guarantee	3	4	3	4
v	More than 20 years guarantee				
	a) 21–30 years guarantee	4	4	4	4
	b) More than 30 years guarantee	4	4	4	4
vii	Lifetime/Lifetime Repair/Infinite/100 years Guarantee				
	a) Lifetime of the product	1	2	2	2
	b) Life of the owner	4	4	4	4
	c) As long as the owner owns the product	4	4	4	4
	d) 100 years/Infinite	4	4	4	4
Criterion 2. Indicator for slower material cycles measured as provision of repair or servicing		*Score B = 0,1,2*			
i	No	0	0	0	0
ii	Yes (Component or attribute)	N.A.	1	N.A.	1
iii	Yes (Complete)	2	2	2	2
Criterion 3. Indicator for closed material cycles measured as provision for post-consumer product care		*Score C = 0,1*			
i	No collection	0	0		
ii	Collection; Free replacement; Trade in	1	1		

* The rationale behind the assignment of these scores is provided in the supplementary material and Appendix C in detail.
** The distinction between the simple and complex products is based on the complexity of the products, in terms of number of different components or materials used and technological aspects. The products that are simpler in its construction such as made with only a single type of material or only a few moving parts are expected to last longer as compared to the more complex products with moving parts or complicated constructions (such as electrical appliances) that are expected to have a limited life-time due to technological limits.

offerings with minimum guarantee as mandated by law or voluntary initiatives for maintenance and post-consumption product recovery within the sector. The offerings with a total score of 3 are considered as slightly better than the sector norm, the total score of 4 considered as much better than the sector norm, and the offerings with the total score more than 4 (i.e. a total score of 5, 6 or 7) are considered as the best practice in a given product sector. A score of 3–7 is ahead of the norm in a given product sector. A detailed explanation of the total score in terms of product offerings or marketing claims is provided in Appendix C. In summary, the

Table 7
Relative significance of aspects of the product based on its durability and resource-intensity.

Factor		Design for longevity	Provision for repair/servicing	Post-consumption product or discard recovery
Durability of product	Semi-durable	Significant	Significant	Very significant
	Durable	Significant	Very significant	Very significant
Resource-intensity of life-phase	Production	Very significant	Very significant	Significant
	Consumption	Significant	Very significant	Very significant
	Waste management	Very significant	Significant	Very significant

Table 8
Classification of analysed products based on the total score (Step 4).

Overall performance indicator	Score A = 0,1,2,3,4	Score B = 0,1,2	Score C = 0,1	Total score*	Description
The sector norm (Total score of 1 or 2)	1	0	0	**1**	The product offerings leading to a score of 1 or 2 are considered as a norm within the sectors. They are typically due to either mandates set by law or voluntary initiatives (total score = 1 or 2).
	0	1	0	**1**	
	0	0	1	**1**	
	2	0	0	**2**	
	1	1	0	**2**	
	1	0	1	**2**	
	0	1	1	**2**	
	0	2	0	**2**	
Slightly better than the sector norm (Total score of 3)	3	0	0	**3**	The product offerings are slightly better than the norm within the sector (total score = 3). They include longer guarantees on products or in some cases repair/maintenance or post-consumer product recovery. The focus is on closing material cycles.
	2	1	0	**3**	
	2	0	1	**3**	
	1	2	0	**3**	
	1	1	1	**3**	
	0	2	1	**3**	
Much better than the sector norm (Total score of 4)	4	0	0	**4**	The product offerings represent much better than the sector norm within the sector. They include either relatively long guarantees (more than 6–10 years for semi-durable or more than 3–5 years for durable products), along with repair and recovery of products in some cases. They include both slowing and closing material cycles (total score = 4).
	3	1	0	**4**	
	3	0	1	**4**	
	2	2	0	**4**	
	2	1	1	**4**	
Best practice within the sector (Total score of 5, 6 or 7)	4	1	0	**5**	The product offerings represented the best practice (total score = 5 or 6 or 7). They include very long guarantees, along with maintenance or repair and recovery of products at end-of-life. Product offerings with a total score of 7 were ideal cases for slowing and closing material cycles.
	4	0	1	**5**	
	4	2	0	**6**	
	4	1	1	**6**	
	4	2	1	**7**	

* Each row represents one of the range of possible scores. A detailed explanation of the total score is provided in Supplementary material and Appendix C.

following assumptions were made during the evaluation of product offerings:

1. In the evaluation criteria, the maximum score that a particular product offering earns within the three defined criterions for: the offered guarantee; for the provision of repair; and post-consumption product/discard recovery is 4, 2, and 1 respectively.
2. A given total score in the evaluation criteria can be achieved by different combinations of the Score A, Score B and Score C. For instance, a total score of 1 for a given product could mean: score of 1 for the Score A and a score of zeros for the Score B and Score C, or a score of 1 for Score B and a score of zeros for the Score A and C, and so on. A detailed description of what a particular score means in terms of product offerings or marketing claims is provided in Appendix C.
3. As mentioned earlier, a particular total score can be achieved by different product offerings. Therefore, different offerings with the same total score are considered as equal in terms of their overall effectiveness to slow and close the material loops.

4. Results and discussion

This section presents the key results from content analysis of the virtual documents on marketing claims or product offerings by manufacturers and retailers. The study identified many examples of product offerings contributing to slowing and closing material cycles. However, only 519 were analysed, due to the scope of the study (Fig. 4). These results are discussed in the context of the sustainable innovations that seek to slowing and closing the material cycles.

4.1. Overview of current efforts to slow and close material cycles

In this study, examples of products offering long-term guarantees (more than 6 years) and repair were found throughout the product sectors (Fig. 5). Large variations were found in product offerings within, as well as across, product sectors. For instance, not all of these offerings included provision for repairing or maintaining products. However, a large majority of the products (445 examples) offered repair or maintenance during the guarantee period. A consistent offer on repair and maintenance could be a critical issue for resource-intensive products where enhancing intrinsic durability requires further (material) resource use during manufacturing.

The market evidence for post-consumer product collection appears to reflect the current linear economy and a purely waste management focus for dealing with products at their end-of-life. Out of 519 products, post-consumer collection was noted only for 50 products. This clearly indicates a gap in current business norms, which do not recover value from post-consumer waste and close the material cycle.

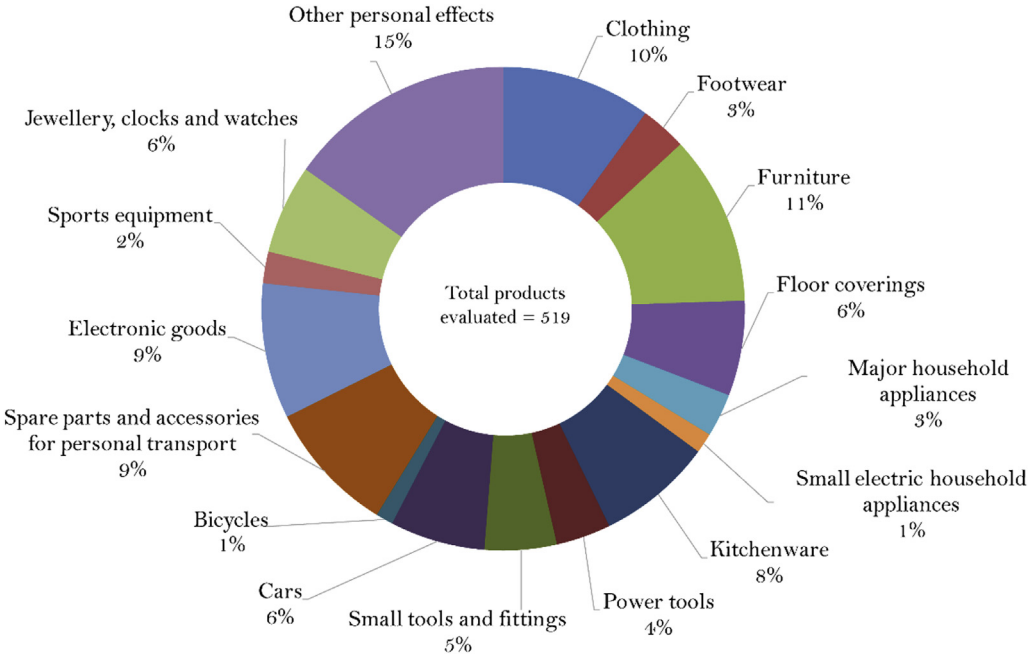

Fig. 4. Number of products evaluated across product sectors (n = 519).

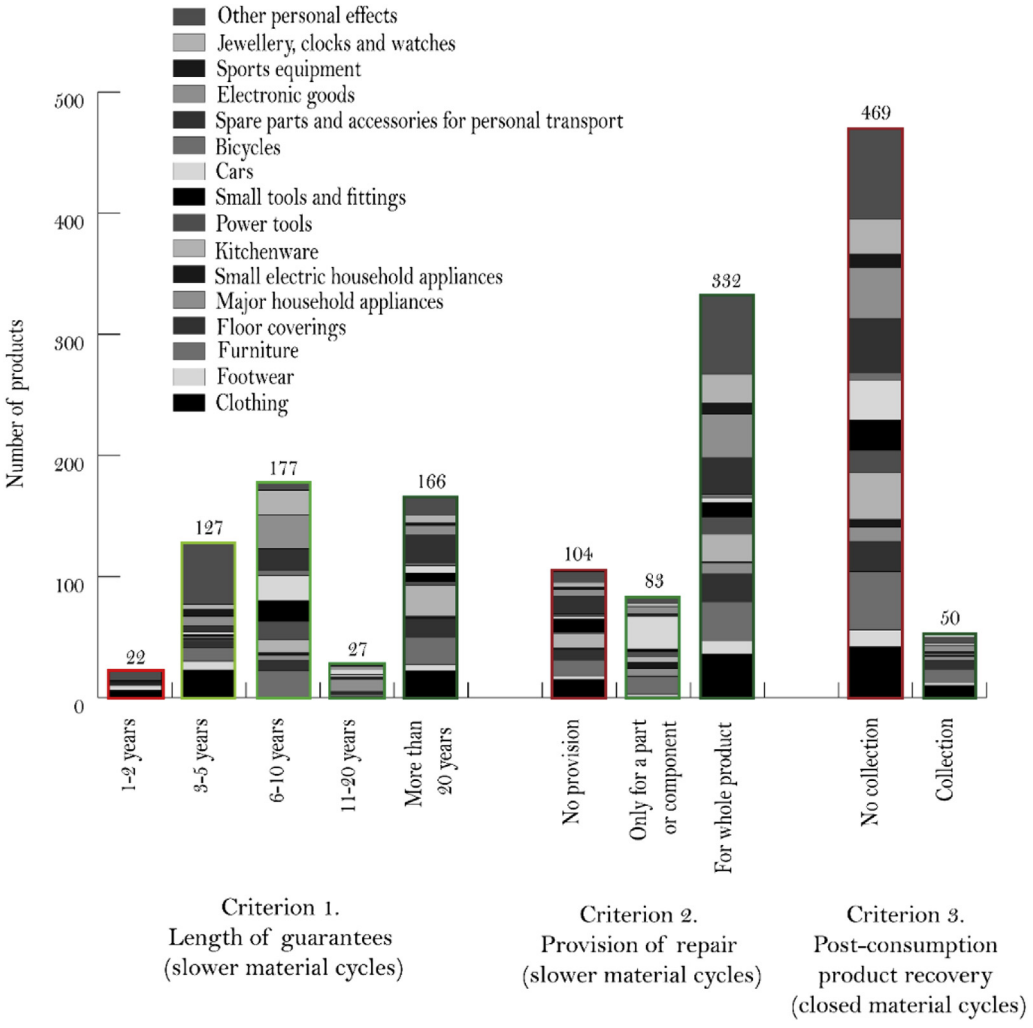

Fig. 5. Overview of analysis based on the products.

4.1.1. Product guarantees at the time of sale across product sectors

The data revealed that long-term guarantees (more than 10 years) are available for both semi-durable as well as durable products (*Fig. 6*). For instance, long-term guarantees are available for clothing and footwear (semi-durable products). These involved both specific long-term guarantees (for example 30 years guarantee on clothing products by Tom Cridland™) as well as non-specific long-term guarantees marketed as 'as long as the owner owns the product' or 'the life of the owner (for example, guarantees offered by Dr. Martens™ on its life range shoes). These guarantees were offered mostly for products that are technologically simpler, with simple components or structure, (such as kitchenware and floor coverings) or used rarely (such as small tools and other personal effects). The data collection and analysis process revealed that definitions of guarantees labelled as *lifetime* or *infinite* vary across product sectors. Out of 519 products 322 products referred to the guarantees in terms of the expected/designed life-span of the product, the life of the owner, and the time span as long as the owner owns the product. In some product sectors, the guarantees were linked to free replacement or trade-in (i.e. return for discount on new purchases).

As noted earlier, the product guarantee or warranty offered was taken as an appraisal of the products' durability or technical life even though for some products (especially durables) their duration is not strongly linked to the technical lifespan. For instance, guarantees for washing machines and refrigerators were found to be generally much shorter than their technical lifespan.

4.1.2. Provision for repair or maintenance across product sectors

Two main types of provision for the repair or maintenance of products were observed (Fig. 7), guarantees for only a part or component and for the whole product. Long-term guarantees for only one component, especially for more complex products, may not necessarily increase service life because the product may fail to deliver its intended function due to faults or wear of other components or parts. For example, long-term guarantees for the motors in food processors or refrigerators do not mean that the whole product functions, as it may become non-functioning due to faults or wear and tear of other components.

A significant number of products were offered without a guarantee. These are still covered by the consumer rights or laws of the country of final consumption that suppliers or manufacturers are obliged to comply with. For instance, within the European Union apart from a minimum two-year guarantee period, each country has specific provisions under national laws (The European Parliament and the Council of the European Union, 1999). For example, in Norway, the legal guarantee for new as well as second-hand goods that are expected to have a longer lifespan is five years (European Union, 2018).

Further, for most product sectors, the conditional provision for repair or maintenance involves free product replacement instead of repair or maintenance of the faulty product during its guaranteed period when repair is not an economically viable option. Indeed, repair services have become costly and unavailable in some product sectors (McCollough, 2009, 2007) particularly when global supply

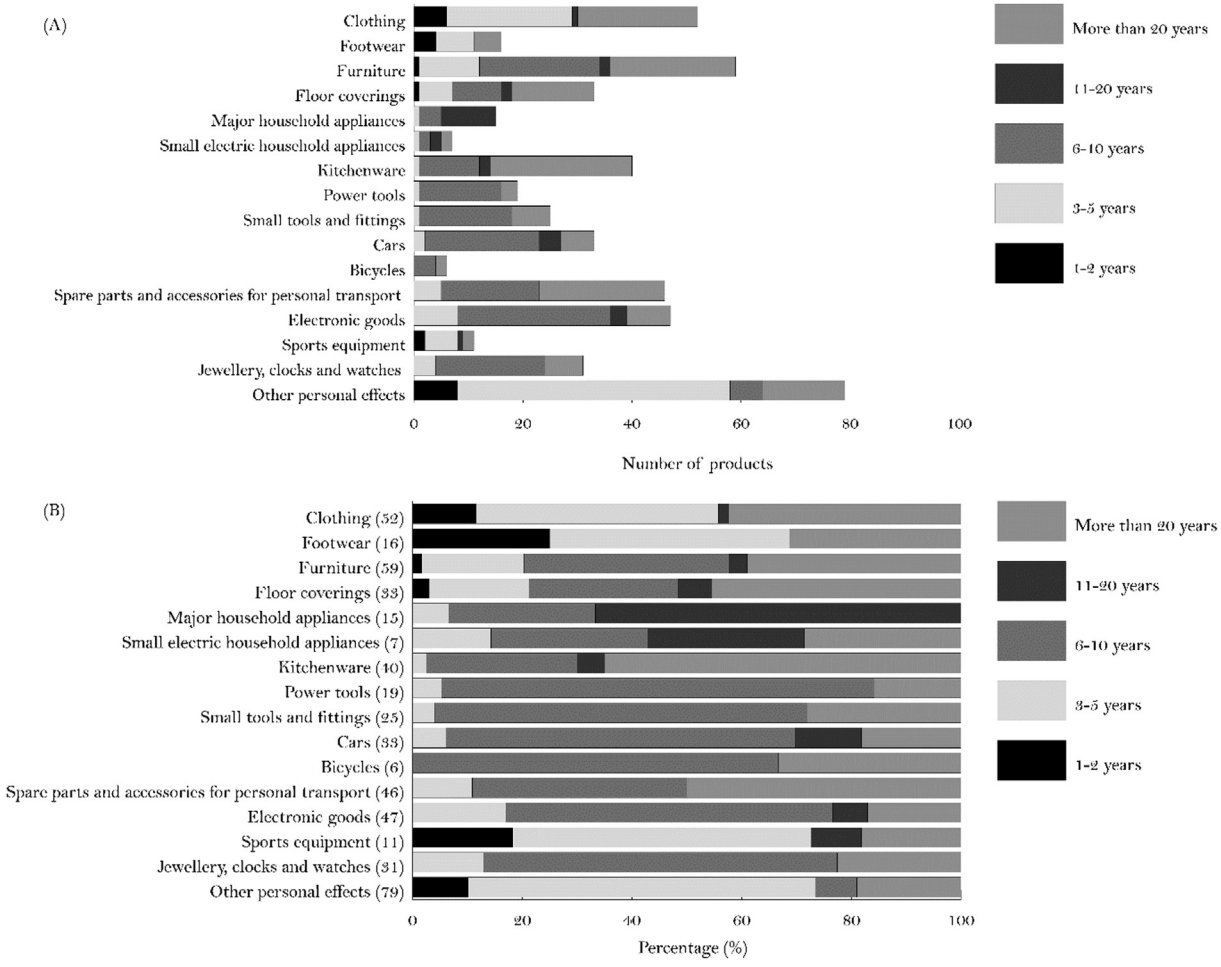

Fig. 6. Overview of product guarantees offered (n = 519).

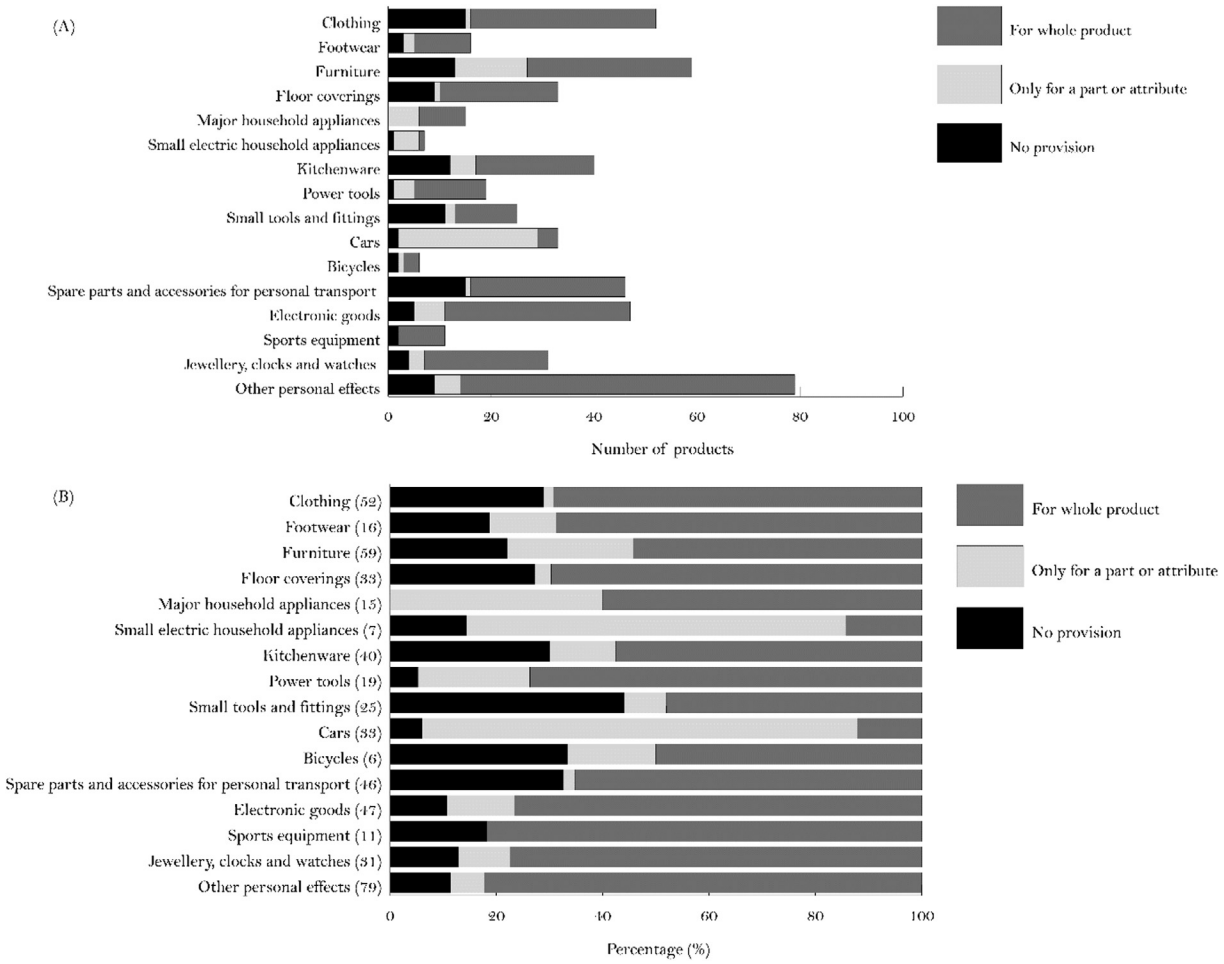

Fig. 7. An overview of provision of repair or maintenance for the studied products (n = 519).

chains make it more expensive to repair products than to purchase replacements (Cooper, 2012) In addition, technological complexity in certain product sectors also restricts repairing of these products. These issues may cause the suppliers or producers to prefer product replacement over repairing it within the guarantee period. Consumers could be offered guidance in purchasing decisions by the introduction of statutory lifespan labelling, or a repair rating such as that used by IFixIt (www.ifixit.com), an online platform that campaigns for repairable products. New business models are therefore needed that facilitate, for example, maintenance or repair through transactional models to retain economic control over products over time (den Hollander et al., 2017) or through the use of new technologies such as 3D printing of replacement parts to facilitate repair.

4.1.3. Post-consumption product recovery

As mentioned earlier, current market offerings regarding post-consumer product or discard collection reflect a predominantly linear economy. Nonetheless, post-consumer discard/product collection by suppliers or producers was observed across some product sectors - clothing, furniture, floor coverings, electronic goods, other personal effects and, major household appliances (see Fig. 8). However, in order to understand the effectiveness of such 'take-back' initiatives to closing material cycles further detailed studies are required.

4.2. Examples of best practices across product sectors

The classification of products based on whether slowing or closing material cycles is shown in Fig. 9 (using the data presented in Table 8). *'Best practice'* within product sectors (with a score of 5, 6 or 7) was represented by 145 products; these included product offerings with relatively much longer guarantees (more than 10 years) than the norm in their respective sectors, and provision for the products' repair/maintenance or post-consumer collection, or both. Products offerings *'slightly better than sector norm'* include longer guarantees on products or in some cases repair/maintenance or post-consumer product recovery. These were represented by 133 products in the study with a focus on closing the material cycles. A large number of products represented *'much better than the sector norm'* within their respective sectors, offering longer guarantees (more than 5 years), provision for repair, and collection of post-consumption products. They include both slowing and closing material cycles; thus, they were close to best practice, but significantly differ in the length of guarantees (*Table 9*). '*The sector norm*' (with a score of 1 or 2) was represented by 76 products; these products included product offerings with minimum guarantee as mandated by law or voluntary initiatives for product repair and post-consumption product recovery.

'Best practice' within product sectors focused on both slowing and closing the material cycles by offering longer life-spans, complete product repair and post-consumption product recovery.

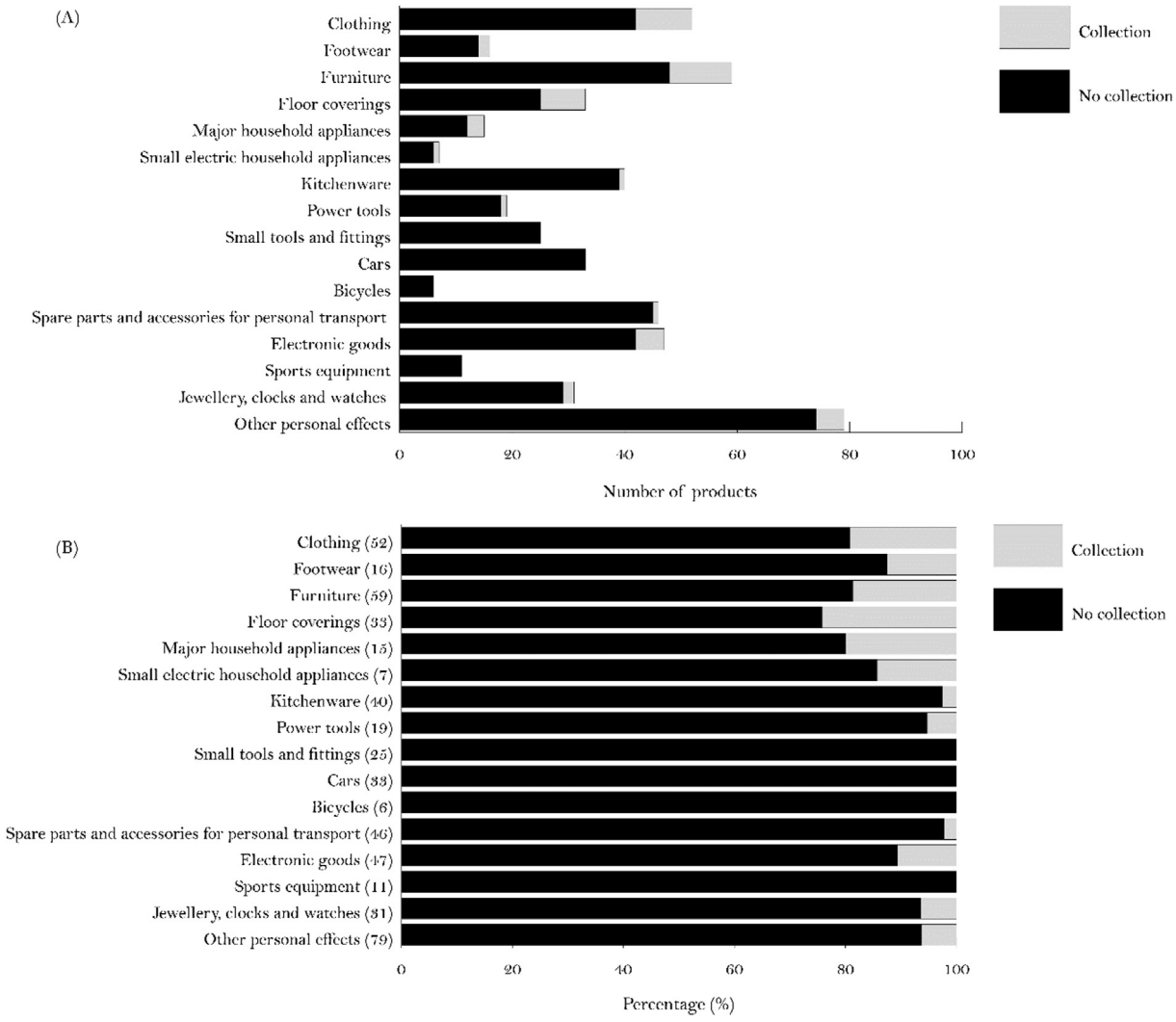

Fig. 8. Overview of provision of post-consumption product or discard recovery (n = 519).

Longer life-spans are desirable from an environmental perspective, especially for products with relatively material-intensive production phase and those that do not consume much energy during their use-phase (Downes et al., 2011). Indeed, in this study, a significant number of identified products offered a life-span of more than 5 years and 10 years - 370 and 193 products respectively. However, longer life-spans may not be desirable for products with relatively energy-intensive use phase. This is because future availability of more energy efficient alternatives could offset environmental gains from prolonged life-spans. Although, in some instances, modular design could enable products to be updated without being completely replaced. The end-of-life phase could also significantly influence net impact of prolonged life-spans. For example, electronic products containing rare-earth metals with high embodied energy. It is, therefore, essential to consider the whole lifecycle of a product in order to optimise the life-span.

4.3. Socio-economic implications for sustainable business innovations

This section discusses some of the overarching socio-economic implications for sustainable business innovations in the studied product sectors. This study has highlighted areas of best practice which could assist in business model transitions towards a circular economy. By also identifying products with relatively inferior offerings there is an opportunity to influence and improve their value propositions to slow and close material cycles. However, there are social, economic and institutional challenges to this approach which include gaps in current product policies, market dynamics, incentive structures, institutional support and competitive advantages due to product image and branding. These may be identified and solutions recommended by performing detailed analyses of the best practices including their value proposition, business strategy and processes, and stakeholder interactions. However, this is beyond the scope of the current study.

Current norms of consumerism, especially in industrialised countries, are primarily driven by technological innovations coupled with fashion-oriented socio-cultural values (Miles, 2010), market competition (Tang, 2006) and businesses' demands for rapid turnover (Laurenti et al., 2016). Consumers also have an important role in influencing product life-spans (Cooper, 2004; Evans and Cooper, 2010) with fashion and the desire to own new products affecting their willingness to adopt longer-lasting products (Cooper, 2010). Indeed, in the UK, a large proportion of discarded appliances and furniture are in functioning condition (Downes et al., 2011; WRAP, 2012). Major barriers to influencing consumers include lack of economic incentives and inadequate product information. To counter this, policy instruments such as

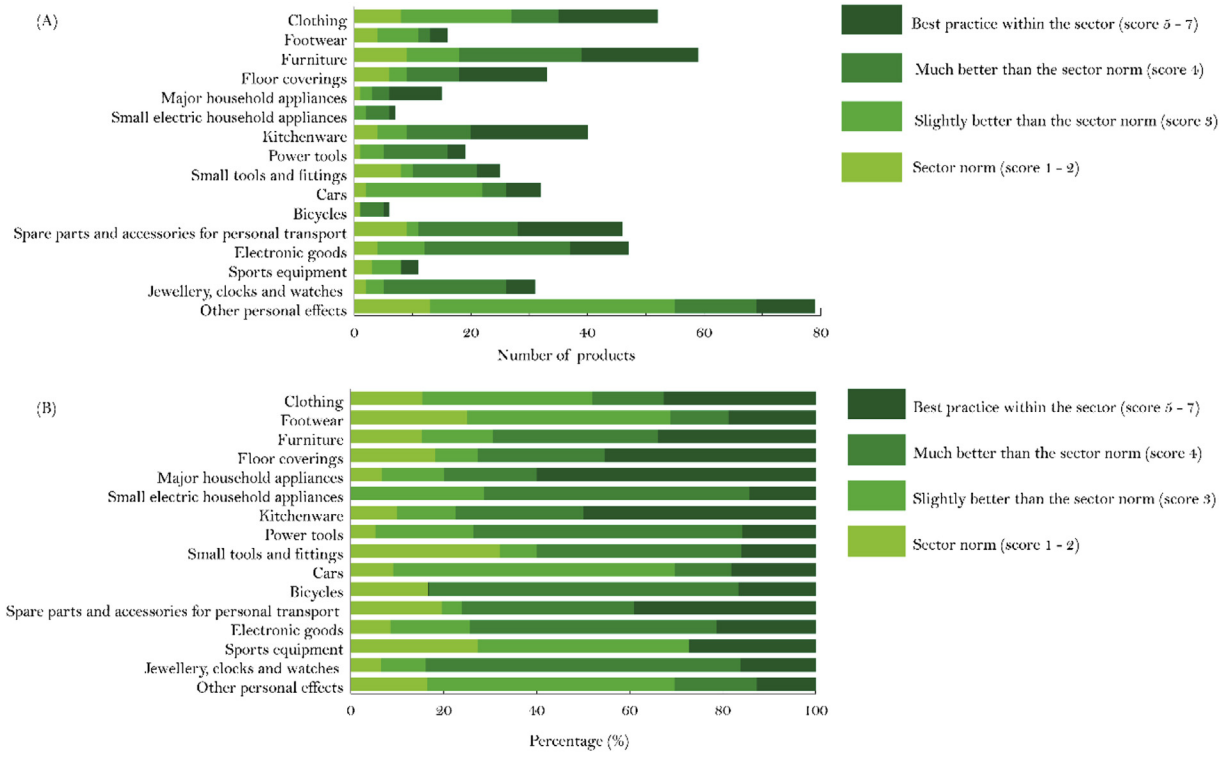

Fig. 9. Overview of the current practices across consumer product sectors.

product labelling and economic incentives such as tax reform could positively influence consumers.

Corporate values play a key role in devising business strategy and activities. Business practices may face many barriers in implementing the radical shifts required to address concerns about global sustainability (Salvia et al., 2016). Slower and closed material cycles promise significant economic potential linked to increased material efficiency (Downes et al., 2011; Ellen MacArthur Foundation, 2014, 2012). For instance, estimates show that 1% increase in value added through economic activities associated with longer product lifetimes could result in an aggregated effect 7.9 billion Euro per year across the European economy (Montalvo et al., 2016). However, this alone may not lead to sustainable business models unless virgin material and non-renewable resources are made less competitive compared to recovered resources (Organisation for Economic Co-operation and Development, 2011), especially in case of globalised value chains. Thus, a better understanding of market dynamics, incentive structures and institutional support at various societal levels is needed.

Global resource consumption is expected to triple by 2050 with current trends in material consumption. This conflicts with the 2° climate change goal (United Nations Environment Programme, 2014). Further, urbanisation and economic growth in developing nations is required in order to meet their basic needs. Indeed, globally, the number of middle class consumers will increase to 4.5 billion by 2030 (Organisation for Economic Co-operation and Development, 2011). Therefore, the examples of best practices identified in this study present an opportunity to secure circular socio-economic development necessary in both the developing and developed nations. Most examples are already in practice in developed countries; however, their market share needs to be increased through supportive policy instruments. For instance, Sweden's reforms reducing taxes on repair of consumer goods by 50% is a positive step towards slowing material cycles through economic incentives (Government Offices of Sweden, 2016). Developing countries can adopt these examples, ensuring the implementation of circular rather than linear business models.

The current industrial sustainability agenda predominantly focuses on eco-innovations, eco-efficiency and corporate social responsibility practices rather than a holistic approach to sustainability (Bocken et al., 2014). However, addressing global challenges such as climate change, resource scarcity, and intergenerational and intra-generational equity require a systemic innovation (Smith et al., 2010), addressing social, economic and ecological sustainability of global resource extraction, production, consumption and end-of-life management of products to produce a fundamental shift in current worldwide production and consumption systems.

4.4. Data quality, methods and future research

The methodology employed for data collection and evaluation is both a strength and a weakness of the study. The main limitation is that the data collection process could exclude products that do not have an online presence or were not captured by the selected keywords. Further, the quality of data depends on the authenticity of claims made by manufacturers or retailers. The data have been assumed to have a reasonable level of authenticity due to trading standards and other legislative measures to protect consumer rights. Despite this, the method chosen was the most feasible considering the broad aim and scope of the study and myriad of products.

An overview, based on current practice across product sectors, offers important insights that could help organisations in a given product sector to identify gaps in their current business models from a sustainable resource management perspective. This may include revisiting business models to incorporate circular product design that focuses on multiple value creation, reverse logistics

Table 9
An overview of the product offerings representing the best practice.

Product sector (Number of products analysed)	Businesses offering best practice within the sector*	Product offerings aimed at slowing or closing material cycles
Clothing (52)	Patagonia, Nudie jeans, Mud jeans, Tom Cridland, Darn Tough, Sloggi (Evernew Collection), Outdoor Research, Feetures	- Long-term guarantees** **(23)** - Infinite free replacements or trade in (return for value) **(5)** - Product repair **(37)** - Post-consumer product care **(10)**
Footwear (16)	Dr. Martens, Pearl Izumi, Blundstone, Rainbow Sandals	- Long-term guarantees for product repair **(5)** - Product repair **(13)**
Furniture (59)	Heal's, Neptune, IKEA, Allsteel, Vispring, Hunter Douglas, Hypnos, Spink & Edgar	- Long-term part guarantees **(25)** - Product repair **(46)** - Post-consumer product care **(11)**
Floor coverings (33)	Desso, Stainmaster, Mohawk, Abingdon Flooring, Kingsmead Carpet, JJ Flooring, Forbo, Amtico, Mannington, Zeftron	- Long-term service guarantees for floor coverings **(17)** - Product repair **(24)** - Post-consumer product care **(8)**
Major household appliances (15)	Miele, Shark, LG, Siemens, Portway, Flavel	- Long-term part guarantees **(10)** - Product repair **(15)** - Post-consumer product care **(3)**
Small household appliances (7)	Magimix, Dualit, Blendtec	- Long-term part guarantees, for instance 30 years warranty on motor of food processors and juicers **(4)** - Product repair **(6)**
Kitchenware (40)	Robert Welch, Le Creuset, Steller Kitchenware, Dudson, All Clad, Circulon	- Long-term product guarantees **(28)** - Product repair **(28)**
Power tools (19)	Ridgid, Craftsman, Battrecon,	- Long-term product guarantees **(3)** - Product repair **(18)**
Small tools and fittings (19)	PB Swiss, Kobalt, Gerber, Duluth Trading, Peli Products	- Long-term product guarantees **(7)** - Product repair **(14)**
Cars (33)	RiverSimple	- Alternative ownership of cars **(1)** - Time- or mileage- bounded maintenance guarantees **(10)** - Vehicle maintenance services **(29)**
Bicycle (6)	Specialized, Trek Bikes	- Long-term parts guarantees, e.g. lifetime of the owner warranty **(1)** - Product repair **(4)**
Spare parts and accessories for personal transport (46)	Halfords (car breaks)	- Long-term guarantees on spare parts such as tyres **(23)** - Product repair **(31)**
Electronic goods (47)	Fair Phone, Phone Blocks, Xerox, Ricoh, Kyocera	- Long-term product guarantees **(11)** - Design for disassembly for product longevity **(6)** - Guarantees for the supply of parts/components **(42)** - Post-consumer product care **(5)**
Sports equipment (11)	Bushnell, Redington	- Long-term product guarantees **(3)** - Product repair **(9)**
Jewellery, clocks and watches (31)	Robert Welch, Furrer Jacot, Love 41	- Long-term repair guarantees **(7)** - Product repair **(27)**
Other personal effects (79)	Patagonia, Eagle Creek, Tripp, Fjäll Raven, Filson	- Long-term product guarantees such as travel bags **(15)** - Product repair **(70)** - Post-consumer product care **(5)**

* More details about the best examples within the sector are provided in the Supplementary material supplied with the manuscript.
** Guarantees of more than 10 years, or timeless guarantees such as “life of the owner”, “as long as the owner owns the product” and “infinite”.

(Cole et al., 2018b) and transactional models (den Hollander et al., 2017; Mestre and Cooper, 2017). Research and innovation studies should, therefore, be planned to test new business models with the help of academia, businesses, industry, consumers and government.

The present study mainly focused on the resource management approaches to enhancing product life-spans and recovery and recycling processes. Other approaches to resource management such as industrial symbiosis were not included in this study. Future studies could be devised to include such approaches to resource management. Further, the study did not explore the social and economic impacts of slower and closed material cycles. Studies focusing on analysing drivers of consumers' attitudes and behaviours within a sustainable business models should, therefore, be planned.

We also acknowledge potential rebound effects originating from consumers (as well as producers), as a result of the anticipated reduced material consumption. Economy-wide adoption of the best practices identified in the study could result in no reduction in material consumption. Thus, an economy-wide quantitative study, such as using input-output analysis (Miller and Blair, 2009), could be employed to explore such unintended ‘spill overs’ and other potential inter-sectoral consequences.

5. Conclusion

The aim of the study was to identify examples of best practices across consumer product sectors that could lead sustainable innovations by evaluating practical approaches to resource efficiency. Based on the analysis of 519 products, it identified a total of 145 examples of product offerings representing best practices within their sector, providing an important insight into the requirements of circular business models in different product sectors.

Long-term guarantees (more than 6 years) and provision for repair were noted throughout the product sectors, although large variations were found within, as well as across, product sectors. A considerable gap was observed in recovering resources from post-consumer products: post-consumer collection was noted only for 50 products, mainly in the clothing, furniture, household appliances and electronic goods sectors.

There are several social and economic challenges to sustainability-driven business model innovation: consumers'

attitude and behaviour to adopt products with longer life-spans; the cost of repair and maintenance services; insufficient incentives to businesses and consumers to change to more sustainable business practices; and lack of institutions and governance at various scales in order to guide transitions to more circular business models. In order to support value creation through multiple use cycles, academia, government and industry require a better understanding of market dynamics, incentive structures and institutional support at various levels in the supply chain.

Declarations of interest

The authors declare that there is no conflict of interests.

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Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.03.203.

Appendix A. Product sectors, product sub-categories and products considered in the study. Adapted from COICOP (Classification of Individual Consumption according to Purpose)

COICOP product categories	Product Sub-Category Description
03.1.2 Garments (SD)	Garments for men, women, children (3–13 years) and infants (0–2 years), either ready-to-wear or made-to-measure, in all materials (including leather, furs, plastics and rubber), for everyday wear, for sport or for work
03.2.1 Shoes and other footwear (SD)	All footwear for men, women, children (3–13 years) and infants (0–2 years) including sports footwear suitable for everyday or leisure wear (shoes for jogging, cross-training, tennis, basketball, boating, etc.).
05.1.1 Furniture and furnishings (D)	Beds, sofas, couches, tables, chairs, cupboards, chests of drawers and bookshelves; and lighting equipment such as ceiling lights, standard lamps, globe lights and bedside lamps
05.1.2 Carpets and other coverings (D)	Loose carpets, fitted carpets, linoleum and other such floor coverings.
05.3.1 Major household appliances whether electric or not (D)	Refrigerators, freezers and fridge-freezers; washing machines, dryers, drying cabinets, dishwashers, ironing and pressing machines; cookers, spit roasters, hobs, ranges, ovens and microwave ovens; air-conditioners, humidifiers, space heaters, water heaters, ventilators and extractor, hoods; vacuum cleaners, steam-cleaning machines, carpet shampooing machines and machines for scrubbing, waxing and polishing floors; other major household appliances such as safes, sewing machines, knitting machines, water softeners, etc.
05.3.2 Small electric household appliances (SD)	Coffee mills, coffee-makers, juice extractors, can-openers, food mixers, deep fryers, meat grills, knives, toasters, ice cream makers, sorbet makers, yoghurt makers, hotplates, irons, kettles, fans, electric blankets, etc.
12.1.3 Other appliances, articles and products for personal care (ND)	Non-electric appliances: razor and hair trimmers and blades; nail clippers; eyebrow curlers
05.4.0 Glassware, tableware and household utensils (SD)	Glassware, crystal ware, ceramic ware and china ware of the kind used for table, kitchen, bathroom, toilet, office and indoor decoration; cutlery, flatware and silverware; non-electric kitchen utensils of all materials such as saucepans, stew-pots, pressure cookers, frying pans, coffee mills, pure'e makers, mincers, hotplates, household scales and other such mechanical devices; non-electric household articles of all materials such as containers for bread, coffee, spices, etc., waste bins, waste-paper baskets, laundry baskets, portable money boxes and strongboxes, towel rails, bottle racks, irons and ironing boards, letter boxes, feeding bottles, thermos flasks and iceboxes.
05.5.1 Major tools and equipment (D)	Motorized tools and equipment such as electric drills, saws, sanders and hedge cutters, garden tractors, lawnmowers, cultivators, chainsaws and water pumps.
05.5.2 Small tools and miscellaneous accessories (SD)	Hand tools such as saws, hammers, screwdrivers, wrenches, spanners, pliers, trimming knives, rasps and files; garden tools such as wheelbarrows, watering cans, hoses, spades, shovels, rakes, forks, scythes, sickles and secateurs; ladders and steps; door fittings (hinges, handles and locks), fittings for radiators and fireplaces, other metal articles for the house (curtain rails, carpet rods, hooks, etc.) or for the garden (chains, grids, stakes and hoop segments for fencing and bordering); – small electric accessories such as power sockets, switches, wiring flex, electric bulbs, fluorescent lighting tubes, torches, flashlights, hand lamps, electric batteries for general use, bells and alarms
07.1 Motor cars (D)	Motor cars, passenger vans, station wagons, estate cars and the like with either two-wheel drive or four-wheel drive.
07.1.3 Bicycles (D)	Bicycles and tricycles of all types
07.2.1 Spare parts and accessories for personal transport equipment (SD)	Tyres (new, used or re-treaded), inner tubes, spark plugs, batteries, shock absorbers, filters, pumps and other spare parts or accessories for personal transport equipment.
07.2.3 Maintenance and repair of personal transport equipment (S)	Services purchased for the maintenance and repair of personal transport equipment such as fitting of parts and accessories, wheel balancing, technical inspection, breakdown services, oil changes, greasing and washing.
08.2 Telephone and telefax equipment (D)	Purchases of telephones, radio-telephones, telefax machines, telephone-answering machines and telephone loudspeakers
09.1.1 Equipment for the reception, recording and reproduction of sound and pictures (D)	Television sets, video cassette players and recorders, television aerials of all types; radio sets, car radios, radio clocks, two-way radios, amateur radio receivers and transmitters; gramophones, tape players and recorders, cassette players and recorders, CD-players, personal stereos, stereo systems and their constituent units (turntables, tuners, amplifiers, speakers, etc.), microphones and earphones.
09.1.2 Photographic and cinematographic equipment and optical instruments (D)	Still cameras, movie cameras and sound recording cameras, video cameras and camcorders, film and slide projectors, enlargers and film processing equipment, accessories (screens, viewers, lenses, flash attachments, filters, exposure meters, etc.); binoculars, microscopes, telescopes and compasses.

(*continued*)

COICOP product categories	Product Sub-Category Description
09.1.3 Information processing equipment (D)	Personal computers, visual display units, printers and miscellaneous accessories accompanying them; computer software packages such as operating systems, applications, languages, etc.; calculators, including pocket calculators; typewriters and word processors.
09.2.2 Musical instruments and major durables for indoor recreation (D)	Musical instruments of all sizes, including electronic musical instruments, such as pianos, organs, violins, guitars, drums, trumpets, clarinets, flutes, recorders, harmonicas, etc.; billiard tables, ping-pong tables, pinball machines, gaming machines, etc.
09.3.1 Games, toys and hobbies (SD)	Card games, parlour games, chess sets and the like; toys of all kinds including dolls, soft toys, toy cars and trains, toy bicycles and tricycles, toy construction sets, puzzles, plasticine, electronic games, masks, disguises, jokes, novelties, fireworks and rockets, festoons and Christmas tree decorations; stamp-collecting requisites (used or cancelled postage stamps, stamp albums, etc.), other items for collections (coins, medals, minerals, zoological and botanical specimens, etc.) and other tools and articles n.e.c. for hobbies
09.3.2 Equipment for sport, camping and open-air recreation (SD)	Gymnastic, physical education and sport equipment such as balls, shuttlecocks, nets, rackets, bats, skis, golf clubs, foils, sabres, poles, weights, discuses, javelins, dumb-bells, chest expanders and other body-building equipment; parachutes and other sky-diving equipment; firearms and ammunition for hunting, sport and personal protection; fishing rods and other equipment for fishing; equipment for beach and open-air games, such as bowls, croquet, frisbee, volleyball, and inflatable boats, rafts and swimming pools; scamping equipment such as tents and accessories, sleeping bags, backpacks, air mattresses and inflating pumps, camping stoves and barbecues.
12.3.1 Jewellery, clocks and watches (D)	Precious stones, metals and jewellery, costume jewellery such as cufflinks and tie pins, and clocks, watches etc.
12.3.2 Other personal effects (SD)	Travel goods and other carriers of personal effects: suitcases, trunks, travel bags, attache' cases, satchels, hand-bags, wallets, purses, etc.; articles for babies: baby carriages, pushchairs, carrycots, recliners, car beds and seats, back-carriers, front carriers, reins and harnesses, etc.; articles for smokers: pipes, lighters, cigarette cases, cigar cutters, ashtrays, etc.; miscellaneous personal articles: sunglasses, walking sticks and canes, umbrellas and parasols, fans, keyrings, etc.

Appendix B. Various sets of keywords utilised to carry out the online searches*

Combination of sets	Keywords		
(1st Set)	Guarantee		
	Warranty		
(1st Set + 2nd Set)	Guarantee	Lifetime	
	Guarantee	Infinite	
	Warranty	Lifetime	
	Warranty	Infinite	
(1st Set + 3rd Set)	Guarantee		Repair
	Guarantee		Part
	Guarantee		Material
	Guarantee		Performance
	Guarantee		Limited
	Guarantee		Care
	Guarantee		Maintenance
	Guarantee		Satisfaction
	Warranty		Repair
	Warranty		Part
	Warranty		Material
	Warranty		Performance
	Warranty		Limited
	Warranty		Care
	Warranty		Maintenance
	Warranty		Satisfaction
(2nd Set + 3rd Set)		Lifetime	Repair
		Lifetime	Part
		Lifetime	Material
		Lifetime	Performance
		Lifetime	Limited
		Lifetime	Care
		Lifetime	Maintenance
		Lifetime	Satisfaction
		Infinite	Repair
		Infinite	Part
		Infinite	Material
		Infinite	Performance
		Infinite	Limited
		Infinite	Care
		Infinite	Maintenance
		Infinite	Satisfaction
(1st Set + 2nd Set + 3rd Set)	Guarantee	Lifetime	Repair
	Guarantee	Lifetime	Part
	Guarantee	Lifetime	Material
	Guarantee	Lifetime	Performance
	Guarantee	Lifetime	Limited
	Guarantee	Lifetime	Care
	Guarantee	Lifetime	Maintenance
	Guarantee	Lifetime	Satisfaction
	Guarantee	Infinite	Repair
	Guarantee	Infinite	Part
	Guarantee	Infinite	Material
	Guarantee	Infinite	Performance
	Guarantee	Infinite	Limited
	Guarantee	Infinite	Care
	Guarantee	Infinite	Maintenance
	Guarantee	Infinite	Satisfaction
	Warranty	Lifetime	Repair
	Warranty	Lifetime	Part
	Warranty	Lifetime	Material
	Warranty	Lifetime	Performance
	Warranty	Lifetime	Limited
	Warranty	Lifetime	Care
	Warranty	Lifetime	Maintenance
	Warranty	Lifetime	Satisfaction
	Warranty	Infinite	Repair
	Warranty	Infinite	Part
	Warranty	Infinite	Material
	Warranty	Infinite	Performance
	Warranty	Infinite	Limited
	Warranty	Infinite	Care
	Warranty	Infinite	Maintenance
	Warranty	Infinite	Satisfaction

* The data was collected/analysed over a period several months (between Feb 2017–September 2017). The 'Date Accessed' mentioned in the supplementary material is the date when the website link was last checked.

Appendix C. Explanation of the scores in terms of the product offerings or marketing claims.

Overall performance indicator	Score A	Score B	Score C	Total score	The total score represented in terms of the product offerings or marketing claims
The sector norm (sum 1 or 2)	1	0	0	1	The product is offered with 1–2 years of guarantee (in case of semi-durable or durable complex products) or 3–5 years of guarantee (in case of semi-durable and durable simpler products). The product is not offered with any provisions for repairs and post-consumer product/discard collection.
	0	1	0	1	The product is offered with a minimum guarantee as demanded by law. The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is not offered with any provisions for repairs and post-consumer product/discard collection.
	0	0	1	1	The product is offered with a minimum guarantee as demanded by law. The product is offered with post-consumer product/discard collection. The product is not offered with provisions for repairs and post-consumer product/discard collection.
	2	0	0	2	The product is offered with 3–5 years of guarantee (in case of semi-durable or durable complex products) or 6–10 years of guarantee (in case of semi-durable and durable simpler products). The product is not offered with any provisions for repairs and post-consumer product/discard collection.
	1	1	0	2	The product is offered with 1–2 years of guarantee (in case of semi-durable or durable complex products) or 3–5 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is not offered with post-consumer product/discard collection.
	1	0	1	2	The product is offered with 1–2 years of guarantee (in case of semi-durable or durable complex products) or 3–5 years of guarantee (in case of semi-durable and durable simpler products). The product is offered with post-consumer product/discard collection. The product is not offered with any provisions for repairs.
	0	1	1	2	The product is offered with a minimum guarantee as demanded by law. The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is offered with post-consumer product/discard collection.
	0	2	0	2	The product is offered with a minimum guarantee as demanded by law. The product is guaranteed for the functionality of the whole product.
Better than the norm (sum 3)	3	0	0	3	The product is offered with 6–10 years of guarantee (in case of semi-durable or durable complex products) or 11–20 years of guarantee (in case of semi-durable and durable simpler products). The product is not offered with any provisions for repairs and post-consumer product/discard collection.
	2	1	0	3	The product is offered with 3–5 years of guarantee (in case of semi-durable or durable complex products) or 6–10 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is not offered with any provisions for repairs and post-consumer product/discard collection.
	2	0	1	3	The product is offered with 3–5 years of guarantee (in case of semi-durable or durable complex products) or 6–10 years of guarantee (in case of semi-durable and durable simpler products). The product is offered with post-consumer product/discard collection. The product is not offered with provisions for repairs and post-consumer product/discard collection.
	1	2	0	3	The product is offered with 1–2 years of guarantee (in case of semi-durable or durable complex products) or 3–5 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the functionality of the whole product.
	1	1	1	3	The product is offered with 1–2 years of guarantee (in case of semi-durable or durable complex products) or 3–5 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is offered with post-consumer product/discard collection.
	0	2	1	3	The product is offered with a minimum guarantee as demanded by law. The product is guaranteed for the functionality of the whole product. The product is offered with post-consumer product/discard collection.
Good practice (sum 4)	4	0	0	4	The product is offered with 11–20 or 21–30 or 30 or more years of guarantee (in case of semi-durable or durable complex products) or 21–30 or 30 or more years of guarantee (in case of semi-durable and durable simpler products) or for the lifetime of the owner, as long as the owner owns the product, 100 years/infinite.
	3	1	0	4	The product is offered with 6–10 years of guarantee (in case of semi-durable or durable complex products) or 11–20 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is not offered with any provisions for repairs and post-consumer product/discard collection.
	3	0	1	4	The product is offered with 6–10 years of guarantee (in case of semi-durable or durable complex products) or 11–20 years of guarantee (in case of semi-durable and durable simpler products). The product is offered with post-consumer product/discard collection. The product is not offered with provisions for repairs and post-consumer product/discard collection.
	2	2	0	4	The product is offered with 3–5 years of guarantee (in case of semi-durable or durable complex products) or 6–10 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the functionality of the whole product.
	2	1	1	4	The product is offered with 3–5 years of guarantee (in case of semi-durable or durable complex products) or 6–10 years of guarantee (in case of semi-durable and durable simpler products). The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is offered with post-consumer product/discard collection.
The best practice (Sum 5,6 or 7)	4	1	0	5	The product is offered with 11–20 or 21–30 or 30 or more years of guarantee (in case of semi-durable or durable complex products) or 21–30 or 30 or more years of guarantee (in case of semi-durable and durable simpler products) or for the lifetime of the owner, as long as the owner owns the product, 100 years/infinite. The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is not offered with any provisions for repairs and post-consumer product/discard collection.

(*continued*)

Overall performance indicator	Score A	Score B	Score C	Total score	The total score represented in terms of the product offerings or marketing claims
	4	0	1	5	The product is offered with 11–20 or 21–30 or 30 or more years of guarantee (in case of semi-durable or durable complex products) or 21–30 or 30 or more years of guarantee (in case of semi-durable and durable simpler products) or for the lifetime of the owner, as long as the owner owns the product, 100 years/infinite. The product is offered with post-consumer product/discard collection. The product is not offered with provisions for repairs and post-consumer product/discard collection.
	4	2	0	6	The product is offered with 11–20 or 21–30 or 30 or more years of guarantee (in case of semi-durable or durable complex products) or 21–30 or 30 or more years of guarantee (in case of semi-durable and durable simpler products) or for the lifetime of the owner, as long as the owner owns the product, 100 years/infinite. The product is guaranteed for the functionality of the whole product.
	4	1	1	6	The product is offered with 11–20 or 21–30 or 30 or more years of guarantee (in case of semi-durable or durable complex products) or 21–30 or 30 or more years of guarantee (in case of semi-durable and durable simpler products) or for the lifetime of the owner, as long as the owner owns the product, 100 years/infinite. The product is guaranteed for the repair of its parts, components or attributes rather than the functionality of the whole product. The product is offered with post-consumer product/discard collection.
	4	2	1	7	The product is offered with 11–20 or 21–30 or 30 or more years of guarantee (in case of semi-durable or durable complex products) or 21–30 or 30 or more years of guarantee (in case of semi-durable and durable simpler products) or for the lifetime of the owner, as long as the owner owns the product, 100 years/infinite. The product is guaranteed for the functionality of the whole product. The product is offered with post-consumer product/discard recovery.

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