sustainability

MDPI

Article

An Explorative Study of Circularity Practices in Swedish Manufacturing Companies

Filip Skärin *, Carin Rösiö and Ann-Louise Andersen

Department of Industrial Product Development, Production and Design, School of Engineering, Jönköping University, 551 11 Jönköping, Sweden; carin.rosio@ju.se (C.R.); ann-louise.andersen@ju.se (A.-L.A.)
* Correspondence: filip.skarin@ju.se

Abstract: Due to the accelerating global warming crisis, interest in the concept of circular economy (CE) has started to excel. Adapting to a CE is especially important for manufacturing companies as they play major part in the global warming crisis. Hence, studying how manufacturing companies are transitioning to fit in a CE is highly relevant. Thus, the research question posed in this study is: How are manufacturing companies approaching circularity and which circularity practices can be identified? To answer the research question, a document study was carried out, wherein the latest available sustainability reports of the 20 largest manufacturing companies in Sweden were studied. A four-step process was followed, including sample selection, circularity extraction, data coding and data analysis. The findings include the creation of 61 unique circularity categories based on numerous identified circularity practices. This study focused identifying circularity practices, not only from a product perspective but for all resources and assets utilized by the company; hence, whilst many of the identified circularity practices involve product design, circularity practices have also been identified related uniquely to, e.g., manufacturing, for instance, in terms of reusing resources. Practical implications for this study include a clear overview of how Swedish manufacturing companies are working towards circularity and which specific circularity practices they mention in their sustainability reports.

Keywords: circularity practices; circular economy; manufacturing; production; sustainability; sustainable production

check for updates

Citation: Skärin, F.; Rösiö, C.; Andersen, A.-L. An Explorative Study of Circularity Practices in Swedish Manufacturing Companies. *Sustainability* **2022**, *14*, 7246. https://doi.org/10.3390/su14127246

Academic Editor: Alessia Amato

Received: 5 May 2022
Accepted: 10 June 2022
Published: 13 June 2022

1. Introduction

During the past 150 years, the linear economy, characterized by a "take-make-use-dispose" product and material view, has dominated. However, the limitations of the linear economy are the unrealistic view of bottomless access to natural resources whilst seeing no scarcity in economic growth [1,2]. In line with the accelerating global warming crisis, the approach of circular economy wherein the utilization and lifetimes of resources and materials are maximized has gained significant increase in attention [3–5]. In fact, from an academic point of view, the number of publications published per year on the circular economy increased more than 2.5 times between 2010 and 2015 [6]. Nowadays, the circular economy is generally accepted as a significant support to sustainable development [1,6,7].

Furthermore, due to the ongoing increase in awareness regarding the global impacts of manufacturing companies [8], a tripartite sustainability focus has started to become interesting for many manufacturing companies. This sustainability focus implies operating the manufacturing companies with the aim of reducing the negative impacts on the environment, economy, and society. For manufacturing companies, this is an especially important issue as they play a major part in the global warming crisis. For instance, in 2019, manufacturing companies were responsible for 23% of the United States' entire carbon dioxide equivalents (CO_2-e) released into the atmosphere [9]. In Sweden, this was even higher the same year, causing almost 32% of the entire country's CO_2-e emissions [10].

An important step to support sustainable manufacturing and, thus, limit manufacturing companies' impact on the ongoing climate crisis involves fitting the company to a circular economy. A circular economy, wherein the utilization and lifetimes of resources and materials are maximized in order achieve a near perpetual closed material loop [11], is realized through circularity practices. In this study, the definition of circularity practices is based on the definition of sustainable manufacturing practices in the study by Alayón et al. [12] (p.4), which is " ... *actions, initiatives and techniques that positively affect the environmental, social or economic performance of a firm* ... ". Hence, a circularity practice is recognized in this study as planned, ongoing, or realized actions, initiatives, and techniques that aid in achieving circular economy.

CE has also become an interesting topic for companies, as indicated by CE being increasingly mentioned in publicly available sustainability reports [13,14]. Hence, investigating sustainability reports enables the possibility of identifying how companies are approaching circularity and the possibility for retrieving an up-to-date clarification regarding their circularity practices. Hitherto, the conducted research focusing on Swedish manufacturing companies whilst scrutinizing sustainability reports is limited. In terms of focusing on circularity practices, it is non-existent. In total, only two papers have been found that focus on Swedish companies whilst studying sustainability reports. Carlsson Kanyama et al. [15] studied yearly reports, webpages and, if available, sustainability reports in order to investigate the climate change mitigation efforts among 85 randomly selected Swedish transportation and manufacturing companies. The focus in their study was climate mitigation in terms of CO_2/GhG emissions and energy use [15]. Paulson and Sundin [16] studied sustainability reports, along with interviews, as a means to describe how two large manufacturing companies included sustainability in their product development. In terms of previous research which focuses on identifying circularity practices by studying sustainability reports, a study was carried out by Calzolari et al. [13], who focused on the adaptation of CE practices within 50 European multi-national enterprises within the agri-food, services, energy, and manufacturing sectors. The latter included companies such as Volkswagen AG (Berlin, Germany), Daimler (Stuttgart, Germany), Siemens (München, Germany), and Unilever (London, UK). Production and manufacturing were found to be primarily related to reuse of parts and components, usage of renewable energy, and increases in production system efficiency [13].

To summarize, circularity practices amongst manufacturing companies have been sparingly researched. Hence, in order to expand the knowledge in terms of circularity practices in manufacturing companies, the objective of this paper is to explore how Swedish manufacturing companies consider circularity and to increase knowledge on how they approach circularity. In this study, the 10R framework was chosen as the basis for the analysis due to its extensiveness in comparison to, e.g., 3R or 6R. The study was carried out in order create insights into the state of circularity practices and to give empirically driven insights to how future research should support industry in adapting to a circular economy. Thus, the research question addressed is: How are manufacturing companies approaching circularity and which circularity practices can be identified by studying sustainability reports?

The remainder of the paper is structured as follows: Section 2 describes the study's background, including the R methodology and circularity practices. Section 3 includes a presentation of state-of-the-art research within the area. Section 4 presents the methodology, including a description of the sample selection, data coding, and data analysis. In Section 5, the identified circularity practices are presented and, thereafter, discussed in Section 6. Lastly, in Section 7, conclusions drawn from the study as well as suggestions for further research are presented.

2. Background

2.1. The R-Methodology and Circularity Practices

The R methodology originates from the introduction of 1R in the 1980s. This stemmed from the lean manufacturing and focused primarily on the reduction of wastes [17]. Later on, during the 1990s, an evolved R methodology covering Reduce, Reuse, and Recycle was adopted by many companies in order to establish more environmentally friendly manufacturing. However, as this R methodology, frequently termed 3R, does not guarantee the possibility of ensuring a total-life-cycle focus, i.e., a continuous focus on the product life-cycle stages, including pre-manufacturing, manufacturing, use, and post-use, it is nowadays frequently recognized as not capable of ensuring sustainable manufacturing on its own [11,18]. Hence, it only supports the cradle-to-grave approach of products [19], which is often adopted in the linear economy. This cradle-to-grave approach solely covers the usage of the product over a single life cycle without considerations for extending the product's life over several cycles. Instead, the nowadays-well-established concept of circular economy, which previously relied heavily on the 3R-methodology, has developed into incorporating at least 6Rs. This approach includes the addition of Recover, Redesign, and Remanufacturing from the previous 3R methodology. By applying the 6R approach, a closed-loop which entails the cradle-to-cradle perspective of products and resources can be implemented within the supply chain in order to set the foundation for sustainable manufacturing [11]. However, in recent years the R methodology has been developed even further. This has led to a numerous Rs being added to the aforementioned 6Rs. For instance, Potting et al. [20] present an additional 4Rs, resulting in a total of 10Rs (see Figure 1).

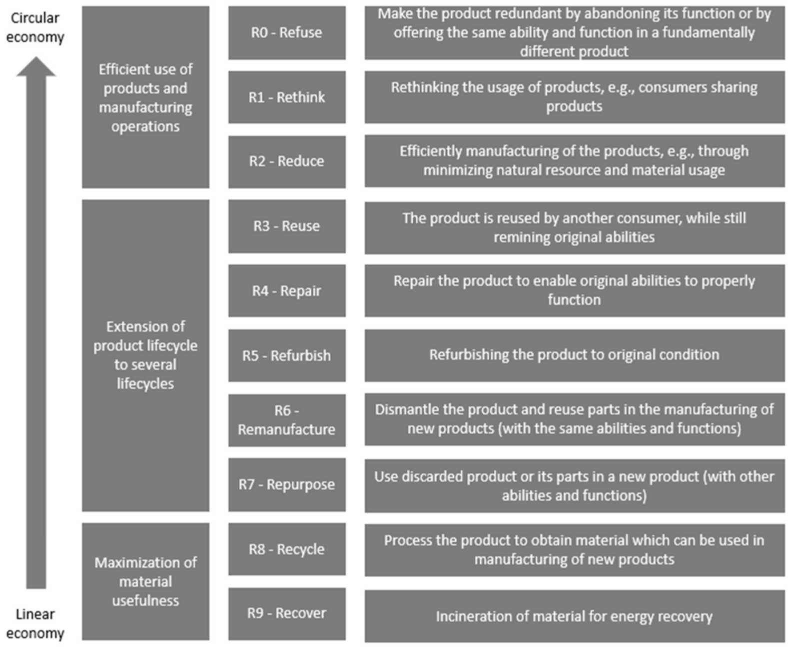

Figure 1. 10R framework, adapted from Potting et al. [20].

The general rule of thumb in the framework by Potting et al. [20] is that a higher focus on the first Rs leads to a higher degree of circularity, which aids in maximizing the utilization of resources, hence limiting the environmental impacts of manufacturing companies. For instance, Refuse, Rethink, and Reduce often occurs before producing the products; therefore, a high possibility of limiting the products' impact even prior to production has been initiated. The aspects of circularity described by Potting et al. [20] are divided into three main categories: (1) efficient use of products and manufacturing operations, (2) extension of product lifecycle to several lifecycles, and (3) maximization of the usefulness of materials. Nevertheless, there is a discrepancy amongst the hitherto conducted research within this field regarding the terminology used in these descriptions of the R methodology. Potting et al. [20] uses similar but not identical terms to the previously discussed 6Rs, whilst also adding Refuse, Rethink, Repurpose, and Recover to the R methodology. Using an extensive framework, such as the 10R framework, might aid in structuring and categorizing the circularity practices mentioned in the sustainability reports of manufacturing companies. Hence, due to the extensiveness of the 10R framework, in comparison to, e.g., 3R or 6R, it was used as the structural basis for this study.

Furthermore, circularity practices are required to be carried out by manufacturing companies in order to reduce their negative environmental impact and, more specifically, in order to maximize the utilization and lifetimes of resources and materials. Circularity practices have for instance been studied previously by Calzolari et al. [13], who identified manufacturing companies mentioning circularity practices divided into Reduce, Renewable energy and resource efficiency, Reuse, Recycle, and Recover. The foremost include, e.g., design for resource recovery, design for environment, modular design, and investing in green infrastructure. Circularity practices in terms of energy sourcing from renewable energy and improving production system efficiency were identified in relation to renewable energy and resource efficiency. Reuse included, e.g., reusing secondhand parts and refurbishing parts for reuse. Further, circularity practices were also mentioned in terms of remanufacturing parts and components, recycling components, recycling production waste materials, having a repair and return service for products, on-site generation and production of renewable energy, and recycling operational waste [13].

2.2. Sustainability Reporting in Sweden

As of 1 January 2017, Swedish companies are, according to Swedish law, required to present an annual sustainability report if the companies meet two of the following requirements: (i) having a total asset of more than 175 million, (ii) having net sales of more than 350 million SEK, or (iii) having an average of 250 employees or more [21]. As of late 2020, a total of 1182 companies were classified as large companies, i.e., having more than 250 employees [22]. This indicates an estimated number of companies which fulfil the requirements and, thus, are required to annually create a sustainability report.

According to the Swedish Companies Registration Office [23], the sustainability report can either be included in the administration report or as a separate appendix in the annual financial report. The sustainability report should provide the reader with insights into the company's impacts in the following areas: the environment, social relations and employees, respect for human rights, and the counteraction of corruption [23]. Companies are obliged to provide sufficient insights into sustainability in order for the reader to gain an understanding of the company's development, position, impacts, and results for the aforementioned four areas. A policy for each area needs to be described in the sustainability report. The policies should include an explanation of the company's fundamental principles for managing the area. In order to being able to report on the result of a policy, the company must continuously follow up and analyze how the policy is carried out and the effect of the policy, and the company must also include a statement regarding the actions taken in accordance with the policy [24]. Hence, the sustainability reports are found to provide enough empirical data to explore how manufacturing companies are approaching circularity and to identify circularity practices.

3. State-of-the-Art Research

The inclusion of circularity in sustainability reports has increased during the past year in several industrial sectors [13,14]. From an academic point of view, a similar increase in interest is present as circularity, or circular economy, has been addressed in several papers wherein the primary research method is through document studies of sustainability reports. However, a scattered focus exists amongst the hitherto conducted research on circularity, covering, for example, green logistics practices [25]; CSR practices [26]; the existence, quality, and detail of GhG reporting [27]; and the barriers and drivers of CE business models [28]. A few papers have used the R as a theoretical foundation in previous research; for instance, Sihvonen and Partanen [29] explored how Asian, European, and North American information and communications technology companies have addressed circular economy in their sustainability reports. The focus regarded the eco-design practices of quantitative environmental targets. Circularity was addressed in terms of the product life cycle phases pre-use, use, and post-phase, including Reduce, Reuse, Recycle, and Recover [29]. Steward and Niero [30] used the same Rs as Sihvonen and Partanen [29] when conducting a document study of sustainability reports from companies within the fast-moving consumer goods sector, including, e.g., H&M (Stockholm, Sweden), Carlsberg (Copenhagen, Denmark), Colgate (New York, NY, USA) and Barilla (Parma, Italy). Rhein and Sträter [31] studied the sustainability reports of 10 global companies with products most frequently found in oceans and on coasts, focusing on the self-commitment of those companies and reconstructing the circular economy concept and the Rs Reduce, Reuse, and Recycle. Moreover, Sehnem et al. [32] conducted a longitudinal study of a Brazilian cosmetics company in order to identify how sustainability principles have evolved in the company. Their study was based on the ReSOLVE framework by the Ellen MacArthur foundation [33], including the CE principles Regenerate, Share, Optimize, Loop, Virtualize, and Exchange. The principles share commonalities with the R framework, for instance, the principle Loop is described as covering circularity practices such as the remanufacturing of components and recycling of materials.

Furthermore, Govindad and Hasanagic [34] conducted a systematic literature review on the drivers, barriers, and practices to the circular economy from a supply chain perspective. Circularity practices related to achieving a cleaner production included integrating 6R practices in the production as a means to increase eco-efficiency. Practices were also mentioned, e.g., in terms of cleaner and greener purchasing; the implementing of supply chain strategies supported by CE; initiating cooperation with other companies in order to enable reuse, recycle, and remanufacture; and ensuring measurable environmental performance data [34].

In summary, a gap exists in terms of investigating how manufacturing companies are addressing circularity and which circularity practices they carry out. As mentioned, circularity practices are in focus primarily in the studies of Calzolari et al. [13] and Govindan and Hasanagic [34]; however, in their studies the focus was not limited to manufacturing companies and instead focused on practices from a supply chain perspective. Several papers briefly mention circularity practices, though none aims at extensively describing circularity practices from a manufacturing company perspective.

4. Methodology

4.1. Document Study

A document study was carried out in order to answer the study's research question, i.e., to investigate how manufacturing companies are approaching circularity and which circularity practices can be identified by studying sustainability reports. The approach was of inductive character, as the categorization used was based on the aforementioned 10R framework; however, no further pre-determined structure was followed. Instead, the categorization and coding of the circularity practices derived from an interactive process of revising, recoding, and re-analyzing the findings. A methodological process consisting of four major steps—sample selection, circularity extraction, data coding, and data analysis—was followed.

4.2. Sample Selection

The companies chosen for the document study were required to fulfil the criteria of being manufacturing companies registered in Sweden. A search was carried out in an online national database (https://www.allabolag.se, accessed on 23 November 2021) for company information for the largest Swedish companies based on net turnover in 2020 (see Table 1). The top 20 largest manufacturing companies were selected for the document study. A focus on the largest manufacturing companies was established due to the assumed possibility of creating an extensive sustainability report. Larger companies were expected to have the resources required to create a sustainability report wherein circularity practices are extensively described. The study was limited to Swedish manufacturing companies due to the barrier of studying sustainability reports written in languages other than Swedish or English. Furthermore, Swedish production has been characterized as fostering the employees' sense of responsibility and participation as well as having a positive view on development and change [35]. Swedish production culture might, through these characteristics, spur the initiation of realizing circularity practices, hence the focus on Swedish manufacturing companies in this study.

Table 1. Study sample and description.

#	Company	Manufacturing Industry	Report Structure	Report Language	Net Turnover (msek)
1	Volvo Group	Automotive	Integrated	English	338,446
2	LM Ericsson	Communication equipment	Separate	English	232,390
3	Volvo Cars	Automotive	Integrated	English	184,417
4	Scania CV	Automotive	Integrated	Swedish	125,125
5	Electrolux	Household appliances	Integrated	Swedish	115,960
6	Atlas Copco	Machines	Integrated	Swedish	99,787
7	AstraZeneca	Medicine	Separate	English	87,469
8	Sandvik	Engineering in mining/quarrying	Integrated	Swedish	86,404
9	SKF	Machines	Integrated	Swedish	74,852
10	Husqvarna	Machines	Separate	English	41,943
11	NIBE Industrier	Machines	Integrated	Swedish	27,146
12	SCA	Paper and packaging	Integrated	Swedish	18,410
13	Holmen	Paper and packaging	Integrated	Swedish	16,327
14	Arla Foods	Diary	Integrated	Swedish	16,717
15	Swedish Match	Tobacco	Separate	Swedish	16,698
16	Essity Hygiene and Health	Hygiene and health	Integrated	Swedish	15,391
17	SSAB EMEA	Metal	Integrated	English	22,829
18	BillerudKorsnäs	Paper and packaging	Integrated	Swedish	14,519
19	ABB	Electronics	Separate	English	14,120
20	Elekta	Electronics	Integrated	English	13,860

The sample included the latest available sustainability reports of the 20 largest manufacturing companies in Sweden according to their net turnover in 2020. The unit of analysis was circularity practices, whereas the aim of the study was to describe how circularity was addressed in the sustainability reports by identifying circularity practices. The search in the database was conducted in November 2021, whereby the document studies cover sustainability reports from 2020 as these were the latest available sustainability reports. Due to an increased frequency and focus on circularity amongst companies in their sustainability reports [13,14], only the latest sustainability report from each company was studied. Companies which were classified as manufacturing companies in the database were included in the document study. The only exceptions were Volvo Lastvagnar AB (Volvo Trucks, Gothenburg, Sweden) and Volvo Construction Equipment, which, due to being subsidiaries of the Volvo Group, are not required to create their own sustainability reports. Instead, their reports are included in the Volvo Group sustainability report, and thus, are already included in this study. In this sample, 15 companies presented their sustainability reports as an integrated part of the annual financial report, whilst 5 published a separate sustainability report.

4.3. Circularity Extraction, Data Coding, and Data Analysis

Once the sample selection was finalized, the sustainability reports were gathered from the companies' websites, and the reports were read in their entirety. During the reading, parts related to circularity were extracted. The sustainability reports were read in English if available, although in the cases where solely a Swedish version of the report was available, the excerpted parts were translated into English after reading the reports in order to synchronize the data analysis. The parts of the reports related to circularity, e.g., in terms of quotes and paragraphs, were thereafter sorted and categorized using the software NVivo. This was based on the 10R framework. The framework was chosen due to its extensiveness in comparison to other R frameworks (e.g., 3R and 6R). However, as the 10R framework described by Potting et al. [20] was focused on circularity for products, the Rs were only used as a foundation for the coding and analysis and the literal definitions for all the Rs were not used per se.

After all relevant paragraphs and quotes were sorted into the relevant Rs, a second round of revising the codes was conducted with the intention of creating suitable categories for each R. These were not pre-determined but derived from the data coding and analysis and were created based on the commonalities within each R. Thereafter, in a third round of data coding and analysis, the excerpts and quotes in each category were once again analyzed in order to identify circularity practices. A circularity practice was defined as planned, ongoing, or realized actions, initiatives, and techniques that aid in achieving circular economy (adapted from Alayón et al. [12]), based on the 10R framework. However, as this study aimed at exploring the circularity practices amongst manufacturing companies, without limiting the study to solely focusing on the products produced (as in the 10R framework), circularity practices exceeding the product focus whilst still determined to belong within the Rs were included. Once this was completed, attempts at combining similar circularity practices within the same category were realized.

5. Findings

5.1. Circularity Practices in Manufacturing Companies

By studying the sustainability reports of the 20 largest manufacturing companies in Sweden, circularity practices describing how companies are approaching circularity were identified (see Table 2). The complete list of identified circularity practices is presented in Table A1 in Appendix A. Based on the circularity practices, categories summarizing the contents of the practices were identified. These categories were based on the 10R framework.

5.1.1. R0—Refuse

Refusing involves making the product redundant by abandoning its function or by offering the same ability and function in a fundamentally different product [20]. In the sustainability reports, Refuse is referred to as the *refusal of harmful* and *non-recyclable materials in products* as well as *non-renewable resources*. The former includes, for instance, the "*Elimination of non-recyclable black plastic cans for our snus range sold in Scandinavia.*", as described by Swedish Match. This was reported as being realized through the circularity practice of transitioning from fossil fuels to biological sources for solvents and plastics. *Refusing harmful materials* was mentioned by Electrolux (Stockholm, Sweden): "*Eliminate harmful materials to enable higher quality of recycled materials and reduce environmental impact.*".

Table 2. Summary of identified circularity categories.

R	Circularity Category
R0—Refuse	Refuse harmful materials in products
	Refuse non-recyclable materials in products
	Refuse non-renewable resources
R1—Rethink	Apply sustainable chemical management
	Develop and adapt circular business models
	Develop and launch circular innovations
	Develop sustainable lubricants
	Use recyclable, recycled, renewable, and sustainable materials in products
	Rethink packaging solutions
	Use recyclable, recycled, and renewable packaging materials
	Rethink ways to enable customer sustainability
	Rethink product design to make it more sustainable and circular
	Increase usage of renewable energy
	Use new sustainable processes and technologies
	Initiate new collaborations which support circularity
	Rethink transportation patterns
	Rethink ways to manage and evaluate supplier sustainability
R2—Reduce	Reduce chemical usage
	Reduce energy usage
	Reduce fuel usage
	Reduce GhG emissions
	Reduce packaging material
	Reduce pollution in air, land, and water
	Reduce resource usage
	Reduce hazardous waste
	Reduce waste sent to landfill
	Reduce waste sent for disposal
	Reduce waste in general
	Reduce water usage
R3—Reuse	Reuse heat, steam from own production
	Reuse residual materials from manufacturing
	Reuse metals
	Reuse thermoplastics
	Reuse materials in general
	Reuse packaging material
	Reuse products
	Reuse resources
	Reuse in general
	Reuse waste (hazardous and non-hazardous)
	Reuse water

Table 2. *Cont.*

R	Circularity Category
R4—Repair	Repair products
	Repair in general
R5—Refurbish	Refurbish products
R6—Remanufacture	Remanufacture products
	Remanufacture in general
R7—Repurpose	Repurpose packaging materials
	Repurpose products
	Repurpose residual materials from manufacturing
	Repurpose waste (hazardous and non-hazardous)
R8—Recycle	Recycle energy from production
	Recycle heat from wastewater and machines
	Recycle excess material from production
	Recycle metals
	Recycle thermoplastics
	Recycle materials in general
	Recycle packaging materials
	Recycle products
	Recycling in general
	Recycle waste (hazardous and non-hazardous)
	Recycle water
R9—Recover	Recover energy through incineration

5.1.2. R1—Rethink

Rethinking, according to Potting et al. [20], involves rethinking the usage of products. In this study, multiple categories of Rethink were created, alongside a numerous circularity practices within each category. Related to products and packaging, the following categories were identified: *develop and launch circular innovations, use recyclable, recycled, renewable, and sustainable materials in products, rethink product design to make more sustainable and circular, rethink packaging solutions* and *use recyclable, recycled, and renewable packaging materials*.

Developing and launching circular innovations is mentioned as realized through using new materials in products and applying clear principles for defining a circular innovation. Circularity practices related to *using recyclable, recycled, renewable, and sustainable materials in products* were mentioned in terms of, e.g., following a clearly stated vision to include a percentage of recycled materials in new products, taking part in research projects, and working closely with suppliers to develop the materials. Furthermore, exploring alternative materials and production methods was mentioned, highlighted by, e.g., Essity's starting to produce tissues from wheat straw, a residual material from agriculture. *Rethink product design to make it more sustainable and circular* was found to be related to circularity practices such as including recycling instructions for customers, ensuring use of life cycle assessments to measure the products' environmental impacts, designing for the easy dismantling of products, developing tools for environmental evaluation, and setting goals for reducing the carbon footprint for all design projects. In terms of packaging, categories including *rethink packaging solutions* and *use recyclable, recycled and renewable packaging materials* were identified. Within these categories, replacing tailor-made packaging with recycled standard (e.g., pallets), launching programs to identify packaging solutions based on fossil-free materials, working with preventive initiatives to reduce litter, and actively working with increasing recycling rates of consumer packaging were some of the mentioned circularity practices in the sustainability reports.

In terms of manufacturing related categories, *use new sustainable processes and technologies, increase usage of renewable energy*, and *apply sustainable chemical management* were identified as categories. The foremost involves allocating funds for research and development and using electrically driven machines running on renewable energy, e.g., electric arc furnaces, as described by Volvo Cars. The category *increase usage of renewable energy* was mentioned in terms of, e.g., investing in solar panels.

Categories such as *initiate new collaborations which support circularity, rethink transportation patterns, rethink ways to manage and evaluate supplier sustainability, and rethink ways to enable customer sustainability* were also identified in the study. In terms of customer sustainability, circularity practices include, but are not limited to, promoting recycling to customers, promoting initiatives against littering, and registering products with the Environmental Product Declaration (EPD). This is an independently verified document providing transparent and comparable information about environmental impacts of products from a lifecycle perspective. *Rethink ways to manage and evaluate supplier sustainability* relates to, e.g., including energy management requirements for purchasing new machines, evaluating suppliers' sustainability impacts by developing digital tools to support the assessment of suppliers CO_2 impacts, as well as encouraging companies to integrate sustainability information into their reporting cycle, e.g., energy, waste, and water footprints. Several companies also reported circularity practices for initiating new collaborations which support circularity, e.g., Treesearch, the CEO Alliance, the Circular Bioeconomy Alliance, and the Ellen MacArthur Foundation.

Furthermore, the following categories were also identified: *develop sustainable lubricants and develop* and *adapt circular business models*. In fact, several companies reported the implementation and adaptation of business models, for instance, through sharing cars: "*Our mobility solution, M, is a testament of how new business models can contribute to our circular economy strategy. As more progressive cities push to reduce emissions, car sharing will be critical in reducing the number of cars in the city. Each shared car can replace up to 8 privately owned cars which helps to free up space as well as achieve substantial resource and emission avoidances.*" (Volvo Cars). Scania (Södertälje, Sweden), a large automotive company, reported a similar adaptation: "*Circular thinking is already part of Scania's value chain and business model today, and we believe that its significance will be decisive in the future*.". Sandvik similarly reported: "*We will drive the shift towards more circular business models and better resource efficiency, strive for closed cycles for our products and create new revenue streams through the processes and materials we use*."

5.1.3. R2—Reduce

Reducing regards the efficient manufacturing of products, e.g., through minimizing natural resource and material usage [20]. By studying the sustainability reports of manufacturing companies, the following categories within Reduce were identified: *chemical usage, energy usage, fuel usage, GhG emissions, packaging material, pollution (in air, land, water), resource usage, waste*, and *water*. Circularity practices were primarily found for *reduce energy usage, GhG emissions* and *resource usage*. In the former, the companies mentioned activities such as using ISO-certified energy management systems, installing more energy-saving machines for manufacturing, setting goals for energy efficiency, taking measures to achieve the goals, and changing to more energy-efficient materials in production. *Reduce GhG emissions* was reportedly realized by carbon capture, having an ongoing dialogue with suppliers to understand their roadmaps to reaching carbon-neutral production, and reducing the amount of business travel, to name a few. Circularity practices mentioned in terms of *reduce resource usage* include, for example, reducing the material spill from production flows and feeding it back into manufacturing processes as raw materials and ensuring that all raw materials are used, e.g., by finding solutions for how to use residual materials in other products.

In terms of *reduce packaging*, circularity practices include setting clear targets to reduce packaging, reducing the number of stock-keeping units, and harmonizing product components, e.g., ingredients and packaging, as in the case of the diary manufacturer Arla Foods.

Reduce water usage was reportedly realized by innovative product design, improving processes, and by extending the scope for water savings. *Reduce waste* was found in terms of reducing hazardous waste, waste sent to landfills, waste sent for disposal, and waste in general. Related to these categories, finding ways to utilize residual/slag products, setting ambitious targets, and preserving packaging well were some of the mentioned circularity practices.

5.1.4. R3—Reuse

Potting et al. [20] described Reuse as occurring when the product is reused by another consumer whilst still retaining its original abilities. The findings of this study include a further categorization of Reuse, apart from reusing products, by also dividing the category into *reuse heat*, *steam*, *residual materials*, *metals*, *thermoplastics*, *materials in general*, *resources*, *waste*, and *water*.

Reuse heat, *residual materials* and *water* were found to be primarily realized through circularity practices occurring in production, for instance, through recovering steam and hot water to generate electricity and heat, through waste management with the aim to have new solutions for waste streams, and by installing equipment to collect and filter rejected water. Furthermore, creating a circular flow within the manufacturing has been found to be possible to realize, partly by reusing, for instance: "*Steam from the mills is used in the drying processes in the integrated sawmills*." (Holmen, Stockholm, Sweden).

Reuse residual materials from manufacturing occurs when the materials used for the initial manufacturing of a product is reused in the manufacturing of new products, as illustrated in the report by SSAB: "*We recirculate much of the material generated from our production back into our own processes, thereby reducing the need for virgin raw materials, CO2 emissions and waste*.".

Apart from the reusing occurring in manufacturing, circularity practices are also found to be realized by companies in order to enable *reusing products* and *materials*. For instance, circularity practices such as establishing repurchasing programs, following global agreements, partaking in circular collaborations, and establishing closed-loop systems with suppliers were also described in the sustainability reports in relation to Reuse.

5.1.5. R4—Repair

Repairing is described as enabling the original abilities to properly function [20]. Repairing was divided into two categories; *repair products* and *repair in general*. The latter solely includes a description of performing the act of repairing, without any further specifications for circularity practices. The former, i.e., *repair products*, was found to be realized through the circularity practices establishing service centres for repairing products and by increasing the service-based business within the company. The utilization of service centres is described by e.g., Atlas Copco (Nacka, Sweden) and SKF (Gothenburg, Sweden) as a key enabler for repairing product and component: "*Atlas Copco has several service divisions which repairs and reuses used products, which prolongs the life of the products and minimizes waste*.". Volvo Group reports a similar view: "*Here, the main elements are to service, maintain and repair to increase the utilization rate of all materials in the products. As we increase our service-based business, the main output is uptime and availability of machines and vehicles. This is a prerequisite to focus even more on recyclability and remanufacturing*".

5.1.6. R5—Refurbish

According to Potting et al. [20], refurbishing involves the act of bringing the product back to its original condition. From the findings of this study, a single categorization was identified, i.e., *refurbish products*. This has been found to be realized through several circularity practices, for instance, by establishing a global network of technological service units, continuously identifying new components fit for refurbishing, and through commercial offerings wherein the companies themselves buy back complete products with the aim of refurbishing them. For instance, the communications equipment manufacturer Ericsson (Stockholm, Sweden) mentioned: "*Ericsson Refurbished Spares is a commercial offering focusing on buy-back, refurbishment and re-use of spare parts from used equipment, to create both customer and sustainability value. Ericsson refurbished spares' quality is comparable to new ones and supports a more efficient way to utilize materials in a circular approach.*". Circularity practices related to establishing programs for extending product life cycles by upgrading the product at optimal intervals and establishing a second-hand market for the refurbished products and establishing specialized teams for refurbishing at specific centres were also described. The latter, for instance, was reported by the Volvo Group: "*For trucks, we also buy back complete vehicles to dismantle and use parts in our network of service workshops. Parts that can be refurbished or remanufactured are kept and used and the rest is sent for materials recycling.*"

5.1.7. R6—Remanufacture

Remanufacturing involves dismantling the product and reusing parts in the manufacturing of new products (with the same abilities and functions) [20]. In this study, Remanufacture was divided into two categories: *remanufacture products* and *remanufacture in general*. The latter solely included a description of performing the act of refurbishing, without any further specifications for circularity practices in the sustainability reports. The former involved the remanufacturing of products and was found to be a considerable option for reducing resource usage, as indicated in one of the reports: "*Volvo Cars' remanufacturing programme restores replaced parts to their original specifications to realize both environmental and financial savings. A remanufactured part requires up to 85 per cent less raw materials and 80 per cent less energy compared to a new part. In 2020, the programme saved approximately 271 tonnes of steel and 126 tonnes of aluminium. The energy saved corresponds to a carbon dioxide emission reduction of 4116 tonnes per year* . . . ". Accordingly, a similar finding was reported by the Volvo Group: "*A remanufactured gearbox can save 50%, and sometimes up to 80%, of resources used compared to a new one. The saving comes from avoiding processing and refining new materials and the associated energy, water and emissions footprint*". Remanufacturing mentioned in terms of circularity practices, such as strategies for how to manage products after their first life cycle and buyback programs, were also mentioned in the sustainability reports. ABB, a manufacturer of industrial robots, seem to have taken remanufacturing a step further, describing a circularity practice consisting of completely remanufacturing products using original design plans, specifications, and dimensional data.

5.1.8. R7—Repurpose

Repurposing is described by Potting et al. [20] as using discarded product or its parts in a new product (with other abilities and functions). Repurposing has been divided into several categories: *products, packaging materials, waste (hazardous and non-hazardous)* and *residual materials from manufacturing*. The latter is partly described as taking place internally within the company; however, it is not limited to the focal company, instead repurposing residual materials is also described as occurring on a supply chain level: "*Hallsta Pappersbruk basically has no emissions of fossil carbon dioxide, which is unique. In the mill's energy solutions, heat is recycled from the wastewater and paper machines, the bark is sold to heating plants and residual products are composted into plant soil*". Similarly, SSAB reports: "*Materials that cannot be recirculated internally can be processed and sold externally to create new revenue streams whilst reducing CO2 emissions by substituting natural resources in other industries. For example, the use of blast furnace slag enables the cement industry to significantly reduce their CO2 emissions*".

Although the financial outcomes of circularity practices seldom are mentioned by companies, an exception was mentioned by ABB, having initiated the repurposing of packaging material: "*Also in Finland, our MOMG Espoo subsidiary purchased a second-hand* *cardboard shredder so it could reuse received packaging as padding for outgoing packages. The shredder, which cost $1700, will pay for itself in less than one year"*.

5.1.9. R8—Recycle

Recycling involves processing the product to obtain materials which can be used in manufacturing new products [20]. In this study, recycling was divided into the following categories: *energy from production, heat from wastewater and machines, excess materials from production, metals, thermoplastics, materials in general, packaging materials, products, recycling in general, waste (hazardous and non-hazardous)* and *water*.

Recycle products is described as being enabled through circularity practices, such as product design and by having a modular product design, thereby easing the disassembly of the product. Partaking in collaborative, industry-wide forums and partaking in circular collaborations were also described as circularity practices within Recycle. The former is related to Swedish companies which aim to increase the circular flow of materials throughout Swedish industry. ABB (Västerås, Sweden), Stena Recycling (Gothenburg, Sweden), Combitech (Växjö, Sweden), and Electrolux have, for example, worked together on a joint trial/pilot project that aims to improve the efficiency of the recycling process for electrical products. Partaking in circular collaborations is exemplified by ABB, which have entered into a local agreement to develop a process where all fractions (iron, copper, and aluminum) in electric motors products can be recycled and reused in new products.

Recycle waste, including both hazardous and non-hazardous, were, in comparison to other circularity categories, described by the companies in terms of key performance indicators (KPIs). Any further circularity practices covering how recycling waste is realized were not possible to derive from studying the sustainability reports.

Furthermore, *recycle packaging material* was described by multiple companies: "*Scania has a goal that 80 percent of the plastic in packaging, from our incoming flow, will be recycled or bio-based by 2025" (Scania), and "Over the past year, in-house recycling and reuse, mainly of packaging materials and thermoplastics, reduced the amount of waste ABB generates by 1700 tons*" (ABB).

5.1.10. R9—Recover

The last R in the 10R framework includes the incineration of material for energy recovery [20]. Whilst being the last R, finding a way to incinerate the materials in order to gain energy rather than sending them to landfills is believed to be a more circular option. This is illustrated by the tobacco manufacturer Swedish Match (Stockholm, Sweden): "*Changed from waste to landfill to waste incineration for power production at the plant in Dothan*". Similar to the aforementioned category *recycling waste (hazardous and non-hazardous)*, companies commonly refer to Recover as expressed as KPIs, which limits the identification of circularity practices related to Recover. Nevertheless, circularity practices identified include increasing transparency and driving improvement by having their own sites be more specific about their waste disposal methods.

6. Discussion

6.1. Circularity Practices in Different Areas/Functions

By studying the sustainability reports of the 20 largest manufacturing companies in Sweden, the 10R framework was extended from focusing primarily on products to including the circularity categories and circularity practices throughout manufacturing companies. A total of 61 unique categories, divided into the 10Rs, were identified in this study. Furthermore, circularity practices for applicable categories were described as an attempt at clarifying which of these circularity categories are realized by manufacturing companies and how these practices are accomplished. These were directly reported by the companies in their sustainability reports. However, circularity practices were, in this study, not solely restricted to a product focus, which is emphasized in the 10R framework. Instead, circularity practices were identified on multiple levels and areas apart from products, primarily in areas related to manufacturing, companies, and supply chains. Whilst many of the identified circularity practices involve product design, as in the 10R framework, circularity practices were also identified related uniquely to, e.g., manufacturing, for instance, in terms of reusing resources. This was previously deemed as solely a customer act, whilst this study shed light on all practices within a manufacturing company. Similarly, circularity practices such as Repurpose were identified as being enabled from a supply chain perspective, whereby the company producing the original product does not necessarily carry out the act of repurposing the product alone. Instead, the need for creating external collaborations is highlighted throughout several of the identified circularity practices.

Whilst the products produced are undoubtedly significant for manufacturing companies, all resources used within the company should be considered through the lens of circularity. For instance, production systems, machines, tools, vehicles, and so on are also assets affecting manufacturing companies CO_2 emissions. Hence, circularity at a manufacturing company needs to exceed its own products and cover all assets and resources. Manufacturing companies might already have an established way of achieving circularity in terms of other factors apart from their own products, which should have been possible to identify in this study since it was not limited to focus only on products. Nevertheless, no such identification was possible to derive from studying the sustainability reports. In this study, although no company mentioned the practice of refurbishing, e.g., production systems, machines, and tools, the cases of ABB and Sandvik, i.e., manufacturers of production robots and manufacturing equipment, indicate that these companies offer the option of prolonging the lifetimes of their products, whereby the manufacturing companies themselves are treated as customers. This practice is confirmed by ABB: " … *previously owned robots, along with peripheral equipment such as controllers and manipulators, are refurbished to "like-new" conditions at one of ABB's Global Remanufacture and Workshop Repair Centers. Through these efforts, as of 2020, we have one of the largest inventories of pre-owned and reconditioned robots across the world, with 400 robots of various types in stock for sale*". Hence, even though these circularity practices are offered as a service, any further identification regarding how this is realized was not possible to derive from studying sustainability reports.

6.2. Circularity Practice Level of Description

Although circularity practices were identified for a majority of the circularity categories, many of these are not described in adequate detail to gain a profound understanding of how to realize these circularity practices. Instead, the circularity practices were often described on an overarching level, without any clear explanation. Similarly, the environmental and economic benefits of realizing circularity practices are seldom described by the manufacturing companies. Whilst the companies are not obliged to describe the practices in detail and extensively, it is difficult to view it as a disadvantage to transparently describe how circularity is achieved in the company. The sustainability reports provide companies the possibility of displaying their practices for how they realize circularity. For the largest manufacturing companies, especially, this could be seen as an opportunity, as they can be recognized as having the resources and internal competence to both carry out circularity practices and also clearly describe them in a public report.

Furthermore, some of the Rs are both per the definition by Potting et al. [20] as well as according to the categorization in this study, covering larger areas than other studies. For instance, comparing Reduce and Remanufacture, whereby it is possible to interpret the former in many different ways, i.e., for an academic but foremost for the companies desiring to work towards circularity. Remanufacture, on the other hand, includes a clearer definition. These differences might partly explain the varying amounts and levels of description of the circularity practices in the categories and Rs. However, although the difference between the Rs might cause some confusion in academia and in companies, this study contributed to clarifying the contents of the circularity categories, i.e., by identifying circularity practices. Moreover, even though the number of identified circularity practices was unique to each R, no significant difference in terms of how detailed the circularity practices are described was identified. For instance, circularity practices related to, e.g., Refurbishing, Remanufacturing, and Repairing are not described in enough detail to gain insights into how these practices are actually realized. Often, buyback programs, product design, and establishing networks of special facilities for managing the product after its first life cycle are mentioned as circularity practices, but they are not described in detail.

6.3. Extending the 10R Framework

This study was carried out with the intention of exploring how manufacturing companies are approaching circularity and which practices can be identified. This was realized based on the 10R framework, whereas the Rs presented in the framework were used as a foundation for identifying and categorizing the circularity practices. Due to the 10R framework primarily focusing on products, without taking a company-wide perspective wherein all materials and resources used by manufacturing companies are taken into consideration, it was deemed necessary to extend the existing 10R framework. For example, in terms of Reuse, companies are seemingly not limited to reusing the products and components produced, in contrast to the definition by Potting et al. [20]. Instead, the focus also involves reusing manufacturing related by-products, such as excess materials, waste, and heat. This insight further strengthens the importance of studying circularity not only from a product perspective but also from a material and resource perspective wherein all materials and resources used in manufacturing are taken into consideration for the circularity practices.

However, extending the scope and not limiting the study to products led to multiple categories, and circularity practices were found to be interlinked and affecting each other. Hence, the results of this study should not be regarded as quantitatively comparable, only resembling the circularity practices presented in the sustainability reports of Swedish manufacturing companies. Furthermore, the sample in this study was comprised of the largest manufacturing companies in Sweden. These companies are international actors, whereas many have globally located production facilities not solely in Sweden. The identified circularity practices were seldom specifically linked to production facilities located in Sweden. It is therefore possible that the identified circularity practices are similar to practices realized by manufacturing companies in countries other than Sweden as well. However, further research is required to verify whether the circularity practices identified in this report also are realized in manufacturing companies in other countries.

Some of the identified circularity practices and categories share similarities with previously identified practices in previous research. Nevertheless, no previous research has focused on extending the 10R framework per se, solely adding to less extensive frameworks such as the 3Rs and 4Rs (e.g., [29–31]). For instance, in terms of Reduce, categories such as *GhG emissions*, *Waste*, *Packaging material* and *Chemical usage*, which all were categories created in this study, can also be identified in previous research as well (e.g., [27,28,30–32]). Similarly, the existence of fewer circularity categories for the Rs Repair, Refurbish, and Remanufacture can be derived from studying previous research, as is also indicated by the results of this study. These Rs are foremost found to be related to products and components, both in previous research and in this study. However, although circularity categories can be identified in previous research, the identification of circularity practices remains a more difficult task. Seldom has previous research focused on clearly describing how the Rs and circularity categories are realized, i.e., through circularity practices, and only a few examples have been given in previous research. In this study, the research gap of identifying how the Rs are realized was therefore sought. Many of the mentioned circularity practices described in this study are also primarily related to manufacturing, and due to the sample, therefore, the results can be considered complementary to previous research by, e.g., Calzolari [13] and Govindan and Hasanagic [34], who focused on global companies from a supply chain perspective.

Extending the 10R framework was deemed necessary as companies, especially manufacturing companies, need to adapt to circularity and, therefore, further clarifying the contents of circularity is crucial. Previous research, such as in the tool circularity scanner by Blomsma et al. [36], has challenged the definitions of the Rs, as has this study. However, although this study extended the 10R framework, challenges for manufacturing companies in using the 10R framework might still exist. Some Rs might not be relevant for all companies, although the aim of carrying out circularity practices within the first Rs still remains and this implies a greater possibility for circularity. Studying sustainability reports has proven to be a sufficient method for identifying and partly describing circularity categories and practices; however, digging deeper into the details of the identified circularity practices might make it possible to identify enablers and barriers for realizing circularity practices.

7. Conclusions, Limitations, and Further Research

This study was carried out in order create insights into the state of circularity practices and also to provide empirically driven insights into how future research should support industry in adapting to a circular economy. The research question addressed through this study was: How are manufacturing companies approaching circularity and which practices can be identified? An investigation of the most recently published sustainability reports of the 20 largest manufacturing companies in Sweden was carried out. A total of 61 unique circularity categories were identified based on numerous identified circularity practices (see Appendix A for entire list). By extending the 10R framework to include both new categories and circularity practices, the practical implications of this study include a clear overview of how Swedish manufacturing companies are working towards circularity. Extending the 10R framework was also required to shift the focus from solely a product perspective to a resource and material focus, wherein a manufacturing company, as described by the companies themselves, clearly needs to approach circularity beyond the product.

The study was limited to Swedish manufacturing companies due to the difficulty of studying sustainability reports written in languages other than Swedish or English. However, the interest in conducting a similar study from a global perspective is present, and thus future research could involve studying how circularity is being addressed amongst the largest manufacturing companies globally. The selection of companies has an impact on the generalization of the results and thereby no restrictions regarding the manufacturing industry were set in this study.

Due to the sustainability reports often being described quite vaguely and on an overarching level, the continuation of this study could be to go deeper into the circularity practices related to each R. Studying sustainability reports has been proven to be a sufficient method to gain an understanding of the circularity practices among the largest manufacturing companies in Sweden; however, a deeper analysis of how these circularity practices are realized, and what hinders them, would be an interesting topic for further research. Similarly, the possibility of studying the most polluting Swedish companies rather than largest in terms of turnover is also possible in order to identify the circularity practices of these companies.

Author Contributions: Conceptualization, F.S., C.R. and A.-L.A.; methodology, F.S., C.R. and A.-L.A.; formal analysis, F.S.; investigation, F.S.; visualization, F.S., C.R. and A.-L.A.; writing—original draft, F.S.; writing—review and editing, C.R. and A.-L.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Overview of the circularity categories and practices mentioned by Swedish manufacturing companies in their sustainability reports.

Circularity Categories	**Circularity Practices**
R0—Refuse	
Refuse harmful materials in products	Transition from fossil fuels to biological sources for solvents and plastics
Refuse non-recyclable materials in products	No further description of practice mentioned
Refuse non-renewable resources	No further description of practice mentioned
R1—Rethink	
Apply sustainable chemical management	No further description of practice mentioned
Develop and adapt circular business models	Offering maintenance services; offering subscription services; through organizing product sharing; offering different business model setups for different customers based on need
Develop and launch circular innovations	Using new materials in products; applying clear principles for defining a circular innovation
Develop sustainable lubricants	Using lubricants based on vegetable oils; by offering changing reconditioned oil as a service, thus prolonging the lifetime of products
Use recyclable, recycled, renewable and sustainable materials in products	By recirculating materials into production processes. If materials cannot be recirculated internally, look for options for materials to be processed into by-products and sold externally. Thus creating new revenue streams for the company; following a clearly stated vision to include a percentage of recycled materials in new products; taking part in research projects; working closely with suppliers to develop the materials; Identifying efficient ways to measure and follow up an established vision; exploring alternative materials and production methods, e.g., Essity's starting to produce tissues from wheat straw, a residual material from agriculture; promoting the use of recycled materials; establishing programs for coordinating and driving design and material related topics
Rethink packaging solutions	Carrying out projects, programs and initiatives in order to identify more sustainable packaging solutions
Use recyclable, recycled and renewable packaging materials	Improving the possibility of recycling the packaging materials; Developing alternative packaging materials; by initiating discussions with suppliers; replacing tailor-made packaging with recycled standard (e.g., pallets); adhering to local legislations regarding recycled materials; actively working with increasing recycling rate of consumer packaging; working with business partners in local markets to increase consumer awareness; working with preventive initiatives to reduce litters; launching programs to identify packaging solutions based on fossil-free materials
Rethink ways to enable customer sustainability	Registering product to Environmental Product Declaration (EPD), an independently verified document providing transparent and comparable information about environmental impacts of products from a lifecycle perspective. The EPD can be used by customers who want to minimize their carbon footprint; promoting recycling to customers; promoting initiatives against littering; increasing availability of spare parts
Rethink product design to make more sustainable and circular	Designing products for recycling; including recycling instructions for customers ensuring easy dismantling of product; designing out negative environmental impacts; using life cycles assessment to measure the products' environmental impacts; developing and using tools for calculating carbon footprint of products which can be used during the design phase; setting goals for reducing carbon footprint for all design projects; driving the application of environmentally conscious design principles during product development lifecycle; developing guidelines for product development; developing tools for environmental evaluation; creating guideless for quantifying and communicating customers' sustainability performance; designing products for recovery, either reusing or recycling (e.g., the EU End-of-Life Vehicle Directive)

Table A1. *Cont.*

Increase usage of renewable energy	Investing in solar panels; using heat from own production
Use new sustainable processes and technologies	Allocating funds for research and development; using electrically driven machines running on renewable energy, e.g., electric arc furnaces
Initiate new collaborations which support circularity	Using robotics and shared product data to scan waste for specific products and materials. Thus identifying recyclable portions and extract those; joining collaborations with the aim of accelerating the transition to a CE, e.g., the Ellen MacArthur foundation; collaborating with waste management suppliers to reduce waste and improve waste management; creating foundations, e.g., the Circular Bioeconomy Alliance.; creating action plans for circular economy; developing roadmaps to integrate circularity across the business; running ideation events to source ideas on how to apply a circular mindset across the value chain (result: a prioritized list of actions for implementation across medicine development, product manufacture, devices, packaging, logistics, facilities, and built assets and procurement); joining national research platforms (e.g., Treesearch); establishing repurchasing programs in collaboration with partners; joining collaborations which aids in coordinating efforts for CO_2 reduction by bringing industries closer together, e.g., the CEO Alliance; promoting projects and investments; working continuously to identify partners who can make use of residual materials from production; joining recycling initiatives
Rethink transportation patterns	No further description of practice mentioned
Rethink ways to manage and evaluate supplier sustainability	Encouraging companies to integrate sustainability information into their reporting cycle, e.g., energy, waste, and water footprints; including energy management requirement for purchasing new machines; evaluating suppliers' sustainability impacts through establishing environmental requirement for business partners, including manufacturing, transport, energy use, GHG emissions, chemicals in manufacturing, product chemical content, and water and waste management; evaluating suppliers' sustainability impacts by establishing Circular Economy and Portfolio Sustainability programs; evaluating suppliers' sustainability impacts by developing digital tools to support the assessment of suppliers CO_2 impacts
R2—Reduce	
Reduce chemical usage	No further description of practice mentioned
Reduce energy usage	Developing innovative products which uses less energy; raising awareness and investing in efficient production equipment; including energy management requirements for purchasing new machines; establishing programs focusing on improving energy consumptions in the company's facilities; annually setting up and following goals for improved energy efficiency; changing to more energy-efficient materials in the production; actively monitoring energy consumption; setting goals for energy efficiency and taking measures to achieve the goals; through reconditioning of products, since it leads to lower maintenance, costs and energy usage; using ISO certified energy management systems; by using a decentralized approach for improving the energy usage and integrating this with the company's environmental management system; linking facilities' energy efficiency to local maintenance strategies; setting group-wide energy targets; though energy recovery at manufacturing sites; through systematic energy management; continuously striving for energy efficiency; installing more energy-saving machines in the manufacturing; by establishing remanufacturing programs
Reduce fuel usage	At customers by offering lighter products, e.g., SSAB producing high-strength steel

Table A1. *Cont.*

Reduce GhG emissions	Through product design; having all division set own target for projects for new or redesigned products which will achieve a significant reduction in carbon footprint; through smart packaging solutions, reducing the air in packaging, thus increasing the utilization of space required during transports; by reducing size and weight of packaging materials; by integrating high-speed machines into important production phases; using low-carbon transport alternatives; reducing amount of business travels; scaling down waste at manufacturing sites; establishing programs for reducing CO_2 emissions; using locally produced biogas; offering the service of reconditioning products; by producing products made from less raw materials, with lower weight and fuel consumption, increased load capacity and longer lifespans. thereby reducing GhG emissions in the use phase of the product; by producing high strength materials, resulting in lower weight and improved fuel economy for the customer; setting science based targets initiative approved targets for GhG emissions; utilizing residuals; using recycled materials as raw materials, thus reducing the need for virgin raw materials; Advancing and improving the manufacturing processes; using high quality materials; recirculating materials into the manufacturing processes, thus reducing the need for virgin raw materials; using larger share of recycled and bio-based materials; increasing resource utilization; minimizing waste; by efficient component value retention; developing new business opportunities; adapting to a circular economy (transforming product design and how products are produced); decreasing GhG emissions from production processes; carbon capturing; having an ongoing dialogue with suppliers to understand their roadmaps to reach carbon-neutral production; through remanufacturing programmes, restoring replaced parts to original specifications
Reduce packaging material	By harmonizing product components, e.g., ingredients and packaging as in the case of the diary manufacturer Arla Foods AB (Solna, Sweden); by reducing the number of stock-keeping units (SKUs); by setting clear targets to reduce selected packaging
Reduce pollution in air, land and water	Through product design
Reduce resource usage	Through increased resource efficiency by setting targets to lower process mass intensity (PMI); using metrics to measure raw material efficiency (e.g., PMI); by upgrading infrastructure and adapting the industry, including technologies and industrial processes; by integrating high-speed machines into important production phases; by ensuring that all raw materials are used, e.g., by finding solutions for how to use residual materials in other products; by seeing the products from a life cycle perspective; through productivity and quality-enhancing measures; by major investment programs in robotics and automation in low-cost countries; by striving for efficient resource management throughout the entire value chain; through innovation and product development; by increasing the process productivity; by enabling customers to send back products and reconditioning them; by creating and finding customer value through productivity which reliable products entails, e.g., as described by ABB, a company aiming at offering reliable rotation solutions.; by condition monitoring and data analysis, creating the possibility for products (e.g., bearings) to be removed from a demanding application and reconditioned before it breaks down; by utilizing residual materials; through remanufacturing programs; establishing materials saving programs (in production); reducing the material spill from production flows and feeding it back into manufacturing processes as raw materials (in production); by increasing the utilization degree of resources (in production)
Reduce hazardous waste	No further description of practice mentioned
Reduce waste sent to landfill	By using waste from production for recycling or extraction of energy; finding ways to utilize residual/slag products
Reduce waste sent for disposal	No further description of practice mentioned
Reduce waste in general	Through prevention, reduction, recycling and reusing waste; through product design; through well-preserving packaging; by setting ambitious targets; throughout the entire value chain
Reduce water usage	By innovative design of products; by improving processes; by extending the scope for water savings

Table A1. *Cont.*

R3—Reuse	
Reuse heat, steam from own production	By, e.g., using steam from mills in drying processes in sawmills; by recovering steam and hot water to generate electricity and heat.
Reuse residual materials from manufacturing	Reusing residual materials as raw materials in own production; by finding new functions for residual materials to be used as raw material in other products; through waste management with the aim to have new solutions for waste streams with the philosophy 'every single step counts'
Reuse metals	Through partaking in circular collaborations, e.g., ABB entering a local agreement to develop a process where all fractions (iron, copper and aluminium) in electric motors products can be recycled and reused in new products; through dismantling faulty or otherwise returned products and parts; through repurchasing programs; by changing from traditional manufacturing processes to electrical processes which uses scrap metals; through establishing a closed loop system with suppliers, e.g., Volvo Cars returning aluminium scrap from production to the suppliers, who in turn reuses is in their production
Reuse thermoplastics	No further description of practice mentioned
Reuse materials in general	Through examining the business opportunities for reusing materials; through product design fulfilling directives for reusability of materials
Reuse packaging material	No further description of practice mentioned
Reuse products	Establishing corporate divisions especially for repairing and reusing products.; by establishing a strategic direction in the portfolio offering to reuse products; by taking back products at end-of-life for refurbishing; by striving for a circular life cycle by investigating possibilities for creating a circular economy for products; through global agreements, creating new circular business, e.g., Volvo Buses and Stena Recycling, reusing bus batteries as energy storage units in buildings
Reuse resources	No further description of practice mentioned
Reuse in general	No further description of practice mentioned
Reuse waste (hazardous and non-hazardous)	No further description of practice mentioned
Reuse water	By establishing capital funds for natural resources reduction investing in projects to find solutions for reusing water; by finding other areas to use rejected water from production; by installing equipment to collect and filter rejected water; by using surface water to transport and wash products, thus being able to reuse the same water multiple times before purifying it in several steps in different combinations of mechanical, biological and chemical purifications.
R4—Repair	
Repair products	By establishing service centres for repairing products; by increasing the service-based business within the company
Repair in general	No further description of practice mentioned
R5—Refurbish	
Refurbish products	Through product design, enabling returning, renovating and reselling products.; through establishing a global network of technological service units; by primarily focusing on climate-intense components for taking back, refurbishing and reusing; by continuously identifying new components fit for refurbishing; by exploring opportunities for refurbishing of products where the company has established a strategic decision in its portfolio offering to do so; through commercial offerings; through buying back complete products to refurbish or remanufacture; by establishing specialized teams for refurbishing at specific centres; by establishing a second-hand market for the refurbished products; by establishing programs for extending products life cycles by upgrading the product at optimal intervals

Table A1. *Cont.*

R6—Remanufacture	
Remanufacture products	By establishing a strategy for how to manage products after their first life cycle; By establishing programs specifically for remanufacturing; by designing components to be remanufactured; by establishing buy back services, where customers can sell inactive or legacy products; by having rigorous check of all second-hand unit products; by having a global network of remanufacturing facilities; by completely remanufacturing products using original design plans, specifications and dimensional data, e.g., in the case of industrial robots, as in the case of ABB
Remanufacture in general	No further description of practice mentioned
R7—Repurpose	
Repurpose packaging materials	By purchasing cardboard shredder to shred packaging and use as padding for outgoing packages.
Repurpose products	By taking back products from customers and repurposing them.
Repurpose residual materials from manufacturing	By processing residual materials internally within the organization; by processing residual materials in by-products and sold externally
Repurpose waste (hazardous and non-hazardous)	No further description of practice mentioned
R8—Recycle	
Recycle energy from production	By feeding surplus energy into the grid; recycle energy flow in the production processes
Recycle heat from wastewater and machines	No further description of practice mentioned
Recycle excess material from production	No further description of practice mentioned
Recycle metals	Establishing repurchasing programs for recycling metals from older equipment at customers
Recycle thermoplastics	No further description of practice mentioned
Recycle materials in general	By buying back products from customers, dismantling the product and recycle materials which cannot be treated in other ways
Recycle packaging materials	By ensuring recyclability through product design
Recycle products	Through partaking in collaborative, industry-wide fosrums. For instance, those related to; Swedish companies which aim to increase the circular flow of materials throughout Swedish industry. ABB, Stena Recycling, Combitech, and Electrolux have, for example, worked together on a joint trial/pilot project that aims to improve the efficiency of the recycling process for electrical products; through partaking in circular collaborations, e.g., ABB entering a local agreement to develop a process where all fractions (iron, copper, and aluminium) in electric motors products can be recycled and reused in new products; by establishing a strategy for how to manage products after their first life cycle; by having a modular product design, thereby easing the disassembly of the product
Recycling in general	By establishing programs focusing on increasing recycling rate; by having all units within the company increase their recycling; by reporting the recycling within the company
Recycle waste (hazardous and non-hazardous)	No further description of practice mentioned
Water	With the intention of realizing water conservation
R9—Recover	
Energy recovery through incineration	Increasing transparency and drive improvement by having own sites being more specific about their waste disposal methods; by changing from landfill to waste incineration; by reporting incineration with and without energy recovery

References

1. Franco, M.A. Circular Economy at the Micro Level: A Dynamic View of Incumbents' Struggles and Challenges in the Textile Industry. *J. Clean. Prod.* **2017**, *168*, 833–845. [CrossRef]
2. Pitt, J.; Heinemeyer, C. Introducing ideas of a circular economy. In *Environment, Ethics and Cultures*; Stables, K., Keirl, S., Eds.; SensePublishers: Rotterdam, The Netherlands, 2015; pp. 245–260.
3. Webster, K. What Might We Say about a Circular Economy? Some Temptations to Avoid If Possible. *World Future J. Gen. Evol.* **2013**, *69*, 542–554. [CrossRef]
4. Bocken, N.M.P.; de Pauw, I.; Bakker, C.; van der Grinten, B. Product Design and Business Model Strategies for a Circular Economy. *J. Ind. Prod. Eng.* **2016**, *33*, 308–320. [CrossRef]
5. Bressanelli, G.; Saccani, N.; Perona, M.; Baccanelli, I. Towards Circular Economy in the Household Appliance Industry: An Overview of Cases. *Resources* **2020**, *9*, 128. [CrossRef]
6. Lieder, M.; Rashid, A. Towards Circular Economy Implementation: A Comprehensive Review in Context of Manufacturing Industry. *J. Clean. Prod.* **2016**, *115*, 36–51. [CrossRef]
7. Ghisellini, P.; Cialani, C.; Ulgiati, S. A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. *J. Clean. Prod.* **2016**, *114*, 11–32. [CrossRef]
8. Johansson, G.; Sundin, E.; Wiktorsson, M. *Sustainable Manufacturing*, 1st ed.; Studentlitteratur AB: Lund, Sweden, 2019.
9. United States Environmental Protection Agency. Sources of Greenhouse Gas Emissions. Available online: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (accessed on 16 November 2021).
10. Statistiska Centralbyrån. Available online: https://scb.se/hitta-statistik/sverige-i-siffror/miljo/utslapp-av-vaxthusgaser (accessed on 23 September 2021).
11. Jawahir, I.S.; Bradley, R. Technological Elements of Circular Economy and the Principles of 6R-Based Closed-Loop Material Flow in Sustainable Manufacturing. *Procedia CIRP* **2016**, *40*, 103–108. [CrossRef]
12. Alayón, C.; Säfsten, K.; Johansson, G. Conceptual Sustainable Production Principles in Practice: Do They Reflect What Companies Do? *J. Clean. Prod.* **2017**, *141*, 693–701. [CrossRef]
13. Calzolari, T.; Genovese, A.; Brint, A. The Adoption of Circular Economy Practices in Supply Chains—An Assessment of European Multi-National Enterprises. *J. Clean. Prod.* **2021**, *312*, 127616. [CrossRef]
14. Tiscini, R.; Martiniello, L.; Lombardi, R. Circular Economy and Environmental Disclosure in Sustainability Reports: Empirical Evidence in Cosmetic Companies. *Bus. Strateg. Environ.* **2022**, *31*, 892–907. [CrossRef]
15. Carlsson Kanyama, A.; Carlsson Kanyama, K.; Wester, M.; Snickare, L.; Söderberg, I.L. Climate Change Mitigation Efforts among Transportation and Manufacturing Companies: The Current State of Efforts in Sweden According to Available Documentation. *J. Clean. Prod.* **2018**, *196*, 588–593. [CrossRef]
16. Paulson, F.; Sundin, E. Inclusion of Sustainability Aspects in Product Development—Two Industrial Cases from Sweden. In Proceedings of the NordDesign 2018 Conference, Linköping, Sweden, 14–17 August 2018.
17. Wu, H.Q.; Shi, Y.; Xia, Q.; Zhu, W.D. Effectiveness of the Policy of Circular Economy in China: A DEA-Based Analysis for the Period of 11th Five-Year-Plan. *Resour. Conserv. Recycl.* **2014**, *83*, 163–175. [CrossRef]
18. Badurdeen, F.; Iyengar, D.; Goldsby, T.J.; Metta, H.; Gupta, S.; Jawahir, I.S. Extending Total Life-Cycle Thinking to Sustainable Supply Chain Design. *Int. J. Prod. Lifecycle Manag.* **2009**, *4*, 49–67. [CrossRef]
19. Bradley, R.; Jawahir, I.S.; Badurdeen, F.; Rouch, K. A Total Life Cycle Cost Model (TLCCM) for the Circular Economy and Its Application to Post-Recovery Resource Allocation. *Resour. Conserv. Recycl.* **2018**, *135*, 141–149. [CrossRef]
20. Potting, J.; Hekkert, M.; Worrell, E.; Hanemaaijer, A. *Circular Economy: Measuring Innovation in the Product Chain*; Planbureau voor de Leefomgeving: The Hague, The Netherlands, 2017.
21. Swedish Parliament. Årsredovisningslag (1995:1554). Available online: https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/arsredovisningslag-19951554_sfs-1995-1554#K6P10 (accessed on 27 January 2022).
22. Ekonomifakta.se. Available online: https://www.ekonomifakta.se/fakta/foretagande/naringslivet/naringslivets-struktur/ (accessed on 27 January 2022).
23. Swedish Companies Registration Office. Available online: https://bolagsverket.se/ff/foretagsformer/aktiebolag/arsredovisning/delar/hallbarhetsrapport-1.17962 (accessed on 27 January 2022).
24. Confederation of Swedish Enterprise. FAQ: Vad Innebär Lagen Om Hållbarhetsrapportering? Available online: http://www.svenskhandel.se/contentassets/e87ba73606274d5e836a9957de534b1a/faq-lag-om-hallbarhetsrapport.pdf (accessed on 7 April 2022).
25. Karaman, A.S.; Kilic, M.; Uyar, A. Green Logistics Performance and Sustainability Reporting Practices of the Logistics Sector: The Moderating Effect of Corporate Governance. *J. Clean. Prod.* **2020**, *258*, 120718. [CrossRef]
26. Istudor, L.G.; Suciu, M.C. Bioeconomy and Circular Economy in the European Food Retail Sector. *Eur. J. Sustain. Dev.* **2020**, *9*, 501–511. [CrossRef]
27. Janik, A.; Ryszko, A.; Szafraniec, M. Greenhouse Gases and Circular Economy Issues in Sustainability Reports from the Energy Sector in the European Union. *Energies* **2020**, *13*, 5993. [CrossRef]
28. Marke, A.; Chan, C.; Taskin, G.; Hacking, T. Reducing E-Waste in China's Mobile Electronics Industry: The Application of the Innovative Circular Business Models. *Asian Educ. Dev. Stud.* **2020**, *9*, 591–610. [CrossRef]

29. Sihvonen, S.; Partanen, J. Eco-Design Practices with a Focus on Quantitative Environmental Targets: An Exploratory Content Analysis within ICT Sector. *J. Clean. Prod.* **2017**, *143*, 769–783. [CrossRef]
30. Stewart, R.; Niero, M. Circular Economy in Corporate Sustainability Strategies: A Review of Corporate Sustainability Reports in the Fast-Moving Consumer Goods Sector. *Bus. Strateg. Environ.* **2018**, *27*, 1005–1022. [CrossRef]
31. Rhein, S.; Sträter, K.F. Corporate Self-Commitments to Mitigate the Global Plastic Crisis: Recycling Rather than Reduction and Reuse. *J. Clean. Prod.* **2021**, *296*, 126571. [CrossRef]
32. Sehnem, S.; Pandolfi, A.; Gomes, C. Is Sustainability a Driver of the Circular Economy? *Soc. Responsib. J.* **2020**, *16*, 329–347. [CrossRef]
33. Ellen MacArthur Foundation. Delivering the Circular Economy: A Toolkit for Policymakers. Selection of Key Exhibition. 2013. Available online: https://www.sustainableislandsplatform.org/wp-content/uploads/EllenMacArthurFoundation_Policymakers-Toolkit_compressed.pdf (accessed on 16 November 2021).
34. Govindan, K.; Hasanagic, M. A Systematic Review on Drivers, Barriers, and Practices towards Circular Economy: A Supply Chain Perspective. *Int. J. Prod. Res.* **2018**, *56*, 278–311. [CrossRef]
35. Södergren, B. *Flaggskeppsfabriken—Styrkor i Svensk Produktion*; Vinnova: Stockholm, Sweden, 2016.
36. Blomsma, F.; Pieroni, M.; Kravchenko, M.; Pigosso, D.C.A.; Hildenbrand, J.; Kristinsdottir, A.R.; Kristoffersen, E.; Shabazi, S.; Nielsen, K.D.; Jönbrink, A.K.; et al. Developing a Circular Strategies Framework for Manufacturing Companies to Support Circular Economy-Oriented Innovation. *J. Clean. Prod.* **2019**, *241*, 118271. [CrossRef]