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Company Perspectives on Circular Economy Management, Assessment and Reporting in the Kymenlaakso Region in Finland

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Abstract: In general, circular economy development is about a system-level change towards significantly enhanced circularity and sustainability encompassing both biological and technical cycles. This study aimed at exploring, identifying, analyzing and synthesizing how companies in the Kymenlaakso region perceive circular economy management, assessment and reporting. This study applied a qualitative research approach using a questionnaire survey as the specific method. The responding companies are of many sizes and represent multiple sectors such as industry, construction and various services. This study addressed a clear gap in research on company-level perspectives. The results indicate that recycling and recovery of materials are perceived as particularly important by companies. In addition, the principles of CE (10Rs) are considered to be important by most companies. Essential management approaches encompass, for example, CE strategy and goals, business ecosystems and development of markets for recycled and recovered products and parts. Companies considered that recycling, recovery, waste minimization and utilization of waste as a raw material, as well as an increase in recycled content in products, reduction in disposable products and prevention of premature obsolescence, are important CE assessment and measurement approaches. For example, continuous reporting of CE as a part of online communication of companies (i.a. sustainability and responsibility), the definition of best practices and best available techniques for CE, and reporting in the whole supply and value chain were perceived as important ways to report CE. However, it is noteworthy that many of the studied aspects of CE were not perceived to be important by companies. Overall, this study contributes to a better understanding of the current state of and future outlook on circular economy development in the studied region and also highlights relevant management, assessment and reporting aspects from the perspective of local companies.

Keywords: circular economy; management; assessment; reporting; Kymenlaakso; Finland

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1. Introduction

1.1. Global, European and National Perspectives

In general, CE development aims at keeping materials, components and products at their highest value and utility at all times covering both technical and biological cycles [1]. There are also many linkages between ways to achieve the CE goals and the UN SDGs [2,3]. For example, CE development can contribute to innovations related to industry (e.g., sustainable and efficient use of resources); sustainable production and consumption (e.g., adoption of sustainable practices by companies including the integration of sustainability information into their reporting cycles, sustainable and efficient use of natural resources, life cycle thinking and reduction in waste generation through prevention, reduction, recycling and reuse); climate action (e.g., reduction in emissions); and supporting more sustainable life on land (e.g., sustainable management and use of forests and associated resources).

In addition, CE redefines how we produce, manage and consume products and materials and creates more value while creating environmental benefits [4]. Nationally, the goal is to achieve a carbon-neutral CE society and the promotion of CE is expected to create positive impacts to address climate change, loss of biodiversity and excessive use of natural resources [2]. In addition, it has been suggested that CE can stop and even partly reverse biodiversity loss globally through, for example, business-led interventions in the forest industry, forestry, building and construction sectors [4].

Globally, the economy is only 7.2% circular, and the situation is not getting any better due to increasing material extraction and use [5]. However, CE could fulfill the needs of the people with significantly reduced use of materials while staying within the safe limits of the planet [5]. The essential current focus areas encompass, for example, the ability of companies to assess their impacts, CE solutions for various sectors and systemic shifts for companies [6]. CE solutions can contribute to climate change mitigation, reduction in biodiversity loss and overall overconsumption of natural resources encompassing, for example, new business models to extend product life cycles and to keep materials in circulation for the maximum amount of time [7]. The key basic approaches to advance CE encompass (1) reduced virgin material extraction (use less); (2) longer and better use of existing materials (use longer); (3) enhanced use of secondary materials (use again); and (4) substitution of fossil fuels with renewable energy and toxic materials with regenerative materials (make clean) [5]. In addition, these approaches are closely connected to product design, functional use and end-of-life phases [5].

At the European level, sustainability principles such as (1) increasing recycled content in products; (2) remanufacturing and high-quality recycling; (3) product durability, reusability, upgradability and reparability encompassing measures to address hazardous chemicals in products; (4) incentives for products with a high level of sustainability performance; (5) reduction in environmental and carbon footprints; (6) digitalization of product information and product-as-a-service models covering whole life cycles; and (7) restrictions related to single-use, premature obsolescence and destruction of unsold durable goods are integrated into the EU CE Action Plan [8]. Additionally, the European Green Deal strongly encourages the integration of sustainability into all policies with special emphasis on CE aspects [9]. It is also interesting to note that long-lived circular materials and products, as well as sustainable use of wood in accordance with the cascading principle, are encouraged by the EU Forest Strategy [10].

At the global level, (1) manufacturing of goods and consumables; (2) the built environment; (3) food systems; and (4) mobility and transport are the systems that create a significant amount of the overall global environmental burden [5]. At the national level, there is a need for sustainable products and services, design for CE, innovations, responsible companies, longer life cycles for materials, CE ecosystems, and market creation to support CE [2]. For example, specific focus areas related to forest industry and forestry encompass an extension of product lifetimes, the reuse of materials and products, and lower demand for timber [4]. Overall, the identified major barriers to CE development encompass, for example, adoption of new business models, investments in established practices, attitudes and lack of experts [2].

1.2. Company and Product Perspectives

The promotion of CE in the field of manufactured goods and consumables requires focus on, for example, industrial symbiosis; material and energy efficiency; extension of the lifetime of goods, machinery and equipment; circular business models; and sufficiency (buying what you need) [5]. In addition, extension of building lifetimes, optimization of active use, increased use of renewable materials, reuse and recycling of materials, and reduction in material use are identified as essential focus areas related to construction and buildings [4]. For example, design for material and energy-efficient buildings, increased use of timber, making most of existing buildings (reuse, repurpose and renovate), and reuse

of components and material are among the priority focus areas to support a more circular built environment [5].

The shared principles for both business leaders and policymakers encompass (1) reduce (shift from efficiency to sufficiency, resilience and adaptiveness), (2) regenerate (shift from extraction to regeneration), and (3) redistribute (shift from accumulation to distribution) [5]. Collaboration between the private and public sectors is essential for the promotion of CE and for well-being within safe limits [5]. In addition, businesses can gain multiple economic opportunities and environmental benefits from CE [4].

Design plays a major role in CE covering, for example, the redesign of products, business models and linear systems [11]. Design for CE requires a new mindset including novel perspectives such as user-centeredness (all usages of materials within a system and needs of all users) and design for evolution [11]. In addition, design can be seen as a continuous and iterative process encompassing continual testing of how designs interact within the wider system and with users [11]. The strategies to integrate the CE principles into design encompass (1) product life extension, (2) circular and safe material choices, (3) modularity, (4) designing for inner loops, (5) moving from products to services, and (6) dematerialization [11].

The circular design process is influenced by design thinking and human-centered design; it encompasses the following phases: (1) understand (the system and the user), (2) define (intention as designer and the design challenge), (3) make (ideate, design and prototype versions), and (4) release (launch of design) [11]. There are specific approaches associated with each circular design phase such as understanding circular flows covering reuse, remanufacturing, recycling and refurbishment; regenerative thinking within a wider ecosystem; turning products into service models; disassembly and recovery of materials and parts; digital systems; and learning from nature and biomimicry (understand phase) [12].

In addition, there are, for example, finding circular opportunities and development and redefinition of business models from a circular design perspective (define phase); and user-centered research covering all actors in the use cycle, feedback loops and smart material choices (make phase). There are also advanced options such as material journey mapping, material selection and product redesign [12]. Furthermore, CE creates significant impacts on skills and jobs including novel competence needs such as (1) life cycle thinking (from design to end-of-life phase), design, reusability of components and materials, novel digital systems, better organization and exchange of information and co-operation between various projects and actors within ecosystems; (2) CE and digital design in the technology sector; and (3) sourcing and processing of recycled raw materials in the chemical sector [7].

For industries and companies, it is very important to both manage and assess because typically you cannot manage what you do not measure/assess. For example, it has been recognized that sustainability assessments are needed to guide industries and businesses considering both sustainable development and environmental, social and economic sustainability [13]. However, it is equally important to build industrial operations and company strategies based on some key principles such as the 10Rs to make sure CE is promoted in a comprehensive and balanced manner. In general, it has been noted that CE is very much about resource use with a special emphasis on maintaining the highest possible economic value of materials, components and products, taking into account possibilities to minimize environmental impacts [14].

Previous studies have recognized, for example, that orientation toward CE could help to mitigate pressures related crossing of planetary boundaries [15,16] and the use of both renewable and nonrenewable natural resources [15]. In addition, the CE concept and associated approaches provide opportunities for and benefits to industrial renewal including the development of novel metrics [17]. Similar promising issues have been identified also in national-level policy development encompassing, for example, a focus on well-being within the planetary boundaries and measures to address the overuse of natural resources [18].

1.3. Regional Perspectives

The Kymenlaakso region was chosen to be the focus area for this study due to multiple reasons such as regional circular economy development aspirations, our previous studies focusing on the region, and support for this study from the regionally oriented institution. This study is regionally focused but it can shed light on company perspectives on CE management, assessment and reporting in general at all levels and in any geographical location. In addition, the results can potentially indicate many economic and environmental aspects that are perceived as important by companies as well as inform other interested parties about how to approach, e.g., public–private partnerships or the creation of various ecosystems in this field. Thus, it can be interesting to a wider audience beyond regional or national actors. It is also important to keep in mind that there are not very many studies on overall company perspectives on CE let alone in this particular field. Additionally, CE development has the potential to create similar benefits in various regions that are often expected at the national level, such as new jobs and entrepreneurship, climate benefits, and a wiser use of resources.

Regionally, there has been focus on CE in Kymenlaakso including, for example, consideration of ways to utilize industry-side streams and novel opportunities linked to cross-sectoral potential [19]. In this region, bioeconomy and CE are strongly linked and there is a particular focus on industry-side streams [20]. In addition, regional focus areas encompass, for example, innovation ecosystems supported by sustainable development and internationality as cross-cutting themes [20]. Some of the identified themes associated with development priorities are the necessary actions and perspectives of regional actors encompassing CE ecosystems, flexible utilization of material streams, CE of construction, development of sustainable housing, renewable materials, and development of packaging value chains [21].

Innovation ecosystems are expected to advance sustainable products, solutions and services for the future based on a high level of know-how and technologies that crosscut the interfaces of different fields of business [22]. The main specific regional focus areas related to CE are (1) renewable materials, reuse of materials and material streams; and (2) solutions related to renewable energy and energy efficiency [19,22]. In addition, specific CE-related focus areas include industrial symbiosis [22]. Sustainability aspects and regional low-carbon goals are also linked to and integrated into these efforts. Interestingly, intensification of life cycle thinking, and service innovations are also among the identified regional focus areas.

Life cycle thinking is expected to create a holistic picture of what, for example, manufacturing of a single item or project entails as a whole, taking into account all raw materials and use of energy [22]. Additionally, life cycle thinking and life cycle assessment (LCA) support products, process and business model design, development and assessment focus on, for example, a reduction in environmental impacts and both resource and energy efficiency [22]. Furthermore, the future regional pathways linked to CE encompass, for example, increased wood construction; bio-based packaging materials; novel materials; sustainable public procurement; sharing economy; and overall innovative technologies related to energy, the environment, automation, batteries and processes [19].

The overall aim of this study was to (1) explore, identify, analyze and synthesize how companies in the Kymenlaakso region perceive circular economy management, assessment and reporting priorities and associated development needs. The chosen approach highlights a better understanding of both the current state of and future outlook on circular economy development in the studied region encompassing specific aspects related to the integration of CE management, assessment and reporting into company practices.

2. Materials and Methods

Overall, this study applied a qualitative research approach [23], encompassing a definition of research aims based on the purpose of the study and an emphasis on new insights and understandings. Even though this study is regionally oriented, it can potentially provide broader insights into regional CE development and company perspectives that can be applied in any region. In addition, it can help to create information to advance the coming together of various regional actors in any geographical location to join forces in the promotion of CE. This study also can be compared to other studies [24–32] that applied a regionally oriented approach including discussion about their key findings. Openness to discovery and insight were also considered to be very important for the chosen approach [23]. The applied specific method was a questionnaire survey [33–41]. The survey was implemented as an online survey that was sent via email directly to respondents. In general, this study is important because it addresses a gap in the research and contributes to the enhanced understanding of CE management, assessment and reporting in the studied region.

Overall, the chosen survey themes, questions and answering options were based on (1) review of international, EU, national and regional sources (e.g., [1–5,8–10,19,20]); (2) literature review and previous studies (e.g., [6,7,11–18]); (3) our previous studies [42–48]; and (4) assessment of the global, EU and national operational environment for CE with special emphasis on management, assessment and reporting aspects. Similar to our previous studies, face validity (peer review) [38] was applied to check the coherence and quality of the overall questionnaire and its parts.

The overall survey themes were CE principles, management, assessment and reporting. In addition, the specific themes were (1) the importance of CE principles for companies; (2) the importance of CE management approaches; (3) the importance of CE assessment and measurement approaches; and (4) the importance of CE reporting approaches.

The survey was voluntary and anonymous, encompassing respondents from various companies. It was not targeted at employees with specific jobs but included multiple professions in a vast variety of different fields. The respondents included, for example, CEOs; managers; experts; project managers and personnel; sales and marketing people; designers; entrepreneurs; and service and maintenance professionals. The questionnaire was sent via email to company respondents (700 in total) in the Kymenlaakso region in Finland. The same survey and associated questions were sent to all respondents. The Webropol Survey and Reporting Platform was used to conduct the survey. The response rate was 17.6% (the number of responding companies was 123), covering companies from various sectors. These sectors are presented in Figure 1. The sizes of the responding companies (number of employees) are presented in Figure 2.

The developed questionnaire was formal and structured including a selection of multiple closed questions. Each question included many options, and the respondents were asked to make a selection between “very important”, “important”, “partly important”, or “not at all important”. The results are presented as figures that encompass the main themes and associated survey questions including specific answering options. The number or percentage of respondents is presented in the columns.

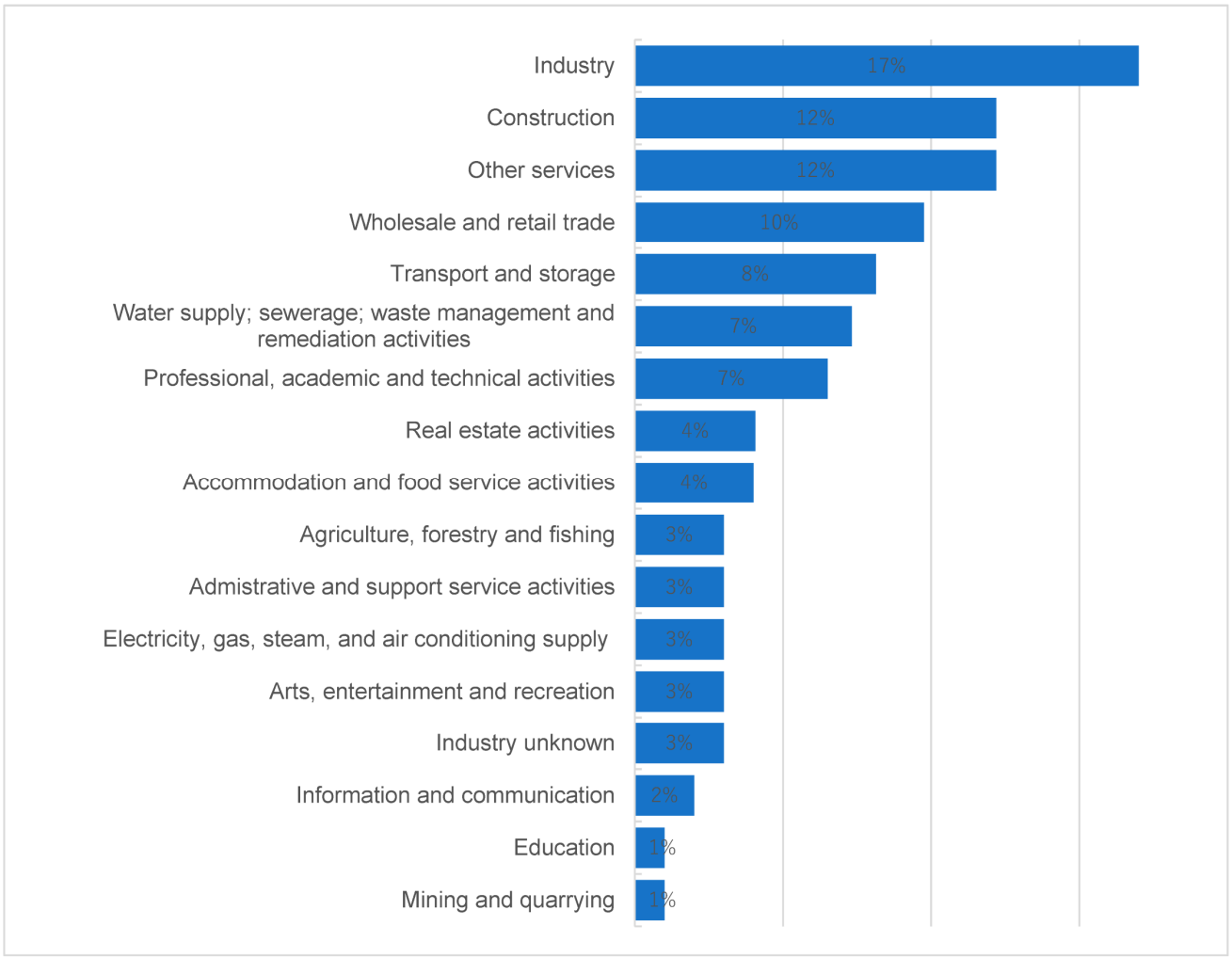

Figure 1. Represented sectors of respondents.

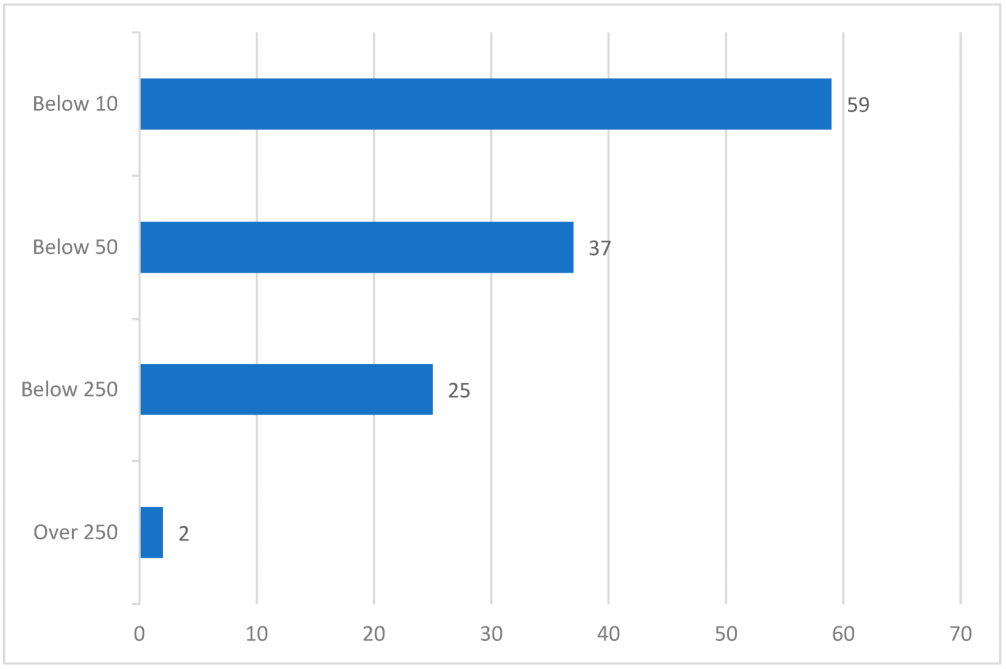

Figure 2. Size of company (number of employees).

3. Results and discussion

3.1. The Importance of CE Principles for Companies

The findings are presented in Figure 3, and they suggest that recycling and recovery of materials (R8 and R9) are perceived as particularly important by companies. Refurbishment of products (R5), reuse of products (R3), and repair of products (R4) are also considered to be very important or important by many companies. However, many companies did not perceive replacement of products or making of products redundant (R0) and remanufacturing of products (R6) as important. Overall, the principles of CE (10Rs) are considered to be important by most companies.

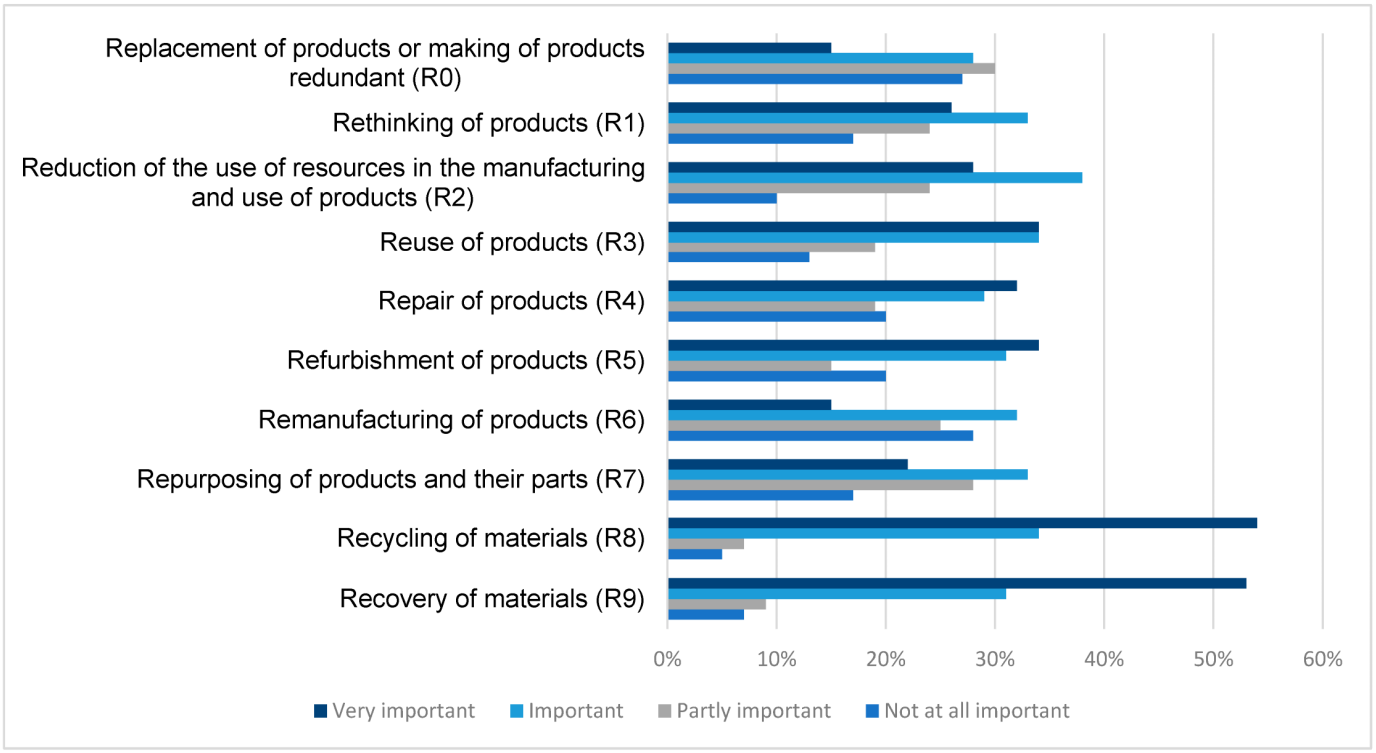

Figure 3. The importance of CE principles for companies.

There is a growing focus on the role of CE principles in the achievement of the goals of sustainable development [49]. In general, CE refers to a sustainable economic system in which economic growth is decoupled from the use of resources through recirculation and a reduction in natural resources [50]. In addition, CE is a vision for a future economy that provides the needs and wants of society within healthy planetary boundaries (the current linear economy is unsustainable since it upsets the balance between nature and the economy) [51]. CE also promotes system innovations that aim at achieving a better balance between the environment, economy and society; increasing resource efficiency; and designing out waste [52]. Overall, innovations for CE require consideration of the product/service; the applied business model; and the overall CE, innovation and business ecosystems surrounding company activities and operations.

One previous regional study noted that (1) CE is identified with raw materials and waste management, and (2) the implementation of CE principles requires long-term planning and financial support [25]. In addition, the adoption of CE principles may potentially improve resource efficiency, generate employment and drive economic growth regionally [30]. Interestingly, one study did not find significant evidence of any influence exerted by the drivers related to resource exploitation risks, the pursuit of environmental values and regulatory pressure [53]. Our previous studies indicate that (1) CE is considered to be important as a concept; (2) CE is a relatively new concept to many companies; (3) companies

need to be familiarized with essential CE aspects such as the cascading use of resources, products as services and sharing platforms; and (4) many essential elements of CE were already in use, coming into use or are under consideration [42].

In addition, important aspects of CE encompass, for example, sustainability and long life cycles of products, components and materials; design for CE, sustainability and long life cycles; communication between designers and both clients and other involved parties; life cycle thinking considering co-creation and cooperation (e.g., entire supply chain); and overall training and competence development [33]. Circular start-ups including associated ecosystems require many new skills related to, e.g., technical knowledge, digitalization, transport and logistics [54]. The implementation of CE provides many benefits, but progress is still very limited at all levels. In addition, even small barriers can stop CE development [55]. For example, small businesses face barriers in their transition to a CE such as a lack of technical skills and of financial resources [56].

In addition, common barriers to CE encompass, e.g., lack of market, low consumer awareness, high up-front investment costs and poor access to finance, and externalities that are not internalized through taxes (including subsidies) [55]. Barriers to CE also include a lack of consumer interest and awareness, high production and marketing costs, and limited CE design options. In addition, there is a limited availability of circular supply chains, and existing production systems are oriented toward linear supply chains [57]. Overall, small and medium-size companies have become more aware of the multiple benefits associated with CE such as enhanced resource efficiency, access to new markets, savings in material costs, and closing of loops [56].

In general, the introduction of CE business models and market creation for CE, the establishment of supporting and enabling ecosystems, and the integration of CE principles and approaches into company practices are very important focus areas. It is important to notice that the establishment of functional and effective ecosystems requires strong cooperation between all actors covering the whole life cycle of activities. Interesting issues also include consideration of both the type of new entrepreneurs needed to promote CE development and novel innovative approaches to advance co-creation and joint design efforts. The maintenance, renovation, refurbishment, retrofitting and conversion of existing products or product systems are also highly relevant in this context.

3.2. The Importance of CE Management Approaches and Process Elements for Companies

The findings are presented in Figure 4 and they suggest that very important management approaches as perceived by companies encompass, for example, CE strategy and goals, development of markets for recycled and recovered products and parts, systems and life cycle thinking, circular supply and value chains, and CE training and supporting R&D. In addition, the responding companies considered that business and innovation ecosystems, design and planning for CE, development of company level CE metrics, CE standards, and development of markets for recycled products and parts are important management approaches. However, many companies did not perceive management approaches such as CE standards and innovation ecosystems as being important.

In brief, CE is an economic model that is regenerative in design and it (1) aims at retaining the value of circulating resources, products, parts and materials through creation of a system that includes innovative business models (covering long life, renewability, reuse, recycling, remanufacturing, refurbishment and biodegradation); (2) provides principles that allow organizations to collaborate to increase resource productivity, design out waste, and keep resource use within planetary boundaries; and (3) requires collaboration and extensive cross-sector, industry and value chain measures [58]. There is an increasing need to involve everyone in working life to enhance their CE skills and to enable their role as CE experts [59]. It has also been noted that CE-related training of the workforce, e.g., to improve their employability, is very important [60]. In addition, the best way to promote transformation toward CE is to involve all people through education [59].

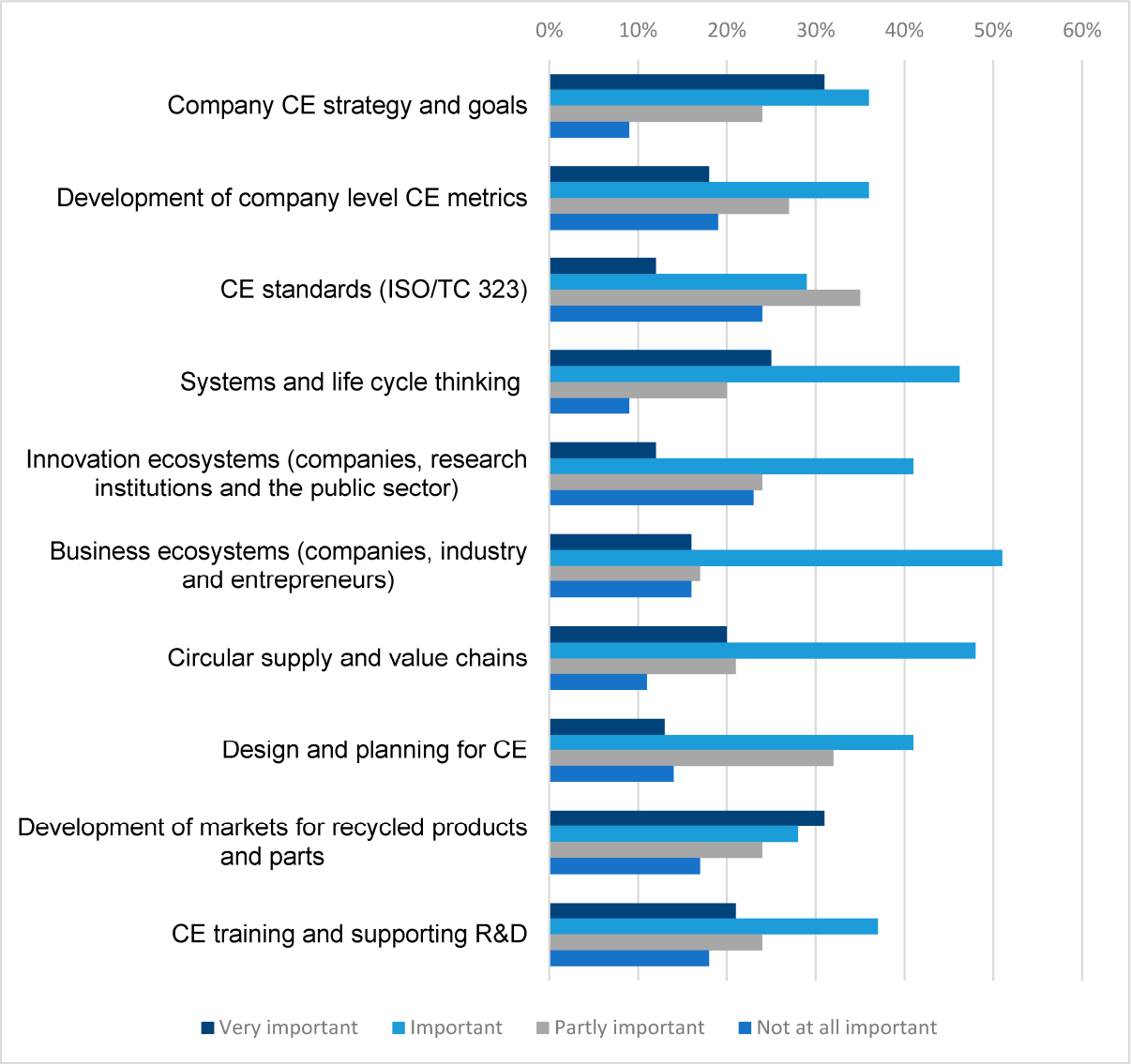

Figure 4. The importance of CE management approaches and process elements for companies.

Previous regional studies have highlighted that (1) a pioneer region can go as far as creating specific laws to advance regional efforts to promote the transition toward a CE [28]; and (2) the most effective supportive approaches include financial resources and incentives as well as awareness of new solutions [29]. An ecosystem perspective on a CE is essential for firms to capture circularity as a systemic property [61]. In addition, systemic change is the beginning of a transition to a CE, and it needs to be started from the ground up by educating people [59]. It has been noted that (1) there is a big gap in research regarding the implementation of CE in practice and approaches to practically transform a linear business model into a circular one, and (2) a clear line of action on how to practically support the change in business model from linear to circular is missing [62]. Circular start-ups typically adopt strategies with higher levels of circularity, and they can make a major contribution to transitioning toward CE [63]. A real transition toward sustainability requires a focus on changing the behavior, cultural habits and values, and attitudes of individuals [59].

Previous regional studies have recognized that (1) the development of digitalization can enable CE development in all European countries, and (2) systemic intermediaries (transition brokers) can be very beneficial to regional CE governance including working with businesses and organizations through their function of system orchestration [26]. However, it has been noted that the overdevelopment of digitalization has a negative impact on CE

development. In general, digitalization can promote collaboration with stakeholders and customers, e.g., through co-creation and networking based on collaboration platforms and virtual technologies. In addition, the development of innovative circular business models requires communication with customers [24]. A previous regional study noted that public awareness is a major driver of CE and that CE can promote sustainable development [25]. In general, transition brokers can support the design of new models of regional governance for CE implementation based on a system-level perspective [26].

Circular business models can help companies to transition toward CE and to adopt associated strategies such as reuse, remanufacturing and repair [64]. CE has the potential to help firms maximize the value of their material resources and minimize the overall use of resources, waste generation, pollution and emissions of their business activities [61]. Research on CE is mainly focused on (1) strategy, learning and innovation; (2) consumer behavior and remanufacturing; (3) supply chains and implementation; (4) circular business models; (5) industrial symbiosis; and (6) emerging technologies [65]. Innovative business models and eco-innovations have received a lot of focus in the field of CE research [66]. It has been noted that research on design and business model strategies needs to focus on essential elements such as the entire supply chain [67].

Business management plays a critical role in translating CE into practice. However, research on CE management is very fragmented and lacks a holistic perspective [65]. CE implementation requires the design of innovative business models such as product/service systems that enable multiple value-creation mechanisms [68]. Circular business models can be associated with different circular strategies and each circular business model can be associated with one particular life cycle stage of a product/service, which also links it better to a specific circular strategy [69]. Mostly, applied circular business models encompass product/service systems and approaches based on reuse, remanufacturing and recycling (3Rs) [70]. However, the majority of modern companies are still based on traditional business models and the internalization of circular economy principles is still at an early stage in companies. In addition, economic drivers were the most effective at encouraging companies to adopt more circular business models [53].

Companies typically intend to increase circularity and to share value with their partners [71]. It has been noted that circular start-ups can be design-based (e.g., adoption of circular innovations such as product design), nature-based (e.g., products and services based on nature-based systemic solutions), waste-based (e.g., value from external waste streams), service-based (e.g., products in service-systems), or platform-based (e.g., sharing/trading business models) [63]. Frameworks such as the Business Model Canvas [72] can be used to develop circular business models based on a circular design perspective encompassing focus on (1) key resources, activities and partnerships; (2) customers; (3) channels; and (4) value proposition [72].

The shift toward CE, including, e.g., design of business strategies, requires the quantification of the circularity of products and services (or of their contribution to the CE), as well as the prioritization of sustainable solutions based on evidence [50]. It is noteworthy that the biased approach to CE (emphasis on the economic dimension of sustainability) can lead to a narrow approach to sustainability and sub-optimizations in the application of CE by companies [52]. In general, transformation from a linear to circular economy requires coherent design and business model strategies potentially encompassing multiple business model and design strategies, approaches, tools and methods to support movement toward CE [67].

Implementation of a CE program requires radical changes in product, business model and ecosystem innovation [61]. However, organizations face multiple barriers to the implementation of CE, and drivers for CE development include, e.g., existing engagement in partnerships and the desire to build a sustainable company image to please customers [71]. Interestingly, social aspects create more barriers to the adoption of CE in the manufacturing sector than environmental and economic aspects [73]. In general, it is essential to address technological, economic and social barriers to CE development such as the lack

of general knowledge about circular economy opportunities and failure to see the "big picture" [34]. It is important to manage the CE aspects of supply chain management and to address major barriers to CE such as profitability and lack of information [36]. The development of CE requires a focus on both sustainability and the long lifespan of products, components and materials [35]. Specific solutions could also encompass the combination of resource-effective (extension of product and material life) and resource-efficiency (focus on prevention) strategies [68].

The best approaches to promote CE encompass the use of sustainable and renewable raw materials; consumer awareness; and the design, use and manufacturing of sustainable, recyclable, reusable and repairable products, components and materials [34]. Important drivers and opportunities associated with CE development encompass totally new products and services as well as the availability of sustainable, long-lasting and fixable products [35]. Therefore, it is important to advance the design and development of CE and sustainability-oriented products, components and materials [34]. In general, sustainability and life cycle thinking are also at the core of CE development in companies including, for example, life cycle management and assessment, materials and energy efficiency, reuse and recycling of products and an overall reduction in greenhouse gas emissions [36–38].

The CE model is considered a key strategy to enhance the overall sustainability performance of products, including a focus on, e.g., improvement in the useful life of products and the closing of material flows to promote circularity [74]. The most important innovation practices in the CE context encompass eco-design business models, waste management, product leasing and collaborative commerce [65]. In addition, design for sustainability is a necessary issue in any product development process. For example, significant efforts are needed to gather information on the life cycle of any product, and there are uncertainties related to stages for which information is not available [74].

Innovation contributes to CE through the generation of reformulation and disruption. In addition, CE innovation typically focuses on the generation and support of alternatives and infrastructure for new ways to retain the value of resources, produce goods, manage waste, and collaboration with customers to obtain data and manage after-sales activities [65]. In addition, the implementation of CE in the context of product family design encompasses major changes in production models, product design methods and consumer philosophy. For example, modularity and modules including the sharing of components among product variants are highly essential for design approaches to promote extended and circular life cycles of products [74]. Energy aspects are also highly relevant including, for example, the means to promote circular and renewable industries through the use of hydrogen solutions with the capability to store renewable energy [75].

3.3. The Importance of CE Assessment and Measurement Approaches for Companies

The findings are presented in Figure 5 and they suggest that companies perceive recycling, recovery, waste minimization and utilization of waste as a raw material; increase in recycled content in products, reduction in disposable products and prevention of premature obsolescence; new business models and innovations; and share of renewable raw materials as very important CE assessment and measurement approaches. In addition, digitalization, databanks, use of data and data management and monitoring systems; life cycle assessment (LCA); CE criteria and indicators; and application of CE principles (10Rs) are considered to be important approaches to assess and measure CE in companies. Interestingly, many companies did not consider that, for example, CE standards and company-level CE metrics and indicators are important assessment and measurement approaches.

CE is a means to achieve the end goal of sustainability and therefore companies need to adopt both sustainability and circularity metrics [51]. Important CE assessment approaches could encompass (1) CE criteria for all project stages; and (2) environmental, economic and social sustainability criteria for the whole life cycle of activities [34]. For example, companies focus on, e.g., sustainability and company-based challenges and apply sustainability checks to support decision-making [70]. In general, transformation from a linear to a circular

economy requires multiple approaches, tools and methods to support movement toward CE [67]. One previous study on regional monitoring concluded that approaches such as regional monitoring frameworks for CE can be developed and applied including links to environmental, economic and social aspects of sustainable development [27]. It has also been recognized that a specific holistic system of indicators can be developed to assess eco-innovations in the context of regional CE development in Europe [31]. The transition toward CE requires the establishment of (1) recommendations for comprehensive support of the CE process, and (2) monitoring of the implementation of CE [32].

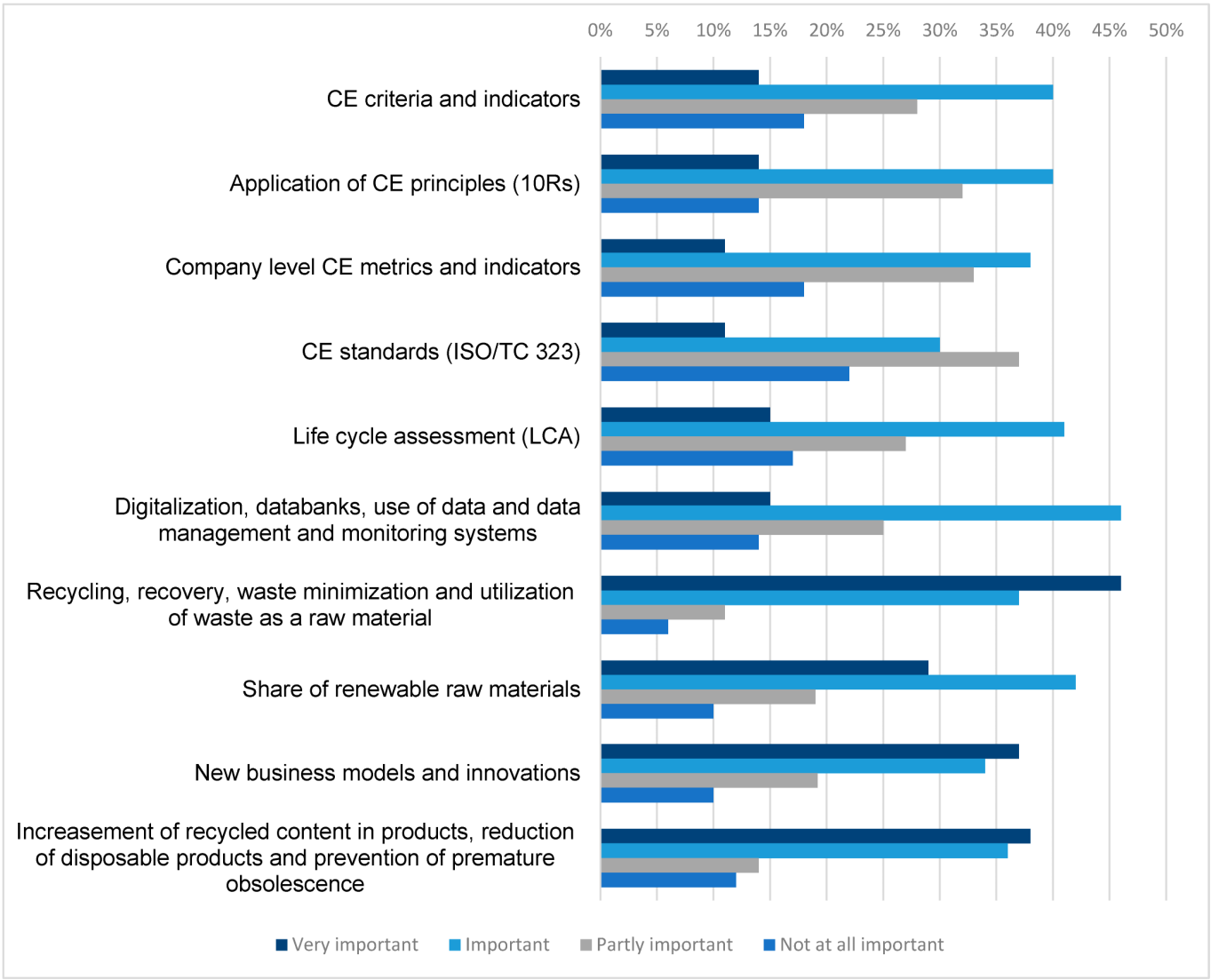

Figure 5. The importance of CE assessment and measurement approaches and tools.

Systems and tools for the full utilization of information and data are very important for CE assessment including focus on specific aspects such as sequential and multiple uses of products, components and materials, aiming at the maintenance of the highest possible utility, usability and value at all times and uses. Our previous studies indicate that (1) many companies were not familiar with the assessment and measurement of CE; (2) companies need to be familiarized with the assessment and measurement of CE; (3) assessment approaches could encompass, for example, traceability of all materials including specific tools such as electronic passports; and (4) specific tools such as product certification and information modeling are very important [42]. Research on circular manufacturing has included a focus on assessment methods and models in the context

of evaluation of the circularity of entities or to support decision processes. In addition, circular manufacturing strategies require a focus on standardization and data exploitation, taking into account social aspects and people as fundamental parts of the ecosystem [76]. For example, social aspects and people could be integrated into CE management and assessment through company-level CE metrics and indicators; CE criteria and indicators; use of data; and social sustainability metrics and approaches, such as the social sustainability handprint [77–79].

The familiar saying, "what gets measured gets done", is very true also in the context of measuring various CE-related impacts of companies on nature. Many metrics, tools and approaches such as the Circular Transition Indicators [58] can be applied at the company level. Interestingly, alarmingly few companies know their impacts on nature (i.e., their baseline knowledge is highly limited) [80]. It has been noted that the gathering of relevant information and data, as well as the addressing of managerial and technological barriers faced by manufacturers in their efforts to use data, is highly important for the promotion of circular manufacturing approaches from a research perspective [81]. In addition, tools and approaches such as the Circularity Deck [82] can be used to analyze, ideate and develop the circularity potential of innovation ecosystems considering product, business model or ecosystem perspectives [61].

The definition of goals and indicators for the assessment of the adoption of CE at the company level is very important [83]. A set of indicators that can be applied to circular business models aiming at covering innovations associated with CE can be based on, e.g., sustainability, CE principles and circular business model (e.g., Canvas Business Model) [84]. For example, the specific elements of the Circularity Deck [82] encompass, e.g., low-impact design, industrial symbiosis, design of connected products, products as services, and resource intensity of products in use [61]. In general, companies need to understand their role and monitor their activities because they are the main actors in the movement toward a CE [83]. One study noted that 74% of the circular indicators can be calculated based on data from Corporate Sustainability Reports [85]. This indicates that sustainability-related information provided by organizations can be applied to the assessment of CE and circularity performance.

New tools are required to support the adoption of CE practices among practitioners and decision makers [49]. In general, metrics refer to a combination of or just one single indicator, tool or methodology, and there can be performance (e.g., performance based on parameters and assessment of processes), process (e.g., information of progress, monitoring of organizational transition and how to advance change) or headline (e.g., state of circularity, level of performance and how circular are businesses or products) indicators [51].

Circularity indicators for companies need to be comprehensive (i.e., capture the characteristics of CE at the company level), be applicable to various types of industries, and be easily adoptable [83]. Circularity metrics can help businesses to (1) measure an indication of the circularity of their organization, product or value chain; (2) create information to promote more circular and sustainable business models; (2) create awareness of CE opportunities to innovate products involving stakeholders, suppliers, employees and customers; (4) search for and identify the solutions that work for their line of business; (5) assess the potential of solutions; (6) build business cases to ensure scaling of implementation; and (7) monitor and report progress toward the implementation of solutions and overall circularity [51].

There is a lot of focus on the development of new circularity metrics. However, metrics often include a contradiction in terms of content and form, which contributes to the misunderstanding and confusion of the CE concept [50]. The monitoring of and innovation for CE require the development of novel metrics and measurements. In addition, different phases of innovation require the application of different metrics to guide the process toward new and environmentally, socially and economically sustainable products [51]. The existing CE metrics (e.g., indices, indicators and assessment frameworks) do not fully address the

CE concept, which can lead to burden shifting from reduced material consumption to increased environmental, social and economic impacts [50].

It has been recognized that indicators for the assessment of the level of CE adoption in companies lack standard approaches on, e.g., social, assets management and water aspects. In addition, they fail to address the reduction in resource use, the control of greenhouse gas emissions, employee wellness and social equity, and the increase in the lifetime of company assets [83]. In general, CE indicators can focus on, e.g., (1) material (e.g., product longevity, renewability, recycling and reuse); (2) financial (e.g., circular investments, innovations, profits and reduction in costs); and (3) social (e.g., mindset/cultural change, job creation, client mindset, stakeholder participation in decision-making processes and employee participation in the circular model) aspects [84].

However, the indicators for the assessment of the level of CE adoption in companies at the moment do not sufficiently cover holistic CE characteristics and there are differences in how practitioners (emphasis on economic aspects) and academics (emphasis on sustainability) see how companies should approach CE [83]. In addition, little progress has been made regarding the measurement of CE, especially in the sector of manufacturing SMEs [86]. Therefore, there is a growing need to monitor CE transition including the measurement of the effects of CE adoption [49]. Tools such as the Circularity Measurement Toolkit can be applied to the assessment of the degree of circularity in manufacturing SMEs including focus on specific aspects such as internal practices (e.g., better design and production), internal awareness of CE, selection of suppliers (e.g., sustainable procurement and environmental criteria), external awareness, longevity (e.g., end of life cycle), and green market [86].

CE is expected to be a pathway to sustainable development and circularity should be simultaneously sustainable for the environment, society and economy. However, current circularity metrics do not fully address CE requirements, including links to the sustainable development concept [50]. In addition, there is a significant gap related to guidance of companies on how to adopt the CE and to measure associated performance. For example, professional practice and academy have divergent views on how to measure circularity in companies [83]. There is also a lack of research on (1) the assessment phase of CE strategies and (2) CE assessment and indicators at the micro level [87]. Managers who want to find CE business investments should increase the engagement of employees in the improvement of specific management and innovation capabilities within their companies [60]. There are several index-based methodologies including, e.g., a set of multiple indicators for the measurement of the adoption of the CE paradigm. The development of methodologies and indicators for the measurement of the application level of CE strategies is particularly important at the micro level [87].

Measures to assess CE such as indicators need to take into account both circularity and longevity (e.g., resource use time, various lifespans of multiple products and times of resource use) to advance overall sustainable resource use [88]. An index can be used to assess the circularity and sustainability of manufacturing companies to support managers in the assessment of the level of circularity and sustainability (environmental, social and economic) including implementation of activities to enhance company performance [89]. In addition, CE indicators can be used for (1) design decisions and product design (e.g., circularity criteria for designers), (2) internal reporting, and (3) producing information on products for other organizations and the public (e.g., to support procurement decisions). In general, approaches to measure how effective companies are in their transition from linear to circular models are currently not very advanced [90].

It is highly important for companies to focus on circular performance including associated opportunities and risks, and how to measure circularity [58]. Organizational-level assessment of CE in manufacturing companies using a specific tool such as the Circular economy Toolkit [91] can focus on (1) design, manufacturing and distribution (e.g., use of biodegradable, recycled, scarce, non-toxic, technical and virgin materials); (2) usage (e.g., lifetime of products and resource/energy efficiency); (3) repair and maintenance of

the product (e.g., cost of repair, availability of suitable repair/maintenance service and spare parts, easiness of fault diagnosis and standardization of components and modules); (4) reuse/redistribution of the product (e.g., market for second hand sales and lifetime of the product); (5) remanufacturing/refurbishment of the product/part (e.g., costs/collection costs, return of products, easiness of disassembly, modularity of parts, upgradability, mechanical connections and need for tools); (6) products as a service (e.g., market and status of current sales); and (7) product recycling at end of life (e.g., number of material combinations and easiness of separation of materials) [91].

The Cirtelligence by BCG [92] tool encompasses focus on, e.g., (1) value chain circularity, (2) business dimensions; (3) ecosystem and collaboration; (4) bio-based and technical inputs such as materials, water and energy; (5) product design; (6) end of life; (7) environmental and economic metrics; and (8) qualitative and quantitative questions reflecting circularity principles (e.g., durability, reuse, replacement, repair, reduction, upgrading, refurbishment, ownership and outsourcing) [92]. Design of indicators for the measurement of product performance in the CE could focus on refining approaches to encourage deeper reflection and on generalization of the approach to different industry sectors, types of products and sustainability frameworks [92].

In addition, tools such as the Circular Transition Indicators [58] can focus on (1) the circularity of companies; (2) targets for improvement; (3) monitoring of achieved improvement through circular activities; (4) monitoring progress in circularity based on a baseline; (5) shared circular priorities in the whole value chain; (6) responding to stakeholders, society and customers; (7) closing, valuing and optimization of the loop; and (8) cascading in both the biosphere and the technical sphere [58]. In general, the transition from linear to a CE faces several challenges such as the need to measure CE product performance through indicators [93]. The Circular Transition Indicators tool does not assess full sustainability performance or evaluate social and environmental impacts but can potentially provide some insight into associated impacts based on an understanding of mass flows [58].

CE metrics typically do not fully and clearly represent the complexities of multiple cycles and the consequences of material downcycling [50]. Indicators and measures are needed to track the progress of a society toward a CE. In addition, there is a lack of focus in the field of CE indicators on the length of time for which resources are in use [88]. For example, the Material Circularity Indicator (MCI) is based on the following principles: (1) sourcing of biological materials from sustained sources, (2) keeping products in use longer, (3) ensuring biological materials remain biologically accessible and uncontaminated, (4) reusing components or recycling materials after the use of the product, (5) making more intensive use of products, and (6) using feedstock from recycled or reused sources [90]. It has been also noted that there is no common standard for the measurement of micro-level circularity and only a limited number of micro-level indicators focus on the inner circles of CE [52].

CE is often presented as a means to sustainable development and, therefore, it is important to consider alignment with the three dimensions of sustainability. Interestingly, most indicators focus on the economy, and there is limited attention given to the environment and society [52]. Existing sustainability indicators approach circularity measurement through single products without considering the entire product family [74]. There are many challenges related to current circularity metrics including (1) difficulties related to the measurement of CE goals covering all dimensions of sustainability, (2) under-presentation of the complexities of multiple cycles/multi-functionality and the consequences of material downcycling, and (3) the evaluation of the scarcity of used materials [50]. Aspects that can be taken into account in evaluating CE indicators can encompass, e.g., whether life cycle thinking is applied or not and effects on environmental, social and economic dimensions [94]. In addition, indicators that can be used to measure circularity can be related to functional performance, material flow, reconfiguration and reusability aspects [74].

There are three levels of indicators for the measurement of CE: (1) micro level (e.g., company or product), (2) meso level (e.g., industrial symbiosis), and (3) macro level

(global, national, regional and city) [52]. Micro-scale indicators can focus on, e.g., CE strategies taking into account the life cycle thinking approach [94]. LCA is the most-used framework to assess circular strategies, despite it also including problems related to solving the complexities of modeling open-loop recycling [50]. In general, there is a need to address the integration of CE and conventional indicators from a holistic perspective to ensure an appropriate design process covering sustainability during the entire product life cycle [74]. Understanding how to measure and document progress toward a CE is lacking, particularly on the micro level [52]. Most indicators focus on, e.g., remanufacturing, end-of-life management and recycling, whereas a more limited focus is on lifetime extension, reuse, resource efficiency, disassembly and waste management [52]. In addition, the potential of CE indicators is linked to design that is oriented to create sustainable products through the reuse, remanufacturing and recycling of components [74].

3.4. The Importance of CE Reporting Approaches for Companies

The results are presented in Figure 6, and they suggest that continuous reporting of CE as a part of online communication of companies (i.a. sustainability and responsibility) and the definition of best practices, and best available techniques for CE were perceived as very important CE reporting approaches by the company respondents. In addition, reporting in the whole supply and value chain, CE certification and product labels, annually as a part of other company reporting, and the development and application of CE criteria and indicators were perceived as important CE-reporting approaches by many companies. Interestingly, many companies perceived reporting based on the digitalization of product information, annual CE reporting, annually as a part of sustainability reporting, CE certification and product labels, and utilization and application of CE standards as not important.

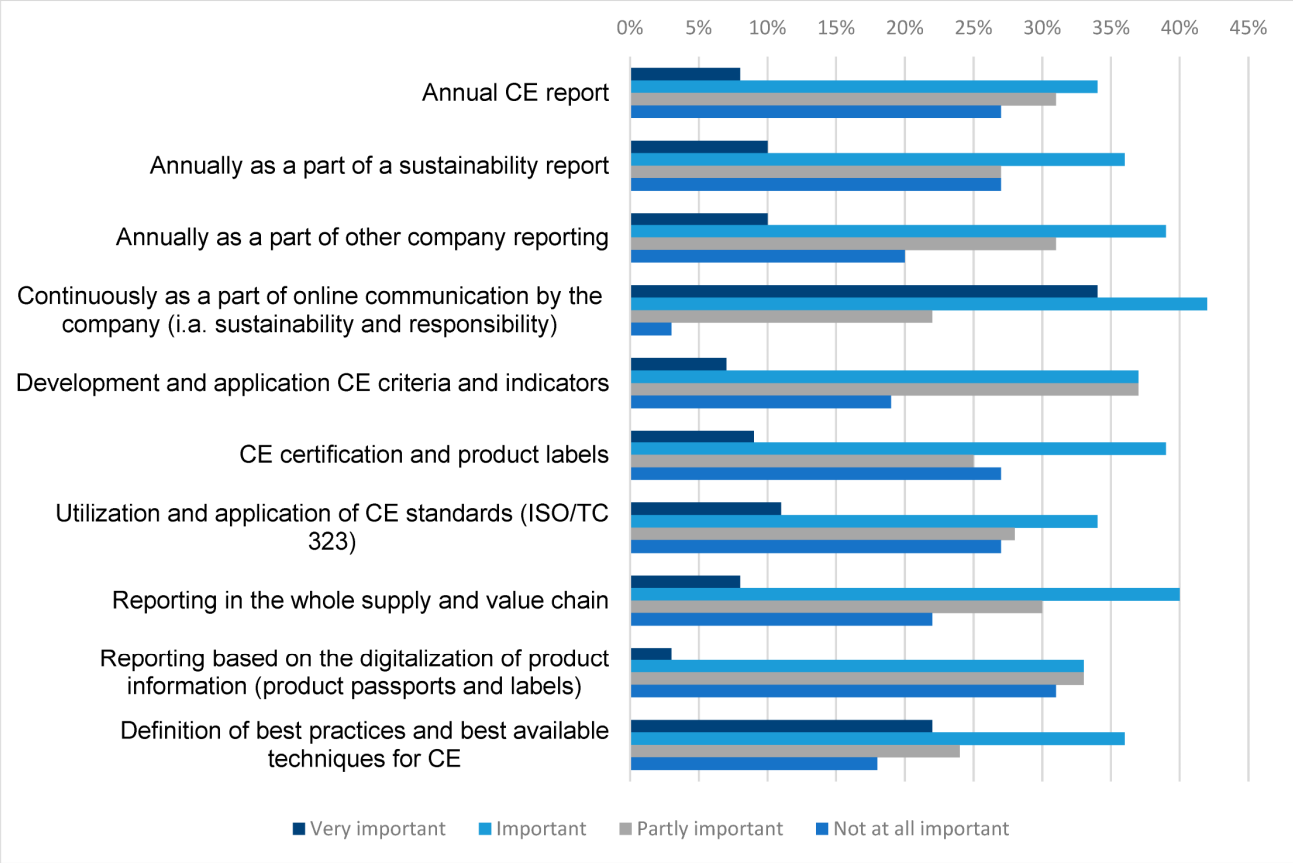

Figure 6. The importance of CE reporting approaches for companies.

Overall, CE refers to a global economic model that (1) decouples economic growth and development from the consumption of finite resources; and (2) is based on the principles of keeping products and materials in use, designing out waste and regenerating natural systems [90]. Manufacturers who want to promote circular manufacturing need to consider all stakeholders along the product life cycle, covering all associated implications and the overall context in which they operate [76]. It is also important to analyze the social aspects (e.g., social metrics) of CE in businesses in addition to research on environmental or economic impacts [60].

The six characteristics of CE at the company level encompass (1) keeping the value of products, components, materials and assets in the economy; (2) increased share of renewable and recyclable resources; (3) promotion of employee wellness and equity; (4) reduced input and use of natural resources; (5) fewer material and water losses/residuals; and (6) reduction in emissions [83,87]. Overall, practitioners are facing a challenge related to better measurement of social impacts of their CE-related activities including the integration of specific circular indicators into sustainability reporting [60]. For example, digital CE can help to create a basis for a sustainable society, and the essential enablers of CE include various digital technologies such as the Internet of Things, data analytics and big data [95]. Public procurement can also advance CE through (1) a focus on both sustainability and CE criteria [38]; and (2) appropriate acknowledgment of and focus on the whole product chain and life cycle and obligatory recycling of products, components and materials [36].

The ability to measure and report on progress is essential for a successful transition to a CE [52]. Sustainable decision making requires comprehensive circularity metrics (to avoid burden shifting) that indicate how the benefits of recycling are allocated between the primary and secondary products [50]. Businesses could apply CE indicators to monitor the implementation of CE strategies [93]. Indicators are typically useful for the advancement of the progress of CE, and there are many challenges related to their development due to various definitions of CE. Most CE indicators focus on the preservation of materials, whereas there are no indicators that address the preservation of functions [94]. It has been recognized that the tradeoff between simplicity and engagement, as well as consideration of other industries, needs to be addressed in the development of a CE indicator for the measurement of product performance [93].

Sustainability reports can be a very useful tool to measure, monitor and communicate the transition of organizations toward CE models. In addition, sustainability reports help organizations in the transition toward more circular economy models including content about measurement, monitoring and communication of the transition and establishment of goals [85]. Important approaches to advance CE encompass, for example, cooperation between all parties associated with the entire life cycle of activities [34]. It is also important to consider the sustainability of products as early as possible in the design phase considering life cycle thinking [35]. In general, product-based approaches, local industrial symbiosis and climate change have received little focus in companies [37]. In addition, international guidelines and best practices, utilization of by-products and side flows, collaboration among various actors and more efficient use of raw materials are considered to be very important [38].

In general, tools such as the Sustainable Circular Index can be used to assess circularity and sustainability at the company level, e.g., to promote associated performances [89]. Companies can use CE indicators both internally and externally to, e.g., compare the circularity of different companies and products [90]. The development of metrics and indicators for CE in the context of corporate sustainability reporting could encompass categories such as design (application of sustainability criteria for the product, product design and circular services), business (circular business models), production (e.g., management systems), R&D in circularity (e.g., investments and patents), suppliers (sustainable suppliers), environmental impact, inputs (e.g., use of new, secondary or reused materials), social (social actions), communication (published environmental reports), and outputs (e.g., waste generation) [85]. In general, tools such as the Cirtelligence by BCG [92] can

support companies in (1) being more in line with sustainability, CE and climate change challenges including a focus on innovation and efficiency; (2) becoming circular businesses and driving more value based on reduced use of raw materials; and (3) carrying out holistic CE assessment [92].

It has also been acknowledged that the use of renewable materials is important for sustainable production, whereas the enhancement of consumer awareness is important for sustainable consumption [34]. In general, CE can benefit both the sustainability and financial performance of companies and an ecosystem perspective can support innovation and entrepreneurship in the context of the CE [96]. However, not many companies currently report on multiple quantitative CE indicators as a part of their sustainability reporting. In general, reporting on CE can advance understanding of other issues and impacts such as climate and biodiversity aspects [80]. In addition, companies can advance CE through new innovations and business models including the use of renewable raw materials [36]. The human factors including social and societal sustainability as well as rethinking of underlying values and premises are also very relevant to CE development [97].

Development of CE reporting can benefit from a focus on multiple aspects such as innovations, drivers, barriers and opportunities. Creation of significant CE innovations includes a focus on (1) sustainable, recyclable, reusable, and repairable products, components and materials; and (2) sustainable and renewable raw materials. Overall, important CE drivers and opportunities encompass, e.g., products that are designed to be repairable and reusable. In brief, it is important to address barriers to CE such as profitability (e.g., economic benefits of recycling and sorting) and lack of comprehensive monitoring with data on, e.g., waste qualities and quantities [34].

4. Conclusions

The findings of this study suggest that the principles of CE (10Rs) are considered important by most companies. Interestingly, recycling and recovery of materials are perceived as particularly important. This result can potentially be related to longer societal and company emphasis on these aspects as compared to other principles. Companies also considered the refurbishment of products (R5), reuse of products (R3), and repair of products (R4) to be very important or important. However, it is noteworthy that many companies did not perceive the replacement of products or making of products redundant (R0) and remanufacturing of products (R6) as important.

In addition, the findings suggest that companies perceived CE strategy and goals, development of markets for recycled and recovered products and parts, systems and life cycle thinking, circular supply and value chains, and CE training and supporting R&D as very important management approaches. This indicates that companies potentially have positive attitudes toward a system-level approach to CE management. Interestingly, many more CE management approaches were considered to be important such as business and innovation ecosystems, design and planning for CE, development of company-level CE metrics, CE standards, and development of markets for recycled products and parts. However, many management approaches such as CE standards and innovation ecosystems were not perceived as important. This may be related to, for example, different company characteristics and development needs.

The findings on CE assessment and measurement approaches suggest that companies perceive recycling, recovery, waste minimization and utilization of waste as a raw material; increase in recycled content in products, reduction in disposable products and prevention of premature obsolescence; new business models and innovations; and share of renewable raw materials as very important approaches. This implies that many material-related aspects were highlighted jointly with more business-oriented approaches. In addition, important approaches encompassed digitalization, databanks, use of data and data management and monitoring systems; life cycle assessment (LCA); CE criteria and indicators; and application of CE principles (10Rs). This indicates that both management and tools are important for CE

assessment and measurement. However, many companies did not perceive CE standards and company-level CE metrics and indicators as important.

The findings suggest that very important CE reporting approaches encompass continuous reporting of CE as a part of online communication of companies (i.a. sustainability and responsibility) and the definition of best practices and best available techniques for CE. This implies that companies prefer reporting through existing channels and that, potentially, there is a need for the development of best practices and best available techniques for CE to support company-level reporting. In addition, important CE reporting approaches comprised reporting along the whole supply and value chain, CE certification and product labels, annually as a part of other company reporting, and the development and application of CE criteria and indicators. This suggests that comprehensive management and assessment approaches can potentially support CE reporting. However, reporting based on the digitalization of product information, annual CE reporting, annually as a part of sustainability reporting, CE certification and product labels, and the utilization and application of CE standards were not perceived as important by many companies.

Future research should focus on the adoption and application of CE principles; the development and implementation of CE management approaches; innovative new ways to assess and measure CE at the company level; and the development and adoption of CE reporting by companies covering all sizes and types of companies at the local, regional and national levels.

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