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Employee skills for circular business model implementation: A taxonomy

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ABSTRACT

A growing body of scholarship has examined circular business models as a pathway towards sustainability. However, employee skills to support such business models have been largely overlooked. Addressing this research gap, this article proposes a comprehensive skill taxonomy for start-ups embracing circular economy transition. As the first large-N effort to develop a comprehensive skill taxonomy for circular business model implementation, this study uses a clustering analysis of self-reported skill profiles for 2407 staff working in circular start-ups. The taxonomy outlines 40 skills across six categories: business innovation, operations, social dimensions, systems, digitization, and technical issues. Findings suggest that circular business model implementation requires a set of general, sustainable, and circular skills, but some of these skills have been neglected in scholarship. Promoting circular narratives as a framing device for skill development can help advance CE towards mainstream uptake, and this study's taxonomy offers a practical framework for using talent to accelerate CE transition.

1. Introduction

Businesses and policy-makers often view the circular economy[1] (CE) as a promising way to reconcile economic growth and sustainable development (Corvellec et al., 2021; Geissdoerfer et al., 2017; Kirchherr, 2022). Years into conceptual development and refinement, CE has been seen in a variety of ways ranging from holistic and comprehensive to only partially beneficial (Corvellec et al., 2021; Geissdoerfer et al., 2017) and even detrimental (Harris et al., 2021; Zink and Geyer, 2017). While the conceptual foundations of CE remain contested (Blomsma and Brennan, 2017; Korhonen et al., 2018a, 2018b; Skene, 2018), the topic is receiving growing scholarly interest (Ehrenfeld, 2004; Kirchherr and van Santen, 2019; Lüdeke-Freund and Dembek, 2017).

Sustainability transitions research suggests that socio-technical transitions involve systemic changes in multiple dimensions beyond technology, including organizational and human decision-making. Such changes are expected to yield innovative products, services, and business models (Geels, 2004; Markard et al., 2012). CE transition is one type of socio-technical transition (Jurgilevich et al., 2016) and scholars have highlighted transition and innovation as conceptual elements of CE (Suchek et al., 2021) – both of which are seen as relevant to circular business models (CBM) (Antikainen and Valkokari, 2016; Bocken et al., 2016; Lewandowski, 2016; Santa-Maria et al., 2021). Relatedly, scholars have proposed various typologies of CBM (Henry et al., 2020; Urbinati et al., 2017) and have focused on CBM strategies, related experimentation (Bocken et al., 2016; Kane et al., 2018; Konietzko et al., 2020),

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[1] This study adopts the CE definition proposed by Kirchherr et al. (2017, pp. 224–225): "an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and be-yond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."

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and enablers and barriers around implementation (Hartley et al., 2021; Ünal et al., 2019; van Keulen and Kirchherr, 2021). While scholarship on CBM is growing (Ferasso et al., 2020; Lüdeke-Freund et al., 2019; Rosa et al., 2019), practical uptake remains limited (Centobelli et al., 2020; Kirchherr et al., 2018b; Urbinati et al., 2017).

One driver of socio-technical transitions is a shift in skills, as some skills relevant in the old system lose their value in a new system (Geels, 2002). Implementation of CE strategies requires businesses to extend their activities along the product life-cycle and integrate more deeply with business partners and the broader ecosystem in order to enable circular innovation (Bocken et al., 2016). While scholarship maintains that firms should develop new employee skills and organizational capabilities to implement CBM, research has only recently begun to examine such skills and organizational capabilities in detail. Some studies have focused on employee skills related to specific roles and circular skills (De los Rios and Charnley, 2017; Sumter et al., 2021), but only two have focused on more comprehensive overviews of general, sustainable, and circular skills for CBM (Ganiyu et al., 2020; Janssens et al., 2021). A modest body of research about specific organizational capabilities for CBM has emerged, focusing on environmental management (Scarpellini et al., 2020b), big data and business analytics (Kristoffersen et al., 2021), and integrative perspectives regarding these capabilities have also emerged, focusing on the intersection of skills, strategies, resources, and processes (Khan et al., 2020; Prieto-Sandoval et al., 2019; Santa-Maria et al., 2022).

This article seeks to contribute towards "our understanding on the implementation of the circular economy" (the aim of a special issue of the *Journal of Cleaner Production*[2]) by offering a systematic examination of skills relevant to the implementation of novel CBM in start-ups. Besides incumbents innovating towards CBM (Santa-Maria et al., 2022), the uptake of circular start-ups[3] is driving the CE transition. Yet, start-ups have been largely overlooked by CE literature on skills and capabilities (more detail in Section 2.2). Skills[4] of individuals enable and enhance the processes, structures, and technologies needed for creating, deploying, protecting, and reconfiguring organizational capabilities required for CBM activities. As such, skills are a micro-foundation of firm-level capabilities[5] – both ordinary and dynamic (we define the terms 'capabilities' and 'skills' in the section 'Theoretical framing'). The relevance of individual employment skills to CBM implementation has yet to be fully researched or integrated into practice. The modest volume of literature offers some insights, but no published academic study, at the time of drafting this article, has developed a comprehensive skill taxonomy for CBM implementation in start-ups. To fill this gap, this study's research question is: What skills should be included in a comprehensive skill taxonomy for CBM implementation in start-ups?

To answer this question, this study analyzes self-reported skill profiles of 2407 staff working in circular start-ups and presents a novel skill taxonomy. Companies developing skill taxonomies often aim for a comprehensive set of high-level skills for successful (in this case, circular) business model implementation – no general, sustainable, or circular skill would be missing, in concept. Accordingly, this study determined that a comprehensive skill taxonomy would be a helpful analytical device. The study focuses on skills for three reasons. First, the unit of analysis lends itself better to a targeted operationalization than does the sometimes ambiguous concept of 'capabilities' (Lankhorst and van Dijk, 2021). Second, the focus on skills enables a deeper connection with emerging research about skills as a principal microfoundation of capabilities, as even a macro-perspective on capabilities must consider constituent elements (Felin et al., 2015). Finally, skills are often a logical starting point for start-up entrepreneurs, as at smaller organizational scales individual skills are more immediately relevant and tangible than are capabilities.

The study finds that CBM implementation requires a set of general, sustainable, and circular skills; some of these skills, such as digital skills, have been neglected. Skills declared as specifically circular are not as prevalent in circular start-ups as the literature suggests. Given that CBM is not an entirely new concept, some skills identified in this study predate the CE concept. Thus, the novelty of skills for CBM implementation is apparent when the organizational context itself shifts; in circular start-ups, employees might apply existing skills to novel or differentiated circular ideas and need to develop an understanding and recognition of those skills in their circular context. Consequently, promoting circular narratives as a framing device for skill development can advance CE towards mainstream uptake. While the taxonomy aims to be an analytical device for both scholars and practitioners, it is not proposed as conclusive but rather as a prompt for further research.

The remainder of this article is structured as follows. Section 2 outlines the theoretical framing of the study, situating it within the literature on capabilities and skills. Section 3 describes methods, Section 4 presents the results and taxonomy, and Section 5 discusses the relevance of the taxonomy for scholarship and practice.

2. Theoretical framing

2.1. Capabilities and skills in organizational management

This study is theoretically situated within literature on organizational capabilities, focusing on a sub-strand addressing employee skills. Capability theory, having evolved over several decades, is expressed through various perspectives including the resource-based view and knowledge-based view (Felin and Hesterly, 2007; Helfat and Peteraf, 2003; Hoopes and Madsen, 2008; Langlois and Foss, 1997). Winter (2003) defines organizational capability "a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type." Capabilities can also be described as firm-specific organizational knowledge (Dosi et al., 2000; Langlois and Foss, 1997) or competences (Teece et al., 1997) that enable an organization to perform activities and improve business performance (Helfat and Peteraf, 2003; Hoopes and Madsen, 2008).

Two types of capabilities are commonly discussed in the literature (Drnevich and Kriauciunas, 2011; Teece, 2014, 2018; Winter, 2003). First, operational (or ordinary) capabilities enable a firm to maintain operations in the short-term (Winter, 2003) and ensure business efficiency. Second, dynamic capabilities are higher-order abilities to respond to opportunities and threats, to reconfigure business operations accordingly, and to maintain a sustainable competitive advantage (Teece et al., 1997). Both types of capabilities are essential and interdependent (Kraaijenbrink et al., 2009).

Capabilities are supported by microfoundations that include individuals and their skills, processes, technology, and structure – as well as interactions among all four (Abell et al., 2008; Felin et al., 2012, 2015). While microfoundations are not limited in perspective to individuals (Barney and Felin, 2013; Dosi et al., 2008), research on microfoundations pays considerable attention to individuals – a starting point for understanding organizational behavior and performance (Barney and Felin, 2013; Campbell et al., 2012; Felin and Foss, 2005; Felin and Hesterly, 2007). One example is employee mobility:

[2] https://www.journals.elsevier.com/journal-of-cleaner-production/forthcoming-special-issues/who-will-benefit-from-the-transition-to-the-circular-economy (accessed 28 Sept 2022)

[3] This study adopts the definition of a circular start-up proposed by Henry et al. (2020, p. 2): "new, independent and active companies pursuing a [circular business model]."

[4] Scholars also use the term 'competency' (e.g., Sumter et al., 2021). We view both terms (skill and competency) as synonymous: successfully performing a task on the individual level. For consistency, we use the term 'skills' throughout the article.

[5] Some studies use the term 'skills' when referring to organizational skills as capabilities. For the remainder of this article, mentions of 'skills' refer to individual skills of employees, unless otherwise specified.

businesses can build new capabilities by recruiting individuals with particular skills (Felin et al., 2012; Felin and Hesterly, 2007). Fig. 1 depicts our conceptualization of capabilities and microfoundations.

The 'collectivity' or aggregation of individuals' skills within an organization can be considered the 'skills of the organization,' and a key management function is to coordinate and utilize the collectivity of these skills effectively (Dosi et al., 2000). As outlined in Fig. 1, organizational capabilities or competences are not simply the sum of individuals and their skills but an aggregation of all microfoundations and their interactions (Barney and Felin, 2013). According to Dosi et al. (2008), it is appropriate to "[bear] in mind that the 'competence of company x in technology y' is something different from 'the ensemble of the individual skills in technology y of all the members of company x.'" Relatedly, synergies created by certain combinations of individual skills, processes, organizational structures, and technologies can generate firm-specific knowledge and capabilities attributable to the organization as a whole.

Building on the above line of reasoning, this study considers skills held collectively by a company (rather than by a single individual) as the starting point for understanding the adoption of processes, structures and technologies for creating, deploying, protecting, and reconfiguring ordinary and dynamic capabilities that enable an organization to perform business model activities (see Fig. 1). For example, microfoundations undergirding project management capabilities constitute not only supporting processes, structures, and technologies but also individual-level skills to develop and enhance these project management microfoundations altogether. There is no automated mechanism that translates the existence of certain skills into a competitive advantage, rather skills existing in a company need to be utilized (Dosi et al., 2000). The skills of an organization can thus be considered a necessary but not wholly sufficient condition for business performance.

2.2. Capabilities and skills for CBM

CBM can be conceptualized as a subset of sustainable business models (Geissdoerfer et al., 2017; Henry et al., 2020) and is a way of operating a business that incorporates CE principles and strategies for slowing, narrowing, or closing resource loops (Geissdoerfer et al., 2020; Pieroni et al., 2019; Santa-Maria et al., 2021). Implementing CE strategies often requires businesses to extend activities beyond those of traditional business models (Bocken et al., 2016). These activities include, depending on the CE strategies, reverse supply chain and logistics activities, higher degrees of collaboration along the value chain, service design activities for product-service systems (Urbinati et al., 2017), and product design, manufacturing, and other enabling activities (Henry et al., 2020). CBM innovations occur either by creating a completely new model (e.g., as a start-up) or by reconfiguring elements of an existing one (Bocken et al., 2019).

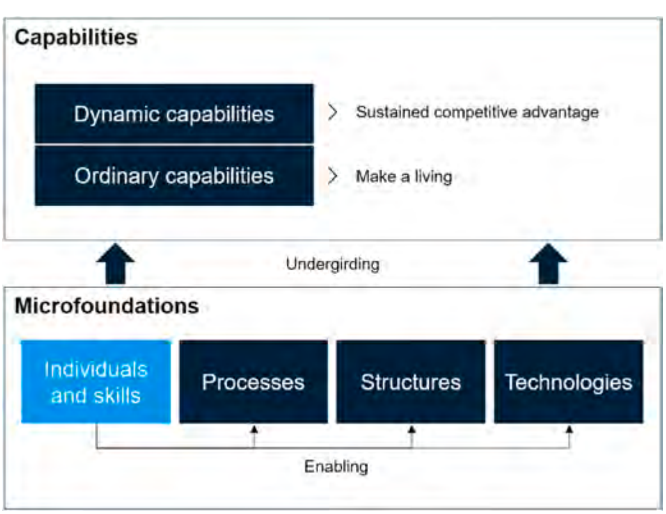

Fig. 1. Conceptualization of capabilities and microfoundations as found in management literature (source: authors).

Accounting for these exigencies, scholarship has argued that firms should develop new employee skills and organizational capabilities; research on both is relatively new but growing within CE literature. This study reviewed articles on individual skills and organizational capabilities for CBM (more detail in the 'Methods' section) and summarized both in a comprehensive overview (Appendix A). CE literature most often focuses on organizational capabilities (Elf et al., 2022; Fernandez de Arroyabe et al., 2021; Khan et al., 2020; Kusumowardani et al., 2022; Marín-Vinuesa et al., 2021; Marrucci et al., 2022; Prieto-Sandoval et al., 2019; Santa-Maria et al., 2022; Scarpellini et al., 2020a,b; Stekelorum et al., 2021). Examples of such capabilities are big data analytics, customer service, (green) marketing, environmental management systems, reverse logistics, and circular patenting. Other research addresses individual skills for CBM implementation (Janssens et al., 2021; Sumter et al., 2020, 2021), including data analytics, material analysis, problem solving, ethical and social principles, circular user engagement, and circular material use (in design).

Scholars have adopted various conceptual approaches and levels of aggregation in studying skills and capabilities for CBM, with some definitional overlaps. For example, Prieto-Sandoval et al. (2019) consider 'research and development' a dynamic capability, while Burger et al. (2019) consider 'science' an individual-level skill. Also, studies of organizational capability have proposed (operational) capabilities, dynamic capabilities, and aggregate microfoundations (avoiding differentiation of individual microfoundations outlined in Fig. 1; see Appendix A), while referring to the same ideas. For example, stakeholder collaboration has been proposed as an operational capability, a dynamic capability, and an aggregate microfoundation. Given these ambiguities, Wang and Ahmed (2007, p. 33) state that "a significant number of empirical studies pertinent to dynamic capabilities do not explicate the concept[s]." Further, Felin & Foss (2005) argue that capability research has faced problems of empirical operationalization, given its vague conceptual origins.

From this study's review of articles about skills and organizational capabilities for CBM, two additional findings deserve mention. First, skills and capabilities for CBM are often categorized as general, sustainable, or circular (Table 1 and Appendix A). Second, research either fails to distinguish CBM innovation between start-ups and incumbents or focuses only on incumbents (e.g., dynamic capabilities or aggregate microfoundations for CBM innovation within existing businesses; Santa-Maria et al., 2022). To the knowledge of the authors, no study of skills or capabilities has focused on start-ups. This trend has been observed in general CBM research (Henry and Kirchherr, 2020) and is notable since start-ups are often considered to be drivers of innovation given their lack of organizational path dependencies (Henry et al., 2020). Start-ups in this context are typically small-scale companies that base their entire business models around CE principles; by contrast, larger incumbents

Table 1
Definitions of skill types.

Skill type	Definition
General	This study adopts the general definition of skills proposed by Burger et al. (2019): "the ability to perform a task well [,] commonly acquired through on-the-job training and/or experience."
Sustainable	Extending the definition of general skill type, this study defines sustainable skills as skills that specifically address aspects of the 'triple bottom line' (social, environmental, economic).
Circular	Extending the definition of general skill type, this study defines circular skills as skills that specifically address aspects of "cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system" (Geissdoerfer et al., 2020).

often diversify rather than transform towards CBM entirely (Geissdoerfer et al., 2020). As such, skills and capabilities in start-ups are often specific to a CBM, whereas larger incumbents also include (legacy) capabilities and skills serving traditional business models. This study develops a comprehensive overview of skills (as a microfoundation of capabilities) needed to implement CBM in start-ups (Fig. 2) by investigating existing skills in start-ups[6] that have adopted a CBM (see 'Methods' section).

2.3. Skill taxonomies

This study introduces a skill taxonomy at the organizational level. While not addressed extensively in the literature, skill taxonomies have received attention in practitioner venues including human resources blogs (AG5, 2021; AIHR, 2021; Creelman, 2021). A skill taxonomy can be defined as "a structured list of skills defined at the organization level" (AIHR, 2021). Such a taxonomy can support a unified language that informs human resources decisions and ultimately drives business performance (AIHR, 2021). Developed under the sponsorship of the Employment and Training Administration at the United States Department of Labor, the O*NET database provides the most commonly used generic skill taxonomy (Creelman, 2021; O*NET, 2022).

Existing taxonomies organize skills into various categories. For example, Burger et al. (2019) distinguish six groups of skills based on O*NET (2022): basic skills, complex problem-solving skills, resource management skills, social skills, systems skills, and technical skills. Janssens et al. (2021) distinguish three groups of skills: transversal skills, valorization skills, and technical skills. Likewise, Kirchherr et al. (2018a) distinguish three groups of skills: technological skills, basic digital skills, and classic skills. The categorization by Burger et al. (2019) forms the conceptual basis of this study's taxonomy. Additionally, there is no fixed number of skills appropriate for a taxonomy. Sumter et al. (2021) propose nine, Janssens et al. (2021) 37, and Burger et al. (2019) 35 skills. Thus, this study aimed to develop a comprehensive taxonomy encompassing 20 to 40 skills to provide a more practical and higher-level overview rather than a long list of detailed skills (this study identified roughly 700 self-declared skills; see Section 3.1).

3. Methods

The proposed skill taxonomy is based on an analysis that includes clustering and synthesis (Fig. 3) – an approach commonly used in the social sciences (Ahlquist and Breunig, 2012; Fonseca, 2013). This is the first study in the CE literature on this topic to adopt a large-N clustering analysis (including natural language processing) that identifies skills for CBM implementation. Most existing research on this topic is qualitative (Khan et al., 2020; Sumter et al., 2020), with some quantitative exceptions or extensions (Burger et al., 2019; Janssens et al., 2021). The latter focus on the relevance of pre-imposed skills, whereas this study's analysis applies unsupervised learning to identify skills.

3.1. Skills clustering

Skills data from employees were collected and clustered into sets. Borrowing from Bastian et al. (2014), Russell and Klassen (2019), and Bothmer and Schlippe (2022), this approach consisted of three steps: data-scraping of LinkedIn profiles, natural language processing, and skills clustering. The anonymized data[7] contained skills from LinkedIn profiles of staff employed in 113 circular start-ups (Fig. 4; Appendix B includes a full list). Data analyzed were taken from the LinkedIn profile section labeled 'Skills & endorsement.' 2407 publicly available staff profiles were examined, with a total of 4830 self-declared skills. The list of circular start-ups was taken from Henry et al. (2020), whose work may be considered the most exhaustive such effort.

It is prudent to note that skills self-declared on LinkedIn profiles are prone to subjectivity. There is a risk that employees might falsely report skills. Additionally, employees might declare skills across differing levels of granularity or abstraction. For example, one employee might declare programing tools (such as C or C#) while another might declare 'application development.' Fig. 5 presents a word cloud of the top-50 most frequently occurring skills (Appendix B presents skill frequencies).

Using the natural language processing technique 'Word2Vec' (Church, 2017; Mikolov et al., 2013), the researchers created context-based word embeddings of the scraped skills data serving as input for clustering. From the LinkedIn data, researchers first generated a comprehensive list of 715 self-declared skills and their frequency (i.e., how often each skill was declared across all start-up employees in the sample data; see Supplementary Materials); long-tail skills with a total frequency below five occurrences were excluded. Based on the researchers' experience, low-frequency skills on LinkedIn are not useful because they are either miss-spellings or not industry-standard. The researchers then generated mathematical vector representations (so-called 'word embeddings') with 100 dimensions using a Word2Vec model based on co-occurrence for every skill in the list.[8] Word embeddings can capture the context of words in a text (such as semantic similarity or co-occurrence) through mathematical representations of these words (in this case, 'skills'; Karani, 2018). The model was trained on co-occurrence of skills in LinkedIn profiles. For example, 'Python' or 'R' might be frequently mentioned along with 'SQL,' so vector representations (or word embeddings) of these skills would be mathematically closer.

Finally, the researchers clustered skills by applying an unsupervised learning algorithm (Hastie et al., 2009) on word embeddings, resulting in 50 clusters. The researchers applied k-means clustering (Hartigan and Wong, 1979) on word embeddings, one of the most common methods in such circumstances (Hastie et al., 2009; Pham et al., 2005). The k-means method requires users to assume and predefine a fixed number of k-clusters as an input parameter before clustering is performed. Determining the value of k is complex (Steinley, 2006) and the model's quality of fit with the data, based on the number of clusters, is a subjective decision (Feldman and Sanger, 2007; Pham et al., 2005). A trial-and-error approach (Pham et al., 2005) was used and clustering was run with 20, 30, and 50 predefined clusters. The researchers ultimately established the number of clusters at 50, perceiving that the majority of clusters contained clearly defined sets of skills. It was thus possible to aggregate clusters again in the subsequent step (skills synthesis) with the aim of 20–40 skills in the taxonomy.

The k-means clustering segmented the 715 self-declared employee skills into 50 distinct and non-overlapping groups based on their co-occurrence in LinkedIn profiles. An example of this effort is represented in Table 2, which presents a skill clustering frequency table showing skills assigned to one of the 50 clusters. These finance and accounting skills, which have been declared by employees with the indicated frequencies, typically co-occur in LinkedIn profiles. The resulting clusters contain 14 to 15 self-declared skills on average, ranging from three skills in the cluster with the least skills assigned to 30 skills in the cluster with the most skills assigned. Roughly 30 clusters contain between 10 and 20 self-declared skills. Full clustering results can be found in the Supplementary Materials.

[6] For the remainder of this article, mentions of employees refer to those in start-ups, unless otherwise specified.

[7] Data were legally acquired under official license agreements from a data vendor, and not directly scraped from LinkedIn.

[8] The Word2Vec skills model used in this analysis has been developed in an industry context and groups skills in businesses. It has been trained on a large amount of LinkedIn skills data across a large number of businesses.

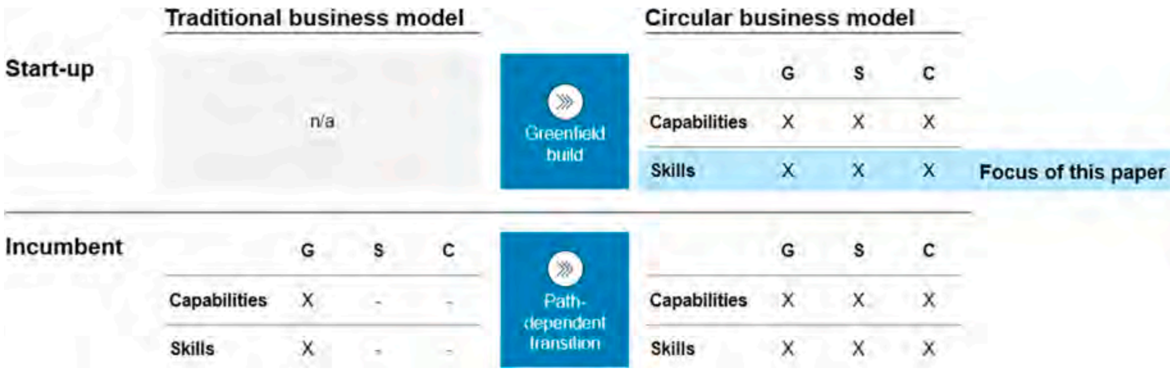

Fig. 2. Type of capabilities and skills needed for CBM innovation in incumbents and start-ups (source: authors).
Note: G/S/C denote the type of capabilities or skills: G = General | S = Sustainable | C = Circular. X indicates whether a type of capability or skill is needed for business model implementation.

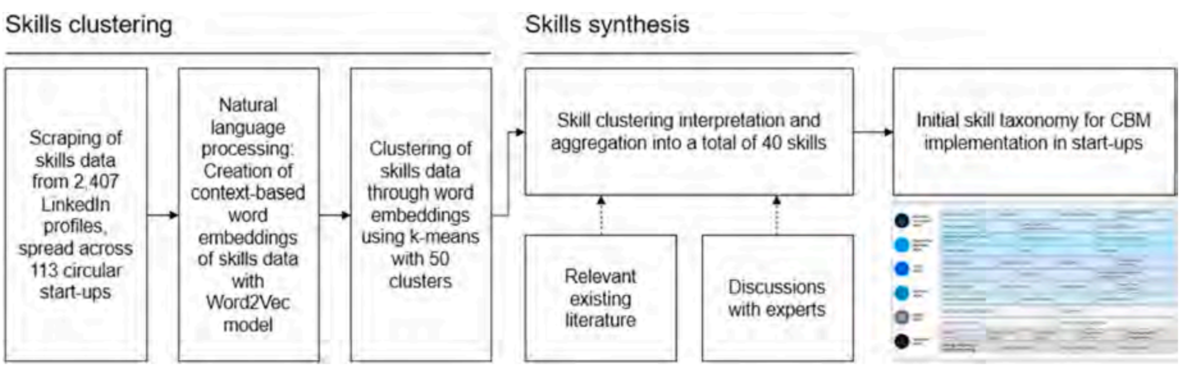

Fig. 3. Methodological approach (source: authors).

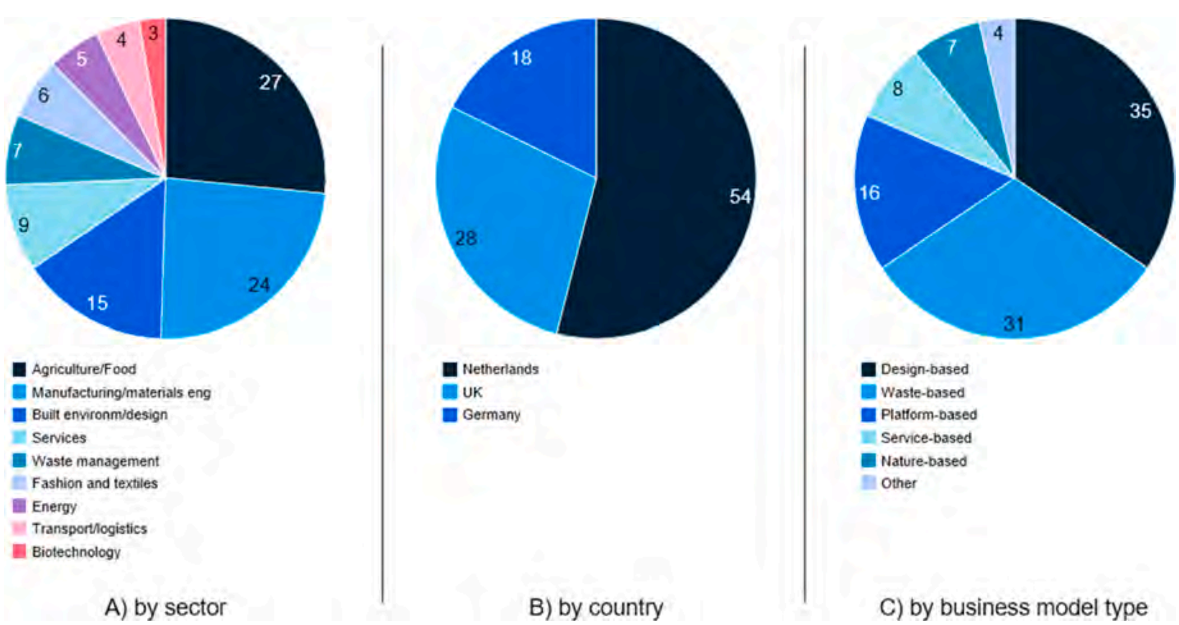

Fig. 4. Overview of start-ups by sector, country, and business model type.
Note: Business model types are based on Henry et al. (2020), a description can be found in Appendix B.

3.2. Skills synthesis

The skill taxonomy is not wholly mechanically developed but utilizes data from desk research about existing literature concerning skills and capabilities in a CE context and expert discussions; this approach seeks to further contextualize and inform the interpretation and aggregation of clusters. The researchers developed the skill taxonomy based on the results of a clustering exercise. K-means, as a traditional cluster analysis method, is an exploratory tool to understand underlying patterns in data but also requires human judgement in labeling and interpretation

Fig. 5. Word cloud of top-50 self-declared skills.
Note: Basic digital tools found within the dataset (e.g., Microsoft Office), social media skills, and language skills were not considered in this figure.

(Ahlquist and Breunig, 2009, 2012; Feldman and Sanger, 2007). As such, there is no purely mechanical way to build such a taxonomy; the process is "a mix of mathematics and intuition" (Dave, 2019). In this case, the clustering effort grouped skills logically based on co-occurrence, and the results formed the starting point for the skill taxonomy. In a manual exercise, the researchers interpreted and labeled each cluster, then aggregated and combined related clusters iteratively towards a total of 20–40 high-level skills (i.e., consolidated sets of self-declared skills, as outlined in the theoretical framing). Some clusters did not contain a meaningful set of self-declared skills.[9]

3.2.1. Review of capabilities and skills proposed in existing CE literature

The authors specifically searched Elsevier's Scopus database for literature proposing skills and capabilities in a CBM context. The search term included 'capabilities,' 'competences,' and 'skills' in conjunction with 'circular economy' and 'business' (as well as synonyms for 'business'). Appendix C provides details about the literature analysis and an overview of the literature reviewed. The researchers searched articles for skills or capabilities that were then used to contextualize and inform the taxonomy (see Section 2.2 and Appendix A for more details on proposed skills and capabilities). For example, the skill 'business propositions/strategy' was interpreted using the perspective of Sumter et al. (2021), who identify the skill as 'circular business propositions.'

3.2.2. Expert interviews

The researchers collected feedback about initial findings from scholars engaged in CE research and from practitioners working mostly in circular start-ups and in CE-related consulting (see Appendix D for more details, including an overview of the expert interviews). First, the researchers explained the idea of a skill taxonomy and how it is typically used. Presenting the initial draft of the skill taxonomy, the researchers asked interviewees the following questions: Is there anything you would want to add to this taxonomy? Is there any skill you would want to omit? Is there any skill you would formulate differently? Are there any other thoughts you want to share with us on this topic? The researchers deliberated on the comments received and accordingly revised the taxonomy. For example, the researchers included the skill 'Policy monitoring' as a skill on its own (rather than combining it with 'Market monitoring') after one interviewee, based on experience, shared how understanding the emerging (usually conducive) CE policy landscape can help a circular venture build a sustained competitive advantage.

4. Results

The proposed skill taxonomy is presented in Fig. 6 (Appendix E lists skill frequencies). In total, the taxonomy includes 40 skills (definitions, in a circular business context, are presented in Table 3) that are grouped into six categories adapted from O*NET (2022). These categories are:

- *Business innovation skills:* Developing and seizing innovative business propositions
- *Operational business skills:* Solving business problems in real-world settings and allocating resources accordingly
- *Social skills:* Working constructively with people to achieve goals
- *Systems skills:* Understanding, monitoring, and improving socio-technical systems
- *Digital skills:* Developing and managing IT and data
- *Technical skills:* Applying technical knowledge in relevant business domains

Distinctive features of the skills in the taxonomy are presented in this section, based on differences across sectors and business model types, perspectives found in CE literature, and expert opinions. Similar to skills and capabilities proposed in the literature (Section 2.2 and Appendix A),

Table 2
Example of cluster including frequency of self-declared skills.

Self-declared skill	Frequency	Self-declared skill	Frequency
financial analysis	50	**auditing**	13
Finance	44	**financial accounting**	11
financial modeling	28	**internal controls**	8
financial reporting	23	**financial audits**	7
accounting	19	**International Financial Reporting Standards**	7
managerial finance	14		

[9] The researchers applied logical disaggregation of a cluster and reassigned skills into more logical skill sets. Additionally, the researchers translated non-English self-declared skills and excluded generic skills related to specific industries (hospitality/food, retail fashion, and non-renewables – as this study aims at a general taxonomy), generic Microsoft Office skills, and language skills.

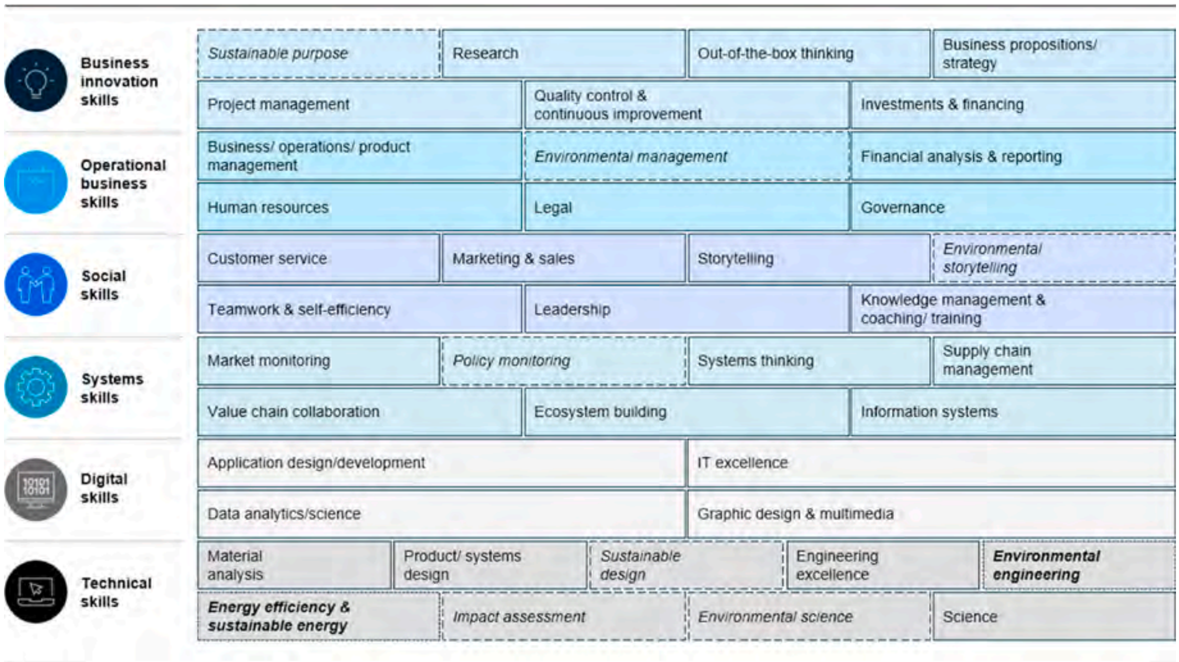

Fig. 6. Taxonomy of skills for CBM implementation.
Note: There is no order of importance among skills in the taxonomy. Different sizes of boxes do not imply order. Sustainability/environmental skills are italicized with a long-dash outline; circular skills are italicized and bolded with a short-dash outline; all other skills are general.

general, sustainable, and circular skills are identified (although the scraping exercise did not identify skills specifically labeled 'circular'). Many general skills are found in circular and linear companies alike, as noted in our discussions with scholars and practitioners.

Interpretation of skill frequency should proceed cautiously. Skills with a low frequency are not necessarily less important, as these might be needed only by relatively few employees (Kirchherr et al., 2018a). Additionally, frequency depends on the level of granularity of skills declared in LinkedIn. For example, software engineers declare many programing tools, adding to the frequency of the skill 'application design/development' (section 4.5); at the same time, many employees declare 'project management' once. Hence, a higher frequency for application design/development does not indicate higher importance than project management. In some cases, a particularly low frequency might indicate that a skill is not common.

4.1. Business innovation skills

Seven skills are listed in the category 'business innovation skills.' The first, 'sustainable purpose,' can be considered fundamental: it may be reflected in the value proposition and the priorities of the management (some start-ups examined are social enterprises or B Corps), and might draw from sustainability frameworks like the SDGs (Santa-Maria et al., 2022). Sustainable purpose helps employees define commitment towards sustainable aims (Kirchherr et al., 2017), and there is increasing focus on environmental commitment by businesses. However, this study indicates that start-ups in the fashion/textiles and transport sectors have particularly low frequencies for this skill.

Any CBM is implemented through 'project management' (Prieto-Sandoval et al., 2019), but implementing them may be as or more difficult than developing them (Janssens et al., 2021). Effective project management is essential, as the implementation of new strategies requires management of change (a skill found among start-up employees). Circular projects can be complex and involve many stakeholders (Köhler et al., 2022; Sanchez and Haas, 2018), often requiring new ways of approaching project management (Ismayilova and Silvius, 2020). Recognizing the importance of CE project management, the French industry organization AFNOR devised associated standards (AFNOR, 2018). For this study, one expert states that project management "is a skill that sounds dull, whereas so essential to get a business off the ground."

Scholars frequently mentioned project management together with 'quality control & continuous improvement.' There exist few proven CBM, particularly regarding sustainability performance. The novelty of CBM as a concept requires continuous improvement (Prieto-Sandoval et al., 2019), including in collaborations within supply chains (Calicchio Berardi and Peregrino de Brito, 2021) and in broader ecosystems across the natural and built environments (Joensuu et al., 2020). According to Velenturf and Purnell (2021), "implementing a circular economy is a process of continuous improvement in which the [circularity and] sustainability of practices is continuously monitored, evaluated and adapted." For example, continuous improvement is found to be an effective enabler for waste elimination in agri-food supply chains (Kusumowardani et al., 2022).

Launching CBM, as with linear models, is dependent in part on 'investments & financing.' Rather than developing necessary capabilities internally, circular businesses might acquire other firms (Khan et al., 2020). While this CBM innovation approach is more common among incumbents (Geissdoerfer et al., 2020), data indicate that employees exhibit these skills across business model types (with the exception of service-based firms). Financial markets might not yet provide sufficient support for circular businesses (Dewick et al., 2020), but investment and financing skills are already apparent.

4.2. Operational business skills

The category 'operational business skills' includes six skills. First, 'business/operations/product management' appear frequently in the data, encompassing basic operational business management skills like 'operations management,' 'negotiation,' 'forecasting,' 'product management,' and 'international business.' The data also show 'management' as the most frequent self-declared skill, indicating that employees need basic, transversal management skills to organize business operations. These 'ordinary' skills, in combination with other skills, can

Table 3
Skills for circular start-ups – Definitions.

Skill Category	Skills	Definition in a circular business context
Business innovation skills	Sustainable purpose	Establishing how the business understands and thinks about sustainable development within its ecosystem
	Research	Using scientific rules and methods to advance CE understanding towards further application
	Out-of-the-box-thinking	Developing original ideas for innovations (e.g., circular products, services) and business improvements
	Business propositions/ strategy	Developing circular business propositions/strategies that aim to slow, close, and/or narrow material and energy loops
	Project management	Planning, managing and executing projects within a given budget and timeframe, and managing associated change
	Quality control and continuous improvement	Conducting tests and inspections of products, services, and processes; and pursuing incremental and breakthrough improvements
	Investments and financing	Managing assets and acquisitions that enable circular business propositions/strategies, identifying financing options and optimizing capital structures
Operational business skills	Business/operations/ product management	Managing day-to-day business and product activities to achieve operational excellence
	Environmental management	Managing environmental issues through frameworks (e.g., ISO14001), accounting, and sustainability/ESG reporting
	Financial analysis and reporting	Conducting financial accounting, controlling, and auditing and providing financial statements
	Human resources	Attracting circular talent, establishing a culture that embraces sustainable CE, and managing human resources functions
	Legal	Advising on legal matters, including topics relevant for ecosystem collaboration and circular patents
	Governance	Establishing rules and structures for CBM implementation, both internally and externally
Social skills	Customer service	Providing services to customers before, during, and after purchase of a circular product or service
	Marketing and sales	Advertising and selling the company's circular products and services
	Storytelling	Strengthening communication and public speaking skills; developing content and managing business communications, both internally and externally
	Environmental storytelling	Creating engaging narratives that strengthen awareness of and support for sustainable CE
	Teamwork and self-efficiency	Collaborating across disciplines and distance, and organizing individual and collaborative work efficiently
	Leadership	Inspiring individuals, teams, and/or an entire organization to strengthen circular business performance
	Knowledge management and coaching/training	Continuously gathering, organizing, and distributing explicit and tacit knowledge for circular solutions, and training employees and stakeholders for CE skills
Systems skills	Market monitoring	Scanning and seizing market developments relevant to CE
	Policy monitoring	Understanding the policy landscape with regards to CE, and seizing public funding opportunities
	Systems thinking	Understanding how a system works and how changes in conditions and operations affect outcomes
	Supply chain management	Managing supplier relations, procurement, and logistics, focusing on forward and reverse chains
	Value chain collaboration	Building and orchestrating trust-based win-win collaborations along and beyond the supply chain
	Ecosystem building	Building networks of like-minded actors beyond one's value chain to achieve at-scale circularity
	Information systems	Establishing and utilizing information systems to track and manage circular ecosystem operations, collaborations, and impacts
Digital skills	Application design/ development	Designing and developing computer software for effective and efficient functioning of CBM
	IT excellence	Managing IT strategy and delivery (e.g., IT architecture, infrastructure, and cloud services)
	Data analytics/science	Collecting, managing, and analysing data (including large volumes of data and advanced quantitative modelling) efficiently to solve complex circular problems
	Graphic design and multimedia	Creating graphics and multimedia formats for commercial and promotional needs
Technical skills	Material analysis	Evaluating materials regarding their circularity potential
	Product/systems design	Designing products and/or systems to meet design excellence and circularity objectives
	Sustainable design	Designing products and services considering sustainability and circularity objectives (e.g., allow for multiple use-cycles) throughout lifecycles
	Engineering excellence	Building processes and systems for products, manufacturing, production, and broader contexts aiming at circular engineering excellence
	Environmental engineering	Capturing value from materials and products typically disposed under linear models and solving associated environmental issues (e.g., recycling and wastewater treatment)
	Energy efficiency and sustainable energy	Establishing a strong energy management function that facilitates CBM implementation
	Impact assessment	Critically measuring the circularity, social, economic, and environmental impacts of a CBM throughout the full life-cycle of its products and services
	Environmental science	Becoming a knowledge expert in the interdisciplinary domain of environmental science
	Science	Accumulating relevant expertise in relevant scientific domains

Source: Adapted from Geissdoerfer et al. (2017), Kirchherr et al. (2018a), O*NET (2022), Sumter et al. (2021), authors' depiction facilitate CBM implementation (Lopes de Sousa Jabbour et al., 2019).

Sustainability and environmental management skills are identified, but with relatively few occurrences compared to their frequent mention in CE literature on capabilities. Lack of environmental management skill constitutes a barrier to CE implementation in small- and medium-sized enterprises such as circular start-ups (Mishra et al., 2022). Environmental commitments should be operationalized, including in supply chains (where policy barriers exist; Kazancoglu et al., 2021). Adequate internalization of environmental management systems (EMS) can promote circular innovations (Geng and Doberstein, 2008; Marrucci et al., 2022; Scarpellini et al., 2020b). The term 'adequate' suggests that EMS should not be limited to achieving formal environmental certification but also include capabilities such as environmental accounting (Scarpellini et al., 2020a,b). For example, some new start-ups are offering carbon accounting solutions, an emergent concept (Planetly, 2022; Watershed, 2022). Another tool in environmental management is sustainability and ESG reporting (Santa-Maria et al., 2022; Lozano, 2020), which appears only modestly in the data. Establishing advanced formal environmental management operations is complex and costly, potentially explaining why start-ups engage less formally and only to the extent needed (Henry et al., 2020).

'Legal' skills ('corporate law,' 'legal advice,' and 'legal research') and 'governance' skills do not appear as frequently as the literature suggests. Internal governance and collaboration-based governance have been cited as important for CE implementation (Khan et al., 2020; Köhler et al., 2022; Scarpellini et al., 2020b), but formal governance structures are often less established in start-ups (Henry et al., 2020). Collaboration within ecosystems and along supply chains (section 4.4) raises issues like intellectual property and legalities around engagement. Scholars argue that intellectual property (e.g., circular patents; Marín-Vinuesa et al., 2021; Portillo-Tarragona et al., 2022) can impact implementation of CE strategies like remanufacturing (den Hollander et al., 2017). Required legal skills might be held by few employees (Janssens et al., 2021) or be outsourced.

4.3. Social skills

The category 'social skills' includes seven skills. The first is 'customer service,' as emphasized by literature on design thinking and CE (Andrews, 2015; Brown et al., 2021; Prieto-Sandoval et al., 2019). Extended customer eco-engagement can facilitate CBM implementation (Elf et al., 2022). This study distinguishes 'customer service' from 'marketing & sales,' as the latter concerns solicitation of new interest as opposed to serving existing customers. This is the most frequently appearing skill across sectors. Similar to basic management skills (section 4.2), these skills can be considered ordinary yet required in any business. Notably, while circular start-ups as new businesses operate in competitive markets alongside linear businesses, few references to marketing and sales appear in the CE literature on skills and capabilities.

'Storytelling' concerns internal and external business communication, individual communication and public speaking skills, and writing skills. While such skills are required in any business and frequently mentioned by employees in the data, only a limited number of employees declare 'environmental storytelling' skills like 'environmental awareness' and 'environmental education.' Circular storytelling, as proposed by Sumter et al. (2021), is not focused solely on selling. It also concerns visioning of circular futures (Bauwens et al., 2020; Calisto Friant et al., 2020) in a way that fosters CE support beyond customers. According to one expert, circular storytelling entails explaining "circular ideas in a 'normal business sense,'" using 'linear language' to meet decisionmakers 'where they are' and ultimately shift priorities and ideas towards circularity.

4.4. Systems skills

Seven skills are classifiable as 'systems skills.' There is little evidence of 'systems thinking' skills in the data, with only five explicit mentions across 113 start-ups. On the other hand, systems thinking is frequently discussed by CE literature and sustainability literature more broadly: Vona (2021) classifies it as a key 'green' skill. The role of systems thinking in CE has also been highlighted by Blomsma and Brennan (2018) and mentioned as a skill by Kristoffersen et al. (2021), Santa-Maria et al. (2022) and Sumter et al. (2021). A circular entrepreneur interviewee stated that "[as a circular start-up founder] you're fighting two fights: one against other companies (like any other new company) and at the same time one against the economic system." Systems thinking entails understanding the currently dominant linear system while identifying opportunities for circular ventures and anticipating sustainability impacts within broader socio-economic and socio-technical systems. Other skills have a systems dimension (e.g., environmental science, supply chain collaboration, environmental engineering, information systems, and application design/development), underscoring the importance of systems thinking even if not explicitly declared by employees.

'Value chain collaboration' concerns developing value chain and supply chain bonds that help CE ventures succeed (Agyabeng-Mensah et al., 2022; Galvão et al., 2020; Geissdoerfer et al., 2018; Kanda et al., 2021; Stekelorum et al., 2021). This skill appears in the data in the context of strategic partnerships and stakeholder engagement. Köhler et al. (2022) highlight the link between cross-sectoral collaboration networks and the advancement of CE innovations in the construction sector. Such collaboration and co-creation involve problem-solving approaches, fair and transparent information- and burden-sharing, and trust-based relations (Agyabeng-Mensah et al., 2022; Köhler et al., 2022; Leising et al., 2018; Schönborn and Junge, 2021). Few employees mentioned this skill, potentially because the sample contained few service-based CBMs and because the start-ups covered seem to engage less formally in their supply chains (Henry et al., 2020).

'Ecosystem building' is frequently mentioned in the data (more so in customer-focused service-based start-ups) and in discussions with experts. This skill focuses on building networks beyond direct business interactions, and can include social networking, community-building, and event management (skills found among start-up employees). Related skills are 'circular storytelling' and the diffusion of circular futures.[10] Occurring also among linear businesses, it can be considered an ordinary, general skill.

4.5. Digital skills

Four digital skills are included in the taxonomy. While some CE literature addresses digitization for supporting CE (Alonso et al., 2021; Okorie et al., 2018; Pagoropoulos et al., 2017) and skills concerning data science (e.g. Kristoffersen et al., 2021), the scholarship largely overlooks digital skills explicitly. Scholar interviewees highlighted the need to include such skills in the taxonomy. Most companies require employees to hold basic digital skills like 'application design/development' and 'IT excellence' (both mentioned frequently in the data). These skills are not only enablers of other skills in the taxonomy but also drivers of digital business models, digital products/services, and smart/IT-based manufacturing activities (Rosa et al., 2020). Application design/development skills are found primarily in platform-based start-ups, but also in design- and service-based start-ups.

The third digital skill, 'data analytics/science,' is necessary for developing 'business analytics' capabilities and facilitating CBM implementation (Awan et al., 2021b; Kristoffersen et al., 2021). This skill is relevant for the types of complex supply chains in which many

[10] Both 'value chain collaboration' and 'ecosystem building' rely fundamentally on social skills. Both are included in specific categories because social skills are more inward-oriented (from a company's perspective), whereas systems skills are more outward-oriented (the exception being 'storytelling').

circular ventures are involved (Stekelorum et al., 2021) and supports the quantitative CE metrics and models needed for circular impact assessments (Pauliuk, 2018; Walzberg et al., 2021). Notably, data revealed that few employees in waste-based start-ups declared data analytics/science skills.

4.6. Technical skills

The 'technical skills' category includes nine skills considered as essential enablers of CE implementation (Triguero et al., 2022). The importance of 'materials analysis' skills is recognized in scholarship (Allwood, 2014; De los Rios and Charnley, 2017; Janssens et al., 2021). This skill is found mostly among employees of agriculture/food and biotech (nature-based) start-ups, but scarcely mentioned in sectors like fashion/textiles and manufacturing/material engineering (where start-ups, mainly design- or waste based, do not seem to conduct deep material analyses themselves or consider new material inputs that need to fulfil sophisticated characteristics).

While design for multiple use-cycles and recovery is frequently proposed as a key CE topic (den Hollander et al., 2017) and as a skill (Sumter et al., 2021), experts noted that this type of design may not be relevant for some CBM. Data indicate that general design-related skills are most frequently declared by employees in the built environment/design and manufacturing/materials engineering sectors. Sustainable product/systems design skills were originally grouped into a single cluster, but the researchers distinguished product/systems design from sustainable design because the majority of skills refer to general design excellence skills (e.g., AutoCAD, Solidworks, and 'design thinking') while few employees declare their design skills as explicitly sustainable.

'Engineering excellence' skills were identified mainly in design-, waste-, and nature-based start-ups, and relates to processes, systems, manufacturing, and production. The less frequent connection to 'environmental engineering' (one of two circular skills identified) focuses on lower-level CBM strategies like recycling (Henry et al., 2020). While the start-ups in the sample also cover higher-level CBM strategies like reducing and reusing (Henry et al., 2020), employees did not explicitly declare related engineering skills (e.g., maintenance, and reverse re-manufacturing/repairing) – contrasting with trends in the literature (De los Rios and Charnley, 2017; Khan et al., 2020; Prieto-Sandoval et al., 2019; Sumter et al., 2021).

The second circular skill identified, 'Energy efficiency & sustainable energy,' is relevant to CE as "eco-innovations to support energy efficiency and the exploitation of renewables are considered important investments in the CE" (Scarpellini et al., 2020b). Energy management (along with an energy efficiency culture) enables other circular activities (Cavicchi et al., 2022) and is thus a key skill (Janssens et al., 2021; Mishra et al., 2022). While common in energy sector start-ups, the frequency of this skill is mixed across other sectors; only declared as a skill by a low number of employees, start-ups rather have energy experts than a widespread energy culture across their employee bases.

Finally, 'impact assessment' is infrequently identified in the data. Though highlighted by the literature (Janssens et al., 2021; Sumter et al., 2021), most companies have not fully developed this skill (Mishra et al., 2022). Methods for measuring the circular economy have risen in research salience (Corona et al., 2019; Moraga et al., 2019; Morseletto, 2020), and industries and institutional bodies continue to identify and elaborate standards and approaches. As such, the low frequency of this skill in the data is notable.

5. Discussion

This section begins by contrasting the identified skills in the taxonomy with the skills and organizational capabilities proposed by CE literature. It then discusses why employees infrequently declare their skills as 'circular.' Further, pathways forward are proposed, including the need to adopt a more holistic perspective in recognizing the broader role of CE and how the taxonomy helps advance this effort. Finally, practical and scholarly implications of the skill taxonomy are discussed.

5.1. Comparison with skills and capabilities proposed in CE literature

The authors analyzed the skills in the taxonomy in two rounds of analysis against the comprehensive sets of (i) individual skills and (ii) organizational capabilities proposed in CE literature (Appendix A). Appendix F offers a detailed description of this comparison. While mapping taxonomy skills against literature skills was a straightforward process, the mapping of taxonomy skills (as a microfoundation of capabilities) against literature capabilities was also possible; some skills and capabilities[11] could be directly mapped (for example, project management) while a partial relationship was found for others (Table F3, Appendix F). This finding is consistent with microfoundations theory: capabilities are not simply the sum of individuals and their skills but an aggregate of all microfoundations (Section 2.1) and their interactions (Barney and Felin, 2013).

Fig. 7 presents a heat map indicating to what extent taxonomy skills are supported across skills and capabilities proposed by CE literature. Many taxonomy skills have been proposed or there exists a correlation with skills or organizational capabilities proposed in the literature; taxonomy skills thus empirically confirm findings in the literature. Furthermore, this study identified new skills to implement a CBM that have not been proposed in the literature. Three taxonomy skills are not found in the CE literature. Two of these, application design/development and graphic design & multimedia, are digital skills. Given that IT excellence has been only partially identified, this study finds that the literature has neglected the need for digital skills (beyond data analytics) in implementing CBM. Data show that the need for digital skills extends beyond platform-based CBM (Section 4.5). The third skill, environmental science, is technical in nature and demonstrates that circular start-ups require a thorough understanding of complex systems in the natural environment. Additionally, eleven skills were only partially identified in CE literature; elements of these skills are newly introduced by this study (Tables F1 and F2, Appendix F).

This study's comparison also identified, from the literature, skills and organizational capabilities that could not be mapped to taxonomy skills. Table 4 shows employee skills that are proposed in existing literature but not found among employees in circular start-ups. Similarly, the table shows organizational capabilities proposed in existing literature, but no employee skills in the data – as a microfoundation of these capabilities – could be mapped to them. This gap might be explained by sampling methods, the labeling of skills by employees on LinkedIn, and the focus of CE research on incumbents. For example, employees declare cloud computing skills (related to Industry 4.0 technology) but start-ups might not adopt other Industry 4.0 technologies like internet-of-things, as no further specialized Industry 4.0 skills (beyond cloud computing) (Wahl and Munch, 2021) could be identified. Research has examined the dynamic capabilities and aggregate microfoundations needed for the process of innovating and transitioning towards CBM within incumbents (rather than the comprehensive set of capabilities required to manage a CBM) (Khan et al., 2020; Santa-Maria et al., 2022); these capabilities are necessary as business model transformation beyond existing structures can be inhibited by a lack of flexibility and a change-resistant culture, also related to jobs that might become obsolete. Nevertheless, such limitations do not typically apply to start-ups adopting CBM, as they are inherently more flexible (Henry et al., 2020).

[11] For the remainder of this article, when referring to the mapping of taxonomy skills against skills and capabilities in the literature, the conceptual difference between organizational capabilities and individual skills (as a microfoundation of these capabilities) is assumed. Consequently, skills and capabilities must not be considered synonyms.

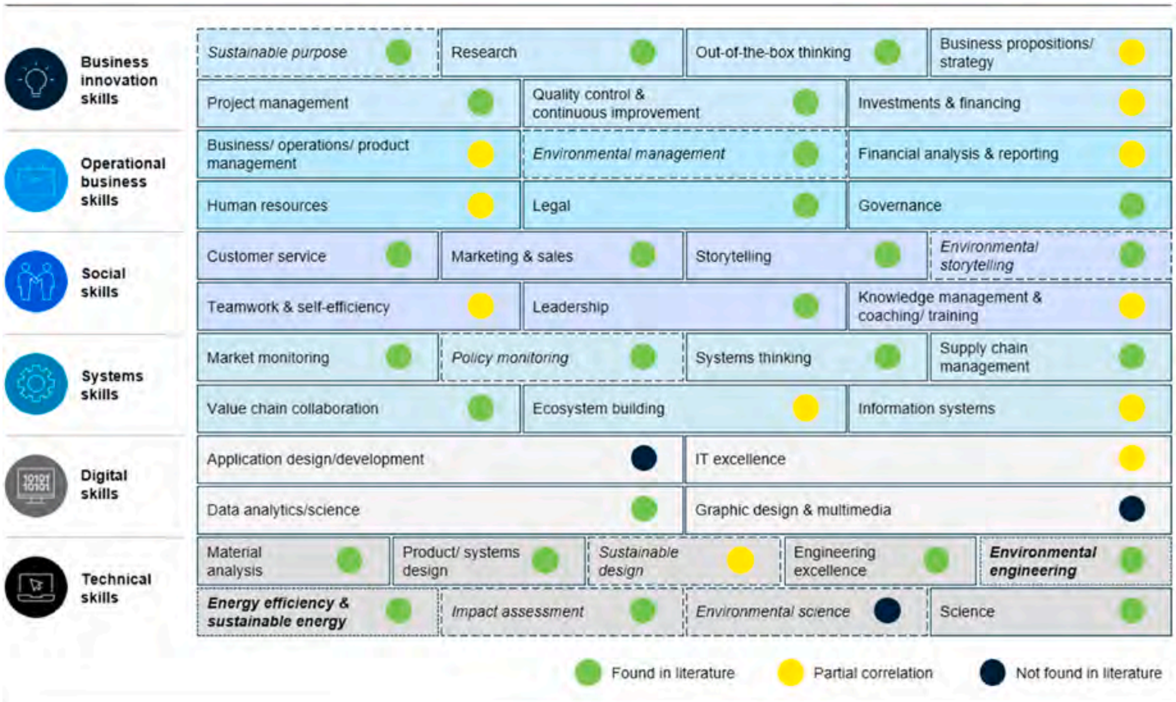

Fig. 7. Heat map of skills in the proposed taxonomy.

Table 4
Skills and capabilities proposed in CE literature and not found in skills of circular start-up employees.

Type	Skill	Capability
General	Flexibility and adaptability	Obsolete job conversion
	Multidisciplinary and lifelong learning	Organizational flexibility
		Technology monitoring
		Data management
		Industry 4.0/Internet of things
Sustainable	–	Focus on sustainable innovation culture
		Green culture
		Energy conservation culture
Circular	Principles of CE	Value retention/recovery, incl. industrial/internal symbiosis
	Industrial and internal symbiosis	Service design (such as maintenance)
	Design for servitization/PSS	Sustainable/circular product/ service development
	Production planning flexibility (for reverse manufacturing)	

With the exception of the two circular skills identified (Section 4), many explicitly circular skills and capabilities proposed in the literature were not found in the data. This finding is unexpected given that the sampled start-ups engage in relevant circular activities like industrial symbiosis and service-based offerings (Henry et al., 2020). Whereas circular skills and capabilities relating to these two activities are proposed in the literature, employees do not declare them explicitly. While some circular skills and capabilities were not found (Table 4), many circular skills and capabilities proposed in the literature were found to be partially related to general or sustainable skills in the taxonomy but lacking circular 'framing' (Table F4, Appendix F). For example, the literature proposes the skill of circular storytelling, while employees declare general and environmental storytelling. Similarly, some sustainable skills and capabilities proposed in the literature were found to be partially related to general skills in the taxonomy (Table F5, Appendix F). For example, 'marketing,' as found in the taxonomy, is proposed in the literature as 'green marketing' in businesses adopting a CBM.

5.2. The role of circular skills in CBM implementation

This section discusses a rationale along five arguments why the majority of skills are not declared by employees as explicitly circular although they are utilized in a circular context. First, although there are some new circular skills identified in the study, a range of general, sustainable, and circular skills is needed for CBM implementation – or, more specifically, to perform the activities necessary for implementing and running CBM in start-ups (including activities unique to CBM). Reverse logistics activities, for example, require general logistics skills (found in this study), i.e., proficiency in moving a good from source to destination, which can be applied to both forward and reverse logistics operations. Additionally, for CE value chain collaboration, employees in circular start-ups declare general collaboration/strategic partnership skills while involved in activities related to network and partnering operations (e.g., fostering industrial symbiosis in waste-based start-ups). As a final example, remanufacturing activities require general manufacturing skills but also skills to handle and integrate used parts in the rebuilding operation, such as quality control of used parts. Quality control (found in this study) is a general skill that is also needed to assess the quality of new parts and thus existed before concepts about circularity arose.

Second, although these business models have been given the 'circular' label, they may not be considered entirely new. As discussed in the literature, notions and variants of CBM have existed for decades (e.g., product-service offerings and waste recycling; Geissdoerfer et al., 2020; Linder and Williander, 2017). As such, skills existing in the workforce for decades may also be expected in this study. The two circular skills present among start-up employees concern sustainable energy and environmental engineering, relating to technical fields including renewables, energy efficiency, waste and water management, and recycling. Notably, environmental engineering skills have existed for some time, including in traditional waste and water management companies adopting lower-level CE strategies.

Third, the use and degree of organizational embeddedness of general, sustainable, and circular skills are crucial determinants of their impact. Or put differently, it is more pertinent what the skills are applied to. For example, utilizing out-of-the-box thinking skills, an employee can determine how to build the next linear business or how to scale a circular start-up. Capability theory suggests that skills are needed in conjunction with other microfoundations (Barney and Felin, 2013) – namely processes, technology, and structures – to enable organizational capabilities and perform activities for CBM implementation. The mapping exercise showed that many capabilities correlate with one or more skills (as a microfoundation) needed to adopt other microfoundations (Table F3, Appendix F). Building on skills as the starting point and enabler (Section 2.1), organizational capability development depends also on the quantity and quality of skills (i.e., how many employees need them and at what level of proficiency) and on their positioning and configuration relative to other microfoundations.

Fourth, sourcing of skills is a relevant factor. Circular businesses deploying innovative business models might not possess all necessary skills to begin. As such, they must channel existing employee skills towards circular ideas and activities, through learning processes and continuous improvement (both identified as skills in this study).[12] This need is especially salient for start-ups that must find employees who are willing to join risky endeavors but might not have perfectly matching skill profiles.

Finally, there exists a crucial institutional dimension from a CE transition perspective. The data show that employees do not declare many of their skills as explicitly circular, even though they work on CBM implementation. For example, these employees declare general supply chain management skills that can apply to forward or reverse supply chains. They may not necessarily consider or interpret skills within the circular context, suggesting that circularity is often shaped by framing in mainstream practice. In strategic and engineering fields, employees may not harbor a 'circular perspective' with respect to their skills and may instead be focused only on the mechanics of operations as taught in mainstream business or engineering schools. Many employees working in other operations of a firm, including those with no role in strategy or engineering, may not consider their own work 'circular' or fail to see a need to reframe their skills.

5.3. Pathways forward towards more circular skills

Findings suggest that skills framed specifically as circular may still be emerging in their practical conceptualizations, including among start-ups. Many skills are prevalent in their general framing among employees and can be applied in varying (linear or circular) contexts. The underdeveloped circular framing of skills constitutes a barrier to the wider dissemination of CE as a concept in business and society.

Given these circumstances, the researchers in this study call for reframing efforts, particularly as certain skills are becoming more mature and differentiated with increasing attention given to regularized and complex circular operations required for CBM implementation. Skills may be interpreted (and distinguished from applications in linear operations) in more nuanced ways in the circular context, as suggested in the literature (Sumter et al., 2021). Accordingly, the taxonomy skills have been defined in a circular context in Table 3 (Section 4). For example, employees in service-based circular start-ups might declare their general business proposition/strategy skills as circular or extend skill-framing to include a service dimension, as they mature in applying their general business proposition/strategy skills in the circular product-service systems context. Also, given that start-ups often already tell explicitly circular stories (e.g., on their websites), employees might declare their storytelling skills as circular.

A stronger effort by businesses is needed to identify and develop circular thinking among all employees. CBM implementation is influenced by decisions across all business functions including in strategic management, marketing, logistics, digital and finance – and execution of these functions from upper management to the 'ground level.' This holistic perspective is under-recognized but has the potential to support novel thinking about CBM implementation and the employee skills needed for it. Circular narratives (through circular storytelling) can promote understanding and recognition of circular skills among the employee base and beyond, enabling wider CE transition towards the mainstream.

Given the ubiquitous relevance and need for mainstreaming CBM among businesses and CE in a wider societal context, research has highlighted the role of universities and education in transitioning towards a CE (Kopnina, 2021; Rokicki et al., 2020; Stevens et al., 2021). Aiming for mainstream, holistic uptake of circular thinking and skills in businesses and society, such educational approaches can go beyond the provision of degrees related explicitly to CE: one example is to require a module or course on CE and sustainability in all degree programs (e.g., business, engineering, and political science) or as a university-wide 'core' subject. Accordingly, Kirchherr & Piscicelli (2019) coined the term 'education for the circular economy' (ECE). Some literature has discussed CE program curricula (Del Vecchio et al., 2021; Giannoccaro et al., 2021; Minguez et al., 2021), CE learning modules such as simulations (de la Torre et al., 2021; Wandl et al., 2019), and collaborations between universities and organizations to promote relevant skills (Summerton et al., 2019; Williams et al., 2018).

The comprehensive skill taxonomy proposed in this study intends to provide a holistic conceptualization of skills required for CBM implementation.

5.4. Practical and scholarly implications of the skill taxonomy

After a skill taxonomy has been developed by a company, the taxonomy typically serves as a basis for quantifying the company's performance on internal skill development. Gaps identified through a taxonomy-based skill analysis can support efforts to drive business performance, whereupon a company may undertake targeted recruitment. Additionally, a company may choose to close skill gaps via selected upskilling and reskilling efforts (Fenton et al., 2021). Companies may also use skill taxonomies in performance management, with skills outlined in the taxonomy serving as a benchmark for performance assessment and pathway for career advancement. In these and other ways, a skill taxonomy can help HR activities meet broader strategic goals.

At the same time, merely closing identified skill gaps may not be sufficient for circular business model performance. As argued in Section 5.2, skills existing in a company need to be utilized. Effective utilization of skills includes and is dependent in part on developing and running processes, organizational structures, and technologies as complementary micro-foundations. Incumbent workers may have no current opportunities to use certain skills because leadership is not aware or fails to appreciate the value of these skills for CBM implementation. This limitation reflects the finding by Kirchherr et al. (2018b) that hesitant company culture is a principal barrier to implementing CBM. Existing skills that enhance CBM performance should be integrated into work streams – an effort that requires companies to coordinate microfoundations and (re)design processes, structures, and technologies. These are the types of systemic interventions, going beyond incidental

[12] Another strategic approach is to recruit key individuals who possess an extensive set of skills in a particular domain, in order to add these skills to the organization's overall skill profile. However, such 'superstars' are limited in number and their employment is often intended for leadership roles (Felin et al., 2012; Felin and Hesterly, 2007). As such, these individuals alone cannot provide the comprehensive mix of skills needed but rather accelerate the development of skills among employees through leadership and coaching (both identified as skills in this study).

personnel or technical adjustments, that are needed for meaningful CBM implementation. Accordingly, a skill taxonomy can be useful also for enterprise architecture functions (Kitsios and Kamariotou, 2019; Zhang et al., 2018), supplementing conceptual tools like capability maps and process maps.

The proposed skill taxonomy can also advance theory. For example, scholars studying CE can map identified skills onto CBM cases, aiming to further understand the role that skills play in implementation. The taxonomy can also serve as an analytical framework to identify capabilities and connect micro-level capacities (i.e., employee skills) with macro-level capabilities at the organizational level (Felin et al., 2015). The taxonomy may also guide further research on ECE, possibly utilizing it as an analytical device to test if the skills that are proposed in this article are included in the CE-oriented curricula and programs.

6. Conclusion

The CE concept has gained substantial momentum in the 21st century as a key facilitator of sustainability efforts. Given the influence of business decisions not only on environmental conditions but also on consumer preferences and habits, the private sector is recognized as a key catalyst for society-wide CE transition. Nevertheless, substantive progress towards CE transition remains limited. While refashioned strategies and supportive infrastructure provide businesses with some pathways, skills for CBM are an often-overlooked topic in the academic literature and in practice. A modestly sized literature offers some useful insights (e.g., Janssens et al., 2021; Sumter et al., 2021) but a systematic understanding about the relevance of employee skills to CBM implementation has yet to be fully researched or integrated into practice. This study has sought to fill this gap not only by outlining skills in circular start-ups but also by presenting a way to refine understandings about these skills and help businesses identify and cultivate them.

This study proposes the first comprehensive skill taxonomy for CBM implementation in start-ups in the literature, as far as the authors can determine. The taxonomy includes 40 skills for CBM implementation and finds that CBM implementation requires a set of general, sustainable, and circular skills. It also finds that some skills, such as digital skills, have been neglected. Skills declared as specifically circular are not as common in circular start-ups as the literature suggests. Given that CBM is not an entirely new concept, some skills identified in this study have existed in the workforce for decades. Thus, the novelty of skills for CBM implementation lies in the shifting context of their application and in their utilization as microfoundations of organizational capabilities. Circular start-ups might need to develop existing employee skills in novel or differentiated circular application contexts. Consequently, using circular narratives as a framing device for skill development can promote understanding and recognition of those skills in efforts to mainstream CE.

Ideally, the skill taxonomy can be used for activities such as skill mapping, targeted recruiting, upskilling and reskilling, performance and career management, and ECE. Additionally, this study merged the skill taxonomy concept with the theory of capabilities, which is largely considered a valuable contribution in understanding skills as key microfoundations.

This study has several limitations that suggest avenues for further research. First, the taxonomy provides an analytical lens to understand skill needs for CBM implementation but does not address organization-wide skill quantity and proficiency. Second, the study takes a supply-side (employee) perspective in examining skills and does not extend to analyzing whether and how these skills match labor demand (i.e., what businesses state that they need). Further research can develop an overview of needs based on activities and capabilities for CBM implementation and can compare those needs to the supply of skills available in the workforce. Such efforts might also consider how skills interact with other microfoundations. Third, this study did not compare skills across different types of businesses, (circular versus linear businesses; circular start-ups versus incumbents adopting CBM; degree of commercial success experienced by businesses) which could generate a more complete overview of skills necessary for CE transition. Fourth, given that this sample of start-ups considered only the Netherlands, UK, and Germany, future research should also examine whether and how skill sets vary by geography. Finally, the study considers only skills declared on LinkedIn, thus missing the skills of employees who do not use LinkedIn or list their skills there. In a self-reporting context like LinkedIn, individual subjectivity may also threaten validity. Regarding analysis of data, the methodological approach required some degree of researcher judgement, so any bias such as it might have arisen could be resolved through the adoption of more quantitative methodologies (e.g., topic modeling and model-based clustering).

While the proposed skill taxonomy aims to be an analytical device for both scholars and practitioners, it is not proposed as conclusive but rather as a prompt for further research. It is anticipated that it will motivate more scholars and practitioners to examine skills for CBM implementation as a worthwhile topic.

CRediT authorship contribution statement

Lucas Straub: Conceptualization, Methodology, Data sourcing, Data curation, Formal analysis, (LinkedIn data clustering), Data sourcing, curation, formal analysis (synthesis based on literature review and expert interviews), Writing – original draft, Writing – review & editing, Visualization. **Kris Hartley:** Writing – review & editing. **Ivan Dyakonov:** Data sourcing, Data curation, Formal analysis, (LinkedIn data clustering). **Harsh Gupta:** Data sourcing, Data curation, Formal analysis, (LinkedIn data clustering). **Detlef van Vuuren:** Supervision. **Julian Kirchherr:** Conceptualization, Methodology, Data sourcing, Data curation, Formal analysis, (synthesis based on literature review and expert interviews), Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Supplementary data. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.137027.

Appendices

Appendix A

Skills of individuals and organizational capabilities proposed in the literature are summarized below. Researchers have used various concepts in the context of organizational capabilities: operational capabilities, dynamic capabilities, and aggregate microfoundations of dynamic capabilities. These are listed in separate tables. Additionally, as the literature was reviewed, three types of skills and organizational capabilities became apparent: *General skills or capabilities* refer to skills or capabilities that can be found in traditional businesses (such as *project management* or *teamwork*). *Sustainable skills or capabilities* refer to skills or capabilities that are related specifically to aspects of the triple bottom line, but not to circularity (such as *sustainable mindset* or *environmental commitment*). Thirdly, *circular skills or capabilities* refer to skills or capabilities that are related specifically to aspects of circularity (such as *reverse logistics* or *industrial symbiosis*). Some scholarly publications do not distinguish between sustainable and circular notions, for example when attributing aggregate microfoundations to business model types (Santa-Maria et al., 2022); yet we deem it important to distinguish them. Accordingly, skills and organizational capabilities are grouped by these skill types in the tables.

Table A1
Operational capabilities for CBM as proposed by CE literature

Type	Operational capability	Source
General	(Exploratory) innovation	Jakhar et al. (2019), Chowdhury et al. (2022)
	Business/Big data analytics	Nobre and Tavares (2020), Awan et al. (2021b), Bag et al. (2021b), Kristoffersen et al. (2021), Perçin (2022), Bag and Rahman (2023)
	Competitor analysis	Prieto-Sandoval et al. (2019)
	Continuous improvement	Kusumowardani et al. (2022)
	Customer engagement in product design	Prieto-Sandoval et al. (2019), Lopes de Sousa Jabbour et al. (2019)
	Customer service	Sousa-Zomer et al. (2018)
	Data management	Awan et al. (2021a)
	Financial	Triguero et al. (2022)
	Internet of things	Nobre and Tavares (2020)
	Market monitoring	Kusumowardani et al. (2022)
	Marketing	Sousa-Zomer et al. (2018), Chaudhuri et al. (2022)
	Material assessment (biological and technical)	Sousa-Zomer et al. (2018), Chaudhuri et al. (2022)
	Project management	Prieto-Sandoval et al. (2019)
	Quality management	Sousa-Zomer et al. (2018)
	R&D	Sousa-Zomer et al. (2018)
	Resource orchestration	Kristoffersen et al. (2021)
	Sales (including after-sales)	Sousa-Zomer et al. (2018)
	Supply chain management (SCM)	Sousa-Zomer et al. (2018), Yu et al. (2022a)
	Technological innovation	Kusumowardani et al. (2022)
	Value chain collaboration (including vertical/horizontal, engagement, information sharing/traceability, governance/trust, shared culture, training, etc.)	Sousa-Zomer et al. (2018), Lopes de Sousa Jabbour et al. (2019), Prieto-Sandoval et al. (2019), Calicchio Berardia and Peregrino de Brito (2021), Agyabeng-Mensah et al. (2022), Chaudhuri et al. (2022), Kusumowardani et al. (2022), Bag and Rahman (2023)
Sustainable	Environmental commitment	Agyabeng-Mensah et al. (2022), Kusumowardani et al. (2022)
	Green marketing	Prieto-Sandoval et al. (2019)
	Green talent management	Prieto-Sandoval et al. (2019)
Circular	CE indicator system	Lopes de Sousa Jabbour et al. (2019)
	Circular (production) process design/planning (including dematerialization, cleaner production, modular assembly, remanufacturing, recycling, maintenance, etc.)	Sousa-Zomer et al. (2018), Prieto-Sandoval et al. (2019), Lopes de Sousa Jabbour et al. (2019)
	Circular financial management	Sousa-Zomer et al. (2018)
	Circular legal	Sousa-Zomer et al. (2018)
	Circular product (eco-) design (including openness to recycled products, use of recycled materials, flexibility, reconfiguration, maintenance, user experience, etc.)	Sousa-Zomer et al. (2018), Prieto-Sandoval et al. (2019), Lopes de Sousa Jabbour et al. (2019), Soh and Wong (2021), Chaudhuri et al. (2022), Yu et al. (2022b)
	Circular SCM/purchasing (including supplier material/parts certification, integrated SCM system)	Sousa-Zomer et al. (2018), Yu et al. (2022a)
	Circular storytelling	Chaudhuri et al. (2022)
	Circular/green IT management	Nobre and Tavares (2020)
	Comprehension of (environmental/circular) regulatory landscape	Sousa-Zomer et al. (2018)
	Reverse logistics	Sousa-Zomer et al. (2018), Prieto-Sandoval et al. (2019), Lopes de Sousa Jabbour et al. (2019)
	Reverse omnichannel	Chaudhuri et al. (2022), De Giovanni (2022)
	Service design (such as maintenance)	Sousa-Zomer et al. (2018), Prieto-Sandoval et al. (2019)
	Sustainable/circular product/service development	Sousa-Zomer et al. (2018), Prieto-Sandoval et al. (2019)
	Value retention/recovery (including industrial/internal symbiosis)	Lopes de Sousa Jabbour et al. (2019), Prieto-Sandoval et al. (2019), Yu et al. (2022b)

Table A2
Dynamic capabilities for CBM as proposed by CE literature

Type	Dynamic capability	Source
General	Access to stakeholder information	Prieto-Sandoval et al. (2019)
	Business model improvement	Prieto-Sandoval et al. (2019)
	Business/Big data analytics	Edwin Cheng et al. (2022)
	Corporate governance	Scarpellini et al. (2020b)
	Empowerment for bottom-up innovation	Prieto-Sandoval et al. (2019)
	Industry 4.0	Belhadi et al. (2022)
	Information processing	Bag et al. (2020)
	Knowledge management/development	Prieto-Sandoval et al. (2019)
	Obsolete jobs conversion	Prieto-Sandoval et al. (2019)
	R&D	Prieto-Sandoval et al. (2019)
	R&D/innovation collaboration	Marín-Vinuesa et al. (2021), Portillo-Tarragona et al. (2022)
	Supply chain ambidexterity	Stekelorum et al. (2021)
	Supply chain big data predictive analytics	Stekelorum et al. (2021)
Sustainable	CSR reporting	Scarpellini et al. (2020a)
	Eco-innovation HR	Scarpellini et al. (2020b)
	Environmental (management) accounting	Scarpellini et al. (2020a,b)
	Environmental management systems	Scarpellini et al. (2020a,b)
	Green culture	Prieto-Sandoval et al. (2019)
	Green leader vision/awareness	Prieto-Sandoval et al. (2019)
	Sustainability	Rana and Ahmed Tajuddin (2021)
	Sustainable business model design and reconfiguration	Prieto-Sandoval et al. (2019)
Circular	Circular manufacturing (including remanufacturing)	Bag et al. (2019), Bag et al. (2021a)
	Circular/Green/Waste-related patenting	Marín-Vinuesa et al. (2021), Portillo-Tarragona et al. (2022)
	Circular/sustainable business experimentation	Weissbrod and Bocken (2017), Bocken et al. (2018), Hofmann & zu Knyphausen-Aufseß (2022)
	Continuous systematic learning from product returns (including identification of valuable information, knowledge infrastructure, integrated return processes (customer 360 and forward/reverse logistics integration), governance, Incentives)	Ritola et al. (2022)

Table A3
Aggregate microfoundations (of dynamic capabilities) for CBM as proposed by CE literature

Type	Aggregate Microfoundation	Source
General	Ecosystem orchestration	Santa-Maria et al. (2022)
	Ecosystem/stakeholder engagement and collaboration (vertical and horizontal) on sensing and seizing	Khan et al. (2020), Cavicchi et al. (2022), Chari et al. (2022), Elf et al. (2022), Marrucci et al. (2022), Santa-Maria et al. (2022), Jayarathna et al. (2023)
	External sensitivity (including market/technology/customer/policy monitoring	Khan et al. (2020), Chari et al. (2022), Elf et al. (2022), Marrucci et al. (2022), Santa-Maria et al. (2022)
	Governance and incentives	Khan et al. (2020), Elf et al. (2022), Santa-Maria et al. (2022)
	Knowledge creation	Khan et al. (2020), Santa-Maria et al. (2022)
	Knowledge management	Khan et al. (2020), Chari et al. (2022), Elf et al. (2022), Marrucci et al. (2022)
	Organizational flexibility	Santa-Maria et al. (2022), Elf et al. (2022)
	Strategic planning and resource orchestration (including co-specialization, organizational restructuring, technological upgradation and team compilation)	Khan et al. (2020), Chari et al. (2022), Elf et al. (2022), Marrucci et al. (2022), Santa-Maria et al. (2022), Jayarathna et al. (2023)
	Technology exploitation (to find opportunities and leverage opportunities)	Chari et al. (2022), Elf et al. (2022), Jayarathna et al. (2023)
	Trust-building communication	Santa-Maria et al. (2022)
Sustainable	Energy conservation culture	Cavicchi et al. (2022)
	Energy management and auditing	Cavicchi et al. (2022), Jayarathna et al. (2023)
	Environmental policy and certificates	Jayarathna et al. (2023)
	Focus on sustainable impact commitment/strategy and innovation/ideation culture	Khan et al. (2020), Chari et al. (2022), Elf et al. (2022), Marrucci et al. (2022), Santa-Maria et al. (2022), Jayarathna et al. (2023)
	Green warehousing	Jayarathna et al. (2023)
	Use of sustainability tools	Khan et al. (2020), Santa-Maria et al. (2022), Jayarathna et al. (2023)
Circular	(Circular/Sustainable) Business propositions/model	Khan et al. (2020), Chari et al. (2022), Elf et al. (2022), Santa-Maria et al. (2022)
	Holistic perspective adoption (including systems and lifecycle thinking)	Santa-Maria et al. (2022)
	Leadership and change management (including circular/sustainable KPI)	Chari et al. (2022), Santa-Maria et al. (2022)

Table A4
Skills for CBM as proposed by CE literature

Type	Skill	Source
General	Analytical and critical thinking	Janssens et al. (2021)
	Customer service and experience	De los Rios and Charnley (2017)
	Data science/analytics	Lopes de Sousa Jabbour et al. (2019), Phung (2019), Janssens et al. (2021), Kristoffersen et al. (2021)
	Development of customized business models	Janssens et al. (2021)
	Economics	Janssens et al. (2021)
	Energy market knowledge	Janssens et al. (2021)
	Engineering (including reliability and maintenance)	De los Rios and Charnley (2017)
	Entrepreneurial	Janssens et al. (2021)
	Financial	Janssens et al. (2021)
	Flexibility and adaptability	Janssens et al. (2021)
	Legal	Janssens et al. (2021)
	Logistics	Ganiyu et al. (2020), Janssens et al. (2021)
	Marketing	Janssens et al. (2021)
	Material analysis	De los Rios and Charnley (2017)
	Modelling and simulation techniques	Ganiyu et al. (2020), Janssens et al. (2021)
	Multidisciplinary and lifelong learning	Janssens et al. (2021)
	Problem solving	De los Rios and Charnley (2017), Janssens et al. (2021)
	Product design	De los Rios and Charnley (2017), Ganiyu et al. (2020), Janssens et al. (2021)
	Project management	Ganiyu et al. (2020), Janssens et al. (2021)
	R&D	Janssens et al. (2021)
	Stakeholder communication	Phung (2019), Ganiyu et al. (2020), Janssens et al. (2021)
	STEM skills	Janssens et al. (2021)
	Systems thinking	Summerton et al. (2019), Janssens et al. (2021), Kristoffersen et al. (2021)
	Teamwork	Janssens et al. (2021)
	User experience	De los Rios and Charnley (2017)
	Visionary, innovative, open-minded and creative thinking	Janssens et al. (2021)
Sustainable	Environmental awareness	Janssens et al. (2021)
	Environmental/ecological economics	Janssens et al. (2021)
	Environmental/social impact assessment	Janssens et al. (2021)
	Ethical and sustainable principles	Janssens et al. (2021)
	Sustainable material	Janssens et al. (2021)
	Sustainable mindset	Janssens et al. (2021)
	Water quality/scarcity	Janssens et al. (2021)
Circular	Build-up of awareness of circular techniques among stakeholders	Ganiyu et al. (2020)
	CE indicator system	Lopes de Sousa Jabbour et al. (2019)
	CE value chain collaboration	Lopes de Sousa Jabbour et al. (2019), Sumter et al. (2021)
	Circular (waste) contractor assessment	Ganiyu et al. (2020)
	Circular (waste-efficient) procurement	Ganiyu et al. (2020)
	Circular business propositions (for PSS)	Sumter et al. (2021)
	Circular clauses in contract documents	Ganiyu et al. (2020)
	Circular impact assessment	Sumter et al. (2021)
	Circular manufacturing (including reverse and re-manufacturing, dematerialization, novel manufacturing solutions and use of IT tool/analytics)	De los Rios and Charnley (2017), Lopes de Sousa Jabbour et al. (2019), Ganiyu et al. (2020), Sumter et al. (2021)
	Circular operational training	Ganiyu et al. (2020)
	Circular storytelling	Sumter et al. (2021)
	Circular systems thinking	Sumter et al. (2021)
	Circular user engagement	Sumter et al. (2021)
	Circular/efficient material use in design	De los Rios and Charnley (2017), Janssens et al. (2021), Sumter et al. (2021)
	Design for recovery and multiple use cycles	Sumter et al. (2021), Lopes de Sousa Jabbour et al. (2019)
	Design for servitization/PSS	Lopes de Sousa Jabbour et al. (2019)
	Industrial and internal symbiosis	Lopes de Sousa Jabbour et al. (2019), Ganiyu et al. (2020)
	Principles of CE	Janssens et al. (2021)
	Production planning flexibility	Lopes de Sousa Jabbour et al. (2019)
	Reverse logistics	De los Rios and Charnley (2017), Lopes de Sousa Jabbour et al. (2019)
	Sustainable energy and energy recovery	Janssens et al. (2021)
	Use of information systems for CE	Lopes de Sousa Jabbour et al. (2019), Ganiyu et al. (2020)
	Value chain collaboration	Ganiyu et al. (2020)
	Waste prevention and recovery (classification, sorting, repairing, recycling, etc.)	Phung (2019), Ganiyu et al. (2020), Janssens et al. (2021)

Appendix B

Skills are scraped from the LinkedIn profiles of staff employed in 113 circular start-ups. The full list of start-ups, based on Henry et al. (2020), is below.

Table B1
List of start-ups considered for skills scraping on LinkedIn

Circular start-up	Sector	Location	Business model type	# of profiles on LinkedIn
Aceleron	Energy	UK	Design-based	24
Aeropowder	Manufacturing/materials eng	UK	Waste-based	5
Aloha Bar	Agriculture/Food	NL	Waste-based	8
Bambooder	Built environm/design	NL	Nature-based	4
Unwaste.	Manufacturing/materials eng	NL	Waste-based	6
Better Future Factory	Manufacturing/materials eng	NL	Design-based	9
bio-bean	Waste management	UK	Waste-based	27
Biohm	Built environm/design	UK	Design-based	16
Bonaverde	Agriculture/Food	GER	Platform-based	6
BroodNodig	Manufacturing/materials eng	NL	Waste-based	7
BrouwBrood	Agriculture/Food	NL	Waste-based	1
Building Bloqs	Services	UK	Service-based	12
Bundles	Services	NL	Service-based	7
Circular IQ	Services	NL	Platform-based	9
Closing the Loop	Waste management	NL	Other	12
CocoPallet	Manufacturing/materials eng	NL	Waste-based	6
Coffee Based	Manufacturing/materials eng	NL	Waste-based	3
Community Plastics	Manufacturing/materials eng	NL	Waste-based	1
Concr3de	Built environm/design	NL	Design-based	9
Coolar	Energy	GER	Design-based	8
CLUBZERØ	Manufacturing/materials eng	UK	Service-based	3
DACHFARM Berlin	Agriculture/Food	GER	Nature-based	1
DryGro	Agriculture/Food	UK	Nature-based	14
Dycle	Manufacturing/materials eng	GER	Service-based	4
ECF Farm Berlin	Agriculture/Food	GER	Nature-based	8
ECO Brotbox	Manufacturing/materials eng	GER	Design-based	8
Enerpy	Energy	NL	Waste-based	3
ENSO Tyres	Manufacturing/materials eng	UK	Design-based	1
Entocycle	Agriculture/Food	UK	Nature-based	16
Enviromate	Built environm/design	UK	Platform-based	3
E-Stone Batteries	Energy	NL	Design-based	3
Excess Materials Exchange	Services	NL	Platform-based	8
Fairphone	Manufacturing/materials eng	NL	Service-based	96
Finch Buildings	Built environm/design	NL	Design-based	11
Super Ninja	Agriculture/Food	NL	Design-based	5
Fruitleather Rotterdam	Fashion and textiles	NL	Waste-based	3
Fungi Factory	Agriculture/Food	NL	Waste-based	4
Globechain	Waste management	UK	Platform-based	4
Green City Solutions	Biotech	GER	Other	39
GreenLab Berlin	Agriculture/Food	GER	Waste-based	1
GreenMe Berlin	Services	GER	Other	3
GrowUp Farms	Agriculture/Food	UK	Design-based	16
HaagseZwam	Agriculture/Food	NL	Waste-based	7
Halo Coffee	Agriculture/Food	UK	Design-based	9
Superuse Studios (Harvestmap)	Built environm/design	NL	Design-based	8
HillBlock	Built environm/design	NL	Design-based	5
Hubble	Services	UK	Platform-based	13
HuisVeendam	Built environm/design	NL	Waste-based	3
Infarm	Agriculture/Food	GER	Design-based	502
Instock	Agriculture/Food	NL	Platform-based	39
Kaffeeform	Manufacturing/materials eng	GER	Waste-based	3
Kartent	Manufacturing/materials eng	NL	Design-based	22
Kromkommer	Agriculture/Food	NL	Waste-based	5
Leihbar	Services	GER	Service-based	2
Library of Things	Services	UK	Service-based	14
Limejump	Energy	UK	Platform-based	110
MasterFilter	Manufacturing/materials eng	UK	Design-based	3
Masters that Matter	Waste management	NL	Design-based	2
Materiom	Manufacturing/materials eng	UK	Platform-based	8
Mayya Saliba Design	Fashion and textiles	NL	Design-based	2
MetroPolder	Built environm/design	NL	Design-based	6
Mifactori	Built environm/design	GER	Design-based	1
mimycri	Manufacturing/materials eng	GER	Waste-based	7
Mitte GmbH	Agriculture/Food	GER	Design-based	77
Makers of Sustainable Spaces (Moss)	Built environm/design	NL	Design-based	7
MotoShare	Transport/logistics	NL	Platform-based	15
New Marble	Built environm/design	NL	Waste-based	1
Nimber	Transport/logistics	UK	Platform-based	10
Okkehout	Manufacturing/materials eng	NL	Design-based	1
OLIO	Agriculture/Food	UK	Platform-based	35
Pentatonic	Services	GER	Design-based	31
Perpetual Plastic	Waste management	NL	Waste-based	1
Photanol	Biotech	NL	Nature-based	38
PickThisUp	Transport/logistics	NL	Platform-based	4

(*continued on next page*)

Table B1 (*continued*)

Circular start-up	Sector	Location	Business model type	# of profiles on LinkedIn
Pinatex	Fashion and textiles	UK	Waste-based	17
Planq	Manufacturing/materials eng	NL	Waste-based	6
Precious Plastic Den Haag	Manufacturing/materials eng	NL	Waste-based	1
RanMarine Technology	Built environm/design	NL	Design-based	12
ReBlend	Fashion and textiles	NL	Design-based	5
Re:Store Refill	Agriculture/Food	UK	Design-based	1
Remakery	Waste management	UK	Service-based	9
Rotterzwam	Agriculture/Food	NL	Design-based	10
Rype Office	Manufacturing/materials eng	UK	Design-based	10
Tradefox	Waste management	NL	Platform-based	10
Seepje	Manufacturing/materials eng	NL	Design-based	17
selo good beverages	Agriculture/Food	GER	Design-based	2
SIRPLUS	Fashion and textiles	UK	Waste-based	14
Skipping Rocks Lab	Agriculture/Food	UK	Design-based	5
SNACT	Agriculture/Food	UK	Waste-based	2
SolaGrow	Agriculture/Food	UK	Design-based	2
soulbottles	Manufacturing/materials eng	GER	Design-based	35
Spireaux (alga.farm)	Biotech	NL	Nature-based	5
StadtFarm	Agriculture/Food	GER	Nature-based	5
StoneCycling	Built environm/design	NL	Waste-based	9
Straw by Straw	Manufacturing/materials eng	NL	Waste-based	5
Sustainer Homes	Built environm/design	NL	Platform-based	30
Sustonable	Built environm/design	NL	Waste-based	7
Swapfiets	Transport/logistics	NL	Service-based	518
The Cheeky Panda	Agriculture/Food	UK	Design-based	32
The Great Bubble Barrier	Built environm/design	NL	Other	13
The Waste Transformers	Waste management	NL	Waste-based	3
TOAST	Agriculture/Food	UK	Waste-based	16
TRYATEC	Services	UK	Platform-based	4
United Wardrobe	Fashion and textiles	NL	Platform-based	25
Upcycle Society	Manufacturing/materials eng	NL	Waste-based	1
Upcycling Deluxe	Manufacturing/materials eng	GER	Waste-based	1
Van.Eko	Transport/logistics	NL	Design-based	2
VanPlestik	Manufacturing/materials eng	NL	Waste-based	9
Vet and Lazy	Agriculture/Food	NL	Design-based	2
Vibers	Agriculture/Food	NL	Design-based	4
Waste2Wear	Fashion and textiles	NL	Waste-based	18
Waste4me	Energy	NL	Waste-based	13
Winnow	Agriculture/Food	UK	Platform-based	102

Henry et al. (2020) identify five business model types for circular start-ups. Short definitions of start-ups, taken from Henry et al. (2020), are provided below:

- **design-based**: adopting circular innovations mostly in the pre-market phase through source material minimization, product design or production process efficiency
- **waste-based**: seeking to extract value from unexploited external waste streams
- **platform-based**: pursuing sharing/trading business models built around B2B, B2C, or C2C marketplaces
- **service-based**: embedding products in service-systems to increase usage efficiency
- **nature-based**: increasing the delivery of (products and) services based on nature-based systemic solutions

The 50 most frequently declared skills on LinkedIn profiles are listed below. Basic digital tools found within the dataset (e.g., Microsoft Office), social media skills, and language skills were not considered.

Table B2
List of 50 most frequently declared skills on LinkedIn profiles

Self-declared skill	Frequency	Self-declared skill	Frequency
Management	372	**negotiation**	92
project management	286	**management consulting**	89
Research	213	**public relations**	87
business strategy	201	**coaching**	86
marketing	191	**illustrator**	84
teamwork	190	**project planning**	76
leadership	166	**team leadership**	76
Strategy	162	**online marketing**	72
customer service	159	**analysis**	71
business development	156	**graphic design**	67
marketing strategy	152	**data analysis**	66
photoshop	152	**communication**	60
Sales	142	**e-commerce**	59

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Table B2 (*continued*)

Self-declared skill	Frequency	Self-declared skill	Frequency
public speaking	127	**javascript**	59
entrepreneurship	125	**market research**	59
strategic planning	117	**event planning**	58
sustainability	113	**sales management**	58
change management	112	**engineering**	58
new business development	108	**concept development**	57
marketing communications	106	**time management**	57
product development	99	**crm (customer relationship management)**	55
event management	98	**python**	55
start-ups	97	**solidworks**	55
social media marketing	93	**business planning**	55
indesign	92	**renewable energy**	54

Appendix C

We reviewed the CE literature on skills and capabilities to identify which skills and capabilities have already been proposed in the context of CBM implementation. Following Henry et al. (2021), we used Elsevier's Scopus database due to its larger coverage compared to Web of Science. We searched for relevant articles with the following search term:

TITLE-ABS-KEY("circular economy" AND (skill* OR capabilit* OR competenc*) AND (business* OR firm* OR enterprise* OR start?up* OR corporate* OR organi?ation*))

The search returned 339 articles, which were then further assessed for their relevance by the authors. First, by reading the title and abstract of each article, we identified whether the article studies skills or organizational capabilities in the context of CBM implementation. Following this criterion, a subset of 82 articles was created. The exclusion of many articles in this step is due to the frequent and broad usage of the term 'capability' beyond the context of organizational capability theory. Next, we examined each of the 82 articles in detail and identified those proposing specific skills or capabilities in the context of CBM implementation. A final set of 57 relevant articles was created (see Supplementary Materials). Lastly, we extracted and summarized skills and capabilities that were proposed in these articles (Section 2.2 and Appendix A), using this information to contextualize and inform the taxonomy.

Appendix D

We conducted expert interviews to collect feedback on our skill taxonomy. Interviewees included scholars engaged in CE research and practitioners (most working in circular start-ups and CE-related consulting). Conducted via e-mail, Zoom, and face-to-face, interviews were structured as follows. First, we explained what a skill taxonomy is (using the definition presented in Section 2.3) and how it is typically used. We then revealed our initial draft of a skill taxonomy and asked the interviewee the following questions: Is there anything you would want to add to this taxonomy? Is there any skill you would want to drop? Is there any skill you would formulate differently? Are there any other thoughts you want to share with us on this topic? 17 expert interviews were conducted. All interviewees were shown the same initial skill taxonomy. We stopped interviewing when it was determined that we had reached thematic saturation, adopting a stopping criterion of 'three' (three interviews in a row did not yield any new comments; Francis et al., 2009; Guest et al., 2020). Table D1 provides an overview of interviewees.

Table D1
Overview of expert interviews

Interviewee	Role	Organization
1	Consultant	Sustainability consultancy
2	Consultant	Sustainability consultancy
3	Associate Partner (specialized in circular economy)	Management consultancy
4	Founder	Circular food start-up
5	Employee	Circular food start-up
6	Employee	Circular food start-up
7	Founder	Circular textiles start-up
8	Co-founder	Circular textiles start-up
9	Chief Operating Officer (COO)	Circular finance start-up
10	Civil servant	German Ministry of Environment
11	PhD student (focused on circular business models)	Belgian university
12	Assistant professor (focused on sustainability policy)	Asian university
13	Assistant professor (focused on circular business models)	Italian university
14	Associate professor (focused on circular economy)	Dutch university
15	Professor (focused on sustainability transitions)	Dutch university
16	Professor (focused on material analysis)	British university
17	Emeritus professor (focused on sustainability)	Swiss university

Appendix E

Table E1 lists the skills in the taxonomy and their frequency. Tables E2 and E3 show skill frequencies by business model types and by sectors of start-ups.

Table E1
Overview of skills in the proposed taxonomy

Skill category	Skill	Type	Frequency
Business innovation skills	Sustainable purpose	Sustainable	316
	Research	General	317
	Out-of-the-box thinking	General	380
	Business propositions/strategy	General	1033
	Project management	General	621
	Quality control and continuous improvement	General	196
	Investments and financing	General	458
Operational business skills	Management - business, product, operations	General	932
	Environmental management	Sustainable	28
	Financial analysis and reporting	General	231
	Human resources	General	221
	Legal	General	18
	Governance	General	17
Social skills	Customer service	General	252
	Marketing and sales	General	1765
	Storytelling	General	653
	Environmental storytelling	Sustainable	41
	Teamwork and self-efficiency	General	274
	Leadership	General	309
	Knowledge management and coaching/training	General	154
Systems skills	Market monitoring	General	95
	Policy monitoring	Sustainable	82
	Systems thinking	General	5
	Supply chain management	General	175
	Value chain collaboration	General	44
	Ecosystem building	General	592
	Information systems	General	43
Digital skills	Application design/development	General	1202
	IT excellence	General	395
	Data analytics/science	General	421
	Graphic design and multimedia	General	1061
Technical skills	Material analysis	General	202
	Product/systems design	General	736
	Sustainable design	Sustainable	38
	Engineering excellence	General	190
	Environmental engineering	Circular	36
	Energy efficiency and sustainable energy	Circular	197
	Impact assessment	Sustainable	28
	Environmental science	Sustainable	99
	Science	General	86

Table E2
Overview of skill frequencies by business model type

Skill category	Skill	Design-based	Waste-based	Platform-based	Service-based	Nature-based	Other
Business innovation skills	Sustainable purpose	92	49	66	55	16	38
	Research	126	27	74	43	31	16
	Out-of-the-box thinking	135	55	91	61	21	17
	Business propositions/strategy	395	157	216	143	52	70
	Project management	244	87	108	125	25	32
	Quality control and continuous improvement	78	31	33	38	9	7
	Investments and financing	166	54	157	20	53	8
Operational business skills	Management - business, product, operations	370	140	189	163	32	38
	Environmental management	11	6	5	2	1	3
	Financial analysis and reporting	96	22	71	28	13	1
	Human resources	90	23	41	63	2	2
	Legal	5	0	11	2	0	0
	Governance	7	2	4	3	0	1
Social skills	Customer service	93	21	68	56	6	8
	Marketing and sales	602	240	377	440	28	78
	Storytelling	226	62	161	168	16	20
	Environmental storytelling	19	5	9	2	2	4
	Teamwork and self-efficiency	87	20	75	74	10	8
	Leadership	123	35	70	56	11	14
	Knowledge management and coaching/training	59	24	25	36	3	7

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Table E2 (*continued*)

Skill category	Skill	Design-based	Waste-based	Platform-based	Service-based	Nature-based	Other
Systems skills	Market monitoring	35	18	19	18	1	4
	Policy monitoring	16	11	27	18	2	8
	Systems thinking	3	0	2	0	0	0
	Supply chain management	68	34	33	33	4	3
	Value chain collaboration	15	6	12	7	1	3
	Ecosystem building	192	60	124	181	18	17
	Information systems	22	4	6	8	2	1
Digital skills	Application design/development	261	5	583	291	10	52
	IT excellence	145	29	115	84	8	14
	Data analytics/science	144	19	170	58	16	14
	Graphic design and multimedia	410	92	218	271	32	38
Technical skills	Material analysis	77	19	15	5	86	0
	Product/systems design	349	84	139	115	28	21
	Sustainable design	16	6	8	4	2	2
	Engineering excellence	99	36	24	17	13	1
	Environmental engineering	18	7	4	0	2	5
	Energy efficiency and sustainable energy	52	46	76	4	13	6
	Impact assessment	9	7	7	1	1	3
	Environmental science	52	11	18	3	9	6
	Science	31	7	26	12	7	3

Table E3
Overview of skill frequencies by sector

Skill category	Skill	A/F	Bio	Built	E	F/T	M/M	S	T/L	W	Other
Business innovation skills	Sustainable purpose	101	14	37	18	3	64	37	7	23	12
	Research	124	23	26	47	8	35	25	12	14	3
	Out-of-the-box thinking	151	15	22	30	15	43	34	36	30	4
	Business propositions/strategy	462	51	53	66	50	123	71	76	63	18
	Project management	233	27	46	58	21	82	43	73	28	10
	Quality control and continuous improvement	81	7	11	9	6	24	12	29	13	4
	Investments and financing	269	21	12	43	19	41	24	9	15	5
Operational business skills	Management - business, product, operations	388	24	54	75	41	105	67	108	61	9
	Environmental management	16	0	0	0	0	2	6	1	3	0
	Financial analysis and reporting	103	8	5	43	16	12	17	19	7	1
	Human resources	98	1	9	11	14	26	10	46	5	1
	Legal	8	0	0	4	0	5	1	0	0	0
	Governance	8	0	2	2	0	4	0	0	0	1
Social skills	Customer service	119	5	10	23	9	19	20	35	12	0
	Marketing and sales	656	18	101	90	103	233	101	330	113	20
	Storytelling	235	7	61	53	30	89	69	69	37	3
	Environmental storytelling	19	0	8	1	0	4	4	1	4	0
	Teamwork and self-efficiency	114	5	15	29	5	21	18	58	9	0
	Leadership	142	8	6	28	10	43	20	31	16	5
	Knowledge management and coaching/training	59	4	14	5	6	26	4	26	8	2
Systems skills	Market monitoring	39	2	4	9	9	11	2	12	6	1
	Policy monitoring	21	3	3	8	1	24	16	0	0	6
	Systems thinking	1	0	2	1	0	0	1	0	0	0
	Supply chain management	77	4	3	6	9	19	9	34	11	3
	Value chain collaboration	19	1	0	1	0	7	8	2	5	1
	Ecosystem building	220	6	41	29	24	81	54	104	30	3
	Information systems	20	2	4	4	1	4	0	8	0	0
Digital skills	Application design/development	372	6	28	255	92	89	91	213	9	47
	IT excellence	138	3	25	54	18	68	47	24	11	7
	Data analytics/science	189	10	20	100	11	25	12	41	8	5
	Graphic design and multimedia	298	17	131	53	87	158	90	158	66	3
Technical skills	Material analysis	74	80	12	18	3	3	0	2	10	0
	Product/systems design	145	26	214	27	15	173	23	75	38	0
	Sustainable design	4	1	21	0	3	6	0	0	2	1
	Engineering excellence	74	3	21	21	0	23	8	15	25	0
	Environmental engineering	20	1	7	0	0	1	3	0	4	0
	Energy efficiency and sustainable energy	48	10	13	81	0	16	13	3	13	0
	Impact assessment	12	0	0	5	0	2	4	1	4	0
	Environmental science	57	2	16	4	0	8	5	2	5	0
	Science	28	8	5	20	3	15	2	5	0	0

Note: Sector abbreviations are as follows: A/F=Agriculture/Food, Bio = Biotech, Built = Built environment/design, E = Energy, F/T = Fashion/Textiles, M/M = Manufacturing/Materials engineering, S=Services, T/L = Transport/Logistics, W=Waste management, Other = skills in data that could not be assigned to any sector.

Appendix F

In two rounds of analysis, the employee skills identified in this study were compared against the lists in CE literature of (i) employee skills and (ii) organizational capabilities (operational capabilities, dynamic capabilities, and aggregate microfoundations) (Appendix A). In particular, mapping skills against capabilities must consider the conceptual relationship of employee skills as one of multiple microfoundations of organizational capabilities, which makes it less likely to identify a one-to-one match. Subsequently, when referring to the mapping of taxonomy skills against skills and capabilities in the literature, the conceptual difference of organizational capabilities and skills as a microfoundation of these capabilities is assumed. Consequently, skills and capabilities must not be considered as synonyms. Every skill in the taxonomy and every skill or capability in the CE literature was then classified as *found* (if a perfect match was identified), *partial correlation* (if a connection was identified based on the researchers' judgement) or *not found*. Classifying any skill-skill or skill-capability comparison as *found* required a perfect match. For example, the skill 'project management' in our taxonomy is proposed as a skill as well as an organizational capability in the CE literature. *Partial correlation* classification was applied if an explicit connection was observable but no perfect match. For example, the skill 'environmental storytelling' in our taxonomy was compared with 'circular storytelling,' proposed as a capability in literature, and classified as a *partial correlation*. We introduced the *partial* correlation classification to avoid exaggerating any contributions of this study by identifying skill as strictly *found* or *not found*. We aimed at making 'fair' arguments and acknowledge that these classifications are judgements of the researchers.

We then summarized our findings into five tables. Table F1 gives an overview of the skills in our taxonomy mapped against skills proposed in the CE literature. Similarly, Table F2 shows an overview of the skills in our taxonomy mapped against capabilities and microfoundations proposed in the CE literature. Tables F1 and F2 also serve as the basis for the heat map in Section 5.1. For each skill in the taxonomy, the mapping against skills and capabilities in CE literature was synthesized through a logical *OR* evaluation. For example, the skill 'science' is indicated as *found* in the CE literature on skills and as *not found* in the CE literature on capabilities. Based on the logical *OR* evaluation, the synthesized classification is *found*, given that the skill has been proposed in CE literature on skills before.

We found it straightforward to map taxonomy skills against literature skills, but also found it possible to map taxonomy skills against literature capabilities. Some skills and capabilities could be directly mapped (such as the project management example mentioned above), while for others a partial correlation was found while a simple aggregation of the skills to match this capability was not possible. Table F3 provides an overview of literature-based capabilities, where related skills exist with *partial correlation* while a simple aggregation of the skills to match this capability was not possible.

Furthermore, we summarized circular skills and capabilities proposed in CE literature for which a related general or sustainable skill exists, yet without a circular framing (Table F4). Similarly, we summarized sustainable skills and capabilities proposed in CE literature for which a related general skill exists (Table F5).

Table F1
Overview of skills in taxonomy mapped against skills proposed in the CE literature

Skill category	Skill	Literature coverage	Rationale (if *partial correlation*)
Business innovation skills	Sustainable purpose	found	
	Research	found	
	Out-of-the-box thinking	found	
	Business propositions/strategy	partial correlation	general business model skills found in literature, also business propositions skills found with circular notion (for PSS) in literature, yet not related to (business) strategy in literature
	Project management	found	
	Quality control and continuous improvement	not found	
	Investments and financing	partial correlation	general financial skill identified in literature, not specifically on investments and financing
Operational business skills	Management - business, product, operations	not found	
	Environmental management	partial correlation	only skills found related to CE indicator system skills in literature, but not for general environmental management skills
	Financial analysis and reporting	partial correlation	general financial skill identified in literature, not specifically on financial analysis and reporting
	Human resources	not found	
	Legal	found	legal skills found in literature, also with circular notion in literature
	Governance	not found	
Social skills	Customer service	found	customer service and experience skills found in literature, also with circular notion in terms of circular user engagement
	Marketing and sales	partial correlation	marketing skills found in literature, but sales skills not found in literature
	Storytelling	found	
	Environmental storytelling	found	environmental storytelling skill found in literature, yet also circular storytelling found in literature
	Teamwork and self-efficiency	partial correlation	teamwork skills found in literature, but self-efficiency (mostly time management) not found in literature
	Leadership	not found	
	Knowledge management and coaching/training	partial correlation	circular operational training organization skills and awareness building for circular techniques among stakeholders found in literature, but nothing specific on knowledge management skills more broadly in literature
Systems skills	Market monitoring	partial correlation	only skills found related to energy market, but not for general market research or competitor analysis
	Policy monitoring	not found	

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Table F1 (*continued*)

Skill category	Skill	Literature coverage	Rationale (if *partial correlation*)
	Systems thinking	found	systems thinking skill found in literature, yet also circular systems thinking found in literature
	Supply chain management	partial correlation	skills found relating to selected functions of SCM (logistics and circular procurement and circular contracting) in literature, also found reverse logistics (another circular notion) in literature
	Value chain collaboration	found	value chain collaboration skill found in literature, yet also CE value chain collaboration found in literature
	Ecosystem building	not found	
	Information systems	partial correlation	information systems (for CE, such as tracking/traceability or collaboration/information sharing along value chain) skills found in literature, but not for general information systems (ERP, neither for GIS) which were identified in startups
Digital skills	Application design/ development	not found	
	IT excellence	not found	
	Data analytics/science	found	
	Graphic design and multimedia	not found	
Technical skills	Material analysis	found	material analysis skill found in literature, yet also sustainable material skills found in literature
	Product/systems design	found	
	Sustainable design	partial correlation	skills related to circular design specifically in literature, not on sustainable design more broadly
	Engineering excellence	found	
	Environmental engineering	found	waste (incl. recovery) and water skills of environmental engineers found in literature, yet also multiple higher-ranked circular manufacturing skills found in literature (which go beyond typical waste recovery as part of environmental engineering)
	Energy efficiency and sustainable energy	found	
	Impact assessment	found	sustainable impact assessment skills found in literature, yet also with circular notion
	Environmental science	not found	
	Science	found	STEM and economics skills found in literature, yet also with sustainable notion (environmental/ ecological economics)

Table F2
Overview of skills in taxonomy mapped against capabilities proposed in the CE literature

Skill category	Skill	Literature coverage	Rationale (if *partial correlation*)
Business innovation skills	Sustainable purpose	found	
	Research	found	
	Out-of-the-box thinking	partial correlation	capabilities found in literature that correlate with this skill (esp. The innovation skills), yet not (relatively explicitly) with entrepreneurship or problem-solving skills
	Business propositions/strategy	partial correlation	capabilities found in literature that correlate with this skill, yet also capabilities found with sustainable and circular notion in literature
	Project management	found	
	Quality control and continuous improvement	found	
	Investments and financing	partial correlation	general financial capabilities identified in literature, also specifically on investments and financing (acquisition, selling, investments, budgeting), yet also financial capabilities found with circular notion in literature
Operational business skills	Management – business, product, operations	partial correlation	resource orchestration capabilities found in literature that correlate with this skill
	Environmental management	found	
	Financial analysis and reporting	partial correlation	general financial capabilities identified in literature, not specifically on financial analysis and reporting, also financial capabilities found with circular notion in literature
	Human resources	partial correlation	(mostly sustainable) HR-related capabilities found in literature that correlate with this skill
	Legal	partial correlation	(mostly circular) capabilities found in literature that correlate with this skill
	Governance	found	
Social skills	Customer service	found	capabilities found in literature that correlate with this skill, yet also capabilities found with circular notion in literature
	Marketing and sales	found	capabilities found in literature that correlate with this skill (for both, marketing and sales), yet also marketing capabilities found with sustainable notion in literature
	Storytelling	found	
	Environmental storytelling	partial correlation	circular storytelling capability found in literature that correlates with this (sustainable) skill
	Teamwork and self-efficiency	partial correlation	one capability found in literature that correlates with this skill (teamwork) broadly, yet no capabilities found in literature that correlate to self-efficiency
	Leadership	found	

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Table F2 (*continued*)

Skill category	Skill	Literature coverage	Rationale (if *partial correlation*)
	Knowledge management and coaching/training	partial correlation	capabilities found in literature that correlate with this skill (both knowledge management and training), yet also capabilities found with sustainable notion in literature (again related to both, both knowledge management and training)
Systems skills	Market monitoring	found	
	Policy monitoring	found	capabilities found in literature that fully correlate with this (sustainable) skill, yet also a capability found with circular notion in literature
	Systems thinking	partial correlation	capabilities found in literature that correlate with this skill, yet also a capability found with circular notion in literature
	Supply chain management	found	capabilities found in literature that fully correlate with this skill, yet also capabilities found with sustainable and circular notion in literature
	Value chain collaboration	found	
	Ecosystem building	partial correlation	capabilities found in literature that correlate with this skill
	Information systems	partial correlation	general and circular capabilities related to information system/processing identified in literature, not specifically on ERP and GIS, (for CE, such as tracking/traceability or collaboration/information sharing along value chain)
Digital skills	Application design/ development	not found	
	IT excellence	partial correlation	circular/sustainable IT management capability found in literature that correlates with this skill
	Data analytics/science	found	
	Graphic design and multimedia	not found	
Technical skills	Material analysis	found	
	Product/systems design	partial correlation	capabilities found in literature that correlate with this skill (in terms of customer focus/engagement in product design/UX), yet not on general product design more broadly
	Sustainable design	partial correlation	circular product design capability found in literature that correlates with this (sustainable) skill
	Engineering excellence	partial correlation	capability (related to restructuring of production/manufacturing) found in literature that correlate with this skill
	Environmental engineering	partial correlation	higher-ranked circular production/manufacturing capabilities found in literature that correlates with this circular skill (which has a focus on lower-ranked circular strategies
	Energy efficiency and sustainable energy	partial correlation	energy-related capabilities found in literature that correlate with this skill
	Impact assessment	found	
	Environmental science	not found	
	Science	not found	

Table F3
Overview of capabilities proposed in the CE literature with partial correlation with skills proposed in the taxonomy of this study

Type	Capability	Mapping against skills in taxonomy
General	Technological innovation (incl. ICT based)	out-of-the-box thinking skills broadly correlate with this capability, together with technical skills and digital (ICT) skills (but tech-based innovation not identified explicitly as a skill)
	Empowerment for bottom-up innovation	out-of-the-box skills thinking broadly correlate with this capability, together with leadership (but bottom-up empowerment not identified explicitly as a skill)
	Ecosystem/stakeholder engagement and collaboration (vertical and horizontal) on sensing and seizing	value chain collaboration skills broadly correlate with this capability, together with ecosystem building, customer service, product design (UX), out-of-the-box thinking, SCM, business propositions/strategy (but collaboration on sensing/ seizing not identified explicitly as a skill)
	R&D/innovation collaboration	value chain collaboration skills broadly correlate with this capability, together with out-of-the-box thinking (innovation) and research (but innovation collaboration not identified explicitly as a skill)
	Value chain (and social) collaboration (including vertical/horizontal, engagement, information sharing/traceability, governance/trust, shared culture, training, etc.)	value chain collaboration skills broadly correlate with this capability, together with skills related to different aspects of value chain collaboration capability, including governance, training, and information systems (but collaboration including all elements proposed by literature not identified explicitly as a skill)
	Access to stakeholder information	value chain collaboration skills broadly correlate with this capability (but stakeholder information access not identified explicitly as a skill)
	Supply chain ambidexterity	SCM skills broadly correlate with this capability, together with out-of-the-box thinking (innovation) and quality control and continuous improvement (but focus on supply chain improvements/innovations not identified explicitly as a skill)
	Supply chain big data predictive analytics	SCM skills broadly correlate with this capability, together with data analytics/ science (but data analytics with focus on supply chain not identified explicitly as a skill)
	Customer engagement in product design	customer service skills broadly correlate with this capability, together with product design (UX) skills and value chain collaboration skills (but customer engagement for product design not identified explicitly as a skill)

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Table F3 (*continued*)

Type	Capability	Mapping against skills in taxonomy
Sustainable	Environmental (management) accounting	environmental management skills broadly correlate with this capability (but environmental accounting not identified explicitly as a skill)
	Energy management and auditing	energy efficiency and sustainable energy skills broadly correlate with this capability, together with environmental management (yet also n/a as these skills do not indicate specifically an intra-organizational energy management and auditing capability)
Circular	Continuous systematic learning from product returns (incl. Identification of valuable information, Knowledge infrastructure, Integrated return processes (customer 360 and forward/reverse logistics integration), Governance, Incentives)	quality control and continuous improvement skills broadly correlate with this capability, also information systems, SCM and governance (but learning from product returns not identified explicitly as a skill), additionally skills found without circular notion in startups

Table F4
Overview of circular skills and capabilities proposed in the CE literature with partial correlation with non-circular skills proposed in taxonomy of this study

Skill	Capability
Circular business propositions (for PSS)	Sustainable/circular product/service development
CE indicator system	Circular/sustainable business experimentation
Circular clauses in contract documents	(Circular/Sustainable) Business propositions/model
Circular user engagement	Leadership and change management (incl. sustainable/circular KPIs)
Circular storytelling	Continuous systematic learning from product returns (incl. forward/reverse logistics integration)
Circular operational training	Circular financial management
Build-up of awareness of circular techniques among stakeholders	CE indicator system
Circular systems thinking	Comprehension of (environmental/circular) regulatory landscape
Reverse logistics	Circular legal
Circular (waste-efficient) procurement	Circular/Green/Waste-related patenting
Circular (waste) contractor assessment	Reverse omnichannel
CE value chain collaboration	Circular storytelling
Use of information systems for CE	Circular SCM/purchasing (incl. supplier material/parts certification, integrated SCM system)
Circular/efficient material use in design	Reverse logistics
Design for recovery and multiple use cycles	Circular/green IT management
Circular manufacturing (including reverse and re-manufacturing, dematerialization, novel manufacturing solutions and use of IT tool/analytics)	Circular product (eco-) design (incl. openness to recycled products, use of recycled materials, flexibility, reconfiguration, maintenance, user experience, etc.)
Circular impact assessment	Circular (production) process design/planning (incl. dematerialization, cleaner production, modular assembly, remanufacturing, recycling, maintenance, etc.)
	Circular manufacturing (incl. Remanufacturing)

Table F5
Overview of sustainable skills and capabilities proposed in the CE literature with partial correlation with general skills proposed in taxonomy of this study

Skill	Capability
Sustainable material	Sustainable business model design and reconfiguration
Environmental/ecological economics	Focus on sustainable impact commitment/strategy and innovation/ideation culture
	Green talent management
	Eco-innovation HR
	Green marketing
	Green warehousing

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