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Mapping the landscape of circular design tools

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ABSTRACT

Circular design tools can help companies to move from linear to circular design practices and an increased uptake of such tools have potential to help realise the circular transition. Despite the existence of numerous circular design tools, companies often find it challenging to identify tools that align with their needs as the tool landscape is difficult to navigate. This paper offers a synthesized overview of 65 circular design tools that uniformly describes the tools' main attributes. The tools are categorized into five families to make it easier to navigate the tool landscape and identify tools for specific needs. The findings offer a useful resource for the research community as well as companies seeking to e.g. design for value retention and extended product lifetimes. Implications for tool developers and practitioners are highlighted, advocating for more effective utilization of existing tools and the alignment of future tool development with circular design practices.

1. Introduction

Shifting to a circular economy, i.e. an economic system built on value creation and preservation that decouples economic growth from the consumption of finite resources (Webster, 2017), requires fundamental systemic changes on the micro, meso and macro levels (Kirchherr et al., 2017). Changes in production and consumption can be enabled by developing products, services, and systems that prolong product lifetimes, retain product values, and enable circular resource flows. Design is therefore often seen as a key ingredient to facilitate the circular transition (Ellen MacArthur Foundation, 2023; Dey et al., 2022; Pigosso and McAloone, 2017; van Dam, et al., 2020). Circular design is about reimagining our current system and designing a new system built on circular principles. It builds on an expansive body of philosophies, including Systems thinking, Cradle to Cradle, Transition Design, Biomimicry, Regenerative Design and others (Ellen MacArthur Foundation, 2023; Hanes-Gadd et al., 2023). An important part of the development of the field has been the emergence of conceptual frameworks that introduce theory, methods that outline how to design for circularity, and practical tools that can be used in design activities. Studies have shown that circular design tools constitute important enablers for companies since they can inspire and aid design processes which in turn will help speed up the circular transition (Hanes-Gadd et al., 2023; Dokter et al., 2020). An increased uptake and application of circular design tools in industry can thus help realise the potential of the circular economy (Ellen MacArthur Foundation, 2023).

However, circular design tools are likely facing similar challenges as design tools in general when it comes to their utilisation. Literature highlights several factors that influence the acceptance and adoption of design tools, where some relate to the companies' knowledge levels, available resources, and organisational issues (Rossi et al., 2016). Other hindrances are more directly linked to the design tools and their attributes. The tools are not always well-designed which can make them less useful, enjoyable, and efficient to use, which will reduce their uptake. Japtap et al. (2014), Pozatti et al. (2020) and Ahmad et al. (2018) argue that design tools should be, for instance, user-friendly, flexible, easy to use and learn, and use suitable vocabulary to increase adoption. Mismatches between available design tools and the needs of companies is another barrier for adoption, such as tools that do not address relevant tasks and problems or over-formalized tools that are not compatible with company processes or existing tools (Jagtap et al., 2014; Pozatti et al., 2020, Rossi et al., 2016). In addition, an oversupply of design tools that include tools with high specificity or tool prototypes, makes tool selection especially difficult and limits adoption (Ahmad et al., 2018; Rossi et al., 2016). A notable example of poor tool uptake is presented by Pieroni et al. (2019), who reviewed 92 approaches (tools, methods etc.) for circular business model innovation and concluded that only 5 of these were regularly applied in companies.

Such hindrances not only suggest that tools should be well designed, but also that companies may benefit from a comprehensive overview of design tools that helps them to understand the tools' key attributes so that they can identify tools fit for their needs. This is valid also when it

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comes to circular design tools. Although there are many circular design tools, some companies still experience a lack of tools that fit their needs (Cambier et al., 2020). Based on a survey of 114 design professionals, Dokter (2023) argues that the designers' perceived lack of circular design tools is a result of tools being inaccessible, and that the range of tools is insufficient to meet the designers' needs. Although this points to an opportunity to expand the range of tools, it also calls for making existing tools easier to find. The importance of highlighting the range of existing tools that can aid practitioners to design and evaluate circular solutions is also emphasised by Ellen MacArthur Foundation (2023) in their Adaptive Strategy for Circular Design.

However, no comprehensive overview that specifically describes the wide range of available circular design tools and their attributes is available. While some of the existing online resources offer a substantial selection of tools, their collections are not nearly complete and often focus on the tools developed by the hosting organisation. In regard to published research, previously conducted review studies cover either a subset of circular design tools, such as tools for assessing designs that enable useful life extension (Royo et al., 2023), user-centered circular design (Camacho-Otero et al., 2019), and circular building (Dervishaj and Gudmundsson, 2024), or reviews that cover tools that are not referred to as circular design tools, such as tools for circular business models (Bocken et al., 2019), circular economy assessment tools (Cardoso Chrispim et al., 2023), sustainable product design (Ahmad et al., 2018), and Ecodesign (Pigosso et al., 2015; Rossi et al., 2016).

This paper therefore seeks to provide a synthesised overview of the landscape of available circular design tools and uniformly describe their main attributes. Differences regarding expected outcomes and scope will be highlighted to aid designers to, for instance, understand whether a specific tool can aid development of long-lasting products that retain value over time. Such a descriptive map of the landscape of circular design tools has potential to help practitioners and tool developers to navigate the existing tool landscape and find tools relevant for their work. The paper also discusses the current landscape regarding how easy it is to navigate, how well it meets practitioners needs, adjacent tools, and implications for tool developers and practitioners.

2. Method

The conducted research included four main parts as illustrated in Fig. 1.

2.1. Data collection

The initial data collection sought to identify circularity-related tools in a broad sense and included four main activities. The methods were chosen to cover both academic and non-academic sources and include the most common ways companies can come across circularity-related tools.

Newsfeeds and other channels were monitored to identify available tools during January 2017 to April 2023 as part of several research projects. Data sources included social media newsfeeds, events and presentations related to circular design, research project websites, databases that list tools related to design and circular economy, books on circular and/or sustainable design, and personal contacts active in the field of circular economy and sustainability. The identified tools were listed in an excel-dataset and downloaded when possible.

Literature searches in Scopus were conducted during January 2023. After conducting iterative searches, the final search string used was (((“circular” OR “circular economy” OR “circularity”) AND (“tool” OR “framework” OR “guidelines” OR “strategies” OR “approach”) AND (“circular design”)) OR ((“circular economy” OR “circularity”) AND (“design tool”))). The final search string resulted in 192 publications after the initial search result of 487 publications was limited to relevant keywords. Titles and abstracts were reviewed and identified tools were added to the dataset and downloaded when possible.

Publications in conference proceedings were reviewed during February 2023, including: PLATE conference proceedings (years 2015, 2017, 2019, 2021); DRS conference proceedings (years 2002, 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020, 2022); and ERSCP conference proceedings (years 2014, 2017, 2019, 2021). Based on titles and abstracts, 40 publications were selected for analysis and identified tools were added to the dataset and downloaded when possible.

Since tools are often made available through other channels than academic publications, complementary web searches were also conducted. For many companies, using keywords to search online for specific tools that match their needs can be a convenient way to learn about and access new tools. To reduce the risk that relevant tools were overlooked, several web searches were therefore conducted during March 2023 using keywords such as design, circular design, design tool, reuse, repair, remanufacturing and recycling. Identified tools were added to the dataset and downloaded when possible.

The data collection resulted in a large dataset that after excluding duplicates comprised close to 300 circularity-related tools, of which the majority were identified by monitoring newsfeeds and other channels. Circularity-related tools made available after March 2023 have not been included in the dataset.

2.2. Criteria selection

A set of inclusion criteria was defined to delineate the initial broad dataset. The criteria were defined in regard to four key aspects: 1) *Design focus* – the design foundations, principles and objectives focused on; 2) *Design support* – the type of design support that is provided; 3) *Design agent* – the main design agents targeted; and 4) *Design object* – the main object that the design work is directed at. This section discusses each aspect and Fig. 2 presents a visual summary of the defined inclusion criteria.

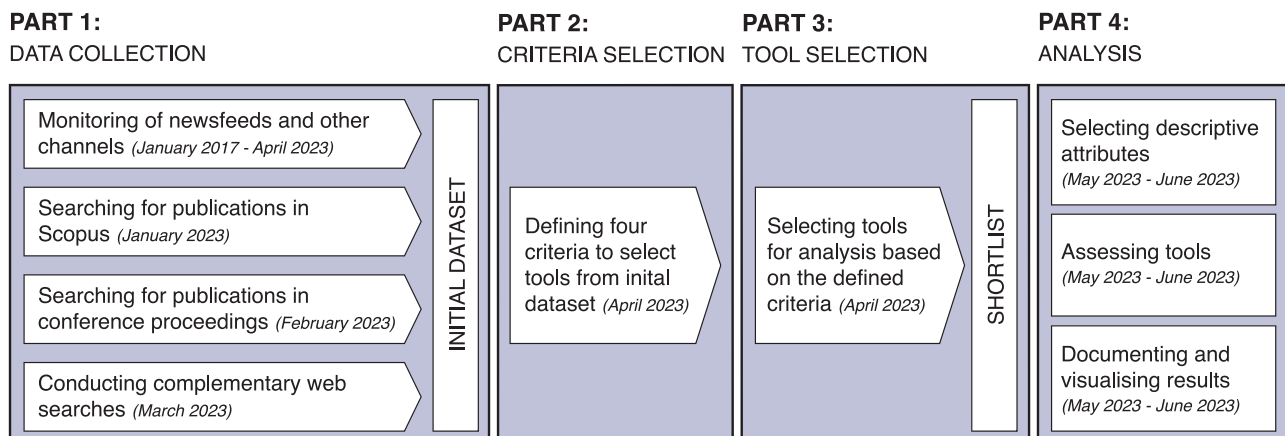


Fig. 1. Overview of conducted activities.

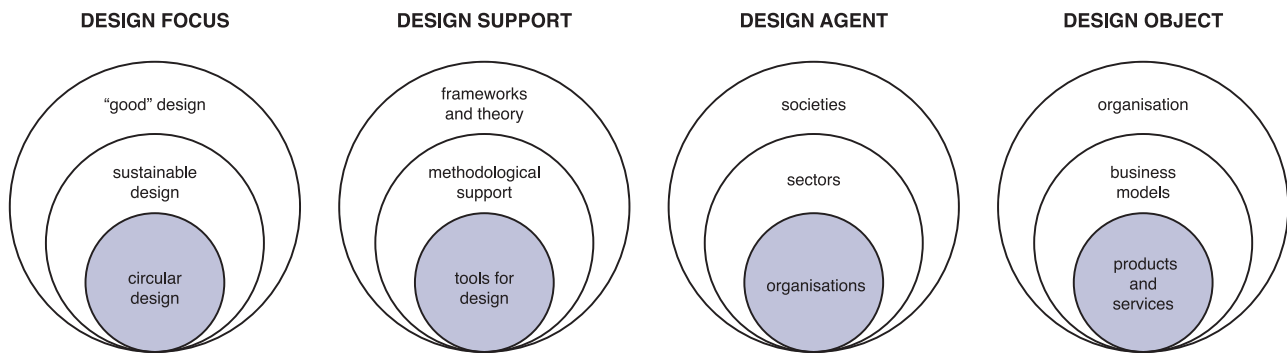


Fig. 2. Visual summary of the inclusion criteria used for selecting circular design tools.

Most design tools focus on spurring designs that can be considered “good” for different purposes and one such focus shared by many tools is to contribute to sustainability. A subset of sustainable design tools focus specifically on circular economy principles and objectives. Following [Ellen MacArthur Foundation’s \(2023\)](#) description of circular design tools, this paper addresses tools that are founded on circular economy policies, principles, and guidelines. In regard to “Design focus”, the following inclusion criteria was used:

Criteria 1: Tools that have been explicitly developed and framed for circular design (not only useful for circular design). Such tools should be founded on, and address, principles, and opportunities relevant for a circular economy.

Circular design can benefit from frameworks that provide a theoretical grounding, methodological support that describe how to carry out certain activities, as well as tools that are used to perform certain actions ([Gericke et al., 2017](#)) and aid everyday design processes by helping designers put theory into practice ([Ellen MacArthur Foundation, 2023](#)). Such tools can be digital or analogue and have varying format and character depending on the type of design activity they are supposed to support. In regard to “Design support”, the following inclusion criteria was used:

Criteria 2: Tools providing design support that have been purposefully embodied into a practical format to support design work. The output of using such tools should be meaningful for the design process and provide input that aid design activity.

There are design tools to aid circular design work on the macro, meso and micro levels. Macro level tools are useful for policy makers, city planners or developers of socio-technical systems while meso level tools can aid actors in specific sectors to enable development of large-scale collaborative circular initiatives. On a micro level, design tools can support organisations to work with circular design. In regard to “Design agent”, the following inclusion criteria was used:

Criteria 3: Tools that aid design activities and decisions that individual organisations have agency over.

Organisations can use tools to further develop their own organisation (e.g. developing competences, partnerships, production processes, and day to day operations), their business models (e.g. developing value propositions, key activities, and cost and revenue structures), as well as their offers in terms of products and services. Companies that want to develop circular product and service offers, will benefit from tools that help them to, for example, explore new functionality, improve the user experience, and identify materials fit for circular flows. In regard to “Design object”, the following inclusion criteria was used:

Criteria 4: Tools that aid development of products and services (not development of business models or organisational change).

2.3. Tool selection

The initial broad dataset was used as a basis for selecting circular design tools to analyse. The four inclusion criteria described in [Section](#)

2.2 were used to compile the shortlist.

The first criteria reduced the dataset to tools that have been explicitly developed for circular design. More generic design tools (e.g. evaluation matrixes and service design tools) or tools for sustainable design (e.g. the LiDS Wheel by [Brezet and van Hemel \(1997\)](#)) were excluded, although many such tools can be useful for design processes aimed at designing products and services fit for the circular economy or tweaked to be even more useful.

The second criteria reduced the dataset to tools that have been packaged into a practical and useful format with the intention to be applied in design activities to generate design outputs. In the initial broad data collection, guidebooks, frameworks, guidelines, approaches and methods (e.g. the framework by [van den Berg and Bakker \(2015\)](#)) were included but these were excluded from the shortlist if not packaged into, or accompanied by, a practical tool. Practical tools only described in academic papers, but inaccessible, were also excluded. Tools that had previously been accessible but were no longer accessible or fully functional at the time of the final selection were excluded from the shortlist. Only tools accessible in English were included.

The third criteria reduced the dataset to tools that target design activities and decisions that individual organisations have agency over. Tools developed to enable development of large-scale collaborative initiatives were excluded from the shortlist (e.g. the Doughnut Design for Business Taster Tool by [Doughnut Economics Action Lab \(2023\)](#)).

The fourth criteria further reduced the dataset to tools created to aid development of products and services. This means that tools for business model innovation and organizational change were excluded from the shortlist (e.g. the Value mapping tool by [Bocken et al. \(2013\)](#)). Tools directed at activities typically not performed by designers, although they may provide valuable input to design (such as tools for assessing environmental implications, e.g. the Idemat app ([Idemat, 2023](#))) were also excluded. Similarly, tools that aid development of solutions commonly not referred to as products, such as cities, buildings and infrastructure, were excluded. As were tools only intended to help designers and others to learn about circular design or circular economy (such as serious games, e.g. Risk and Race by [Whalen \(2017\)](#)).

After reviewing the dataset in relation to the four inclusion criteria, a shortlist of 65 circular design tools that met the criteria was compiled. The shortlist is provided in [Appendix A](#).

2.4. Analysis

To be able to uniformly portray each design tool, and allow meaningful comparisons between the tools, a selection of descriptive attributes was made. Certain attributes, such as the tool’s name and purpose were chosen before analysing the tools given their obvious relevance. However, during the analysis, other attributes were added or required refinement to ensure their applicability and relevance to all the tools under consideration. The final set of attributes, presented in [Appendix B](#), was thoughtfully chosen to encompass various aspects of the tools,

including their purpose, design (in terms of format and content), and the effort required when using them. Most of the attributes are categorical variables and have a predefined set of possible values, to facilitate the analysis. Some of the attributes allow multiple values simultaneously. As an example, a single tool can have more than one expected outcome and be offered in multiple formats.

To describe each tool based on the selected attributes, a careful inspection and analysis of each tool was conducted by the authors. For attributes involving ratings, such as Content extensiveness, a more comprehensive analysis was necessary during which the authors followed a process akin to what one would undertake when utilizing the tool in a design activity. The focus was to comprehend the tool's purpose, appropriate usage scenarios, and operational procedures, among other aspects. To ensure consistency, certain tools required re-analysis, ensuring uniform treatment across all tools.

It is important to acknowledge that the tools were not subjected to actual design activities during the analysis. The sheer number of tools made it impractical to conduct such comprehensive testing, especially if one desired to evaluate the quality, relevance, and usefulness of the output within an authentic enough context. Therefore, there are no attributes employed to assess the overall effectiveness of the tools. Consequentially, it needs to be noted that the ratings assigned to certain attributes, notably Use complexity, were not derived from real tests but rather based on the authors' estimates made during the inspection and analysis.

When all tools had been uniformly described, additional analyses were made to categorize and compare the tools. While some analyses were obvious to make, such as counting the number of tools of each format, other analyses were made using a more explorative approach driven by curiosity. The aim with these was to search for interesting patterns among the tools in terms of their character. Specific pairs of tool attributes were juxtaposed using contingency tables, and the resulting correlations between these attributes were visually represented through diagrams. Two of these comparisons of attributes are included in this paper, since they revealed interesting correlations. The relationship between Scope and Content extensiveness was explored to see if the specialised tools had a more extensive content than the general tools. The relationship between Content extensiveness and Use complexity was explored to see if the tools with a more extensive content required larger effort.

A holistic analysis of the tool landscape was also carried out, commencing with a qualitative approach. Already during the tool collection and inspection process, discernible patterns among the tools began to emerge, for instance that specific types of tools typically were used to generate certain types of outcomes. Guided by these observed patterns, the shortlisted 65 tools were subsequently categorized into five distinct tool families. While some tools may share characteristics with multiple families, each could be clearly assigned to a specific family based on its predominant features. Finally, a more detailed depiction of the tool families was crafted by scrutinizing the collective data pertaining to all tools classified within each respective family.

2.5. Reflections on method

It's important to acknowledge that the landscape of circular design tools presented in this paper heavily relies on the methods employed for their selection and analysis. The authors have endeavoured to maintain a high level of structure in this regard, but the challenges of determining which tools to include and how to categorise them were still significant. Moreover, to complete the analysis, the authors had to establish a deadline beyond which new tools would no longer be considered for analysis. Consequently, it's worth noting that new tools have emerged since the stipulated deadline. Additionally, it's important to recognise that some of the included tools are part of sets of tools or are accompanied by supplementary materials, such as reports, method descriptions, and learning resources. Analysing these tools in isolation from their broader context may not align with the original intentions of the tool developers. However, for practical reasons, it was not feasible to

incorporate all the additional materials that extend beyond the scope of circular design tools.

3. The character of circular design tools

This section provides a summary of the analysed 65 circular design tools that are described in detail in [Appendix A](#). This summary includes an overview of the character of the tools and condensed descriptions of how the tools vary in terms of expected outcome(s), format(s), component(s), scope, content extensiveness, and use complexity.

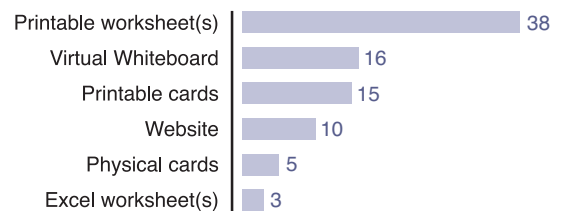
3.1. Expected outcome(s), format(s) and component(s)

The tools can be used for various purposes and [Fig. 3a](#) presents an overview of the types of outcomes that can be expected when using the tools. Many of the tools can be used for multiple purposes and contribute multiple outcomes. The most common types of outcomes are *opportunities identified*, *designs assessed*, and *ideas/concepts created*. There can of course be additional outcomes of using the tools that are not directly

EXPECTED OUTCOME(S)



FORMAT(S)



COMPONENT(S)

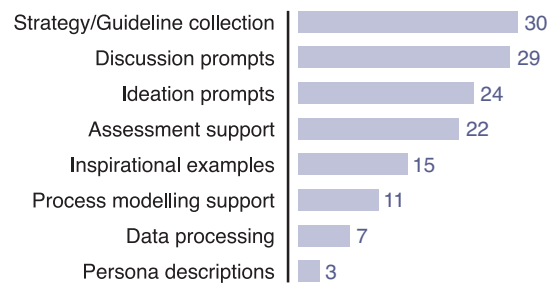


Fig. 3. The shortlisted tools' a) expected outcome(s), b) format(s), and c) component(s). Note that each tool can have multiple values for each attribute.

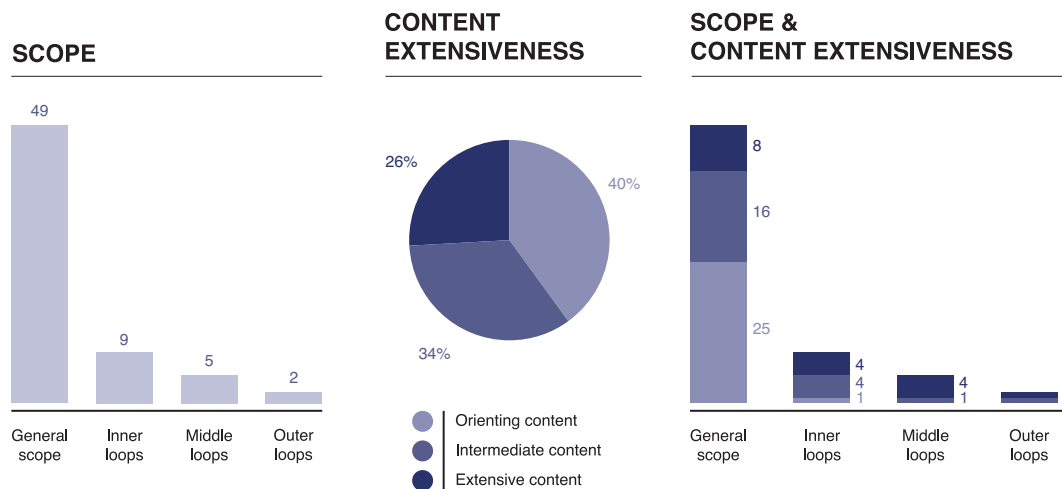


Fig. 4. The shortlisted tools' a) scope, b) content extensiveness, and c) scope in relation to content extensiveness.

related to the design process, such as increased knowledge of circularity and its importance, but these are not highlighted here.

As illustrated in Fig. 3b, the tools have varying formats; some make use of several formats or are provided in two or more versions with different formats. The dominant format among the tools is worksheets, either printable ones or digital ones provided on virtual whiteboards such as Miro and Mural. Printable or pre-printed physical card sets are also common, as is websites.

How the tools are utilised depends not only on the format but on their "active ingredients", referring to the specific components or building blocks designed to facilitate the design work. Among these components, the most prevalent are strategy and guideline collections, as shown in Fig. 3c. Many of these tools appear to have been developed with the purpose of gathering strategies and guidelines from scientific publications and subsequently adapting them into more user-friendly formats such as cards or worksheets.

Closely associated with these collections are discussion and ideation prompts, which often cover similar topics as the strategy/guideline collections but are restructured into a more stimulating format. For instance, a prompt might pose a question like, "Could the product be replaced by a service?" These prompts serve to trigger discussions and generate ideas. In certain cases, components aimed at supporting assessment also rely on prompts. However, the focus here shifts toward evaluating the qualities of new and/or existing products/services. Some tools featuring such prompts incorporate a data processing component as well, which generates recommendations based on responses to the assessment prompts.

Process modelling support is commonly found in tools utilised to create visual representations of circular flows. These tools enable users to visually depict and analyse the various stages and interactions within a circular process. Lastly, tools designed to support creative activities, such as idea generation, frequently include elements such as inspirational examples and persona descriptions to help users consider different possibilities and perspectives during the ideation process.

3.2. Scope and content extensiveness

Regarding the scope covered by the tools, some focus on circularity in a general sense while others specialise on *inner* (sharing and reuse), *middle* (repair, remanufacturing, upcycle) or *outer* loops (recycling), see Fig. 4a. The inner loop is the most common among the specialised tools, while tools focusing on the outer loop are rarer. The analysis indicates that there are more tools aimed at designing products that retain value during longer lifespans and throughout multiple use-cycles, compared to tools focusing on designing for recycling processes. Tools that focus on a specific industry are relatively rare among the shortlisted tools, with four focusing on

packaging (tool IDs 51, 53, 59, 60), three on apparel and textiles (tool IDs 25, 26, 58), and one on furnishing (tool ID 41). While this indicates that there are significantly fewer tools with a more specific scope, this does not necessarily mean that there exists only, for instance, two design tools focused on recycling. There can be other tools available that did not meet the selection criteria. For example, tools created before the concept of circular economy was popularized are most often not framed as tools for "circular design" and thus not covered in this analysis.

How extensive the tools' content is, such as the breadth and depth of included guidelines, prompts, and other content, was assessed as either *orienting*, *intermediate* or *extensive*. Fig. 4b shows that the selected tools are distributed relatively evenly in terms of their content extensiveness, with a slight disproportion towards more orienting content. Tools with orienting content are however overrepresented among the general circular design tools while the tools that focus on a specific circular loop are commonly more extensive, see Fig. 4c.

3.3. Use complexity

Regarding their use complexity the tools were rated from *low complexity*, which is a 'pick up and use' tool, to *high complexity*, which refers to a tool that would require a considerable effort to use to generate a meaningful output. As depicted in Fig. 5a, approximately half of the analysed tools were assessed as having low use complexity, while a relatively small number of tools were deemed to be very complex to use. It should be noted that the attribute use complexity was challenging to assess, since the effort it takes to use a tool is not only dependent on its complexity, but also on the complexity of the task as well as on the knowledge level and ambitions of the user.

Fig. 5b highlights that tools with an orienting content are generally easier to use compared to those featuring more extensive content. This finding is not surprising, as the presence of extensive content in a tool is likely to impact both the ease of obtaining an overview and the duration required to utilize the tool (given that most tools are designed to employ their entire content). When looking at the tools rated to have low use complexity and orienting content, the format printable worksheet is well represented with 16 out of 21 tools.

4. The landscape of circular design tools

The previous section introduced the range of available circular design tools by providing an overview of how the tools listed in Appendix A vary in terms of different attributes. Building on the previously presented data, this section seeks to provide a more meaningful overview of the tool landscape that makes it easy to identify tools for certain needs.

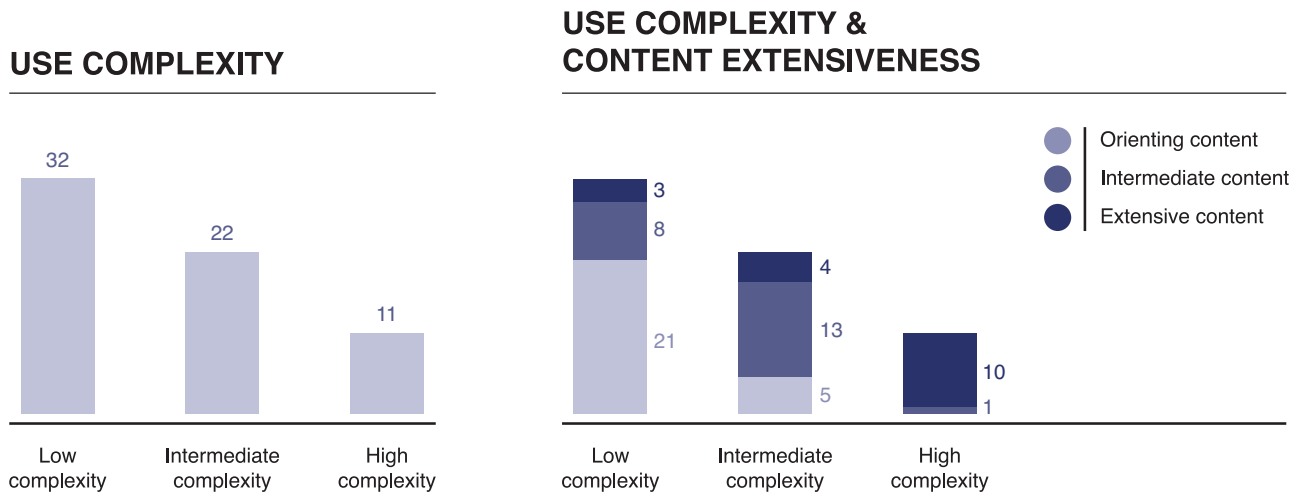


Fig. 5. The shortlisted tools' a) use complexity, and b) use complexity in relation to content extensiveness.

Fig. 6 presents the landscape of circular design tools in the form of tool families that were discerned when analysing similarities in the characteristics of the shortlisted 65 circular design tools. The landscape includes five distinct families: *Circular activators*, *Circular prompters*, *Circular analysts & advisors*, *Circular flow visualisers*, and *Circular design enrichers*. The families are positioned in relation to two main axes, which differentiate the families in terms of their main target group – *For who?* – and the type of design activity they support – *For what?*. The tool family *Circular activators*, and partly *Circular prompters* and *Circular analysts and advisors*, cover tools that are oriented toward aiding a wide range of circular agents seeking to explore design opportunities in a broad sense, while the others can be seen as more oriented toward supporting designers exploring circular opportunities in more detail. The *Circular activators*, *Circular design enrichers*, *Circular prompters*, and partly *Circular flow visualisers* are oriented towards aiding creative and divergent design work, while the family *Circular analysts and advisors* gathers tools that focus more on aiding analytical and convergent design work.

As visualised in Fig. 6, the number of tools in each family varies. In the analysed sample of 65 circular design tools, *Circular activators* (22 tools) and *Circular prompters* (21 tools) are most common followed by *Circular analysts & advisors* (11 tools). There are fewer *Circular flow visualisers* (5 tools) and *Circular design enrichers* (6 tools), but they nevertheless represent distinct types of circular design tools. The overall analysis shows that there is an emphasis on tools designed to support circular agents to explore circular opportunities through creative and divergent design activities. Table 1 describes each tool family regarding typical outcomes, formats, and components.

It is important to note that the characteristics of the tools covered in each family varies. Some circular design tools are designed to be used by anyone and for both divergent and convergent work, and others can be adapted to meet additional needs. The simplified overview in Fig. 6 does therefore not seek to portray a detailed and exhaustive map of the

landscape but presents a practical starting point for identifying potentially suitable tools for different design activities based on the perceived primary focus of the tools.

A comprehensive list of the tools is provided in Appendix A, with tool families highlighted in the right-hand column. Appendix A also provides additional information about providers and access. All digital tools are free to access online although registration is required for some. The physical tools can be purchased, and most are also available in free online versions. Typical examples of tools for each tool family are presented in Fig. 7 and the tool families are further described in the following sub-sections.

4.1. Circular activators

Tools referred to as circular activators introduce circular economy-related concepts to support companies to get familiarized with the topic of circularity and get started with circular design. These tools often provide basic prompts and overviews of the main circular design opportunities. The most common format is printable worksheets that are often designed to be used in workshops to activate a circular mindset or highlight circularity related challenges and opportunities. All the tools address circularity in a general sense and the majority provides orienting content. Since they are less extensive, they are commonly easy and time-efficient to use. Many are intended for learning activities where one addresses fictive cases rather than company specific challenges. The main takeaways when working with these types of tools are an increased understanding of circularity and high-level opportunities for circular design.

4.2. Circular prompters

This tool family gathers tools that present circular design strategies and provide prompts that highlight opportunities or challenges related

Table 1
The identified tool families and their characteristics.

Circular design tool families (number of tools analysed)	Typical expected outcome(s) (number of occurrences)	Typical format(s) (number of occurrences)	Typical component(s) (number of occurrences)
Circular activators (22 tools)	Opportunities identified (12)	Printable worksheets (19)	Discussion prompts (12); Strategy/guideline collection (10); Ideation prompts (9)
Circular prompters (21 tools)	Ideas/concepts created (12); Opportunities identified (7); Designs assessed (7)	Printable worksheets (12); Cards (8); Virtual whiteboards (7)	Strategy/guideline collection (14); Discussion prompts (11); Ideation prompts (11)
Circular analysts & advisors (11 tools)	Designs assessed (9); Strategies/guidelines prioritised (4)	Websites (6); Excel worksheets (3)	Assessment support (11); Data processing (6); Strategy/guideline collection (6)
Circular flow visualisers (5 tools)	Visual representations created (5)	Virtual whiteboards (2); Printable worksheets (2)	Process modelling support (5)
Circular design enrichers (6 tools)	Design insights gained (4); Ideas/concepts created (4)	No typical formats	Discussion prompts (5); Ideation prompts (3)

THE LANDSCAPE OF CIRCULAR DESIGN TOOLS

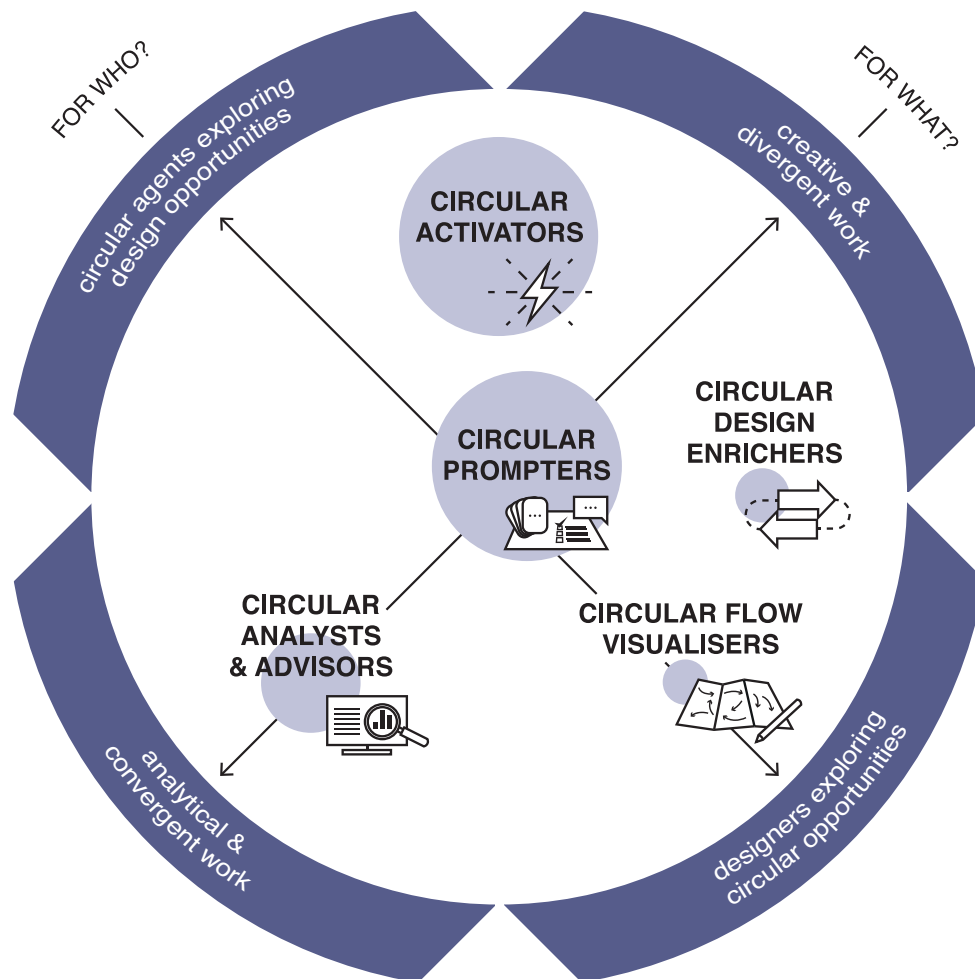


Fig. 6. The landscape of circular design tools with five tool families. The number of tools in each family is indicated by the size of the circles.

to the strategies. One half of the tools offer overviews and strategies that cover a broad scope while the other half deep-dives in a particular topic or sector to provide in-depth strategies and guidelines. They commonly offer text, images and examples in handy formats, such as printable worksheets, cards, and virtual whiteboards, to help designers and others to absorb the content and apply the strategies to real world tasks. In contrast to the Circular activators, which are often orienting and used to activate a circular mindset, the Circular prompters are generally more extensive and designed to be used in daily work to prompt a focus on circular design strategies during design processes. The tools can facilitate discussions, provide structure to design activities, and stimulate ideation or rational discussions.

4.3. Circular analysts and advisors

Circular analysts and advisors aid rational assessments and prioritisations of designs and circular design strategies. While some of them are focused primarily on assessing current designs and operations to identify circular opportunities, others can be used for assessing new circular ideas and concepts. Typical formats are websites and excel worksheets that provide a structure for how to conduct an assessment. Some of the

tools provide support for manual assessments while others are interactive and provide data processing. In addition to tools that purely help companies to analyse designs and circular design strategies, this tool family includes tools that also provide advice on how to prioritise between the analysed alternatives. Based on the input provided for the assessment, the advisers provide outputs such as recommendations regarding designs with the highest circular potential or the most relevant circular design strategies to address.

4.4. Circular flow visualisers

When designing for circularity, it is key to start thinking in flows and to consider the various materials, stakeholders and activities involved throughout different processes. This tool family covers tools that aid mapping, modelling, and visualisation of circular flows. They can help create an understanding of, for instance, how a product is produced, distributed, used, and circulated; how consumers obtain, use and clear products; and how different stakeholders contribute to various flows in a business ecosystem. The tools are typically printable worksheets, on which the flows are drawn by hand, or tools that provide predefined elements that can help modelling flows on physical or virtual boards. There is

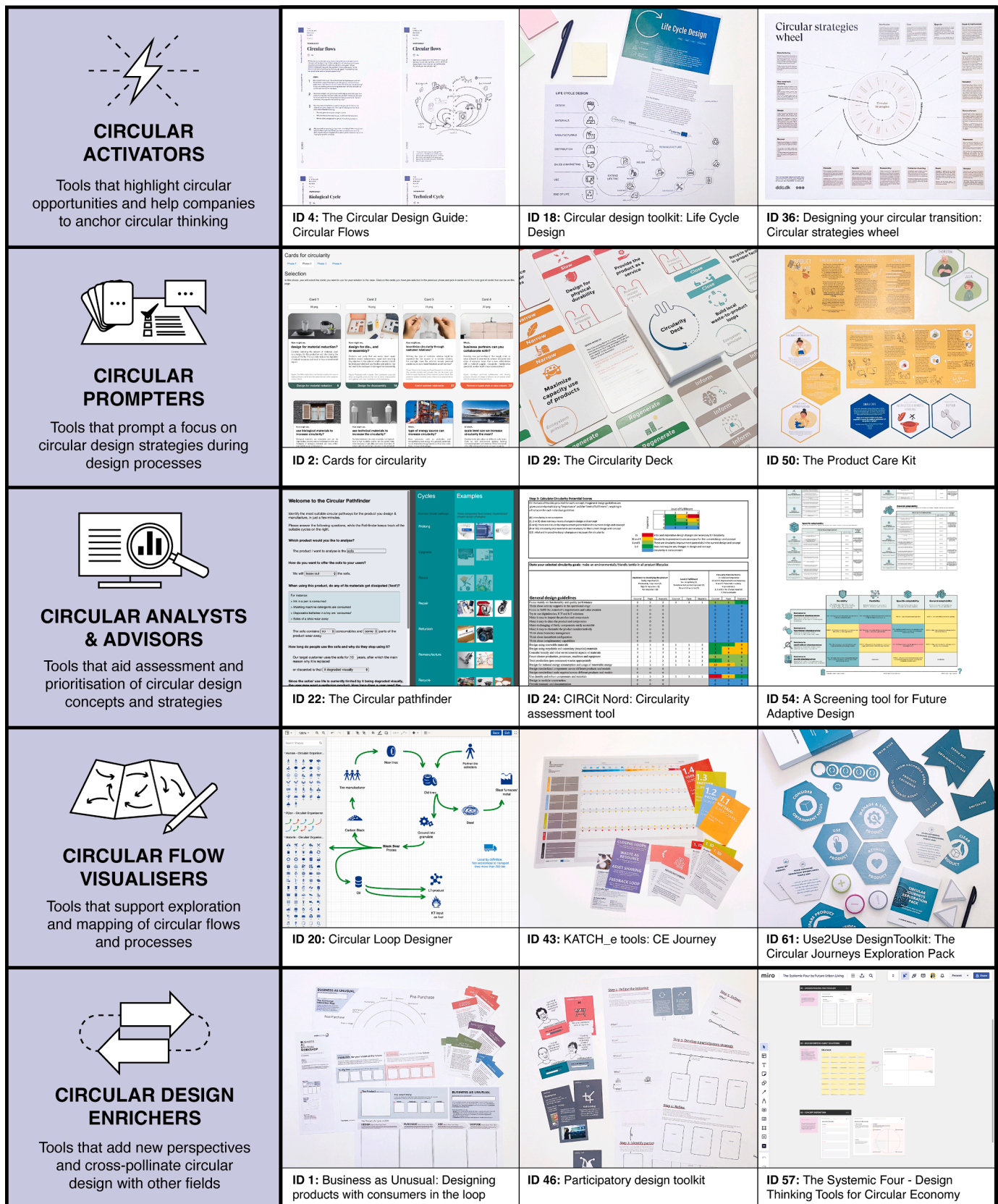


Fig. 7. Examples of typical tools for each tool family. The tool IDs refer to the identification numbers provided in [Appendix A](#).

commonly a modelling language or structure that helps to create a visual output that provides a description of the circular flow in focus.

4.5. Circular design enrichers

Among the circular design tools there are several tools that can be considered to merge the notion of circular design with other perspectives. These tools often centre around other design approaches, such as service design, participatory design and strategic design, to enrich circular design activities with supplementary perspectives. They all cover different topics but are similar in the way they transfer knowledge from other approaches and aim to cross-pollinate circular design with other fields. Since the tools vary in character, the formats also vary; some tools are provided as printable worksheets while other are virtual whiteboards or printable cards.

5. Discussion

The landscape of circular design tools, presented in [Sections 3 and 4](#), are discussed below regarding how easy it is to navigate, how it fits with the evolving role of designers, its relation to adjacent tools, and implications for tool developers and practitioners.

5.1. A challenging landscape to navigate

Although a multitude of circular design tools are readily available, they form a landscape that is both fragmented and constantly evolving with new tools emerging and others becoming inaccessible over time. This poses significant challenges for companies seeking the tools that best suit their needs. This situation can be likened to the one observed by Rossi and colleagues in their review of ecodesign methods and tools, where they noted that “...a lot of methods and tools are available in the market and in prototype versions, among which it is difficult to identify the right one for a company without experiences” (Rossi et al., 2016, p. 369). In addition to this fragmented landscape, comprehending the individual tools and distinguishing them from similar options can also be a perplexing endeavour, as the authors experienced during their analysis. Often, the expected outcomes, required time investments, and other essential details are inadequately described, and a consistent vocabulary for such descriptions is notably lacking.

It is also noteworthy that the tools considered in this review are primarily described by their creators regarding their intended use and expected outcomes rather than actual use and validated outcomes. The tools often lack substantial descriptions of real-world testing or reviews and recommendations from individuals who have applied the tools. There is thus a need to leverage the tools already available, as suggested by van Dam and colleagues in their exploration of circular economy in industrial design research: “...besides proposing new design tools, methods, and frameworks, design researchers should also carefully assess possibilities and limitations of existing ones” (van Dam et al., 2020, p. 13). In addition, it is important that tool testing and evaluations are carried out also by others than the tool creators themselves, to avoid bias.

5.2. A field in transition

As described in the introduction, numerous studies underscore a common pattern within industry—limited adoption of design tools and methods (Jagtap et al., 2014; Pozatti et al., 2020). Although there are several reasons for this, the most basic requirement for a design tool is that it should effectively assist its users during design activities. When reflecting on the current landscape of circular design tools, many of the tools appear to have been developed without a precise understanding of actual company needs, as also concluded by Cambier and colleagues in their review of design support tools for circular buildings (Cambier et al., 2020). This may be due to that many tools have been developed by circular economy advocates to push the concept of circularity out into the world to increase awareness and inspire action. The large proportion

of tools within the family Circular activators underscores this, with its apparent focus on supporting introductory workshops. As the circular economy concept becomes more widespread, there is an increasing need for tools to focus more on implementation, and a step towards this could be to develop more practice-oriented tools, addressing the needs of designers and industry (cf. Bocken et al., 2023).

Furthermore, one can debate whether the current circular design tools are pushing the boundaries far enough to truly facilitate a comprehensive shift towards a circular model. Several of the tools scrutinized in this review, and often a significant amount of the content of the individual tools, appear to be more akin to ‘ecodesign in disguise’ rather than concentrating on genuinely systemic long-lasting changes, which is something that The Ellen MacArthur Foundation (2023), among others, calls for.

5.3. A landscape in a larger landscape

Circular design is more complex compared to linear design and requires more than just designing new products and services (e.g. Hanes-Gadd et al., 2023; Wang et al., 2022; Dokter et al., 2021). A more holistic approach is needed, both with regards to what is being designed (a more complex system), and the timescales of the design process (with more involvement post market release). This implies that new competencies and skills are needed, such as circular systems thinking, circular impact assessment, circular economy collaboration and circular business propositions (Sumter, 2021). Moreover, circular design is about creating the conditions for circularity to manifest. As Dokter et al. (2021) state, a circular design practitioner may act more as a change agent than as an object maker. This poses new challenges and opportunities for designers, who may need to use different types of tools than the ones traditionally used in design. Design tools have typically focused on supporting a creative problem-solving process that involves empathizing, ideating, prototyping, and testing. Many of the 65 circular design tools described in the presented landscape reflect this approach, and they are seemingly built on an assumption that circular design is foremost a creative challenge.

If designers are to become more change agents than object makers, they might need to complement their typical toolbox with other tools that can support them in their new role. While topics such as product lifetime extension, value retention processes through circular loops, and consumer behaviour are well represented in the analysed tools, other relevant topics such as impact assessment (cf. Harris et al., 2021), stakeholder engagement (cf. Kujala et al., 2023), policies (cf. Fitch-Roy et al., 2021) and circular business models (cf. Bocken et al., 2019), are not. Therefore, circular design practitioners may benefit from looking beyond the landscape of circular design tools described in this paper and explore other tools that can help them address circular challenges effectively (cf. Bocken et al., 2023). On a larger scale, organisations can strive to strengthen their overall circular design capability by cultivating a range of specialist competencies with a widespread circular economy understanding (Ellen MacArthur Foundation, 2023).

5.4. Implications for tool developers and practitioners

The conducted tool analysis and the topics discussed in [Sections 5.1–5.3](#), point to several implications for tool developers and practitioners. The authors’ reflections regarding implications of the research are presented in the form of recommendations for tool developers, as well as for practitioners.

Recommendations for tool developers:

I. Maximize utilization of existing tools: Prioritize thorough testing and utilization of existing tools in circular design research and practice. Avoid unnecessary tool duplication by exploring and building upon what’s already available.

II. Promote integration and complementarity: Contribute to the integration, contrast, and linkage of tools. Ideally, old and new tools should be uniformly described and form a comprehensive menu covering all relevant needs. Everyone is invited to make use of the collection and categorisation of tools presented in this article, if deemed valuable.

III. Clarify tool purpose and use: Ensure that both existing and newly developed tools have a clear and well-defined purpose. Clearly articulate how they should be used and their specific contributions to circular design practice.

IV. Secure the sustainability of tools: Commit to maintaining the availability and relevance of tools over time. Providing support for existing tools is crucial for their long-term usefulness.

V. Employ a needs-driven tool development approach: Base the development of new tools on the actual needs of companies and other stakeholders involved in circular design. Prioritize tools that address specific real-world challenges and can be adapted to practical conditions.

VI. Ensure that tools promote systemic, long lasting, impactful changes: There is no time to reduce environmental impact incrementally, focus on tools enabling radical changes.

Recommendations for practitioners:

I. Select tools based on circular design needs: The tool landscape is challenging to navigate. Specify your design needs thoroughly before exploring the various resources since this will make it easier to identify suitable tools.

II. Test tools for practical suitability: Recognize that descriptions of existing tools are often based on their intended use rather than actual effectiveness. Try out tools to form your own opinions and share your experiences with others in your industry.

III. Be ready to adjust the tools and their use to specific needs: While some tools are more flexible than others, they are rarely designed with your exact situation in mind. When needed, adjust and use them in a way that is more meaningful for you.

IV. Prepare for complexity: Understand that tools designed to address complex challenges may also be more intricate to use. Be prepared for a learning curve and time investment.

V. Complement skills with tools: While tools can be valuable, they are not miraculous formulas capable of producing high-quality output without skilled users. Make sure to have a proficient design team that can effectively utilize tools to enhance their work when necessary. The use of tools can, however, also play a role in the educational development of the team, actively contributing to the enhancement of their circular design competencies.

VI. Integrate an action focus: When employing creative circular design tools, ensure there is a concurrent emphasis on the practical implementation of circular ideas. Bridging the gap between creative design and implementation is crucial for successful circular initiatives.

6. Conclusions and future work

This paper provides a synthesised overview of the landscape of circular design tools that uniformly describes the tools' main attributes and supports navigation in the tool landscape. Key contributions are the

compiled list of 65 analysed tools provided in [Appendix A](#) and the division of the tools into five families: Circular activators, Circular prompters, Circular analysts & advisors, Circular flow visualisers, and Circular design enrichers. The research highlights that there is a multitude of tools readily available that can support designers to, for instance, design for prolonged product lifetimes, retained product value, and circular resource flows. However, designers may find it difficult to find and utilise relevant tools as the tool landscape is fragmented and constantly evolving. While this paper provides both an overview of the tools and detailed descriptions of each one, it is important to acknowledge that this information could be made even more accessible to practitioners. One avenue for future work is thus to explore how the tool landscape could be presented in a format that enables searching or sorting of the tools. Furthermore, disseminating it through a more industry-oriented channel than a scientific paper would also benefit practitioners. Regarding future tool development, the findings suggest that tool developers should focus less on introducing circularity to designers and instead aim to support companies in implementing circular design practices.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT to refine and check language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Oskar Rexfelt: Writing – original draft, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anneli Selvefors:** Writing – original draft, Visualization, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Oskar Rexfelt reports financial support was provided by The Kamprad Family Foundation. Anneli Selvefors reports financial support was provided by The Kamprad Family Foundation. If there are other authors, they 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

All data is included in the appendices

Acknowledgements

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
1	Business as Unusual: Designing products with consumers in the loop	To explore new circular customer journeys based on customer touchpoints and to identify future circular PSS strategies.	Design insights gained; Ideas/concepts created	Printable cards; Printable worksheet(s)	Ideation prompts	General scope	Extensive content	Intermediate complexity	Free	RECODE Network	https://figshare.com/articles/dataset/BAU_Workshop_Materials_and_Interaction_Cards_v1/4,749,727	Circular design enrichers
2	Cards for circularity	To explore circular design strategies and come up with ideas.	Ideas/concepts created	Website	Ideation prompts; Inspirational examples	General scope	Intermediate content	Low complexity	Free	Giliam Dokter	https://giliam.shinyapps.io/10_CircularityCards/	Circular prompters
3	The Circular Design Guide: Barriers Breakdown	To discuss circular goals, plan the approach, and ideate on how to overcome expected challenges.	Goals formulated; Challenges identified; Plan formulated	Printable worksheet(s)	Discussion prompts	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/j08cti4ivmlr-8yfaih/@/preview/1?o	Circular activators
4	The Circular Design Guide: Circular Flows	To reflect on product-related opportunities in relation to technical and biological circular flows.	Opportunities identified	Printable worksheet(s)	Strategy/ Guideline collection	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/11lpr2l0gled-s27447/@/preview/1?o	Circular activators
5	The Circular Design Guide: Circular opportunities	To identify circular opportunities based on circular strategies.	Opportunities identified	Printable worksheet(s)	Strategy/ Guideline collection; Ideation prompts	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/1u4xpwjwy2g-7imev/@/preview/1?o	Circular activators
6	The Circular Design Guide: Circular strategies workshop	To explore, design and rationalise circular ideas during a workshop session.	Opportunities identified	Printable cards; Printable worksheet(s)	Strategy/ Guideline collection; Ideation prompts; Inspirational examples	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://www.circulardesignguide.com/resources	Circular activators
7	The Circular Design Guide: Ideas Capture	To generate and document ideas for circular designs.	Ideas/concepts created	Printable worksheet(s)	Ideation prompts	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/abt7j0py5e32-i13way/@/preview/1?o	Circular activators
8	The Circular Design Guide: Product journey mapping	To map a product's journey throughout its life, including multiple use-cycles.	Design insights gained	Printable worksheet(s)	Discussion prompts	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/gf9p70ze9886-7q2bch/@/preview/1?o	Circular activators
9	The Circular Design Guide: Safe & Circular Materials Journey Mapping	To explore what implications materials choices have at each phase of a product's life cycle and which potential chemical risks that can make the design unfit for a circular economy.	Designs assessed; Opportunities identified	Printable worksheet(s)	Process modelling support; Discussion prompts	General scope	Orienting content	Intermediate complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/whhb5ynunli-jookrn/@/preview/1?o	Circular activators

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
10	The Circular Design Guide: Safe & Circular Product Redesign Workshop	To identify chemicals of concern that can be found in a product, and to generate ideas and concepts to design out such substances.	Challenges identified; Ideas/concepts created	Printable cards; Printable worksheet(s)	Discussion prompts; Strategy/ Guideline collection; Inspirational examples	General scope	Orienting content	Intermediate complexity	Free	Ellen MacArthur Foundation; IDEO	https://www.circulardesignguide.com/resources	Circular prompters
11	The Circular Design Guide: Service Flip	To explore opportunities for shifting from selling a product to offering a service.	Opportunities identified	Printable worksheet(s)	Discussion prompts	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/aq57c67hm9hj-7wryh0/@/preview/1?o	Circular activators
12	The Circular Design Guide: Smart material choices	To explore a product's materials and to identify opportunities for choosing materials fit for the circular economy using a decision tree.	Challenges identified; Opportunities identified	Printable worksheet(s)	Discussion prompts; Ideation prompts	General scope	Orienting content	Low complexity	Free	Ellen MacArthur Foundation; IDEO	https://emf.thirdlight.com/link/a2zpj0t0ou2g-ik89s/@/preview/1?o	Circular activators
13	Circular Design Guide: Circular Ventures workshop	To support actors from multiple organisations to identify opportunities for joint circular ventures in a workshop.	Opportunities identified	Printable cards	Strategy/ Guideline collection; Inspirational examples; Assessment support	General scope	Orienting content	Intermediate complexity	Free	Ellen MacArthur Foundation; IDEO	https://www.circulardesignguide.com/resources	Circular activators
14	Circular design radar chart	To reflect on how circular a product is in relation to 11 aspects using a radar chart.	Designs assessed; Strategies/ guidelines prioritised; Visual representation created	Printable worksheet(s)	Strategy/ Guideline collection; Assessment support	General scope	Orienting content	Low complexity	Registration required	Reframe Design Studio	https://mailchi.mp/c080f5dad907/freeguide	Circular activators
15	Circular design toolkit: Circular Design Brief	To define a circular design brief based on user needs and environmental impacts.	Challenges identified; Goals formulated	Printable worksheet(s)	Discussion prompts	General scope	Orienting content	Low complexity	Free	EcoDesign Circle	https://circulardesign.tools	Circular activators
16	Circular design toolkit: Ecodesign Assessment Product	To assess a current product, benchmark products, or compare ideas and concepts against a current product using a radar chart.	Designs assessed; Visual representation created	Printable worksheet(s)	Assessment support	General scope	Intermediate content	Intermediate complexity	Free	EcoDesign Circle	https://circulardesign.tools	Circular analysts and advisors
17	Circular design toolkit: Ecodesign Assessment Services	To assess a current service, benchmark services, or compare ideas and concepts against a current service using a radar chart.	Designs assessed; Visual representation created	Printable worksheet (s); Virtual Whiteboard	Assessment support	General scope	Intermediate content	Intermediate complexity	Free	EcoDesign Circle	https://circulardesign.tools	Circular analysts and advisors

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
18	Circular design toolkit: Life Cycle Design	To explore circular opportunities starting from inner loops and moving outwards.	Opportunities identified	Printable worksheet (s); Virtual Whiteboard	Discussion prompts	General scope	Orienting content	Low complexity	Free	EcoDesign Circle	https://circulardesign.tools	Circular activators
19	Circular design toolkit: Life Cycle Discussion	To explore opportunities for circular products and services.	Opportunities identified	Printable worksheet (s); Virtual Whiteboard	Discussion prompts; Ideation prompts	General scope	Orienting content	Low complexity	Free	EcoDesign Circle	https://circulardesign.tools	Circular activators
20	Circular Loop Designer	To easily sketch material loops on an online whiteboard.	Visual representation created	Website	Process modelling support; Inspirational examples; Process modelling support	General scope	Orienting content	Low complexity	Registration required	Saxion Hogeschool	https://businessmodellab.nl/en/tools	Circular flow visualisers
21	Circular Mindset (& Impact Business Model Canvas)	To generate project and business ideas based on circular strategies.	Opportunities identified; Plan formulated	Virtual Whiteboard	Strategy/ Guideline collection; Discussion prompts; Ideation prompts	General scope	Orienting content	Intermediate complexity	Free	Laura Duarte	https://miro.com/miroverse/circular-mindset-and-impact-business-model-canvas/	Circular prompters
22	The Circular pathfinder	To identify suitable circular strategies for a product and a preferred revenue model.	Strategies/ guidelines prioritised	Website	Assessment support; Data processing; Strategy/ Guideline collection; Inspirational examples	General scope	Orienting content	Low complexity	Free	ResCoM consortium; IDEAL&CO Explore BV	https://www.ideal-co.nl/pathfinder/	Circular analysts and advisors
23	CIRCit Nord: Circular strategies scanner	To generate ideas for increased circularity based on circular strategies.	Opportunities identified	Printable worksheet(s)	Strategy/ Guideline collection	General scope	Orienting content	Low complexity	Free	CIRCit Nord	https://circuitnord.com/tools/the-circular-strategies-scanner2/	Circular activators
24	CIRCit Nord: Circularity assessment tool	To evaluate developed concepts based how well they fulfil key guidelines, resulting in a Circularity Score for each concept.	Designs assessed	Excel worksheet(s)	Strategy/ Guideline collection; Assessment support	General scope	Extensive content	Intermediate complexity	Free	CIRCit Nord	https://circuitnord.com/tools/circularity-assessment-tool/	Circular analysts and advisors
25	The Circular Toolbox: Generating key insights	To synthesise research data and identify and describe design challenges. For the apparel industry.	Challenges identified	Virtual Whiteboard	Assessment support; Discussion prompts	General scope	Intermediate content	Intermediate complexity	Registration required	Circle Economy	https://www.thecirculartoolbox.com/all-resources	Circular design enrichers
26	The Circular Toolbox: Research wall	To identify and understand one's target customer and market, by aggregating data from research activities. For the apparel industry.	Design insights gained	Virtual Whiteboard	Assessment support; Discussion prompts	Inner loops	Extensive content	High complexity	Registration required	Circle Economy	https://www.thecirculartoolbox.com/all-resources	Circular design enrichers

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
27	Circularity calculator	To assess, optimise, and visualise the circularity of your products based on material flows.	Designs assessed; Visual representation created	Website	Assessment support; Data processing	General scope	Extensive content	High complexity	Registration required for free version; Purchase required for full version	ResCoM consortium; IDEAL&CO Explore BV	http://www.circularitycalculator.com	Circular analysts and advisors
28	Circularity check	To assess and score the circularity of products and operations across certain circular indicators using a checklist.	Designs assessed	Website	Assessment support; Strategy/Guideline collection; Data processing	General scope	Extensive content	High complexity	Registration required	Ecopreneur.eu	https://ecopreneur.eu/circularity-check-landing-page/	Circular analysts and advisors
29	The Circularity Deck	To identify opportunities based on circular strategies and generate ideas on three levels: product, business model and ecosystem.	Ideas/concepts created; Visual representation created	Virtual Whiteboard; Physical cards; Printable worksheet(s)	Strategy/Guideline collection; Inspirational examples	General scope	Intermediate content	Intermediate complexity	Free online access; Purchase required for hard copies	Circular strategies	https://miro.com/app/board/uXjVMTI5U7s=/	Circular prompters
30	Circulate it!	To understand factors that hinder a product from being recirculated by users, and generate ideas to enable recirculation.	Design insights gained; Opportunities identified	Printable cards; Printable worksheet(s)	Assessment support; Ideation prompts; Discussion prompts	Inner loops	Extensive content	High complexity	Free	Elin Ljungberg; Sandra Sköld	https://odr.chalmers.se/server/api/core/bitstreams/5f2b569d-d283-44c0-ac07-39aa94ae8530/content	Circular prompters
31	Design Principles for Waste Prevention and Systems-Thinking: Checklist	To identify opportunities to design out waste based on key principles using a checklist.	Opportunities identified	Printable worksheet(s)	Ideation prompts; Strategy/Guideline collection	General scope	Orienting content	Low complexity	Free	National Zero Waste Council	http://www.nzwc.ca/Documents/WastePreventionInfographics-ChecklistKeyQuestions.pdf	Circular activators
32	A Design for Remanufacture toolkit	To assess an existing product based on remanufacturing guidelines, or design a new one.	Designs assessed; Ideas/concepts created	Printable cards	Strategy/guideline collection; Inspirational examples	Middle loops	Extensive content	Low complexity	Free	Scottish Institute for Remanufacturing	https://www.scot-reman.ac.uk/tools/design-for-remanufacture-toolkit/	Circular prompters
33	Design for X tool	To get an overview of, and select relevant, circular and sustainable strategies.	Strategies/guidelines prioritised	Website	Strategy/Guideline collection; Discussion prompts; Data processing	General scope	Extensive content	Low complexity	Free	Alessio Franconi	https://www.circulardesign.it/design-for-x/#Reuse	Circular prompters
34	Designing your circular transition: Brainstorm Sudoku	To generate new ideas based on an identified circular challenge or opportunity.	Ideas/concepts created	Printable cards; Printable worksheet(s)	Strategy/Guideline collection; Ideation prompts	General scope	Intermediate content	Intermediate complexity	Free	DDC – Danish Design Center	https://ddc.dk/tools/tool-03-brainstorm-sudoku/	Circular prompters
35	Designing your circular transition:	To describe and refine a circular solution in relation to pre-use,	Visual representation created; Ideas/	Printable worksheet(s)	Process modelling support	General scope	Orienting content	Low complexity	Free	DDC – Danish Design Center	https://ddc.dk/tools/tool-04-circular-storyboard/	Circular activators

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
36	Circular Storyboard Designing your circular transition: Circular strategies wheel	during use, and post-use. To identify circular opportunities and challenges over a products lifespan based on circular strategies.	concepts refined Opportunities identified	Printable worksheet(s)	Strategy/ Guideline collection	General scope	Intermediate content	Low complexity	Free	DDC – Danish Design Center	https://ddc.dk/tools/tool-01-circular-strategies-wheel/	Circular activators
37	Designing your circular transition: Expanded Circular Storyboard	To visualise the basic components (e.g. material flows and partner roles) of a future circular concept.	Ideas/concepts refined; Visual representation created	Printable worksheet(s)	Process modelling support; Assessment support	General scope	Orienting content	Intermediate complexity	Free	DDC – Danish Design Center	https://ddc.dk/tools/tool-07-expanded-circular-storyboard/	Circular flow visualisers
38	Disassembly map (FRI adapted)	To assess, score, and improve product repairability	Designs assessed; Visual representation created	Virtual Whiteboard	Process modelling support	Middle loops	Extensive content	High complexity	Free	Lotte Fontijne	https://miro.com/app/board/o9J_lyEPMrU=/	Circular flow visualisers
39	Disrupt Design: Circular Economy ReDesign Workshop Kit	To conduct a workshop to generate a concept for how a product or system can become circular.	Design insights gained; Ideas/concepts created	Printable worksheet(s)	Strategy/ Guideline collection; Discussion prompts; Ideation prompts; Process modelling support	General scope	Intermediate content	Intermediate complexity	Registration required	Disrupt Design	https://www.disruptdesign.co	Circular activators
40	Disrupt Design: 3D Framework for Sustainability in Business Free Starter Kit	To assess the current state, explore circular and sustainable opportunities, and identify actions to move forward.	Goals formulated; Challenges identified; Plan formulated	Printable worksheet(s)	Assessment support; Strategy/ Guideline collection; Discussion prompts	General scope	Intermediate content	Intermediate complexity	Registration required	Disrupt Design	https://www.disruptdesign.co	Circular activators
41	IKEA Circular design guide	To assess a current design and identify opportunities for improvement. For the furnishing industry.	Designs assessed; Strategies/guidelines prioritised	Website	Strategy/ Guideline collection; Assessment support; Discussion prompts; Inspirational examples; Data processing	General scope	Orienting content	Low complexity	Free	IKEA	http://circularityblueprint.ikea.net	Circular analysts and advisors
42	KATCH_e tools: CE Designer	To assess the relevance of circular design strategies and to configure and quantitatively compare concepts based on the prioritised strategies.	Strategies/guidelines prioritised; Designs assessed	Website	Strategy/ Guideline collection; Assessment support; Data processing	General scope	Intermediate content	High complexity	Registration required	KATCH_e	https://www.katche.eu/knowledge-platform/	Circular analysts and advisors

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
43	KATCH_e tools: CE Journey	To describe and analyse the journey for a product/ service/ system and different stakeholders, to explore touchpoints, and to identify opportunities for improvements.	Visual representation created; Opportunities identified	Printable cards; Printable worksheet(s)	Process modelling support; Ideation prompts	General scope	Extensive content	High complexity	Registration required	KATCH_e	https://www.katche.eu/knowledge-platform/	Circular flow visualisers
44	Life Cycle Analysis	To generate and prioritise circular opportunities for a product.	Design insights gained; Opportunities identified	Virtual Whiteboard	Discussion prompts; Persona descriptions; Ideation prompts	General scope	Orienting content	Low complexity	Free	Minou Schillings	https://miro.com/miroverse/life-cycle-analysis/	Circular activators
45	Nike circularity guide	To assess current designs and explore circular and sustainable opportunities.	Designs assessed; Ideas/concepts created	Printable worksheet (s); Website	Discussion prompts; Ideation prompts; Strategy/ Guideline collection; Inspirational examples	General scope	Intermediate content	Intermediate complexity	Free	Nike	https://www.nikecirculardesign.com	Circular prompters
46	Participatory design toolkit	To support development of circular initiatives through participatory design.	Design insights gained; Ideas/ concepts created; Visual representation created	Printable cards; Printable worksheet(s)	Discussion prompts; Process modelling support; Persona descriptions; Ideation prompts	General scope	Extensive content	Intermediate complexity	Free	Fieke Thijssen	https://repository.tudelft.nl/islandora/object/uuid%3A65e494d9-06b9-40c4-8d18-b152eafc1b6f?collection=education	Circular design enrichers
47	Planetary Design Circle	To set the scene for the design work by considering the four stakeholders: people, planet, business, and design.	Design insights gained; Ideas/ concepts created	Printable worksheet(s)	Discussion prompts	General scope	Intermediate content	Intermediate complexity	Free	Fraunhofer IZM	https://re-fream.eu/planetary-design-circle-a-holistic-and-strategic-design-tool/	Circular design enrichers
48	Product-as-a-Service toolbox: Customer journey mapping: Product-as-a-service	To envision the customer journey of a PaaS offering.	Design insights gained; Opportunities identified	Printable worksheet(s)	Ideation prompts	Inner loops	Intermediate content	Low complexity	Registration required	Stena Circular Consulting; Cradlenet	https://www.stenarecycling.se/circularconsulting/inspiration-insikter/product-as-a-service/download-paas/	Circular prompters
49	Product-as-a-Service toolbox: Product assessment form and ideation exercise	To identify challenges and opportunities to turn a product into a PaaS offering.	Design insights gained; Opportunities identified; Ideas/concepts created	Printable worksheet(s)	Assessment support; Ideation prompts	Inner loops	Intermediate content	Low complexity	Registration required	Stena Circular Consulting; Cradlenet	https://www.stenarecycling.se/circularconsulting/inspiration-insikter/product-as-a-service/download-paas/	Circular prompters
50	The Product Care Kit	To gain inspiration about and design for product care.	Design insights gained; Ideas/ concepts created	Printable cards	Strategy/ Guideline collection; Discussion prompts; Ideation prompts; Persona descriptions; Inspirational examples	Middle loops	Extensive content	Intermediate complexity	Free	Mahana Tuimaka	https://designforproduct.care/ueber-uns/	Circular prompters

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
51	RecyClass analysis tool	To assess the recyclability of plastic packaging and to identify opportunities for making packaging fit for recycling. For the plastic packaging industry.	Designs assessed; Opportunities identified	Website	Assessment support; Strategy/Guideline collection; Data processing	Outer loops	Extensive content	High complexity	Free	Plastics Recyclers Europe	https://recyclclass.eu/recyclability/online-tool/	Circular analysts and advisors
52	REDIG tool	To get relevant design strategies and guidelines based on your product type, using a decision tree.	Strategies/guidelines prioritised	Excel worksheet(s)	Assessment support	General scope	Intermediate content	Low complexity	Free	Siri Willskytt; Sergio Brambila-Macias	https://www.mdpi.com/2071-1050/12/12/4953/s1	Circular analysts and advisors
53	The Round Table Management Guidelines	To assess designs and to consider design strategies to identify opportunities for improvement using a checklist. For the plastic packaging industry.	Designs assessed; Opportunities identified	Printable worksheet(s)	Assessment support; Strategy/Guideline collection; Ideation prompts; Discussion prompts	General scope	Extensive content	High complexity	Free	Round Table for Eco Design of Plastic Packaging	https://ecodesign-packaging.org/en/downloads/	Circular prompters
54	A Screening tool for Future Adaptive Design	To assess how well an existing design can resist obsolescence and to identify opportunities to make a design adaptable to future requirements to reduce risks of premature obsolescence.	Designs assessed	Excel worksheet(s)	Discussion prompts; Assessment support	Middle loops	Extensive content	High complexity	Free	RISE Research Institutes of Sweden	https://www.ri.se/en/what-we-do/expertises/future-adaptive-design-for-a-circular-economy	Circular analysts and advisors
55	A Service-design Tool for Repair	To assess and document actions, observations, and decisions required during troubleshooting, and to design a product that is easy to diagnose and repair using troubleshooting enablers.	Challenges identified; Ideas/concepts created	Printable worksheet(s)	Discussion prompts	Middle loops	Intermediate content	Intermediate complexity	Free	Grace Kane	https://gracemkane.com/2017/04/28/a-service-design-tool-for-repair/	Circular prompters
56	Sharing economy design cards	To create concepts for a sharing economy platform or service and to evaluate existing sharing economy services.	Challenges identified; Ideas/concepts created; Designs assessed	Virtual Whiteboard; Printable cards; Printable worksheet(s)	Strategy/Guideline collection; Discussion prompts; Inspirational examples	Inner loops	Intermediate content	Intermediate complexity	Free	Sharing & Caring - COST Action CA16121	https://www.sharingeconomy.cards	Circular prompters
57	The Systemic Four - Design Thinking Tools for Circular Economy	To develop, detail, and assess circular products and services by considering the four personas: humans, business, local context, and ecosystem.	Challenges identified; Ideas/concepts created; Designs assessed	Virtual Whiteboard	Ideation prompts; Discussion prompts; Process modelling support; Assessment support	General scope	Intermediate content	Intermediate complexity	Free	Future Urban Living	https://miro.com/miroverse/the-systemic-four-design-thinking-tools-for-circular-economy/	Circular design enrichers

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CIRCULAR DESIGN TOOLS												
ID	Tool name	Purpose	Expected outcome(s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source	Tool family
58	The Ten - card deck	To identify important areas to address and to explore circular opportunities. For the apparel industry.	Opportunities identified	Physical cards	Strategy/ Guideline collection	General scope	Orienting content	Low complexity	Purchase required	Centre for Circular Design, Chelsea College of Art & Design	https://www.circulardesign.org.uk/research/ten/	Circular prompters
59	Ten tips to design easily recyclable packaging	To assess how easily recyclable packagings are based on detailed design guidelines using a checklist. For the packaging industry.	Designs assessed	Printable worksheet(s)	Strategy/ Guideline collection; Assessment support	Outer loops	Intermediate content	Low complexity	Free	Ecoembes	http://www.cibr.es/ka/apps/cibr/docs/decalogo-reciclabilidad.ingles.pdf	Circular prompters
60	Upstream Innovation: packaging solution workshop	To generate, prioritise, and detail ideas and concepts for packagings based on circular strategies. For the packaging industry.	Ideas/concepts created; Designs assessed; Plan formulated	Virtual Whiteboard	Strategy/ Guideline collection; Ideation prompts; Discussion prompts; Inspirational examples	General scope	Intermediate content	Intermediate complexity	Free	Ellen MacArthur Foundation	https://miro.com/miroverse/upstream-innovation-packaging-solution-workshop/	Circular prompters
61	The Use2Use Design Toolkit: Circular Journeys Exploration Pack	To map circular consumption processes and identify opportunities for products and services for circular consumption.	Visual representation created; Opportunities identified	Virtual Whiteboard; Physical cards; Printable cards	Process modelling support	Inner loops	Extensive content	High complexity	Free online access; Free printable version; Purchase required for hard copies	Chalmers University of Technology	www.use2use.se	Circular flow visualisers
62	The Use2Use Design Toolkit: Circular Designs Evaluation Pack	To assess and compare circular ideas and concepts.	Designs assessed	Virtual Whiteboard; Printable worksheet(s)	Assessment support	Inner loops	Orienting content	Low complexity	Free online access; Free printable version; Purchase required for hard copies	Chalmers University of Technology	www.use2use.se	Circular prompters
63	The Use2Use Design Toolkit: Circular Designs Ideation Pack	To generate design ideas to enable reuse in the everyday	Ideas/concepts created	Virtual Whiteboard; Physical cards; Printable cards	Strategy/ Guideline collection; Ideation prompts; Inspirational examples	Inner loops	Extensive content	Low complexity	Free online access; Free printable version; Purchase required for hard copies	Chalmers University of Technology	www.use2use.se	Circular prompters
64	The Use2Use Design Toolkit: Multiple Use-cycles Exploration Pack	To identify design challenges of particular relevance to products that will be used by sequences of users, and to identify design opportunities.	Design insights gained; Opportunities identified	Virtual Whiteboard; Physical cards; Printable cards	Discussion prompts	Inner loops	Intermediate content	Low complexity	Free online access; Free printable version; Purchase required for hard copies	Chalmers University of Technology	www.use2use.se	Circular prompters
65	30 ideas to kickstart your circular business	To generate ideas for circular products, services and business models.	Ideas/concepts created	Printable cards	Ideation prompts; Inspirational examples	General scope	Intermediate content	Low complexity	Free	Knowledge Transfer Network (KTN)	https://www.innovationcanvas.ktn-uk.org/resources/30-ideas-to-kickstart-your-circular-business	Circular activators

Appendix B

ATTRIBUTES USED TO DESCRIBE THE SHORTLIST OF CIRCULAR DESIGN TOOLS											
	Tool name	Purpose	Expected outcome (s)	Format(s)	Component(s)	Scope	Content extensiveness	Use complexity	Access	Provided by	Source
Description	The name of tool (including the name of the overall resource if it is part of a collection of tools)	A short description of what the tool is for	The character of the expected results	The overall format of the tool	The building blocks of the tool, the 'active ingredients'	If it is a general tool or if it focuses on a particular circular loop	How extensive (breadth & depth) the content is	How quick and easy it is to use the tool, including preparations needed	Whether the tool is free to access, and if registration is required	The person (s) or organisation (s) who provides the tool	Where to find the tool
Range of values	-	-	Challenges identified; Opportunities identified; Goals formulated; Plan formulated; Design insights gained; Strategies/guidelines prioritised; Ideas/concepts created; Ideas/concepts refined; Visual representation created; Designs assessed	Printable worksheet(s); Printable cards; Physical cards; Website; Virtual Whiteboard; Excel worksheet(s)	Strategy/Guideline collection; Discussion prompts; Ideation prompts; Assessment support; Inspirational examples; Process modelling support; Data processing; Persona descriptions	General; Inner (Reuse, share); Middle (repair, remanufacture); Outer (recycling)	Orienting; Intermediate; Extensive	Low; Intermediate; High	Free; Registration required; Purchase required	-	-
Single-valued /Multi-valued	Single-valued	Single-valued	Multi-valued	Multi-valued	Multi-valued	Single-valued	Single-valued	Single-valued	Multi-valued	Multi-valued	Single-valued

References

- Ahmad, S., Wong, K.Y., Tseng, M.L., Wong, W.P., 2018. Sustainable product design and development: a review of tools, applications and research prospects. *Resour. Conservat. Recycl.* 132, 49–61.
- Bocken, N., Baldassarre, B., Keskin, D., & Carel Diehl, J. (2023) Design thinking tools to catalyse sustainable circular innovation. In Lehtimäki, H., Aarikka-Stenroos, L., Jokinen, A., & Jokinen, P. (Eds.). (2023). *The Routledge Handbook of Catalysts for a Sustainable Circular Economy* (1st ed.). Routledge.
- Bocken, N., Short, S., Rana, S., Evans, S., 2013. A value mapping tool for sustainable business modelling. *Corp. Governance* 13 (5), 482–497.
- Bocken, N., Strupeit, L., Whalen, K., Nußholz, J., 2019. A review and evaluation of circular business model innovation tools. *Sustainability*. 11 (8), 2210.
- Brezet, H., van Hemel, C., 1997. *Ecodesign: A Promising Approach to Sustainable Production and Consumption*. United Nations Environment Programme, Paris, France.
- Camacho-Otero, J., Selvefors, A., Boks, C., 2019. Circular design tools: (how) do they understand the consumer?. In: In Proceedings of the 3rd PLATE 2019 conference on Product Lifetimes and the Environment, Berlin, Germany. TU Berlin University Press, Berlin, pp. 18–20. September.
- Cambier, C., Galle, W., De Temmerman, N., 2020. Research and development directions for design support tools for circular building. *Buildings* 10 (8), 142.
- Cardoso Chrispim, M., Mattsson, M., Ulvenblad, P., 2023. The underrepresented key elements of circular economy: a critical review of assessment tools and a guide for action. *Sustain. Prod. Consum.* 35, 539–558.
- Dervishaj, A., Gudmundsson, K., 2024. From LCA to circular design: a comparative study of digital tools for the built environment. *Resour. Conservat. Recycl.* 200, 107291.
- Dey, P.K., Malesios, C., Chowdhury, S., Saha, K., Budhwar, P., De, D., 2022. Adoption of circular economy practices in small and medium-sized enterprises: evidence from Europe. *Int. J. Prod. Econ.* 248, 108496.
- Dokter, G. (2023) *Circular Design Through Co-creation: Exploring Perspectives and Future Directions for Design in a Circular Economy*. Doctoral thesis. Department of Architecture and Civil Engineering, Chalmers University of Technology.
- Dokter, G., Thuvander, L., Rahe, U., 2021. How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy. *Sustain. Prod. Consum.* 26, 692–708.
- Dokter, G., Van Stijn, A., Thuvander, L., Rahe, U., 2020. Cards for circularity: towards circular design in practice. In: *IOP Conference Series: Earth and Environmental Science*, 588. IOP Publishing, 042043.
- Doughnut Economics Action Lab (2023). Doughnut design for business taster tool. <https://doughnuteconomics.org/tools/206>. Accessed 2023-11-25.
- Ellen MacArthur Foundation (2023) Adaptive strategy for circular design. <https://ellen-macarthurfoundation.org/adaptive-strategy-6-tools>. Accessed 2023-08-05.
- Fitch-Roy, O., Benson, D., Monciardini, D., 2021. All around the world: assessing optimality in comparative circular economy policy packages. *J. Clean. Prod.* 286, 125493.
- Gericke, K., Eckert, C., & Stacey, M. (2017) What do we need to say about a design method? In proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 7: Design Theory and Research Methodology, Vancouver, Canada, 21–25 August 2017.
- Hanes-Gadd, M., Bakker, C., & Charnley, F. (2023) Circular design in practice: eight levers for change. *Handbook of the Circular Economy: Transitions and Transformation*, 97.
- Harris, S., Martin, M., Diener, D., 2021. Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy. *Sustain. Prod. Consum.* 26, 172–186.
- Idemat (2023) Idemat app. <https://idematapp.com>. Accessed 2023-11-25.
- Jagtap, S., Warell, A., Hiort, V., Motte, D., & Larsson, A. (2014) Design methods and factors influencing their uptake in product development companies: a review. In DS 77: Proceedings of the DESIGN 2014 13th International Design Conference.
- Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. *Resour. Conservat. Recycl.* 127, 221–232.
- Kujala, J., Heikkinen, A., & Blomberg, A. (2023) Stakeholder Engagement in a Sustainable Circular Economy: Theoretical and Practical Perspectives. Palgrave Macmillan, Switzerland.
- Pieroni, M.P., McAloone, T.C., Pigosso, D.C., 2019. Business model innovation for circular economy and sustainability: a review of approaches. *J. Clean. Prod.* 215, 198–216.
- Pigosso, D.C.A., McAloone, T.C., Rozenfeld, H., 2015. Characterization of the state-of-the-art and identification of main trends for Ecodesign Tools and Methods: classifying three decades of research and implementation. *J. Indian Inst. Sci.* 95 (4), 405–428.
- Pigosso, D., & McAloone, T. (2017) How can design science contribute to a circular economy? In DS 87-5 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 5: Design for X, Design to X, Vancouver, Canada, 21–25.08. 2017 (pp. 299–307).
- Pozzatti, M., Bernardes, M.M.E.S., Vieira, D.R., Chain, M.C., 2020. Frame conditions for implementing design methods in the product development industry. *Int. J. Product Dev.* 24 (4), 297–319.
- Rossi, M., Germani, M., Zamagni, A., 2016. Review of ecodesign methods and tools. Barriers and strategies for an effective implementation in industrial companies. *J. Clean. Prod.* 129, 361–373.

- Royo, M., Chulvi, V., Mulet, E., Ruiz-Pastor, L., 2023. Analysis of parameters about useful life extension in 70 tools and methods related to eco-design and circular economy. *J. Ind. Ecol.* 27 (2), 562–586.
- Sumter, D., de Koning, J., Bakker, C., Balkenende, R., 2021. Key competencies for design in a circular economy: exploring gaps in design knowledge and skills for a circular economy. *Sustainability*. 13 (2), 776.
- van Dam, K., Simeone, L., Keskin, D., Baldassarre, B., Niero, M., Morelli, N., 2020. Circular economy in industrial design research: a review. *Sustainability*. 12 (24), 10279.
- van den Berg, M.R., & Bakker, C.A. (2015) A product design framework for a circular economy. In conference proceedings of Product Lifetimes And The Environment 2015, pp. 365–379.
- Wang, J.X., Burke, H., Zhang, A., 2022. Overcoming barriers to circular product design. *Int. J. Prod. Econ.* 243, 108346.
- Webster, K. (2017). *The Circular economy: A wealth of Flows*. 2nd edition. Ellen MacArthur Foundation, United Kingdom.
- Whalen, K. (2017). Risk & race: creation of a finance-focused circular economy serious game. In *PLATE: Product Lifetimes and the Environment* (pp. 422–425). IOS Press.