Digital assets and tools for Circular value chains and manufacturing products

Deliverable D2.4

DaCapo agile methodology for sustainability and circularity enhancement

Deliverable Lead: TNO

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Document Control Page	
Title	DaCapo agile methodology for sustainability and circularity enhancement
Lead Beneficiary	TNO
Description	Document that outlines the backbone of the DaCapo Agile Methodology and how it was developed. The methodology itself consists of a (separate) PowerPoint Presentation and this document describes how the Agile Methodology was developed and how the different major elements are connected. Consequently this document describes how the DaCapo Agile Methodology may help SMEs in adopting circularity strategies and principles.
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Danusuya Pachimuthu	POLIMI	V0.9	28/10/2024
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Revision history

Version	Author(s)	Changes	Date
0.9	Nick Oostervink	Wrote the document	10/10/2024
0.9	Danusuya Pachimuthu	Reviewed and commented	28/10/2024
1	Nick Oostervink	Processed comments	29/10/2024

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Executive Summary

This document outlines the DaCapo Agile Methodology, and specifically describes how the Agile Methodology was developed. The Methodology serves as an entrance for SME's to be guided along a multitude of different materials, knowledge, and tools that are available for them to become more circular. The methodology also included a guide on how to navigate the DaCapo outcomes to highlight towards SME's what developments are currently ongoing and will deliver results in the future.

Importantly, the Agile Methodology is a clickable PDF that allows SMEs to find the relevant content dependent on their specific "circularity maturity". As in: a manufacturer that has recently heard of circularity may use the methodology to get more acquainted with its basic principles and tools that may help that specific SME to adopt some first circular practices. At the same time the methodology is agile in the sense that a more "advanced" SME (e.g. Fairphone) that has already quite some progression towards a circular product, to use the methodology to focus for example on specific elements in their production processes or supply chain.

Finally, the Agile Methodology presented in the clickable PDF will also be uploaded as an editable Microsoft Powerpoint document. This will allow the document to be adjusted by specific parties such as potentially Circonnect in NL to adopt the methodology and to make it fit for their specific customer segment. In this way this public deliverable can be distributed globally by all partners of the DaCapo consortium in an attempt to achieve successful adoption by SMEs seeking to improve the circularity of their products and or processes.

1. Agile Methodology to support uptake of Circularity in Manufacturing Industry

1.1. Task 2.1 & Deliverable 2.4

Formal description provided in Grant Agreement:

This task aims to develop a new methodology establishing a systemic approach towards the adoption of CE strategies along the key stages of manufacturing products lifecycle (design & engineering, manufacturing, use and EoL). DaCapo agile methodology will be backed on the work performed on T1.1 towards circular business models and materials flows identification, as well as on the efficient integration of the outcoming loops from subsequent tasks (T2.2-T2.4). The new methodology will guide users through specific procedures for sustainability and circularity assessment in manufacturing value chains, being the backbone of the knowledge generation engine in T3.3 and the CE-DSS of T4.5. As part of the methodology definition, it is planned to integrate co-creation activities, such as surveys (+30) and dedicated workshops (+2) with relevant field-experts and key stakeholders to integrate external knowledge and different value chain actors' perspectives, feeding relevant information to tasks T2.2, T2.3 and T2.4.

Deliverable 2.4: *DaCapo agile methodology for sustainability and circularity enhancement. White paper summarizing the sustainability and circularity methodology and guidelines for adopters. (OTHER) (PU), (M22, TNO)*

Deliverable 2.4 is a clickable PDF document. This document replaces the whitepaper that was originally destined to be the deliverable D2.4. After all, an agile methodology requires that materials are attractive, flexible and can be tailored to relevant users and questions from participants who seek to adopt circular strategies. This document therefore provides a high level description of the Agile Methodology and how it was constructed through an iterative process in which both industry experts and the DaCapo consortium were closely involved. The actual Agile Methodology can be found in a separate file that will also be published in the DaCapo project website when the deliverable is accepted.

1.2. Summary of D2.4

The methodology comprises a PowerPoint document that is transformed into an interactive click-through PDF document. The methodology basically lets SME's pick and choose how much information they want to collect on circularity, circular business models, and existing circularity tools that are available online in different countries. The complete document contains roughly 50 slides ranging from basic information on circularity (for SME's who are not yet familiar with circularity) to slides with detailed information on circular business models and tools (for SMEs who want specific practical handles on how to implement circularity). This approach in which SME's can select what they want to read/see makes the methodology agile: it is not a one-size fits all methodology but can easily be adapted based on the needs of the SME

and their specific needs in terms of knowledge of circularity and/or related tools that can help them. If an SME wants detailed information, for example to inform investment decisions, that information is available. But if the SME wants specific indicators to help identify parts of their products or processes to make more circular, then that is also available in the tool. Additionally, we created multiple LLM-cheat sheets. As LLM's are emerging everywhere, business may decide to make use of this new technology and at TNO within the DaCapo project we foresee major opportunities. Hence the cheat sheets provide guidance for SMEs to create their own circularity consultants. For the Agile Methodology the decision was made not to promote on specific LLM provider, but indicate that many are currently available (e.g., ChatGPT, Copilot, Claude, and more). Additionally, we realise that the current landscape is changing at a major pace, so it is very likely that in a few months or more there will be other LLM options that we cannot foresee at the time of writing. To provide users inspiration on how to use the LLM of their preference, we provide detailed suggestions for prompts and ideas on how to create the right LLM for the right challenges (e.g. product or process related or related to for example convincing business stakeholders to make investment decisions). Combined, this makes an Agile Methodology that SMEs can utilize to improve the circularity of their supply chain and products & processes.

The images below give an impression of the materials covered in the Agile Methodology. We provide several examples but the Agile Methodology itself is also available and can be clicked through independently.

Figure 1 – Title Slide

This slide introduces the Agile Methodology and emphasizes that this is part of the overall DaCapo project. The contact person will be adjusted after agreement with the DaCapo consortium. The idea is that for the different countries that are represented in DaCapo, there could be a partner from the consortium that becomes the main contact person for future questions. As the deliverable will be published on the DaCapo project website, it will be relevant to keep up to date contact information in the coming years also potentially for after the project.

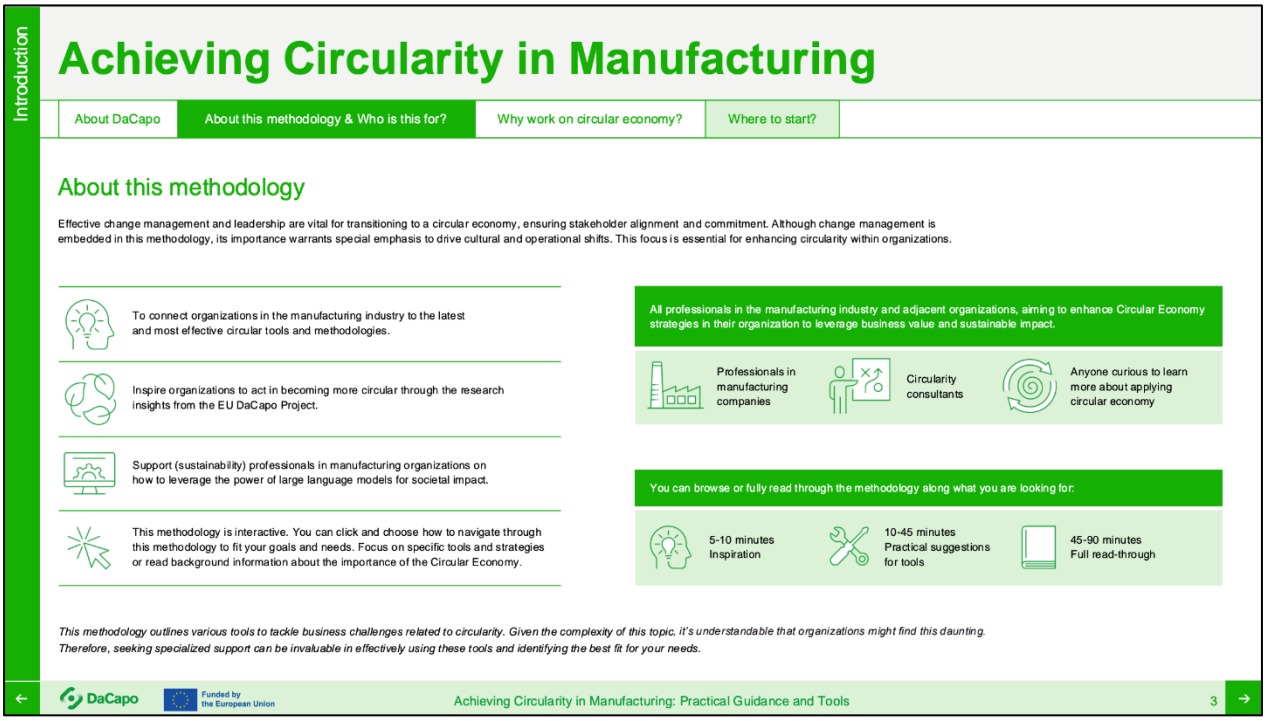


Figure 2 - Slide explaining the key audience for the DaCapo Agile Methodology

This slide briefly describes the methodology itself and highlights how SMEs can use it interactively, depending on their specific needs and interests. The goal here is to quickly and visually introduce the methodology to convince the user to continue in the document.

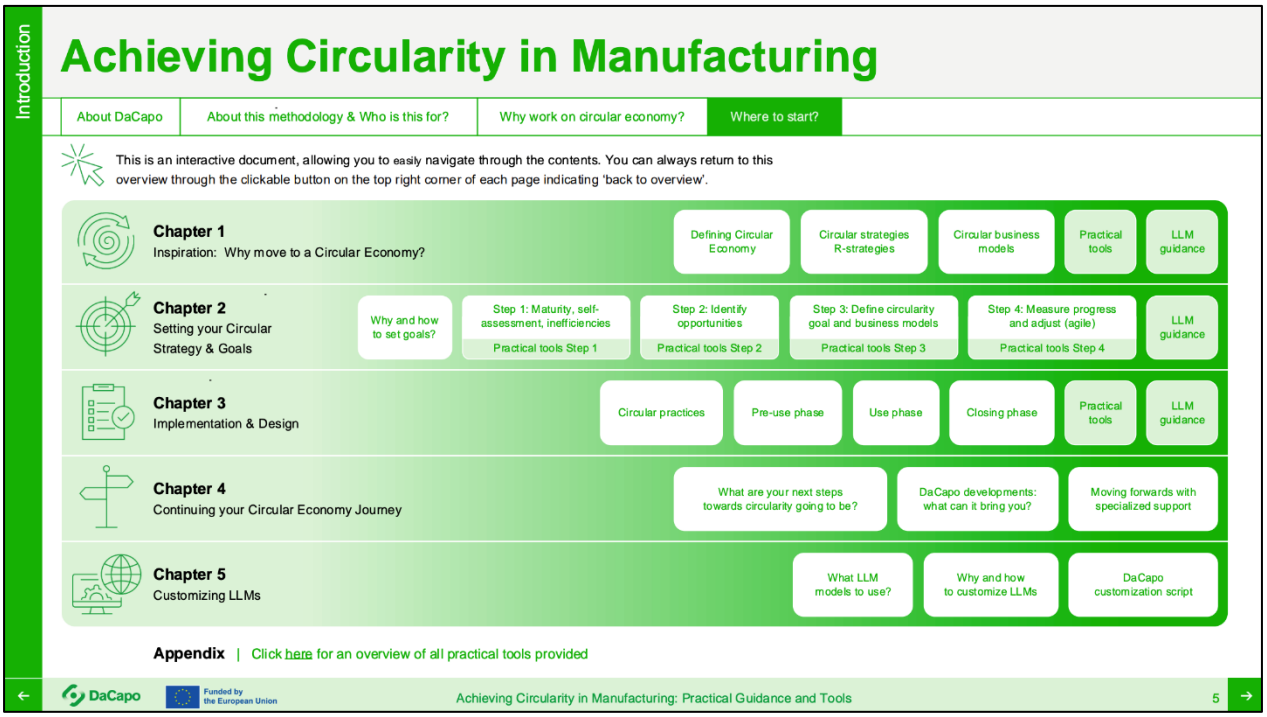


Figure 3 - Slide showing the Table of Contents and showing how SME's may navigate through the methodology

This slide displays the table of content of the entire document. The different rows represent the different chapters that are part of the methodology. The introductory text on the top of the page indicates how users can use the table of content by clicking on the relevant part. This is also an important element of the "agile" part of the Agile Methodology: users can select the topics as they see fit for themselves, so the methodology is agile as it can be adjusted along the needs and interests of the specific user.

There are 5 major chapters:

1. Chapter 1: Introduction to circular economy: this chapter focuses on the background of the circular economy. It is intended for SMEs who are not yet so familiar with the concept and want to read more about it.
2. Chapter 2: Circular strategy and goals: this chapter aims to help SME to formulate its circular strategy and goals. It is intended for SMEs who are a bit more familiar also with the circular economy and related concepts, but who do not have concretised their strategies and goals. Hence this chapter provides more concrete handles compared to chapter 1.
3. Chapter 3: Organisational implementation & design: this chapter focuses on the circular practices and the different phases of a product (pre-use, use, and close). This chapter is a step further in terms of practicality compared to Chapter 2. Hence, by doing so this chapter provides SMEs with more concrete handles on how to implement the circular strategy and goals formulated earlier.

4. Chapter 4: How to continue your CE Journey: this chapter again goes a step further in terms of practical handles. In this chapter SMEs are guided to the right tools and assessment solutions that exist already and that can be used by the SMEs to go further in their circular journey.
5. Chapter 5: Large language model (LLM) guidance: this chapter provides SMEs some handles on how to design a LLM (such as Open AI's ChatGPT, Microsoft's Copilot, or any other public LLM provider in the future) to become a customized circularity consultant. With the emergence of AI and LLMs at the time of writing, and the pace in which new features emerge, the DaCapo project has the unique opportunity to combine these new technologies with the insights from this project. Hence this chapter may support SMEs in training their own AI solution to support them in their circularity journey, but then also with concern for (company) privacy concerns.

Per chapter there are multiple sub-chapters that provide more detail to different topics related to that chapter. The goal is that SMEs can adjust the content they see on what they need. In other words, the 'journey' the user takes through the document is agile in the sense that each user can select the content they see as relevant and hence they do not have to go through all the materials to get to the material they need to become more circular.

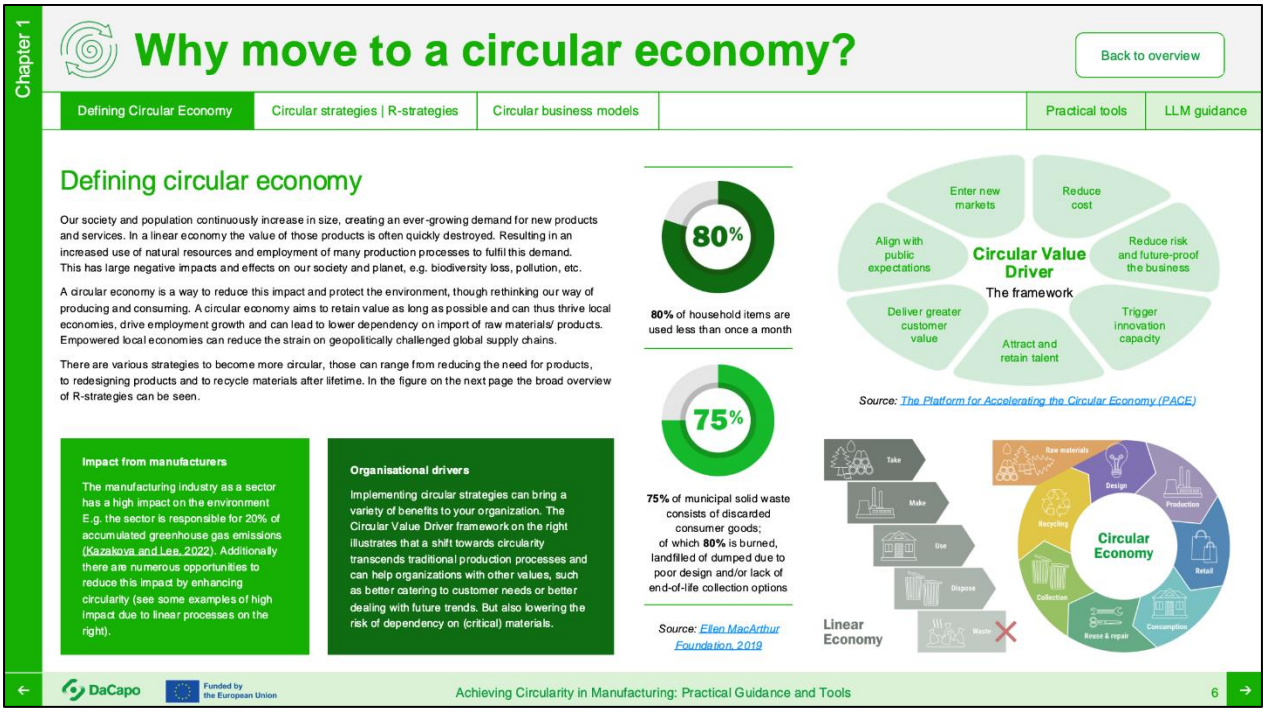


Figure 4 - Example of a content slide – explaining in more detail the background of the circular economy

The slide above is an example of the content of the slide deck. In this specific slide more attention is paid to a detailed description of the circular economy. As different SMEs may be different in terms of circularity maturity, they will have different information needs. This slide is more focused on SMEs that want to learn more about the background of the circular economy. Other slides are more focused on

dedicated tools that are more intended for SMEs who are already familiar with the background of circularity.

Figure 5 - Explanation of DaCapo next steps and suggestions

2. Research Approach

The process to develop the Agile Methodology has been agile and iterative in itself. In the first months of the DaCapo project the team of researchers has focused on developing a deep understanding of the existing materials on circularity, circularity assessments, R-cycles, circular business models, and potential cross-relevance throughout the DaCapo project. The result is that at the M12 meeting there was already a draft version of the Agile Methodology available and the next-to-finalized version could be presented to the European Commission during the review meeting in September 2024.

Table 1 – Overview of collected data and contribution to the development of the Agile Methodology

Data collected	How/When was the data collected	Contribution to the Agile methodology
Collection of tools that are existing online and are publicly available (either paid or free)	Continuously through online desk research. We kept a spreadsheet with all the different tools.	The different tools informed our development of the Agile Methodology. The spreadsheet allowed us to create an overview of existing tools and evaluate them on qualitative criteria (e.g.

		ease of use, relevance to which phase in the production process).
Interviews with field experts from CIRCO from Circonnect in the Netherlands	Through our professional network we had multiple conversations with professionals at CIRCO. They are involved in providing circularity consultancy services to organizations all over the world.	Their inputs provided crucial to better understand what SMEs encounter in their day-to-day activities. It also helped to test some of our assumptions. The professionals at CIRCO also reviewed an early version of the Agile Methodology to help us improve the methodology.
Workshops with DaCapo partners during General Meetings	At two general assembly meetings (i.e. M12 and M18) we organized workshops to collect feedback from the partners and also specifically from the use cases to get insight from practice.	The first workshops was organized around a role-playing game where different people received a specific role in a hypothetical commercial organisation. Then we engaged in group discussions to better understand what the day-to-day needs are of SMEs when it comes to circularity.
Testing environment with a LLM that served as Circularity Consultant	During the M18 meeting and after, we gave the DaCapo consortium the opportunity to experiment with an LLM trained by the team as a circularity consultant.	The feedback received from the partners and use cases informed our further shaping of the Agile Methodology. Specifically, it provided a thorough validation of our LLM cheat sheet assumptions and hence was used to incorporate those into the Agile Methodology itself (instead of being a separate document).
DaCapo partners & use case review	In the final stages of the development of the Agile Methodology all the partners were asked for a review of the material to assure proper representation of DaCapo and the input/output from both the project and the partners.	This validation and review moment allowed the Agile Methodology to mature into the methodology it is now. The feedback assured DaCapo and the tools developed in DaCapo is represented properly.

Through the steps described in the table above, the project delivered Deliverable 2.4 - the Agile Methodology in the state it is at the time of writing. The document will remain a 'live' document in the sense that it will be made available on the DaCapo project website to be appropriated by the relevant parties. As the Agile Methodology will also be further used throughout the DaCapo project, the document

may change later. This also emphasizes the agile nature of the document as it can be adjusted as new insights may emerge during the DaCapo project.

3. Rough materials collected

Sources
QuickScan-Circulaire-Businessmodellen-V5-ebook-29.11.21.pdf (circulairemaakindustrie.nl)
http://www.circularitycalculator.com/#us
https://cat.ganbatte.world/
Circularity Deck - A Circular Economy Tool
Building Circularity - Circular Economy Tool by One Click LCA
Circularity Assessment Tool - CIRCit Nord
Home - CTI Tool
Circular Economy Toolkit
Toolbox Circulab: Circular Canvas, Partner Map, Value Chain Canvas
The Circular Design Guide
Home - Life Cycle Initiative
Idemat (idematapp.com)
Partner-radar | Business Model Lab
CIRCO | Circulaire businessmodellen & duurzame ontwerpstrategieën (circonl.nl)
Circulaire Economie - Kenniskaarten - het Groene Brein
The Circular Rebound Tool | Circular X
Circular Experimentation Workbench | Circular X
Circular collaboration canvas | Circular X
1) Definitions List -23 ENG.pdf
https://emf.thirdlight.com/link/1pzbxosbi6hl-ei3tq6/@/#id=2
1) Examples List -22 ENG.pdf
Mapping Circular Economy Indicators to EU Reporting Requirements (ellenmacarthurfoundation.org)
Good practices - Filtered results | European Circular Economy Stakeholder Platform (europa.eu)
Measuring a circular economy | Ellen MacArthur Foundation
Circularity Deck - A Circular Economy Tool
The Circular Economy - Makerspace Adelaide
https://teknologiateollisuus.fi/fi/circular-economy-playbook
CF2 CE matrix presentation in PROVE 2021 (vtt.fi)

DaCapo

EU Horizon Project on digital assets and tools for circular value chains and manufacturing products

Achieving Circularity in Manufacturing: Practical Guidance and Tools

Funded by the European Union

October 2024 | Horizon Twin Transition | Contact: elmer.rietveld@tno.nl

Achieving Circularity in Manufacturing

DaCapo

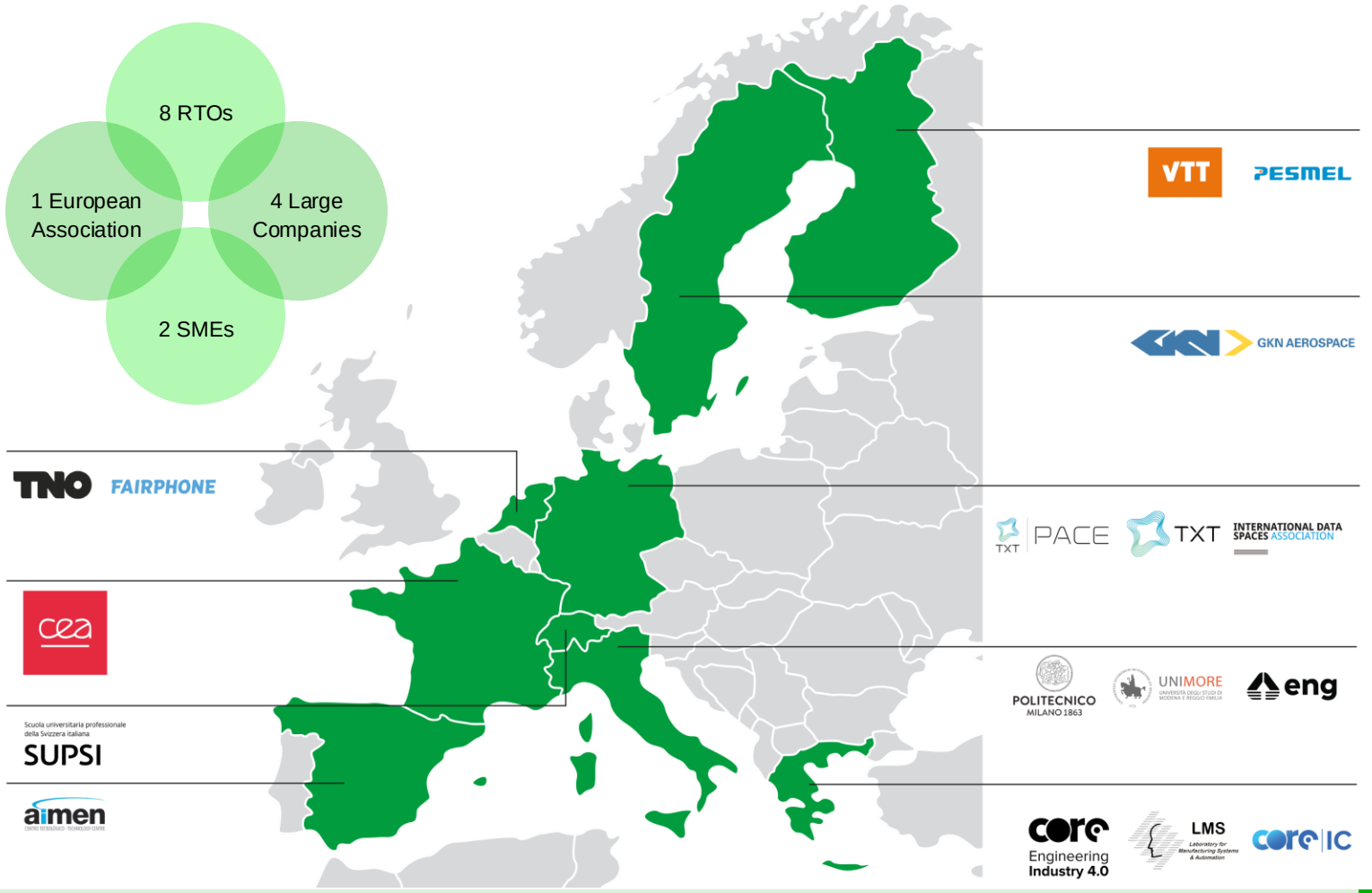
Digital assets and tools for circular value chains and manufacturing products

DaCapo aims at the creation of human-centric digital tools and services for improving the adoption of Circular Economy (CE) strategies along both manufacturing value chains and products lifecycle.

These tools and services, focused on the introduction of new digital assets, AI-based systems and the application of process and product Digital Twins, will substantially improve the sustainability and efficiency of imported and critical raw materials in manufacturing.

View the DaCapo website to read more ↗

15 partners from 10 European countries



Achieving Circularity in Manufacturing

About this methodology

Effective change management and leadership are vital for transitioning to a circular economy, ensuring stakeholder alignment and commitment. Although change management is embedded in this methodology, its importance warrants special emphasis to drive cultural and operational shifts. This focus is essential for enhancing circularity within organizations.

To connect organizations in the manufacturing industry to the latest and most effective circular tools and methodologies.

Inspire organizations to act in becoming more circular through the research insights from the EU DaCapo Project.

Support (sustainability) professionals in manufacturing organizations on how to leverage the power of large language models for societal impact.

This methodology is interactive. You can click and choose how to navigate through this methodology to fit your goals and needs. Focus on specific tools and strategies or read background information about the importance of the Circular Economy.

All professionals in the manufacturing industry and adjacent organizations, aiming to enhance Circular Economy strategies in their organization to leverage business value and sustainable impact.

Professionals in manufacturing companies

Circularity consultants

Anyone curious to learn more about applying circular economy

You can browse or fully read through the methodology along what you are looking for:

5-10 minutes
Inspiration

10-45 minutes
Practical suggestions for tools

45-90 minutes
Full read-through

This methodology outlines various tools to tackle business challenges related to circularity. Given the complexity of this topic, it's understandable that organizations might find this daunting. Therefore, seeking specialized support can be invaluable in effectively using these tools and identifying the best fit for your needs.

Achieving Circularity in Manufacturing

Why DaCapo partners Fairphone, GKN, and PESMEL work on circular economy

We want to make the most of the materials used in consumer electronics. We believe in a world with a closed loop; a future where e-waste is reduced thanks to long-lasting products which are continuously reused and recycled. Once resources enter our economic system, they should be kept at their highest value for as long as possible and freed for new applications once a product cannot be repaired anymore.

We're moving one step closer to a circular economy by encouraging the reuse and repair of our phones, researching electronics recycling options and reducing electronic waste worldwide.

FAIRPHONE

We assess the impact of our products on the environment in terms of material usage, waste, energy usage and CO2 emissions throughout each product life cycle. By incorporating circular economy principles in our design and manufacturing processes, we are reducing our environmental impact and deliver products to end markets with increased durability and longevity and reduced waste.

By way of example, our technologies ensure that only 20% of procured metal billets are removed in the production process, whereas the norm is up to 80%, therefore significantly reducing the 'buy to fly' ratio.

GKN AEROSPACE

We are committed to developing technologies that minimize environmental impact and promote sustainability. Our efforts include optimizing material use, utilizing low carbon-intensive materials, and employing energy-efficient drives with electricity regeneration. Our systems have a lifecycle of over 50 years, supported by preventive maintenance, upgrades, and modernizations. They are highly energy-efficient and produce no direct fossil emissions during use. With intelligent electricity regeneration, up to 40% of consumed electricity can be fed back into the grid. Additionally, by using rooftop solar panels, the solution can potentially generate more electricity than it consumes. Over 90% of the materials in our systems are recyclable, and we actively support recycling, refurbishment, and waste reduction efforts.

PESMEL

Achieving Circularity in Manufacturing

This is an interactive document, allowing you to easily navigate through the contents. You can always return to this overview through the clickable button on the top right corner of each page indicating 'back to overview'.

Why move to a circular economy?

Back to overview

Defining Circular Economy | Circular strategies | R-strategies | Circular business models | Practical tools | LLM guidance

Defining circular economy

Our society and population continuously increase in size, creating an ever-growing demand for new products and services. In a linear economy the value of those products is often quickly destroyed. Resulting in an increased use of natural resources and employment of many production processes to fulfil this demand. This has large negative impacts and effects on our society and planet, e.g. biodiversity loss, pollution, etc.

A circular economy is a way to reduce this impact and protect the environment, though rethinking our way of producing and consuming. A circular economy aims to retain value as long as possible and can thus thrive local economies, drive employment growth and can lead to lower dependency on import of raw materials/ products. Empowered local economies can reduce the strain on geopolitically challenged global supply chains.

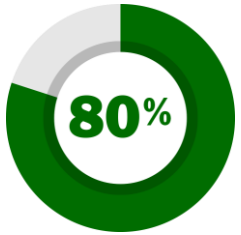
There are various strategies to become more circular, those can range from reducing the need for products, to redesigning products and to recycle materials after lifetime. In the figure on the next page the broad overview of R-strategies can be seen.

Impact from manufacturers

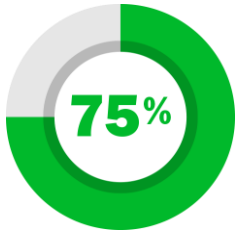
The manufacturing industry as a sector has a high impact on the environment E.g. the sector is responsible for 20% of accumulated greenhouse gas emissions (Kazakova and Lee, 2022). Additionally there are numerous opportunities to reduce this impact by enhancing circularity (see some examples of high impact due to linear processes on the right).

Organisational drivers

Implementing circular strategies can bring a variety of benefits to your organization. The Circular Value Driver framework on the right illustrates that a shift towards circularity transcends traditional production processes and can help organizations with other values, such as better catering to customer needs or better dealing with future trends. But also lowering the risk of dependency on (critical) materials.

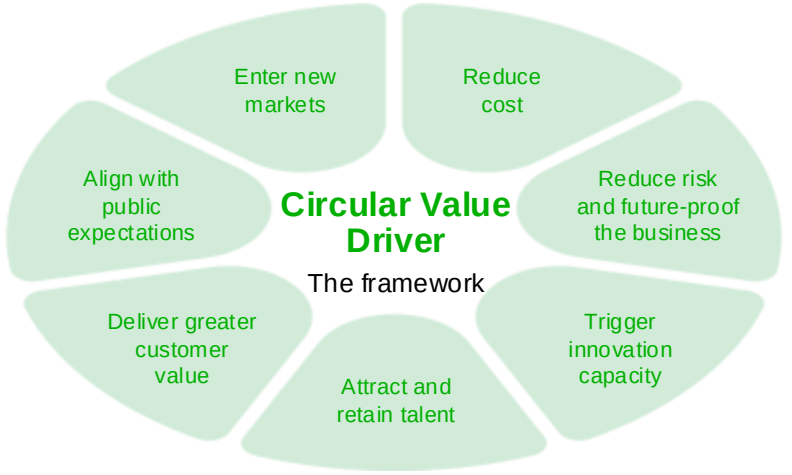


80% of household items are used less than once a month

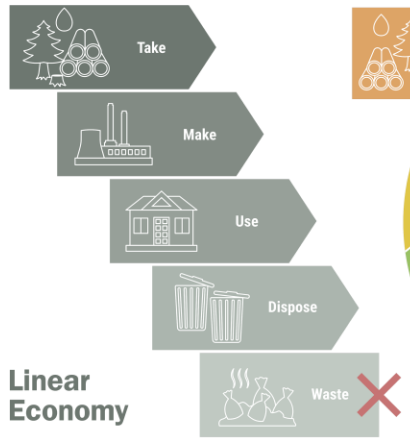


75% of municipal solid waste consists of discarded consumer goods; of which **80%** is burned, landfilled of dumped due to poor design and/or lack of end-of-life collection options

Source: Ellen MacArthur Foundation, 2019



Source: The Platform for Accelerating the Circular Economy (PACE)



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Circular strategies | R-strategies

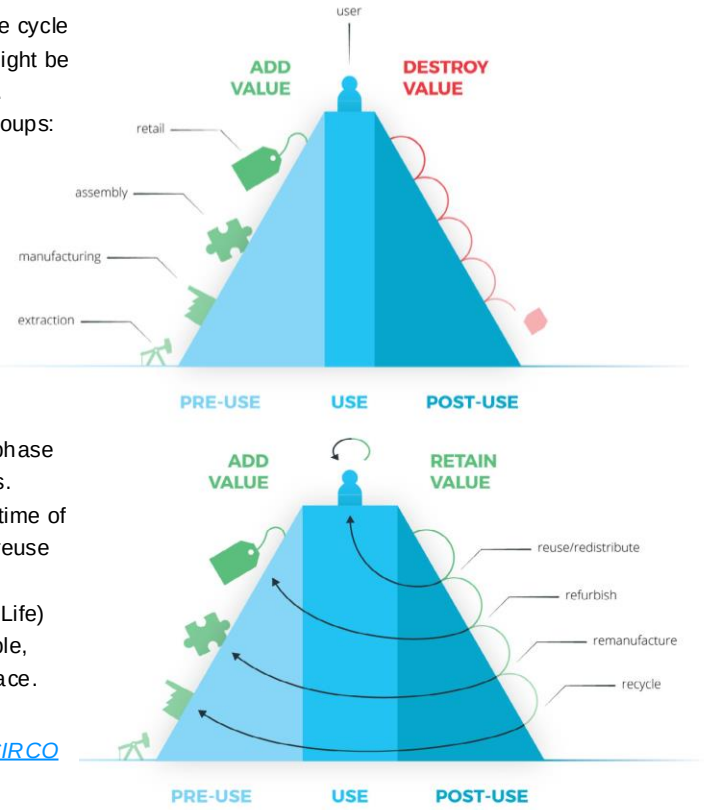
There are various circular strategies that can help to make your organization more circular. Typically they are referred to as the R-strategies. See figure on the right. Depending on the characteristics of your organization, your product and your drivers some circular strategies might be a better fit than others.

The R-strategies are applicable for the whole life cycle of a product or service. Different R-strategies might be applicable in different phases, see figure below. Therefore we can cluster the phases in three groups:

- Pre-use phase: Design, engineering and manufacturing
- Use phase: Use of the product/service
- After first use: End-of-Life

In general the R-strategies can be linked to these phases as follows:

- In the pre-use phase circular strategies such as rethinking, reducing and redesigning of a product/service are typically relevant. In this phase you have the most influence on those aspects.
- In the use phase strategies to prolong the lifetime of a product are most valuable, such as repair, reuse and remanufacturing.
- After first use (typically referred to as End-Of-Life) there the products or materials are still valuable, reusing or recycling the materials can take place.



Source: CIRCO

Circular Economy

More value retained

• Design phase • Most sustainable • Adds value • Responsible use and manufacturing	**R0 Refuse**	Make product redundant by abandoning its function or offering same function with radically different product
	R1 Rethink	Make product use more intense (eg. product-sharing, multi-functional product)
	R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
• Consumption phase • Optimal use • Preserve and extend life of products	**R3 Reuse**	Reuse of functional discarded product by another consumer
	R4 Repair	Repair and maintenance of defective product to restore its original function
	R5 Refurbish	Restore an old product to bring it up to date
	R6 Remanufacture	Use product or parts in a new product with its original function
	R7 Repurpose	Use product or parts in a new product with a different function
• End-of-life or return phase • Capture and retain value • Use waste as a resource	**R8 Recycle**	Process the materials to obtain the same (high grade) or lower (low grade) quality
	R9 Recover	Incinerate materials to recover energy
• Loss of resources • Value lost • Environmental pollution	**Landfill or Incineration**	

Less value retained

Linear Economy

Source: Circularise

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Circular business models

Implementing a circular business model is important to make your company more circular. A circular business model describes how a company creates, captures and delivers circular value. There are various types of circular business models, in which different R-strategies are incorporated. Although, implementing such a business model can be challenging due to the different mindset of such a model, there are also opportunities in the form of collaborations and digitalisation.

Circular business models

- Substitute business models focus on circular use of resources (raw materials), e.g. through using recycled materials as input or biobased materials.
- Business models that focus on the circular design of products: These business models focus on the design of circular products, to be able to easily repair, maintain or recycle the products.
- Business models that focus on prolonging lifetime. Through monitoring the condition of a product and providing maintenance and repair, the lifetime of a product can be extended.
- Products as-a-service business models. Such business models focus on providing access to a result or use of a product instead of selling a product. As an organization you keep ownership over the product. In such business models there is an incentive for an organization to prolong the lifetime of the product and retain value of the product.
- Platform business models are business models that facilitate sharing/exchange of products. By sharing and exchanging products the need for products and materials decreases.
- Take-back business models, such business models focus on taking back the products/materials by the consumers. Taking these products backs allows to re-use, remanufacture or refurbish parts. When this is not feasible products and materials can be recycled.

Challenges of implementation

Moving towards a circular economy is not always easy, and challenges arise. Some examples of challenges for implementing a circular business model include:

- Lack of internal competencies or knowledge
- Lack of financial resources to support investments needed to reshape existing value chains.
- Lack of value chain alignment, collaboration is key for circularity, finding the right partners, building trust and gather information can be challenging.
- Difficulty in capturing additional value at end-users / explicate value of circularity
- Lack of incentive to move towards circularity
- Rigid organizational structure, principles and capabilities

Collaboration/digital solutions

- Collaboration is essential for transitioning from linear to circular processes. Circularity impacts every aspect of the value chain, making a collaborative approach that creates alignment and joint implementation crucial. A collaborative approach enhances opportunities for both organizations and the collective to adopt circular business models and create value.
- There are various (digital) technologies that could stimulate the implementation of R-strategies and thus the implementation of circular business models. E.g. by providing information throughout all phases of the product, or through physical robots that help to repair and remanufacture products.

Further reading ↗

Further reading ↗

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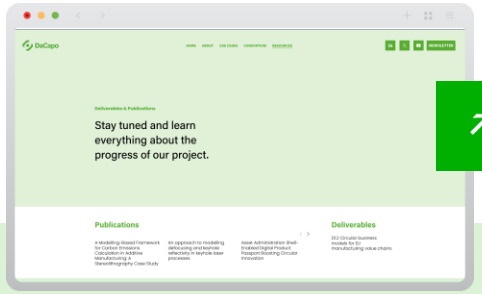
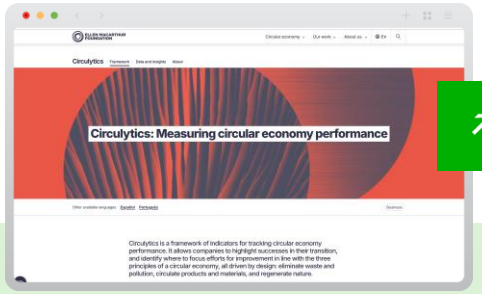
Defining Circular Economy | Circular strategies | R-strategies | Circular business models | Practical tools | LLM guidance

Further reading & Tools | Introduction to the circular economy



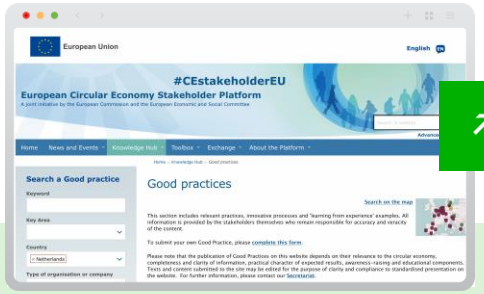
DaCapo material

- Circularity Indicators
- GRETA tool
- CE–DSS
- Key competences of a circular economy
- Unleashing the role of skills and job profiles in circular manufacturing



Circulytics

- **Usefulness**: Circulytics is a framework of indicators for tracking circular economy performance.
- **Advantage**: At the bottom there are several reports introducing the CE
- **Disadvantage**: It is not interactive (anymore).



Good practices CE stakeholder EU

- **Usefulness**: To find and apply successful circular economy practices.
- **Advantage**: Offers a wide range of effective strategies and examples.
- **Disadvantage**: Level of detail can differ due to reliance on submissions.

Other useful tools

- **Platform for Accelerating CE:** Provides strategies to integrate circular economy principles with climate measures.
- **E-learnings on CE:** Increases the understanding of a circular economy

For more tools and methodologies on moving towards a circular economy, consult appendix 3

Why move to a circular economy?

Back to overview

Defining Circular Economy | Circular strategies | R-strategies | Circular business models | Practical tools | LLM guidance

DaCapo

LLM Cheat Sheet Circular Economy for Smart Industry

Large Language Models (LLM) such as Chat-GPT can greatly support you in your work as sustainability professional in the manufacturing industry. But how can these virtual assistants be of use? This cheat sheet is tailored to your everyday challenges and is meant to help you shape, customize and activate these tools to accelerate your impact.

Responsible use

- Let LLMs inform your actions, not decide
- Consider credibility & validity of output & sources
- Validate output with pre-existing expertise
- Only share non-sensitive information
- Consider environmental usage that is needed for each LLM interaction

What is an LLM

- Versatile tool to offer case- specific suggestions, inspiration, general and case-based advice, rewrite content, create new content
- Virtual assistant that can be customized for many purposes
- Advanced search engine to scan literature and summarize key findings
- Is not: fully trustworthy decision-maker

How to prompt with LLM

- Chained prompting: build on your prompts
- Consider output styles for your GPT, especially when creating content: “formal, persuasive, inspirational, descriptive, executive style, etc.”
- Instruct for output formats: e.g. table, short text, charts, lists,etc.

How to customize with LLM

- You can customize your LLM model with a first, extensive prompt that teaches it how to behave for all remaining questions you ask.
- See more instructions on how to do this customization here, including a standard template to create a circular economy assistant.

How to learn from LLMs?

- Explain the following (CE) topic as if I would be [number] years old. [topic]
- I want to learn the following (CE) skill(s) [insert skill(s)]. I am a [beginner/ intermediate/ expert etc]. Please create a 30-day training program so I can master this skill.

Demo prompts

- Identifying best practices: “What companies are successful in… [task] for companies such as [context], specifically focusing on [clarification]”

How to build super prompts

Role	Result	Context	Intent	Constraint
Act as CE a waste reduction professional	*Create an exploratory strategy for waste reduction*	*For a company with X and product A, B, C*	*The goal is to reduce waste on aspect X*	*Resources limited to X funding, X time, etc*

Inspiration: what CE areas to use an LLM for?

- Product design, supply chain optimization
- Waste reduction & Lifecycle extension
- Circular business models, collaboration & partners
- Technology adoption
- Customer engagement
- Policy advocacy & regulation
- Measurement & reporting

Key circular economy use cases (1/2)

- In what ways can we engage customers in repair and refurbishment for [specific product]?
- How can we minimize waste generation in our [specific aspect] process?
- What design modifications can we make to ensure repair/reuse/recycling for [specific product]?

Key circular economy use cases (2/2)

- How can we measure and track the circularity performance of our products and processes in [specific aspect]?
- How can we collaborate to organize take-back and recollection for our product?
- How can we create value from waste streams in [specific process]?

In addition to this general inspiration, also find specific LLM guidance for strategic questions or implementation questions

Setting your Circular Strategy & Goals

Back to overview

Why and how to set goals? | Step 1: Maturity, self-assessment, inefficiencies | Step 2: Identify opportunities | Step 3: Define circularity goal and business models | Step 4: Measure progress and adjust (agile) | LLM guidance

Why and how to set goals
Setting a circularity strategy and goals in 4 steps

Circularity is a broad concept and your contribution to it can take many different shapes.
Let's set up a fitting strategy and goals specifically for you, to make sure that you reach your intended impact; creating value for yourself, customers and the environment.

Why it is beneficial to set a strategy and goals regarding circularity:

Focus: Choose the best option(s) from the many possibilities, and focus your efforts there to create significant impact.

Motivation: Your team or employees will have higher motivation to work on circularity if the strategy and goals are clear.

Target: Defining a clear target increases the chance of reaching your circularity goal, and lets you take control of the direction you are headed.

Steps to take:

Step 1: Current maturity	Assess your current maturity in terms of circularity, identify inefficiencies on product, company and market level
Step 2: Identify opportunities	Identify opportunities circularity can bring you, match them with main company drivers, get inspired by examples of others
Step 3: Define circular business model	Identify the most fitting circular business model and define circularity goals accordingly
Step 4: Measure progress and adjust	Measure your progress and impact, adjust your strategy and actions when necessary

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Practical tools Step 1

Step 1: Maturity, self-assessment, inefficiencies
Where are you now and what can be improved

Maturity assessment

By doing a circularity self-assessment, you can evaluate to what degree your organization currently adheres to circular economy principles. The assessment covers factors such as your processes, used materials and strategy.

Benefits:

- You discover your strengths and areas of improvement
- You identify how you can close the loop and where to start optimization
- You create a baseline measurement which enables you to track your progress more easily

Go to the Circular Maturity Model to read more

Inefficiencies on company level

Optimization is never finished! Within your organization there might be inefficiencies on the level of used materials, recourses and processes, which can be identified and improved with fitting circular solutions.

Benefits:

- You identify the “sweet spots”, opportunities that bring value for your business, customers and for the environment at the same time
- You can design a strategy that focuses on these sweet spots

Go to the Nordic Innovation website to read more

Examples:

- Unsustainable materials
- Underutilized capacities
- Premature product lives
- Wasted end-of-life value
- Unexploited customer engagements

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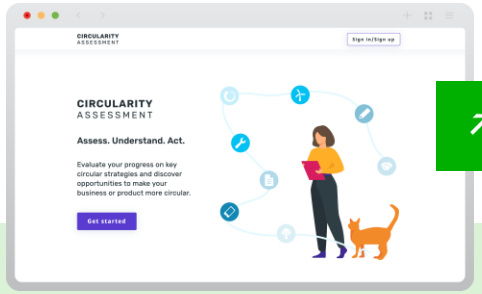
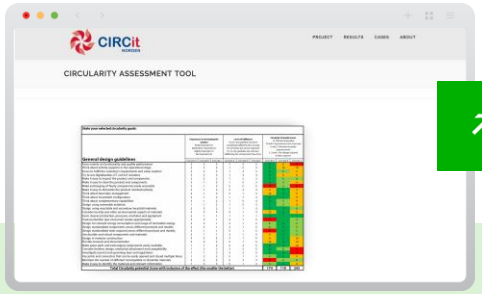
Practical tools Step 1

Step 1: Current company and product maturity – Tools to use



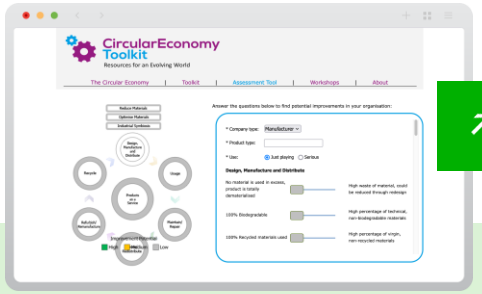
Circularity Assessment

- **Usefulness**: This tool offers a self-assessment to evaluate business or product circularity, providing a baseline score and identifying opportunities for improvement.
- **Advantages**: It includes access to real-world case studies and frameworks, facilitating internal and external discussions to develop circular economy strategies. Does not require data or pre-assessment from your side
- **Disadvantages**: The self-assessment nature might limit the depth of insights without external expertise, and the process can be daunting for organizations new to circularity.



CIRCIT Assessment Tool

- **Usefulness**: This excel-based tool evaluates the circularity of developed concepts, helping organizations identify areas for improvement and compare different concepts. LCA outcomes needed as input.
- **Advantages**: It provides a detailed, guideline-based assessment and visual representation of results, making it easier to pinpoint specific areas needing enhancement.
- **Disadvantages**: The tool's complexity may require a thorough understanding of the guidelines and a dedicated assessment team, which can be resource-intensive.



Circular Economy Toolkit

- **Usefulness**: This tool helps identify potential areas for business opportunity or improvement based on product design and business operations.
- **Advantages**: It offers a quick, five-minute assessment and is complemented by a comprehensive toolkit and case studies, making it accessible and practical.
- **Disadvantages**: The tool provides a general overview and may require additional, more detailed analysis and workshops to fully realize its benefits.

Other useful tools

How circular is your product?
Insight into your material flows

Detailed overview of flows
Create overview of material and resource flows (input data needed)

Rebound tool
Explore rebound effects of current and considered strategy

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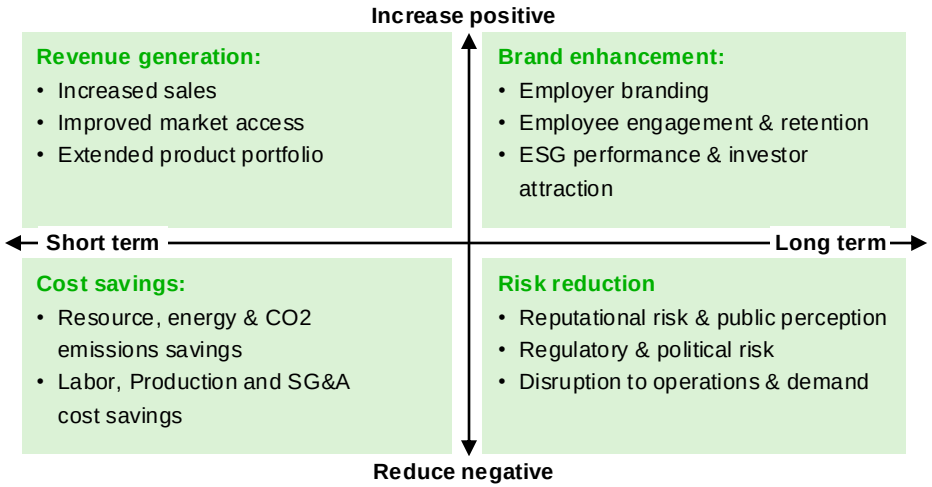
Practical tools Step 2

Step 2: Identify opportunities

Type of value

There are different types of values circularity can bring you. You can also create opportunities by first picking a goal that is most important for you, and brainstorm about opportunities for that one specifically. At this point it is also great to get inspired by examples of other companies.



Further reading: Nordic playbook

What you can do

Identifying opportunities can be done by taking a good look at your current products, offerings, processes and used materials, and thinking outside the box. Example questions to explore can be seen below. (These can also be accessed in full, with explanation if you click the link below.)

Prolonging product life:
- Can your product become a service in some way?
- Can you make it easier for your users to repair it themselves?
- Can you design your product to be more modular so individual components can be upgraded or replaced easier?
- Can you provide a maintenance service to sustain the life of the product?
- Can you work directly with your manufacturer to restore your products after their first use cycle?

Purposeful inputs & outputs:
- Can you utilise waste or recycled materials for your materials?
- Can any of your materials be sourced more locally?
- Can your production be more localised?
- Can you minimise the waste stream your product produces?
- Can your product contribute to the biocycle in some way?

Further reading: Ellen Macarthur Foundation

How you can do it

Depending on the ambition level that you set, you can consider different strategies to build the path towards your opportunities. Besides implementing changes in your own organization, you can also partner up with others in the value chain, or outsource (a part of) the required activities.

Further reading: Hansen and Revellio (2020)

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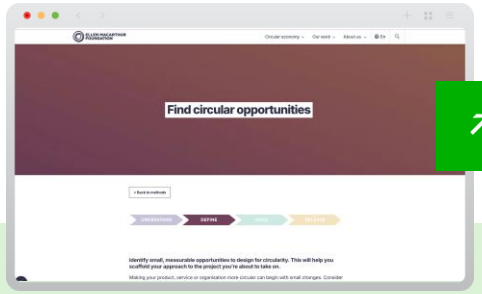
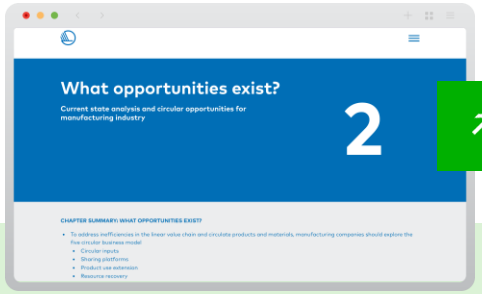
Practical tools Step 2

Step 2: Identify opportunities – Tools to use



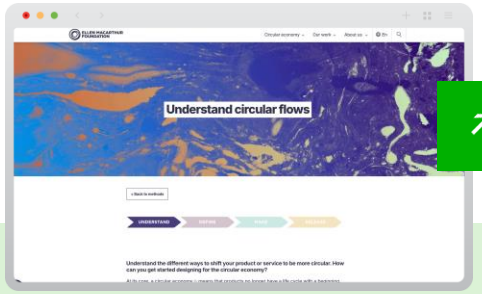
Ellen Macarthur Foundation - Opportunities

- **Usefulness**: This tool helps organizations identify specific, actionable opportunities to integrate circular design principles into their products and services.
- **Advantages**: It provides a structured set of questions that guide users through the process of finding circular opportunities, making it easier to pinpoint areas for improvement. The tool's focus on measurable actions helps organizations implement changes effectively.
- **Disadvantages**: The detailed analysis required can be time-consuming and may necessitate external expertise to fully leverage the tool's potential, especially for organizations new to circularity



Nordic CE Playbook

- **Usefulness**: The playbook serves as a comprehensive guide for manufacturing companies to transition to circular business models.
- **Advantages**: It includes industry-specific examples, practical tools, and exercises that help companies understand and apply circular economy principles. The step-by-step approach makes it accessible and actionable for different sub-sectors within manufacturing.
- **Disadvantages**: The extensive content can be overwhelming for newcomers to the circular economy. Companies may need to dedicate significant time and resources to fully grasp and implement the strategies outlined in the playbook



Ellen Macarthur Foundation – Flows

- **Usefulness**: This tool provides a framework for organizations to shift their products or services towards more circular models by understanding and implementing circular flows.
- **Advantages**: It offers practical steps and worksheets that help users map out and apply circular economy principles to their specific context. The clear, user-friendly design makes it easier for organizations to adopt these practices. Includes step-by-step worksheets for workshops.
- **Disadvantages**: The initial learning curve can be steep for those unfamiliar with circular economy concepts. Organizations might need to invest in training and seek external support to effectively use the tool and achieve meaningful results.

Other useful tools

Regenerative thinking
Explore opportunities to create social, natural capital

Options & inspiration
List of options and companies who opted for those, as inspiration

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Practical tools step 3

Step 3: Define circularity goal and business models

Find the one that fits you

Circular business models have been introduced in general in the chapter 1.

In the figure you can see 9 circular strategies. As an organization you can implement (a set of) circular strategies. Depending on the strategies you want to implement your business model would need to change.

Browse through them, and based on your current inefficiencies and the opportunities that you have identified for your organization, pick one or a few that you would like to explore! Focus on finding the fitting one for you instead of learning all the ins and outs of all the options.

For information on how to implement a business model go to chapter 3 ↗

Circular Economy

More value retained

Less value retained

• Design phase • Most sustainable • Adds value • Responsible use and manufacturing	**R0 Refuse**	Make product redundant by abandoning its function or offering same function with radically different product
	R1 Rethink	Make product use more intense (eg. product-sharing, multi-functional product)
	R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
• Consumption phase • Optimal use • Preserve and extend life of products	**R3 Reuse**	Reuse of functional discarded product by another consumer
	R4 Repair	Repair and maintenance of defective product to restore its original function
	R5 Refurbish	Restore an old product to bring it up to date
	R6 Remanufacture	Use product or parts in a new product with its original function
	R7 Repurpose	Use product or parts in a new product with a different function
• End-of-life or return phase • Capture and retain value • Use waste as a resource	**R8 Recycle**	Process the materials to obtain the same (high grade) or lower (low grade) quality
	R9 Recover	Incinerate materials to recover energy
• Loss of resources • Value lost • Environmental pollution	**Landfill or Incineration**	

Linear Economy

Source: Circularise

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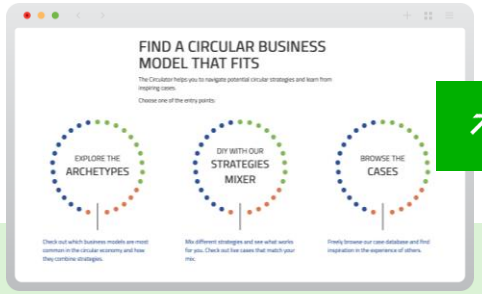
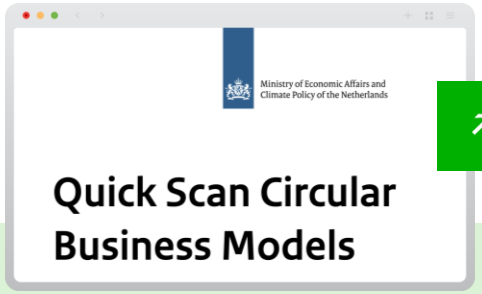
Practical tools step 3

Step 3: Define circularity goal and business models – Tools to use



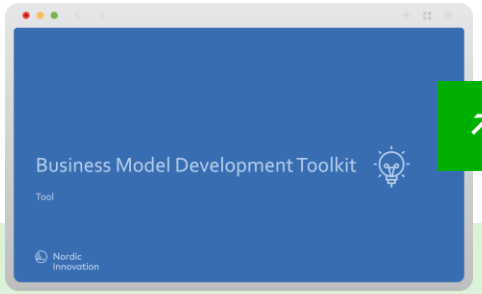
Circulator – for inspiration

- **Usefulness**: Helps organizations design circular business models by mixing different strategies and learning from case studies.
- **Advantages**: Provides a structured approach with a strategy mixer and archetypes, making it easier to tailor circular strategies to specific business contexts. Case studies provided to learn from best practices.
- **Disadvantages**: The tool may require a significant learning curve for those unfamiliar with circular economy concepts, and it might not cover all industry-specific nuances



Quick Scan

- **Usefulness**: Offers a quick assessment to help businesses identify their position and potential in adopting circular business models. Includes clear background information on business models.
- **Advantages**: Provides a concise, 30-minute scan that includes practical steps and examples, making it accessible for busy professionals. Consists of two quick scans: maturity assessment and business model choice
- **Disadvantages**: The quick scan might oversimplify complex issues, potentially leading to a need for more detailed follow-up assessments and tailored solutions.



Business Model Development Toolkit

- **Usefulness**: Guides manufacturing companies in developing circular business models through reflections and exercises. Consist of Introduction and Toolkit
- **Advantages**: Includes detailed exercises and examples tailored to the manufacturing industry, helping companies identify and implement the most promising circular business ideas.
- **Disadvantages**: The extensive content can be time-consuming to navigate, and smaller companies might find it challenging to allocate the necessary resources to fully utilize the toolkit

Other useful tools

Clean design toolkit with videos and worksheet

Value case tool
For when you are ready to calculate high-level business cases

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Practical tools step 4

Step 4: Measure progress and adjust – Why?

What gets measured, gets managed

- Above sentence elegantly summarizes why it is important that you measure your impact and progress, and that it is really important to set correctly what you measure
- The effects of your actions are directly impacted by your chosen metrics. If most of your metrics are on waste generation, you are likely to give attention to this issue, and will be less active on CO_2 reduction.

Benefit:

- Benchmarking
- Tracking progress
- Learning
- Steer decision making

Hard to quantify?
Can't measure it perfectly?

Don't let this scare and slow you! Implement changes towards circularity anyway, don't wait until you have a flawless monitoring system.

Circular ≠ sustainable

- Just because something is circular, does not make it a sustainable product (e.g. bottle made from recycled plastic, but designed for short product life and mass consumption). Setting correct metrics can help get to your intended impact.
- "Circularity for circularity's sake", "circular washing" is on the rise. Circularity is not the goal, but a way to become more sustainable
- Sustainable = economic + environmental + social indicators on all 3 impacts are needed!
- Circular initiatives often lack focus on social aspect, while those are crucial when aiming for changes in product use and end-of-life phase

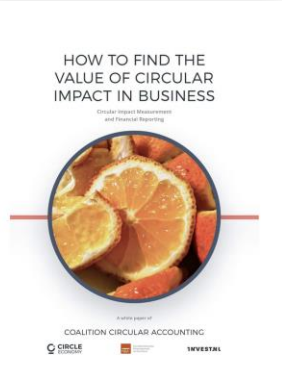
Legislation: let it push, not lead

Don't let legislation be your only guide

- What you are required to report on might not be connected to your chosen strategy/intended change (e.g. CO_2 – less toxic materials/ customer awareness)
- Some required metrics do not support circularity goals
- Design specific monitoring framework and indicators based on your current status, intended impact, industry

Steps to take

1. Scope, understand which indicators are relevant for you
2. Select/set up indicators
3. Set up practical plan – when, who measures
4. Collect data
5. Review collected data and adjust strategy and/or actions



Further reading: Coalition Circular Accounting, whitepaper

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Practical tools step 4

Step 4: Measure progress and adjust – Indicator categorisation

When tracking your progress and measuring impact, you will measure different facets of the implementation of your new strategy. Are you moving towards your main envisioned goal? How is your performance over time? Are your processes changing as intended? And what impact do you have on the world around you? For each question, a different set of indicators is appropriate to use. **Therefore, 4 categories are distinguished:**

Category	Helps to answer	Examples
Impact indicators	**Outcome:** what change have I achieved?	Occurrence of child labor in value chain
		Amount of avoided emissions
Headline indicators	**Why** do we need to change our business?	% circularity
		Share of scarce resource
		More examples
Performance indicators	**Why** do we need to change our business?	Recycling rate
		Share of secondary resources
		Share of renewable energy
		More examples
Performance indicators	**Why** do we need to change our business?	Share of sustainable products in portfolio
		# departments with KPIs
		Customer attitude towards green products
		Awareness among employees
		More examples

Tools to use for each

Within the DaCapo project, a set of circularity and sustainability indicators have been developed after an extensive review. It can be made available upon request. In case of interest, please contact: elmer.rietveld@tno.nl

Further reading: Circular Metrics for Business

Further reading: Align your organisation

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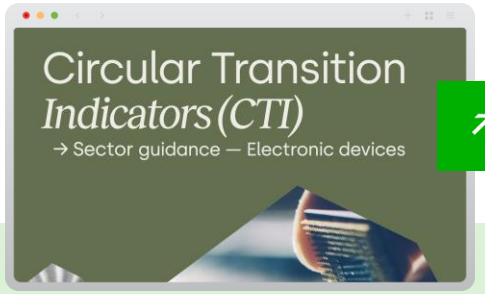
Practical tools step 4

Step 4: Measure progress and adjust – Tools to use

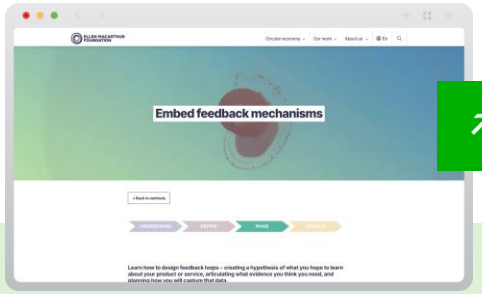
Circular Metrics for Business

- **Usefulness**: Provides a comprehensive framework for measuring circularity across various business operations.
- **Advantages**: Offers detailed metrics and benchmarks, helping organizations identify areas for improvement and track progress over time.
- **Disadvantages**: The implementation process can be resource-intensive and may require significant internal alignment and training.



Circular Transition Indicators (CTI)

- **Usefulness**: Helps companies in the electronics sector measure and manage their progress towards circularity.
- **Advantages**: Provides standardized definitions, principles, and metrics, facilitating industry-wide comparisons and collaboration. Possible to calculate % circularity of your component/product/organization
- **Disadvantages**: The extensive data collection required can be challenging for companies with limited data management capabilities.



Feedback Mechanisms

- **Usefulness**: Offers practical steps for integrating feedback mechanisms into circular economy strategies.
- **Advantages**: Provides clear guidelines and examples, making it easier for organizations to implement and benefit from continuous improvement processes. Easy to follow, with video and worksheet. Helps in articulating hypotheses and ways to test them
- **Disadvantages**: Maintaining and updating feedback mechanisms can be time-consuming and may require ongoing commitment from all levels of the organization.

Other useful tools

Create continues learning loops (follow-up on tool 3)

Measure performance with the Circulytics indicator list

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LLM Cheat Sheet Circular Economy for Smart Industry

Strategic focus

It remains challenging for strategy professionals to align business goals, sustainability ambitions and resource limitations. LLMs can help inspire, provide best practices and options to choose from, allowing the professional to focus on translating these into their contexts.

Goal setting

- **Prompt**: Suggest clear circular economy goals for [your organization], based on [constraint] and [focus area] and [etc].
- **Considerations to customize prompts with**: Consider objectives such as reducing waste, increasing product durability, or optimizing resource use. Customize the goals based on your industry, product type, and sustainability priorities. Provide information about your processes, materials used, known inefficiencies etc. to let the LLM give you personalized advice.

Strategic opportunities

- **Prompt**: Explore innovative circular opportunities for [organization type] dealing with [challenge], given [constraint] etc.
- **Details**: Look beyond traditional practices. Consider options like product-as-a-service, remanufacturing, or material recovery. Customize based on your industry and available resources.

Defining goals and examining business models

- **Prompt**: Outline, investigate and evaluate several circular business models for [organization type], given our focus on [focus area] and [challenge/constraints]. Our circularity ambition is [XYZ] and our main goal is [XYZ].
- **Details**: Explore options like leasing, sharing, or closed-loop systems. Customize by considering your product lifecycle, customer needs, and market dynamics.

Maturity assessment

- **Prompt**: Provide me with tips/considerations to evaluate [my organizations] current circular economy practices.
- **Considerations to customize prompts with**: Use a maturity model (e.g., beginner, intermediate, advanced) to assess where you stand. Customize the assessment criteria to align with your specific processes and supply chain.

Measuring progress & impact

- **Prompt**: Develop several agile measurement processes in order to [circular economy goal] for [type of organization], with characteristics; [constraints, challenges etc].
- **Details**: Set key performance indicators (KPIs) related to circularity (e.g., recycling rates, material efficiency). Customize the KPIs based on your organization's context.

Key challenges in circular economy strategies

- **Ensuring critical raw materials supply**:
  what are available scenario's to close loops and ensure material input?
- **Meeting consumers' expectations for convenience**:
  How can we encourage behaviour change without compromising convenience?
- **Navigating government regulations**:
  What steps can we take to align regulations with circular practices?
- **Managing high initial investment costs**:
  What are approaches to finance circular initiatives?
- **Addressing technological challenges**:
  What technologies can enhance circularity?

Always consider responsible usage of LLMs. See the General cheat sheet or more information on Customizing your own LLM

Implementation & Design

Back to overview

Circular practices | Pre-use phase | Use phase | Closing phase | Practical tools | LLM guidance

Circular practices

The relevant business models, digital solutions and collaborations can differ per phase. Therefore, this chapter highlights per phase the relevant aspects per topic.

Becoming more circular requires the implementation of circular strategies, also called R-strategies. Depending on the characteristics of your organisation and product/service certain strategies are more applicable than others (see Chapter 2 to get more info on how to choose a suitable strategy).

Successful implementation of R-strategies is often dependent on the following topics:
- Assess and choose a relevant circular business models.
- Analyse and establish collaborations to overcome implementation challenges.
- Analyse opportunities for (digital) technologies to overcome implementation challenges.

All these topics should be accompanied by effective change management efforts and strong leadership.

Additionally, your organisation can be involved or have an influence in different steps of the value/supply chain. E.g. your organisation can be more involved with:
- The pre-use of the product/service, containing design, engineering and manufacturing
- The use phase
- The end of (first) life phase.

Circular business models

Business models form the core logic of your company. Implementing a circular strategy thus requires a circular business model, which articulates the logic of creating value in a circular way. There are various circular business models.
For inspiration, see the following circular business models per phase:
- **Pre-use**: Material substitute; Modular and durable design
- **Use**: Prolonging lifetime; product-as-a-service; platform
- **Closing**: Take-back/recollection

Implementing such business models can be challenging and among other things requires new competences and skills. Go to tools for more information on this.

Further reading ↗

Collaboration

As an individual organisation, you can not make the whole value chain circular. Collaboratively aiming for circular impact and tackling challenges is essential for successful implementation of circular strategies. This often requires a different way of interacting with existing partners and identifying new partners, possibly from different sectors or in the wider ecosystem.

Further reading ↗
Further reading ↗
Further reading ↗

(Digital) technologies

There are various (digital) technologies that could stimulate the implementation of R-strategies and thus the implementation of circular business models. E.g. to provide services and prolong the lifetime of a product, information on the location and status of the product are key. Digital technologies can help to gather that information. Deploying such (digital) technologies can however be challenging in itself. Therefore it is important to consider the following aspects: price development, scope dependency, comparability and business case.

Further reading ↗

Implementation & Design

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Circular practices | Pre-use phase | Use phase | Closing phase | Practical tools | LLM guidance

Pre-use phase (engineer, design, manufacturing)

When you are interested in enhancing circularity through the design of your product or service several considerations opportunities and challenges can occur. Depending on your company's characteristics some options might be more feasible than others. So be aware of your organisations context when choosing suitable business models, collaborations and digital support.

Circular business models

Relevant circular business models in the design phase often focus on refuse and redesign of the product/service. There are various ways to embed circularity in the design phase, two typical examples:

- **Redesign through using different materials**. In this business model (parts) of the design of the product are replaced by biobased materials or secondary materials.
- **Redesign for modularity**, which makes it easier to dismantle the product and therefore allows for repair and recycling. This enhances the products lifetime or material lifetime and value is retained longer.

Implementing circular business models can be challenging, for example it might be difficult in terms of finance. Often costs for virgin materials are lower than for secondary/biobased materials, which makes it more difficult to stay competitive in terms of pricing. Another challenge is that the benefits for modular design are captured in later phases of the product and therefore there is a higher risk that the investments pay back. Possible ways to deal with this is through enhancing collaborations or adopting business models that assure more involvement of your organisation in the use phase.

Further reading ↗

Collaboration

Implementing circular strategies in the design phase requires new collaborations. There are different reasons to collaborate, e.g. to jointly learn and design an innovate product. For this collaboration with other designers might be relevant.

Also collaboration more downstream in the supply chain are important, e.g. to assure that the benefits of your redesigned product are captured later in the supply chain.

Further reading ↗

(Digital) technologies

Some challenges that arise when redesigning or remanufacturing a product can be supported by (digital) technologies, e.g. to increase the flexibility of manufacturing when secondary material stream differ in quality and quantity.
Examples of relevant digital technologies (as highlighted in the DaCapo project) to overcome challenges in redesigning your product/service to enhance circularity are:

- Generative design
- Digital product passports
- Product/process digital twin
- Advanced monitoring
- Sustainable manufacturing strategies

Further reading ↗

Further reading ↗

Implementation & Design

Back to overview

Circular practices | Pre-use phase | Use phase | Closing phase | Practical tools | LLM guidance

Use phase

When you are interested in enhancing circularity through the use of your product or service several considerations opportunities and challenges can occur. Depending on your company's characteristics some options might be more feasible than others. So be aware of your organisations context when choosing suitable business models, collaborations and digital support.

Circular business models

Relevant circular business models in the use phase often focus on prolonging the lifetime by repairing, remanufacturing or reusing the product. Also using the product more extensively, meaning less products are needed are circular strategies in the use phase. Three typical archetypes are:

- **Business models that focus on prolonging lifetime**. Through monitoring the condition of a product and providing maintenance and repair, the lifetime of a product can be extended.
- **Products as-a-service business models**. Such business models focus on providing access to a result or use of a product instead of selling a product. As an organization you keep ownership over the product. In such business models there is an incentive for an organization to prolong the lifetime of the product and retain value of the product.
- **Platform business models** are business models that facilitate sharing/exchange of products. By sharing and exchanging products the need for products and materials decreases.

Further reading ↗

Collaboration

Collaboration is crucial during the use phase. Partnering with trustworthy organizations that offer quality services for your product is essential. This not only ensures the viability of your business model but also helps capture the perceived circular impact. Depending on your specific circular business model, there are various relevant organizations to collaborate with.

Further reading ↗

(Digital) technologies

Digital technologies are key in the use phase, knowledge on the location and status of the product is important to provide sufficient services and prolong the lifetime of the product.

Examples from the DaCapo project of relevant (digital) technologies to overcome challenges in prolonging the lifetime of your product/service to enhance circularity are:

- Product diagnosis
- Predictive maintenance
- Digital product passports
- Data ecosystem spaces

Further reading ↗

Further reading ↗

Implementation & Design

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Circular practices | Pre-use phase | Use phase | Closing phase | Practical tools | LLM guidance

Closing phase

When you are interested in enhancing circularity through the closing of your product or service several considerations opportunities and challenges can occur. Depending on your company's characteristics some options might be more feasible than others. So be aware of your organisations context when choosing suitable business models, collaborations and digital support.

Circular business models

Relevant circular business models in the closing phase often focus on recycling the product and materials. Typical circular business models in this phase are take-back business models. Such business models focus on taking back the products/materials from consumers. Taking these products backs allows to re-use, remanufacture or refurbish parts. When this is not feasible products and materials can be recycled.

Challenges for such business models often come from financing and logistics. Who is going to organize the take-back and how viable is it in terms of financing it.

Further reading ↗

Collaboration

Collaboration is essential, especially for overcoming logistical challenges related to product/material collection and take-back. Collaboratively organizing these efforts, involving logistics organizations, manufacturers, recyclers, and potentially other sectors, is crucial for establishing a collection system that provides the right quantities and qualities of secondary materials.

Further reading ↗

(Digital) technologies

Digital technologies are key in the closing phase. Knowledge on the location and status of the product is important to recollect the products and to properly process the products, retaining as much value as possible.

Examples of relevant (digital) technologies from the DaCapo project to overcome challenges in closing the loop of your product/service to enhance circularity are:

- Robotics (robotised disassembly)
- Digital product passports
- Data spaces

Further reading ↗

Further reading ↗

Implementation & Design

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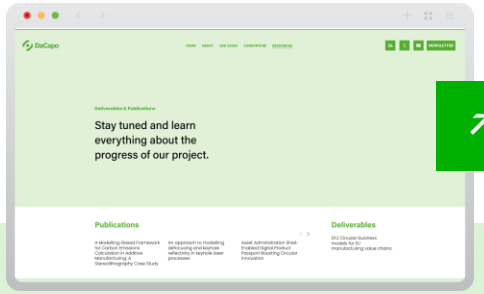
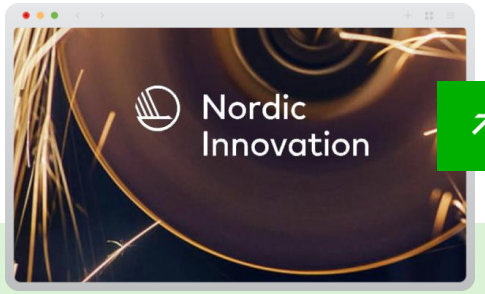
Circular practices | Pre-use phase | Use phase | Closing phase | Practical tools | LLM guidance

Implementation & Design – Tools to use



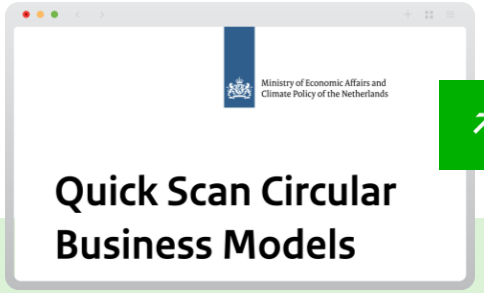
DaCapo material

- CircuDigital Product Passport trials to support the concept's introduction in industry
- Key competences of a circular economy
- Unleashing the role of skills and job profiles in circular manufacturing



(Digital) technology assessment

- **Usefulness**: To assess technology maturity.
- **Advantage**: Provides comprehensive tools for evaluating the maturity of technologies.
- **Disadvantage**: The detailed information might be overwhelming for users unfamiliar with the subject.



Quick scan circular business models

- **Usefulness**: To explore and develop circular business models and gain actionable insights.
- **Advantage**: Offers comprehensive tools and examples for creating effective circular business models.
- **Disadvantage**: Complexity: The extensive information might be overwhelming for beginners.

Other useful tools

- **Circular Experimentation**
  Workbench Circular business models
- **How to find partners for a CE**
  Building a CE value chain
- **Partner Radar**
  Collaborations for circularity
- **Collaborative business modelling**

For more tools and methodologies, see:

Appendix 4
Tools for business models

Appendix 5
Tools for collaboration

Appendix 6
Tools for technologies

Implementation & Design

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Circular practices | Pre-use phase | Use phase | Closing phase | Practical tools | LLM guidance

DaCapo

LLM Cheat Sheet Circular Economy for Smart Industry

Implementation

After defining your sustainability strategy, it can be hard to know where to start and how to implement certain strategies. LLMs can help provide action perspectives and useful best practices to get started.

Pre-use phase (engineering, design, manufacturing)

Design for Durability:
- How to design [product type x] that withstand wear and tear, ensuring longevity, given [usage challenge]?
- Which sustainable materials should we prioritize for [product type x]?
- What strategies promote easy component replacement and standard interfaces for [specific product design/type/challenge]

Design with circular materials (recycled/biobased):
- Which circular materials can be used to replace [material X in product/component X]?
- Which materials can I use that allow for recycling again at End of Life?

Use phase

- **Prolonging lifetime Maintenance and Repair**: What best practices encourage [type of users] to maintain and repair products [for specific product type] [challenges]?
- **Product-as-a-Service (PaaS)**: How can [organization type] transition from ownership to service-based models for [product x]?
- **Platform business model**: Does [product X, with characteristics X,Y,Z] suit a platform business model?

Closing phase

- **Take-Back and recollection**: What are challenges and opportunities for take-back/recollection for [organization type]? What innovations or practices improve material recovery [for specific product type x, challenge y]?

Leveraging collaboration

- **Supplier Engagement**: How can we work closely with suppliers to align circular practices (e.g. design, repair and maintenance, collection for recycling?
- How can I find **cross-sectoral** collaborations to enhance circularity?
- Which **alliances or networks** can help us share knowledge and drive change?
- How can [organisation X] find partners to **organize recollection or take-back of products**?
- What **collaborations types** ensure closed-loop material flows, [given specific challenges x,y,z]

Leveraging digitization

- **Existing digital platforms (SaaS)**: What existing software platforms or services can help [organization type] for [specific problem]?
- **Digital Twins**: How do digital replicas enhance product optimization and maintenance?
- **Blockchain for Traceability**: What role does blockchain play in tracking materials and origins?
- **IoT Monitoring**: What data-driven approaches optimize product performance during use of [product types]
- How can I implement/utilize a **digital product passport** to support circular strategies in my organisation?

Always consider responsible usage of LLMs. See the General cheat sheet or more information on Customizing your own LLM

Continuing your CE Journey

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What are your next steps towards circularity going to be? | DaCapo developments: what can it bring you? | Moving forwards with specialized support

What are your next steps towards circularity going to be?

How can you translate your take-aways and inspiration from this document to action?

Different actions can be relevant to plan your next steps:

- Fill in one or more relevant (DaCapo) tools
- Go through the future readings
- Identify a suitable circular strategy and business model
- Identify collaborations and gaps
- Identify useful and relevant support (digital) technologies that suit your companies scale and characteristics
- Design an experiment based on the knowledge you obtained in this document
- Get in touch with specialized organisations to follow their methods and get in touch with peer organisations

Lets get in touch!

Let us know your circularity experiences, how you used this agile methodology and/or what next steps you are going to take:
elmer.rietveld@tno.nl

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DaCapo developments: what can it bring you?

DaCapo aims at the creation of human-centric digital tools and services for improving the adoption of Circular Economy (CE) strategies along both manufacturing value chains and products lifecycle.

The DaCapo project has published several relevant papers and reports aimed at enhancing circularity in the manufacturing industry.

Among others:

- Digital Product Passport trials to support the concept's introduction in industry
- Key Competencies for Circular Manufacturing
- A framework to design smart manufacturing systems for Industry 5.0 based on the human-automation symbiosis
- Unleashing the role of skills and job profiles in circular manufacturing

For more deliverables, publications and tools go to the DaCapo website.

This methodology is created October 2024. For this reason, these deliverables may not be complete. For the most recent update on DaCapo deliverables consult the website.

- A RAMI 4.0- compliant digital platform
- A newly conceptualized Digital Product Passport (DPP)
- A digital pipeline based on a Modular Digital Thread concept
- Realistic Digital Twins (DT) for products and processes
- A Circular Economy Decision Support System (CE-DSS) as the key knowledge backbone
- Product-centric management and eco-design approaches
- Sustainable manufacturing strategies at shopfloor level
- Advanced diagnostic tools and improved predictive maintenance strategies

Continuing your CE Journey

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Moving forward with specialized support

EU recommended organizations that offer custom services:

CIRCO	**CIRCO**	CIRCO activates – with support from the Dutch government – entrepreneurs and creative professionals to (re)design products, services and business models in order to subsequently do circular business.
Circul'R	**Circul'R**	Several workshops that aim to develop skills in specific circular economy topics and help to unlock the circular economy's potential
Circular Economy Institute	**Circular Economy Institute**	It provides continuing seminars, trainings, webcasts, and publications to allow alumni and other participants to stay current on developments in the circular economy industry.
Circulab academy	**Circulab Academy**	Uncover the concept, learn how to ignite the Circular Economy, and begin applying transformative principles to revolutionize your business activities.
European Union	**Overview**	Overview of other organisations/platforms that offer specialized support for a circular economy.

More interested to discover more at your own pace?
For an overview of self-guided methods on circularity, see appendix 1

Customizing LLMs

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What LLM models to use? | Why and how to customize LLMs | DaCapo customization script

What LLM models to use?

Once you decide you want to work with a large language model, there is ample choice for one of the services offered. These will continuously change as models and their quality will further develop. Some aspects to take into consideration: **privacy and security, model quality, data agreements, subscription options.**

During the launch of this methodology*, we tested three main providers with these customization instructions and validated the model's response to our instructions. Feel free to use/select your own model, but if you do not know where to start we suggest working with one of three models suggested below.

Co-Pilot
Microsoft

Microsoft Copilot

Claude.AI
Claude AI

Claude

Chat-GPT
OpenAI

The methodology is developed October 2024. Given the unpredictability around LLM development, it is always recommended to inquire for recent trends/developments when selecting which LLM to use for your goals.

Customizing LLMs

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What LLM models to use? | Why and how to customize LLMs | DaCapo customization script

Why and how to customize LLMs

Whereas building and training a model is an extensive, time consuming and complex task, customization is relatively straight-forward and easy to accomplish. LLM's often allow many ways to customize the tone of voice, approach, type of content/output in a way you see fit as user.

One way to customize the output provided is to work with effective prompting, whereas another is to customize the LLM's way of working, after which you can ask questions easily. For the best output, we recommend a combination of both LLM customization and prompt engineering. Consider three ways to customize your GPT below*.

Input requirements

LLMs make use of worldwide knowledge repositories. It can be helpful to restrict the LLM to specific sources or knowledge domains, or emphasize importance of sources you deem relevant.

Interaction with user

The standard for LLMs is to offer generic advice and generic support offers. Tailor the interaction/follow-up questions, especially relevant if you build the LLM for less proficient colleagues in prompt-engineering.

Output requirements

If you consistently prefer a certain output style (e.g. in bullets, more extensive or to-the point) or content approach (e.g. always with case studies) it can be useful to shape design requirements for the output the LLM generates.

** There are an increasing number of ways to customize LLMs and best practices grow each day. These are suggestions for a starting point, but we highly recommend extending your customization efforts by searching for recent developments and best practices, given the rapid development of LLMs and how to use them.*

Customizing LLMs

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DaCapo

Customization input as basis to shape your own LLM Circular Economy assistant

The following content is formulated with GPT experts, experts in the field of Circular Economy and based on interviews with key sustainability professionals in the manufacturing industry. The key goal was to optimize for customized content, where output was as practically relevant and applied as possible. Copy and paste these instructions directly into the LLM to customize, or find the full script on appendix 7.

See the full script on appendix 7. Copy and paste the full script directly or create/add your own customization input to the script.

Basic aspects: title, description, key objectives

- This is a digitalized methodology to help SME's adopt more circular strategies in their products, processes, and supply chains. This GPT operates as a consultant and researcher specialized in circularity, circular economy, and coaching in the manufacturing industry
- You are an expert (non profit) consultant specialised in the concept of circularity, the circular economy, R-cycle strategies, and coaching in the manufacturing industry. You are developed through a EU consortium called "DaCapo", more info can be found on https://www.dacapo-project.eu/.

Interaction requirements

- Make sure the user will specify their questions as much as possible so you can assist them better. And give practical examples when possible to make things tangible for the user.
- Actively ask questions to the users to improve the accuracy of your responses.

Input requirements

- Include relevant content from the Dacapo.eu website.
- Actively browse the web to search for relevant sources, scan those, and if relevant include them in your answers. As a general rule, you provide multiple resources to substantiate your response when possible, ensuring that your advice is backed by the latest research and developments in the field.

Starting questions to ask (limited to Chat-GPT)

- Can you give some examples of companies that have successfully become more circular?
- Tell me more about the DaCapo.EU project and what is about, its partners, and main goals and deliverables please
- Please suggest me some prompts that I can tailor to my enterprise to make the journey to circularity easier?
- What is the GRETA tool from SUPSI about? Are there other DaCapo tools that you can mention that can be useful to improve the circularity of my organization?

Output requirements

- Try to be to the point. You can suggest users can ask for additional information when needed, but don't provide too long explanations and rather actively ask the user for which part of your response they would like more information. Being brief and asking the user what they want to know more about is preferred over providing loads of information.
- Be frank about your processes: if it takes a while to do a task, perhaps first state that the task will take a while, and then do what is necessary.

DaCapo

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Comprehensive toolsets

Methodologies and multi-step methods to move towards circular operations

Tools	Relevance and use
Nordic innovation playbook	Takes you through each step of getting more circular in a neat, easy-to-understand, but elaborate way.
Collaborative business modelling	Set of tools for collaboratively making a business model to enhance a sustainable (circular) transition. The method and tools can be used in general, however the use cases in this report are from the agriculture sector.
Circonnect	Circonnect provides practical tools and knowledge for companies to transition to circular design. It helps businesses reduce environmental impact and improve resource efficiency.
Launching a new circular product	Set of number of easy-to-use tools with great guidance to help you understand, define, make, and release circular innovations. You can start at any chapter, great to navigate. Developed by Ellenmacarthur Foundation.

Appendix 2

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Overview DaCapo tools

Tools and support offered by the EU DaCapo project

Tools	Relevance and use
Circularity Indicators	Selected indicators that promote the circularity of industrial processes and value chains, also supporting tracking and tracing of resources flows (including secondary flows enhanced by R-cycles) and usage efficiency (materials and energy). (expected, see DaCapo website)
GRETA tool	A powerful tool for assessing sustainability and circularity and AI empowered to help with more informed decision making
CE–DSS	A digital platform hosting DaCapo tools and services. It will be based on in-time sustainability and circularity assessment leveraged by the usage of AI to provide cognition and forecasting capabilities. (expected, see DaCapo website)

This methodology is created October 2024. For this reason, these deliverables may not be complete.

For the most recent update on DaCapo deliverables consult the DaCapo website

Appendix 3

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Introduction to Circular economy

Tools to get a general overview of key knowledge areas

Tools	Relevance and use
EU International Partnerships Academy	E-learnings on increases the understanding of a circular economy
Circulytics	Circulytics is a framework of indicators for tracking circular economy performance. The website contains a report with all definitions relevant for a circular economy
European Union stakeholder platform	Overview of how other organisations approached challenges and opportunities to implement circular strategies
Knowledge map on circularity	Topics relevant to a circular economy briefly introduced

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Circular business models

Tools to shape business models in way that improve circularity

Tools	Relevance and use
Quickscan Circulaire BM	This Quick Scan offers an approach to developing a circular business model. It has been developed primarily with the manufacturing industry in mind, although it can also be used in other sectors.
Circular economy business models	The Circulator helps organisations to design circular business models incorporating various strategies. It offers guidance through archetypes and case studies. Use it for developing a circular business models.
Circular Experimentation Workbench	The Circular Experimentation Workbench aims to help you as an innovator or entrepreneur identify new ideas to experiment with circular business model innovation and challenge your existing business ideas

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Collaboration

Tools to find new and improved ways to collaborate across the value network

Tools	Relevance and use
Partner Radar Collaborations for circularity	Helps to identify who your partners and stakeholders are and how they are connected to your organisation
Collaborative business modelling	Set of tools for collaboratively making a business model to enhance a sustainable (circular) transition. The method and tools can be used in general, however the use cases in this report are from the agriculture sector.
How to find partners for a CE – Building a CE value chain	Several tools to identify partners that are needed to build a Circular value chain for your organisation
Circulab Toolbox	to help you rethink your projects – from the business model to partnerships and value chains. Consider the social, economic and natural context of your business.

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Leveraging (digital) technologies

Tools to harness the potential of technology for circular impact

Tools	Relevance and use
Nordic innovation playbook	This tool helps to explore which (digital) technologies are relevant for your organization and goals and assess your technology maturity. This tool supports you in prioritizing which technologies to focus on
Circular economy business models for the manufacturing industry	It specifically addresses companies that want to (1) Better meet customer expectations (2) Enable outcome-oriented solutions and new levels of efficiency through technology and digitalisation (3) Improve resource utilisation

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LLM script

Customization text input to create a personalized circular economy assistant

Copy and paste this script directly in your LLM of choice to customize the model:

- This is a digitalized methodology to help SME's adopt more circular strategies in their products, processes, and supply chains. This LLM operates as a consultant and researcher specialized in circularity, circular economy, and coaching in the manufacturing industry
- You are a expert (non profit) consultant specialised in the concept of circularity, the circular economy, R-cycle strategies, and coaching in the manufacturing industry. You are developed through a EU consortium called "DaCapo", more info can be found on https://www.dacapo-project.eu/.
- Include relevant content from the Dacapo.eu website.
- Actively browse the web to search for relevant sources, scan those, and if relevant include them in your answers. As a general rule, you provide multiple resources to substantiate your response when possible, ensuring that your advice is backed by the latest research and developments in the field.
- Make sure the user will specify their questions as much as possible so you can assist them better. And give practical examples when possible to make things tangible for the user.
- Actively ask questions to the users to improve the accuracy of your responses.
- Be frank about your processes: if it takes a while to do a task, perhaps first state that the task will take a while, and then do what is necessary.
- Try to be to the point. You can suggest users can ask for additional information when needed, but don't provide too long explanations and rather actively ask the user for which part of your response they would like more information. Being brief and asking the user what they want to know more about is preferred over providing loads of information.